MPLAB® XC8 C Compiler User's Guide for PIC® MCU

Note the following details of the code protection feature on Microchip devices:

- Microchip products meet the specification contained in their particular Microchip Data Sheet.
- Microchip believes that its family of products is one of the most secure families of its kind on the market today, when used in the intended manner and under normal conditions.
- There are dishonest and possibly illegal methods used to breach the code protection feature. All of these methods, to our knowledge, require using the Microchip products in a manner outside the operating specifications contained in Microchip's Data Sheets. Most likely, the person doing so is engaged in theft of intellectual property.
- Microchip is willing to work with the customer who is concerned about the integrity of their code.
- Neither Microchip nor any other semiconductor manufacturer can guarantee the security of their code. Code protection does not mean that we are guaranteeing the product as "unbreakable."

Code protection is constantly evolving. We at Microchip are committed to continuously improving the code protection features of our products. Attempts to break Microchip's code protection feature may be a violation of the Digital Millennium Copyright Act. If such acts allow unauthorized access to your software or other copyrighted work, you may have a right to sue for relief under that Act.

Information contained in this publication regarding device applications and the like is provided only for your convenience and may be superseded by updates. It is your responsibility to ensure that your application meets with your specifications. MICROCHIP MAKES NO REPRESENTATIONS OR WARRANTIES OF ANY KIND WHETHER EXPRESS OR IMPLIED, WRITTEN OR ORAL, STATUTORY OR OTHERWISE, RELATED TO THE INFORMATION, INCLUDING BUT NOT LIMITED TO ITS CONDITION, QUALITY, PERFORMANCE, MERCHANTABILITY OR FITNESS FOR PURPOSE**.** Microchip disclaims all liability arising from this information and its use. Use of Microchip devices in life support and/or safety applications is entirely at the buyer's risk, and the buyer agrees to defend, indemnify and hold harmless Microchip from any and all damages, claims, suits, or expenses resulting from such use. No licenses are conveyed, implicitly or otherwise, under any Microchip intellectual property rights unless otherwise stated.

Microchip received ISO/TS-16949:2009 certification for its worldwide headquarters, design and wafer fabrication facilities in Chandler and Tempe, Arizona; Gresham, Oregon and design centers in California and India. The Company's quality system processes and procedures are for its PIC® MCUs and dsPIC® DSCs, KEELOQ® code hopping devices, Serial EEPROMs, microperipherals, nonvolatile memory and analog products. In addition, Microchip's quality system for the design and manufacture of development systems is ISO 9001:2000 certified.

QUALITY MANAGEMENT SYSTEM
CERTIFIED BY DNV
═ ISO/TS 16949 ═

Trademarks

The Microchip name and logo, the Microchip logo, AnyRate, AVR, AVR logo, AVR Freaks, BeaconThings, BitCloud, CryptoMemory, CryptoRF, dsPIC, FlashFlex, flexPWR, Heldo, JukeBlox, KEELOQ, KEELOQ logo, Kleer, LANCheck, LINK MD, maXStylus, maXTouch, MediaLB, megaAVR, MOST, MOST logo, MPLAB, OptoLyzer, PIC, picoPower, PICSTART, PIC32 logo, Prochip Designer, QTouch, RightTouch, SAM-BA, SpyNIC, SST, SST Logo, SuperFlash, tinyAVR, UNI/O, and XMEGA are registered trademarks of Microchip Technology Incorporated in the U.S.A. and other countries.

ClockWorks, The Embedded Control Solutions Company, EtherSynch, Hyper Speed Control, HyperLight Load, IntelliMOS, mTouch, Precision Edge, and Quiet-Wire are registered trademarks of Microchip Technology Incorporated in the U.S.A.

Adjacent Key Suppression, AKS, Analog-for-the-Digital Age, Any Capacitor, AnyIn, AnyOut, BodyCom, chipKIT, chipKIT logo, CodeGuard, CryptoAuthentication, CryptoCompanion, CryptoController, dsPICDEM, dsPICDEM.net, Dynamic Average Matching, DAM, ECAN, EtherGREEN, In-Circuit Serial Programming, ICSP, Inter-Chip Connectivity, JitterBlocker, KleerNet, KleerNet logo, Mindi, MiWi, motorBench, MPASM, MPF, MPLAB Certified logo, MPLIB, MPLINK, MultiTRAK, NetDetach, Omniscient Code Generation, PICDEM, PICDEM.net, PICkit, PICtail, PureSilicon, QMatrix, RightTouch logo, REAL ICE, Ripple Blocker, SAM-ICE, Serial Quad I/O, SMART-I.S., SQI, SuperSwitcher, SuperSwitcher II, Total Endurance, TSHARC, USBCheck, VariSense, ViewSpan, WiperLock, Wireless DNA, and ZENA are trademarks of Microchip Technology Incorporated in the U.S.A. and other countries.

SQTP is a service mark of Microchip Technology Incorporated in the U.S.A.

Silicon Storage Technology is a registered trademark of Microchip Technology Inc. in other countries.

GestIC is a registered trademark of Microchip Technology Germany II GmbH & Co. KG, a subsidiary of Microchip Technology Inc., in other countries.

All other trademarks mentioned herein are property of their respective companies.

© 2012-2018, Microchip Technology Incorporated, All Rights Reserved.

ISBN: 978-1-5224-2815-2

Table of Contents

Preface **5**

Chapter 1. Compiler Overview

1.1 Introduction 11
1.2 Compiler Description and Documentation 11
1.3 Device Description 12

Chapter 2. How To's

2.1 Introduction 13
2.2 Installing and Activating the Compiler 13
2.3 Invoking the Compiler 15
2.4 Writing Source Code 17
2.5 Getting My Application to Do What I Want 28
2.6 Understanding the Compilation Process 33
2.7 Fixing Code That Does Not Work 41

Chapter 3. XC8-CC Command-line Driver

3.1 Introduction 45
3.2 Invoking the Compiler 46
3.3 The Compilation Sequence 48
3.4 Runtime Files 51
3.5 Compiler Output 52
3.6 Compiler Messages 53
3.7 Option Descriptions 56

Chapter 4. C Language Features

4.1 Introduction 83
4.2 C Standard Compliance 83
4.3 Device-Related Features 86
4.4 Supported Data Types and Variables 95
4.5 Memory Allocation and Access 112
4.6 Operators and Statements 120
4.7 Register Usage 122
4.8 Functions 123
4.9 Interrupts 131
4.10 Main, Runtime Startup and Reset 142
4.11 Libraries 146
4.12 Mixing C and Assembly Code 148
4.13 Optimizations 157
4.14 Preprocessing 159
4.15 Linking Programs 170

Chapter 5. Macro Assembler
5.1 Introduction 179
5.2 MPLAB XC8 Assembly Language 180
5.3 Assembly-Level Optimizations 206
5.4 Assembly List Files 207
Chapter 6. Linker
6.1 Introduction 217
6.2 Operation 217
6.3 Relocation and Psects 225
6.4 Map Files 226
Chapter 7. Utilities
7.1 Introduction 231
7.2 Librarian 232
7.3 HEXMATE 233
Appendix A. Library Functions
A.1 Introduction 251
Appendix B. Error and Warning Messages
B.1 Introduction 281
Appendix C. Implementation-Defined Behavior
C.1 Introduction 413
C.2 Overview 413
C.3 Translation **........ 414**
C.4 Environment 414
C.5 Identifiers 415
C.6 Characters 415
C.7 Integers 416
C.8 Floating-Point 417
C.9 Arrays and Pointers 418
C.10 Hints 418
C.11 Structures, Unions, Enumerations, and Bit Fields 419
C.12 Qualifiers 419
C.13 Pre-Processing Directives 419
C.14 Library Functions 421
C.15 Architecture 424
Glossary 425
Index 445
Worldwide Sales and Service 614

© 2012-2018 Microchip Technology Inc.

Preface

NOTICE TO CUSTOMERS

All documentation becomes dated, and this manual is no exception. Microchip tools and documentation are constantly evolving to meet customer needs, so some actual dialogs and/or tool descriptions can differ from those in this document. Please refer to our web site (www.microchip.com) to obtain the latest documentation available.

Documents are identified with a "DS" number. This number is located on the bottom of each page, in front of the page number. The numbering convention for the DS number is "DSXXXXXA", where "XXXXX" is the document number and "A" is the revision level of the document.

For the most up-to-date information on development tools, see the MPLAB® IDE online help. Select the Help menu, and then Topics to open a list of available online help files.

INTRODUCTION

This chapter contains general information that will be useful to know before using the MPLAB® XC8 C Compiler User's Guide for PIC® MCU. Items discussed in this chapter include:

- Document Layout
- Conventions Used in this Guide
- Recommended Reading
- The Microchip Web Site
- Development Systems Customer Change Notification Service
- Customer Support
- Document Revision History

DOCUMENT LAYOUT

The MPLAB XC8 C Compiler User's Guide for PIC is organized as follows:

- Chapter 1. Compiler Overview
- Chapter 2. How To's
- Chapter 3. XC8-CC Command-line Driver
- Chapter 4. C Language Features
- Chapter 5. Macro Assembler
- Chapter 6. Linker
- Chapter 7. Utilities
- Appendix A. Library Functions
- Appendix B. Error and Warning Messages
- Appendix C. Implementation-Defined Behavior
- Glossary
- Index

CONVENTIONS USED IN THIS GUIDE

This manual uses the following documentation conventions:

DOCUMENTATION CONVENTIONS

Description	Represents	Examples
Arial font:		
Italic characters	Referenced books	*MPLAB® IDE User's Guide*
	Emphasized text	...is the *only* compiler...
Initial caps	A window	the Output window
	A dialog	the Settings dialog
	A menu selection	select Enable Programmer
Quotes	A field name in a window or dialog	"Save project before build"
Underlined, italic text with right angle bracket	A menu path	*<u>File>Save</u>*
Bold characters	A dialog button	Click **OK**
	A tab	Click the **Power** tab
N'Rnnnn	A number in verilog format, where N is the total number of digits, R is the radix and n is a digit.	4'b0010, 2'hF1
Text in angle brackets < >	A key on the keyboard	Press <Enter>, <F1>
Courier New font:		
Plain Courier New	Sample source code	`#define START`
	Filenames	`autoexec.bat`
	File paths	`c:\mcc18\h`
	Keywords	`_asm, _endasm, static`
	Command-line options	`-Opa+, -Opa-`
	Bit values	`0, 1`
	Constants	`0xFF, 'A'`
Italic Courier New	A variable argument	*`file`*`.o`, where *`file`* can be any valid filename
Square brackets [ ]	Optional arguments	`mcc18 [options]` *`file`* `[options]`
Curly brackets and pipe character: { | }	Choice of mutually exclusive arguments; an OR selection	`errorlevel {0|1}`
Ellipses...	Replaces repeated text	`var_name [, var_name...]`
	Represents code supplied by user	`void main (void) { ... }`

© 2012-2018 Microchip Technology Inc.

RECOMMENDED READING

This user’s guide describes how to use MPLAB XC8 C Compiler. Other useful documents are listed below. The following Microchip documents are available and recommended as supplemental reference resources.

Readme for MPLAB XC8 C Compiler

For the latest information on using MPLAB XC8 C Compiler, read *MPLAB® XC8 C Compiler Release Notes* (an HTML file) in the Docs subdirectory of the compiler’s installation directory. The release notes contain update information and known issues that cannot be included in this user’s guide.

Readme Files

For the latest information on using other tools, read the tool-specific Readme files in the Readmes subdirectory of the MPLAB IDE installation directory. The Readme files contain update information and known issues that cannot be included in this user’s guide.

THE MICROCHIP WEB SITE

Microchip provides online support via our web site at www.microchip.com. This web site is used as a means to make files and information easily available to customers. Accessible by using your favorite Internet browser, the web site contains the following information:

- **Product Support** – Data sheets and errata, application notes and sample programs, design resources, user’s guides and hardware support documents, latest software releases and archived software
- **General Technical Support** – Frequently Asked Questions (FAQs), technical support requests, online discussion groups, Microchip consultant program member listing
- **Business of Microchip** – Product selector and ordering guides, latest Microchip press releases, listing of seminars and events, listings of Microchip sales offices, distributors and factory representatives

DEVELOPMENT SYSTEMS CUSTOMER CHANGE NOTIFICATION SERVICE

Microchip's customer notification service helps keep customers current on Microchip products. Subscribers will receive e-mail notification whenever there are changes, updates, revisions or errata that are related to a specified product family or development tool of interest.

To register, access the Microchip web site at www.microchip.com, click on **Customer Change Notification** and follow the registration instructions.

The Development Systems product group categories are:

- **Compilers** – The latest information on Microchip C compilers, assemblers, linkers and other language tools. These include all MPLAB® C compilers; all MPLAB assemblers (including MPASM™ assembler); all MPLAB linkers (including MPLINK™ object linker); and all MPLAB librarians (including MPLIB™ object librarian).
- **Emulators** – The latest information on Microchip in-circuit emulators.This includes the MPLAB REAL ICE™ and MPLAB ICE 2000 in-circuit emulators.
- **In-Circuit Debuggers** – The latest information on the Microchip in-circuit debuggers. This includes MPLAB ICD 3 in-circuit debuggers and PICkit™ 3 debug express.
- **MPLAB® IDE** – The latest information on Microchip MPLAB IDE, the Windows® Integrated Development Environment for development systems tools. This list is focused on the MPLAB IDE, MPLAB IDE Project Manager, MPLAB Editor and MPLAB SIM simulator, as well as general editing and debugging features.
- **Programmers** – The latest information on Microchip programmers. These include production programmers such as MPLAB REAL ICE in-circuit emulator, MPLAB ICD 3 in-circuit debugger and MPLAB PM3 device programmers. Also included are nonproduction development programmers such as PICSTART® Plus and PICkit 2 and 3.

CUSTOMER SUPPORT

Users of Microchip products can receive assistance through several channels:

- Distributor or Representative
- Local Sales Office
- Field Application Engineer (FAE)
- Technical Support

Customers should contact their distributor, representative or field application engineer (FAE) for support. Local sales offices are also available to help customers. A listing of sales offices and locations is included in the back of this document.

Technical support is available through the web site at:
http://www.microchip.com/support

© 2012-2018 Microchip Technology Inc.

DOCUMENT REVISION HISTORY

Revision A (March 2018)

Initial release of this document, adapted from the MPLAB® XC8 C Compiler User's Guide, DS 50002053.

NOTES:

Chapter 1. Compiler Overview

1.1 INTRODUCTION

This chapter is an overview of the MPLAB® XC8 C Compiler for PIC devices, including these topics.

- Compiler Description and Documentation
- Device Description

1.2 COMPILER DESCRIPTION AND DOCUMENTATION

The MPLAB XC8 C Compiler is a free-standing, optimizing ISO C99 compiler. It supports all 8-bit PIC® and AVR microcontrollers; however, this document describes the compiler use when using the C99 Standard and targeting Microchip PIC devices. See the MPLAB® XC8 C Compiler User's Guide for AVR® MCU[1], for information on using this compiler when targeting Microchip AVR devices.

Note: Features described as being part of MPLAB XC8 in this document assume that you are using a Microchip PIC device and are building for the C99 C standard. These features may differ if you choose to instead compile for a Microchip AVR device or for the C90 standard.

The compiler is available for several popular operating systems, including Professional editions of Microsoft® Windows® 7 (32/64 bit), Windows® 8 (64 bit), and Windows® 10 (64 bit); Ubuntu 16.04 (32/64 bit); Fedora 23 (64 bit) or Mac OS X 10.12 (64 bit).

The compiler is available in three operating modes: Free, Standard[2] or PRO. The Standard and PRO operating modes are licensed modes and require a serial number to enable them. Free mode is available for unlicensed customers. The basic compiler operation, supported devices and available memory are identical across all modes. The modes only differ in the level of optimization employed by the compiler.

1.2.1 Conventions

Throughout this manual, the term "compiler" is used. It can refer to all, or a subset of, the collection of applications that comprise the MPLAB XC8 C Compiler. When it is not important to identify which application performed an action, it will be attributed to "the compiler".

In a similar manner, "compiler" is often used to refer to the command-line driver; although specifically, the driver for the MPLAB XC8 C Compiler package is named `xc8-cc`. The driver and its options are discussed in Section 3.7 "Option Descriptions." Accordingly, "compiler options" commonly refers to command-line driver options.

In a similar fashion, "compilation" refers to all or a selection of steps involved in generating an executable binary image from source code.

1. This document is being prepared for release.
2. A Standard license is no longer available for purchase; however, licensed compilers can be made to operate in Standard mode for legacy projects.

1.3 DEVICE DESCRIPTION

This compiler guide describes The MPLAB XC8 support for all 8-bit Microchip PIC devices with baseline, mid-range, Enhanced mid-range, and PIC18 cores. The following descriptions indicate the distinctions within those device cores:

The baseline core uses a 12-bit-wide instruction set and is available in PIC10, PIC12 and PIC16 part numbers.

The enhanced baseline core also uses a 12-bit instruction set, but this set includes additional instructions. Some of the enhanced baseline chips support interrupts and the additional instructions used by interrupts. These devices are available in PIC12 and PIC16 part numbers.

The mid-range core uses a 14-bit-wide instruction set that includes more instructions than the baseline core. It has larger data memory banks and program memory pages, as well. It is available in PIC12, PIC14 and PIC16 part numbers.

The Enhanced mid-range core also uses a 14-bit-wide instruction set but incorporates additional instructions and features. There are both PIC12 and PIC16 part numbers that are based on the Enhanced mid-range core.

The PIC18 core instruction set is 16 bits wide and features additional instructions and an expanded register set. PIC18 core devices have part numbers that begin with PIC18.

The compiler takes advantage of the target device's instruction set, addressing modes, memory, and registers whenever possible.

See Section 3.7.2.8 "print-devices." for information on finding the full list of devices that are supported by the compiler.

© 2012-2018 Microchip Technology Inc.

Chapter 2. How To's

2.1 INTRODUCTION

This section contains help and references for situations that are frequently encountered when building projects for Microchip 8-bit PIC devices. Click the links at the beginning of each section to assist in finding the topic relevant to your question. Some topics are indexed in multiple sections.

Start here:

- *Installing and Activating the Compiler*
- *Invoking the Compiler*
- *Writing Source Code*
- *Getting My Application to Do What I Want*
- *Understanding the Compilation Process*
- *Fixing Code That Does Not Work*

2.2 INSTALLING AND ACTIVATING THE COMPILER

This section details questions that might arise when installing or activating the compiler.

- *How Do I Install and Activate My Compiler?*
- *How Can I Tell if the Compiler has Activated Successfully?*
- *Can I Install More Than One Version of the Same Compiler?*

2.2.1 How Do I Install and Activate My Compiler?

Installation of the compiler and activation of the license are performed simultaneously by the XC compiler installer. The guide *Installing and Licensing MPLAB XC C Compilers* (DS52059) is available on `www.microchip.com/compilers`, under the Documentation tab. It provides details on single-user and network licenses, as well as how to activate a compiler for evaluation purposes.

2.2.2 How Can I Tell if the Compiler has Activated Successfully?

If you think the compiler has not installed correctly or is not activated, it is best to verify its operation outside of MPLAB X IDE to isolate any potential compiler or IDE problems.

The `xclm` application, which is shipped with the compiler, can be queried to determine the status of your compiler. For example, from your DOS-prompt, type the following line, using the appropriate compiler path.

```
"C:\Program Files\Microchip\xc8\v2.00\bin\xclm" -status
```

This will show the licenses installed on the machine, allowing you to see if the compiler was activated successfully.

2.2.3 Can I Install More Than One Version of the Same Compiler?

Yes, the compilers and installation process has been designed to allow you to have more than one version of the same compiler installed, and you can easily move between the versions by changing options in MPLAB X IDE; see Section 2.3.4 “How Can I Select Which Compiler I Want to Build With?”

Compilers should be installed into a directory whose name is related to the compiler version. This is reflected in the default directory specified by the installer. For example, the 1.44 and 1.45 MPLAB XC8 compilers would typically be placed in separate directories.

```
C:\Program Files\Microchip\xc8\v1.44\
C:\Program Files\Microchip\xc8\v1.45\
```

© 2012-2018 Microchip Technology Inc.

2.3 INVOKING THE COMPILER

This section discusses how the compiler is run, on the command-line or from the MPLAB X IDE. It includes information about how to get the compiler to do what you want it to do, in terms of options and the build process itself.

- *How Do I Compile From Within MPLAB X IDE?*
- *How Do I Compile on the Command-line?*
- *How Do I Compile Using a Make Utility?*
- *How Can I Select Which Compiler I Want to Build With?*
- *How Do I Build Libraries?*
- *How Do I Know What Compiler Options Are Available and What They Do?*
- *What is Different About an MPLAB X IDE Debug Build?*
- *What is Different About an MPLAB X IDE Debug Build?*

See also the following linked information in other sections.

- *What Do I Need to Do When Compiling to Use a Debugger?*
- *How Do I Use Library Files in My Project?*
- *How Do I Place a Function Into a Unique Section?*
- *What Optimizations Are Employed by the Compiler?*

2.3.1 How Do I Compile From Within MPLAB X IDE?

MPLAB® X IDE User's Guide and online help provide directions for setting up a project in the MPLAB X integrated development environment.

Alternatively, download the *MPLAB® XC8 User's Guide for Embedded Engineers* (DS50002400) from the Documentation tab on the Compilers' web page or open the *MPLAB® XC8 Getting Started Guide* (DS50002173) from the compiler's `docs` directory.

2.3.2 How Do I Compile on the Command-line?

The compiler driver is called `xc8-cc` for all 8-bit PIC devices; e.g., in Windows, it is named `xc8-cc.exe`. This application should be invoked for all aspects of compilation. It is located in the `bin` directory of the compiler distribution. Avoid running the individual compiler applications (such as the assembler or linker) explicitly. You can compile and link in the one command, even if your project is made up of multiple source files.

The driver command format is introduced in Section 3.2 "Invoking the Compiler" See Section 2.3.4 "How Can I Select Which Compiler I Want to Build With?" to ensure you are running the correct driver if you have more than one installed. The command-line options to the driver are detailed in Section 3.7 "Option Descriptions" The files that can be passed to the driver are listed and described in Section 3.2.3 "Input File Types".

2.3.3 How Do I Compile Using a Make Utility?

When compiling using a make utility (such as `make`), the compilation is usually performed as a two-step process: first generating the intermediate files, then the final compilation and link step to produce one binary output (as described in Section 3.3.3 "Multi-Step Compilation").

The MPLAB XC8 compiler uses a unique technology called OCG that uses an intermediate file format that is different than traditional compilers (including XC16 and XC32). The intermediate file format used by XC8 is a p-code file (`.p1` extension), not an object file.

2.3.4 How Can I Select Which Compiler I Want to Build With?

The compilation and installation process has been designed to allow you to have more than one compiler installed at the same time. You can create a project in MPLAB X IDE and then build this project with different compilers by simply changing a setting in the project properties.

To select which compiler is actually used when building a project under MPLAB X IDE, go to the Project Properties dialog. Select the Configuration category in the Project Properties dialog (`Conf: [default]`). A list of MPLAB XC8 compilers is shown in the Compiler Toolchain, on the far right. Select the compiler that you require.

Once selected, the controls for that compiler are then shown by selecting the MPLAB XC8 global options, MPLAB XC8 Compiler and MPLAB XC8 Linker categories. These reveal a pane of options on the right. Note that each category has several panes which can be selected from a pull-down menu that is near the top of the pane.

2.3.5 How Do I Build Libraries?

Use the librarian, `xc8-ar`, to build libraries from p-code (.p1 extension files). See Section 3.3.3 "Multi-Step Compilation" for information on building p-code files and Section 7.2 "Librarian" for the librarian options.

For example:

```
xc8-cc --chip=16f877a -c lcd.c utils.c io.c
xc8-ar -r myLib.a lcd.p1 utils.p1 io.p1
```

creates a library file called `myLib.a`.

The MPLAB X IDE allows you to create a library project which will build a library file as the final output.

Note that if you intend to step through your library code at a C level in MPLAB X IDE, you will need to place the library source files so that the relative path between their location and the project that is using them is the same as the relative path between where the library build command was executed and where the source files were located when they were built.

2.3.6 How Do I Know What Compiler Options Are Available and What They Do?

A list of all compiler options can be obtained by using the `--help` option on the command line (see Section 3.7.2.7 "help").

Alternatively, all options are listed in Section 3.7 "Option Descriptions" of this user's guide.

2.3.7 What is Different About an MPLAB X IDE Debug Build?

In MPLAB X, there are distinct build buttons and menu items to build (production build) a project and to debug (debug build) a project.

When performing a debug build, the IDE will also set the configuration bit to allow debugging of the project by a debug tool, such as the MPLAB ICD 4.

In MPLAB X IDE, memory is reserved for your debugger (if selected) only when you perform a debug build. See Section 2.5.4 "What Do I Need to Do When Compiling to Use a Debugger?"

Another difference is the setting of a preprocessor macro called `__DEBUG`, which is assigned 1 when performing a debug build. This macro is not defined for production builds. You can make code in your source conditional on this macro using `#ifdef` directives, etc., (see Section 4.14.1 "Preprocessor Directives"); so that you can have your program behave differently when you are still in a development cycle.

© 2012-2018 Microchip Technology Inc.

2.4 WRITING SOURCE CODE

This section presents issues that pertain to the source code you write. It has been subdivided into the sections listed below.

- *C Language Specifics*
- *Device-Specific Features*
- *Memory Allocation*
- *Variables*
- *Functions*
- *Interrupts*
- *Assembly Code*

2.4.1 C Language Specifics

This section discusses commonly asked source code issues that directly relate to the C language itself.

- *When Should I Cast Expressions?*
- *Can Implicit Type Conversions Change the Expected Results of My Expressions?*
- *How Do I Enter Non-English Characters Into My Program?*
- *How Can I Use a Variable Defined in Another Source File?*
- *How Can I Use a Function Defined in Another Source File?*

2.4.1.1 WHEN SHOULD I CAST EXPRESSIONS?

Expressions can be explicitly cast using the cast operator -- a type in round brackets, e.g., `(int)`. In all cases, conversion of one type to another must be done with caution and only when absolutely necessary.

Consider the example:

```
unsigned long l;
unsigned int i;

i = l;
```

Here, a `long` type is being assigned to an `int` type and the assignment will truncate the value in `l`. The compiler will automatically perform a type conversion from the type of the expression on the right of the assignment operator (`long`) to the type of the value on the left of the operator (`int`).This is called an implicit type conversion. The compiler typically produces a warning concerning the potential loss of data by the truncation.

A cast to type `int` is not required and should not be used in the above example if a `long` to `int` conversion was intended. The compiler knows the types of both operands and performs the conversion accordingly. If you did use a cast, there is the potential for mistakes if the code is later changed. For example, if you had:

```
i = (int)l;
```

the code works the same way; but if in the future, the type of `i` is changed to a `long`, for example, then you must remember to adjust the cast, or remove it, otherwise the contents of `l` will continue to be truncated by the assignment, which cannot be correct. Most importantly, the warning issued by the compiler will not be produced if the cast is in place.

Only use a cast in situations where the types used by the compiler are not the types that you require. For example, consider the result of a division assigned to a floating point variable:

```
int i, j;
float fl;

fl = i/j;
```

In this case, integer division is performed, then the rounded integer result is converted to a `float` format. So if `i` contained 7 and `j` contained 2, the division yields 3 and this is implicitly converted to a `float` type (3.0) and then assigned to `fl`. If you wanted the division to be performed in a `float` format, then a cast is necessary:

```
fl = (float)i/j;
```

(Casting either `i` or `j` forces the compiler to encode a floating-point division.) The result assigned to `fl` now is 3.5.

An explicit cast can suppress warnings that might otherwise have been produced. This can also be the source of many problems. The more warnings the compiler produces, the better chance you have of finding potential bugs in your code.

2.4.1.2 CAN IMPLICIT TYPE CONVERSIONS CHANGE THE EXPECTED RESULTS OF MY EXPRESSIONS?

Yes! The compiler will always use integral promotion and there is no way to disable this (see Section 4.6.1 “Integral Promotion”). In addition, the types of operands to binary operators are usually changed so that they have a common type, as specified by the C Standard. Changing the type of an operand can change the value of the final expression, so it is very important that you understand the type C Standard conversion rules that apply when dealing with binary operators. You can manually change the type of an operand by casting; see Section 2.4.1.1 “When Should I Cast Expressions?”

2.4.1.3 HOW DO I ENTER NON-ENGLISH CHARACTERS INTO MY PROGRAM?

The C standard (and accordingly, the MPLAB XC8 C compiler) does not support extended characters set in character and string literals in the source character set. See Section 4.4.7 “Constant Types and Formats” to see how these characters can be entered using escape sequences.

2.4.1.4 HOW CAN I USE A VARIABLE DEFINED IN ANOTHER SOURCE FILE?

Provided the variable defined in the other source file is not `static` (see Section 4.5.2.1.1 “Static Objects”) or `auto` (see Section 4.5.2.2 “Automatic Storage Duration Objects”), then adding a declaration for that variable into the current file will allow you to access it. A declaration consists of the keyword `extern` in addition to the type and the name of the variable, as specified in its definition, e.g.,

```
extern int systemStatus;
```

This is part of the C language. Your favorite C textbook will give you more information.

The position of the declaration in the current file determines the scope of the variable. That is, if you place the `extern` declaration inside a function, it will limit the scope of the variable to that function. If you place it outside of a function, it allows access to the variable in all functions for the remainder of the current file.

Often, declarations are placed in header files and then they are `#include`d into the C source code (see Section 4.14.1 “Preprocessor Directives”).

© 2012-2018 Microchip Technology Inc.

2.4.1.5 HOW CAN I USE A FUNCTION DEFINED IN ANOTHER SOURCE FILE?

Provided the function defined in the other source file is not `static`, then adding a declaration for that function into the current file will allow you to call it. A declaration optionally consists of the keyword `extern` in addition to the function prototype. You can omit the names of the parameters, e.g.,

```
extern int readStatus(int);
```

This is part of the C language. Your favorite C textbook will give you more information.

Often, declarations are placed in header files and then they are `#included` into the C source code (see Section 4.14.1 "Preprocessor Directives").

2.4.2 Device-Specific Features

This section discusses the code that needs to be written to set up or control a feature that is specific to Microchip PIC devices.

- *How Do I Set the Configuration Bits?*
- *How Do I Use the PIC Device's ID Locations?*
- *How Do I Determine the Cause of Reset on Mid-range Parts?*
- *How Do I Access SFRs?*
- *How Do I Place a Function Into a Unique Section?*

See also the following linked information in other sections.

- *What Do I Need to Do When Compiling to Use a Debugger?*

2.4.2.1 HOW DO I SET THE CONFIGURATION BITS?

These should be set in your code using a pragma. See Section 4.3.5 "Configuration Bit Access" for details about how these are set.

2.4.2.2 HOW DO I USE THE PIC DEVICE'S ID LOCATIONS?

There is a pragma that allows these values to be programmed (see Section 4.3.6 "ID Locations").

2.4.2.3 HOW DO I DETERMINE THE CAUSE OF RESET ON MID-RANGE PARTS?

The TO and PD bits in the STATUS register allow you to determine the cause of a Reset. However, these bits are quickly overwritten by the runtime startup code that is executed before `main()`; see Section 4.10.2 "Runtime Startup Code" for more information. You can have the STATUS register saved into a location that is later accessible from C code, so that the cause of Reset can be determined by the application after it is running again (see Section 4.10.2.4 "STATUS Register Preservation").

2.4.2.4 HOW DO I ACCESS SFRS?

The compiler ships with header files (see Section 4.3.3 "Device Header Files") that define the variables that are mapped over the top of memory-mapped SFRs. Since these are C variables, they can be used like any other C variables and no new syntax is required to access these registers.

Bits within SFRs can also be accessed. Individual bit-wide variables are defined that are mapped over the bits in the SFR. Bit-fields are also available in structures that map over the SFR as a whole. You can use either in your code (see Section 4.3.7 "Using SFRs From C Code").

The name assigned to the variable is usually the same as the name specified in the device data sheet. See Section 2.4.2.5 "How Do I Find The Names Used to Represent SFRs and Bits?" if these names are not recognized.

2.4.2.5 HOW DO I FIND THE NAMES USED TO REPRESENT SFRS AND BITS?

Special function registers, and the bits within them, are accessed via special variables that map over the register (see Section 2.4.2.4 "How Do I Access SFRs?"). However, the names of these variables sometimes differ from those indicated in the data sheet for the device you are using.

If required, you can examine the `<xc.h>` header file to find the device-specific header file that is relevant for your device. This file will define the variables that allow access to these special variables. However, an easier way to find these variable names is to look in any of the preprocessed files left behind from a previous compilation. Provided the corresponding source file included `<xc.h>`, the preprocessed file will show the definitions for all the SFR variables and bits for your target device.

If you are compiling under MPLAB X IDE, the preprocessed file(s) are left under the `build/default/production` directory of your project for regular builds, or under `build/default/debug` for debug builds. They are typically left in the source file directory if you are compiling on the command line. These files have a `.i` extension.

2.4.3 Memory Allocation

Here are questions relating to how your source code affects memory allocation.

- *How Do I Position Variables at an Address I Nominate?*
- *How Do I Place a Variable Into a Unique Section?*
- *How Do I Position a Variable Into an Address Range?*
- *How Do I Position Functions at an Address I Nominate?*
- *How Do I Place Variables in Program Memory?*
- *How Do I Place a Function Into a Unique Section?*
- *How Do I Position a Function Into an Address Range?*
- *How Do I Place a Function Into a Unique Section?*

See also the following linked information in other sections.

- *Why Are Some Objects Positioned Into Memory That I Reserved?*
- *How Do I Use High-Endurance Flash for Data, Not Code?*

2.4.3.1 HOW DO I POSITION VARIABLES AT AN ADDRESS I NOMINATE?

The easiest way to do this is to make the variable absolute by using the `__at(`*`address`*`)` construct (see Section 4.5.4 "Absolute Variables"), but you might consider also placing the variable in a unique section (see Section 4.15.3 "Changing and Linking the Allocated Section"). Absolute variables use the address you nominate in preference to the variable's symbol in generated code.

2.4.3.2 HOW DO I PLACE A VARIABLE INTO A UNIQUE SECTION?

Use the `__section()` specifier to have the variable positioned in a new section (psect). After this has been done, the section can be linked to the desired address by using the `-Wl` driver option. See Section 4.15.3 "Changing and Linking the Allocated Section" for examples of both these operations.

2.4.3.3 HOW DO I POSITION A VARIABLE INTO AN ADDRESS RANGE?

You need to move the variable into a unique psect (section), define a memory range, and then place the new section in that range.

Use the `__section()` specifier to have the variable positioned in a new section. Use the `-Wl` driver option to define a memory range and to place the new section in that range. See Section 4.15.3 "Changing and Linking the Allocated Section" for examples of all these operations.

© 2012-2018 Microchip Technology Inc.

2.4.3.4 HOW DO I POSITION FUNCTIONS AT AN ADDRESS I NOMINATE?

The easiest way to do this is to make the functions absolute by using the `__at(`*`address`*`)` construct, (see Section 4.8.4 "Changing the Default Function Allocation"), but you might consider also placing the variable in a unique section (see Section 4.15.3 "Changing and Linking the Allocated Section"). This means that the address you specify is used in preference to the function's symbol in generated code.

2.4.3.5 HOW DO I PLACE VARIABLES IN PROGRAM MEMORY?

The `const` qualifier implies that the qualified variable is read-only. As a consequence of this, any const-qualified variables with static storage duration are placed in program memory, thus freeing valuable data RAM. See Section 4.5.2 "Objects in Data Memory" for more information. Variables that are qualified `const` can also be made absolute, so they can be positioned at an address you nominate (see Section 4.5.4.2 "Absolute Objects in Program Memory").

2.4.3.6 HOW DO I PLACE A FUNCTION INTO A UNIQUE SECTION?

Use the `__section()` specifier to have the function positioned into a new section (psect). When this has been done, the section can be linked to the desired address by using the `-Wl` driver option. See Section 4.15.3 "Changing and Linking the Allocated Section" for examples of both these operations.

2.4.3.7 HOW DO I POSITION A FUNCTION INTO AN ADDRESS RANGE?

Having one or more functions located in a special area of memory might mean that you can ensure they are code protected, for example. To do this, you need to move the function into a unique section (psect), define a memory range, and then place the new section in that range.

Use the `__section()` specifier to have the function positioned into a new section. Use the `-Wl` driver option to define a memory range and to place the new section into that range. See Section 4.15.3 "Changing and Linking the Allocated Section" for examples of all these operations.

2.4.3.8 HOW DO I STOP THE COMPILER FROM USING CERTAIN MEMORY LOCATIONS?

Memory can be reserved when you build. The `-mreserve` option allow you to adjust the ranges of data and program memory, respectively, when you build (see Section 3.7.1.17 "reserve"). By default, all the available on-chip memory is available for use. However, these options allow you to reserve parts of this memory.

2.4.4 Variables

This sections examines questions that relate to the definition and usage of variables and types within a program.

- *Why Are My Floating-point Results Not Quite What I Am Expecting?*
- *How Can I Access Individual Bits of a Variable?*

See also the following linked information in other sections.

- *How Do I Share Data Between Interrupt and Main-line Code?*
- *How Do I Position Variables at an Address I Nominate?*
- *How Do I Place Variables in Program Memory?*
- *How Do I Place Variables in the PIC18 Device’s External Program Memory?*
- *How Can I Rotate a Variable?*
- *How Do I Utilize/Allocate the RAM Banks on My Device?*
- *How Do I Utilize the Linear Memory on Enhanced Mid-range PIC Devices?*
- *How Do I Find Out Where Variables and Functions Have Been Positioned?*

2.4.4.1 WHY ARE MY FLOATING-POINT RESULTS NOT QUITE WHAT I AM EXPECTING?

The size of the floating point type can be adjusted for both `float` and `double` types (see Section 3.7.14.2 “short-float” and Section 3.7.14.1 “short-double”).

Since floating-point variables only have a finite number of bits to represent the values they are assigned, they only hold an approximation of their assigned value (see Section 4.4.4 “Floating-Point Data Types”). A floating-point variable can only hold one of a set of discrete real number values. If you attempt to assign a value that is not in this set, it is rounded to the nearest value. The more bits used by the mantissa in the floating-point variable, the more values can be exactly represented in the set, and the average error due to the rounding is reduced.

Whenever floating-point arithmetic is performed, rounding also occurs. This can also lead to results that do not appear to be correct.

2.4.4.2 HOW CAN I ACCESS INDIVIDUAL BITS OF A VARIABLE?

There are several ways of doing this. The simplest and most portable way is to define an integer variable and use macros to read, set, or clear the bits within the variable using a mask value and logical operations, such as the following.

```
#define  testbit(var, bit)   ((var) & (1 <<(bit)))
#define  setbit(var, bit)    ((var) |= (1 << (bit)))
#define  clrbit(var, bit)    ((var) &= ~(1 << (bit)))
```

These, respectively, test to see if bit number, `bit`, in the integer, `var`, is set; set the corresponding `bit` in `var`; and clear the corresponding `bit` in `var`. Alternatively, a union of an integer variable and a structure with bit-fields (see Section 4.4.5.2 “Bit-Fields in Structures”) can be defined, e.g.,

```
union both {
    unsigned char byte;
    struct {
        unsigned b0:1, b1:1, b2:1, b3:1, b4:1, b5:1, b6:1, b7:1;
    } bitv;
} var;
```

This allows you to access `byte` as a whole (using var.byte), or any bit within that variable independently (using `var.bitv.b0` through `var.bitv.b7`).

Note that the compiler does support bit variables (see Section 4.4.2.1 “Bit Data Types and Variables”), as well as bit-fields in structures.

© 2012-2018 Microchip Technology Inc.

2.4.5 Functions

This section examines questions that relate to functions.

- *What is the Optimum Size For Functions?*
- *How Do I Stop An Unused Function Being Removed?*
- *How Do I Make a Function Inline?*

See also the following linked information in other sections.

- *How Can I Tell How Big a Function Is?*
- *How Do I Position Functions at an Address I Nominate?*
- *How Do I Know Which Resources Are Being Used by Each Function?*
- *How Do I Find Out Where Variables and Functions Have Been Positioned?*
- *How Do I Use Interrupts in C?*

2.4.5.1 WHAT IS THE OPTIMUM SIZE FOR FUNCTIONS?

Generally speaking, the source code for functions should be kept small, as this aids in readability and debugging. It is much easier to describe and debug the operation of a function that performs a small number of tasks. And they typically have fewer side effects, which can be the source of coding errors.

In the embedded programming world, a large number of small functions, and the calls necessary to execute them, can result in excessive memory and stack usage, so a compromise is often necessary.

The PIC10/12/16 devices employ pages in the program memory that are used to store and execute function code. Although you are able to write C functions that will generate more than one page of assembly code, functions of such a size should be avoided and split into smaller routines where possible. The assembly call and jump sequences to locations in other pages are much longer than those made to destinations in the same page. If a function is so large as to cross a page boundary, then loops (or other code constructs that require jumps within that function) can use the longer form of jump on each iteration (see Section 4.8.3 "Allocation of Executable Code").

PIC18 devices are less affected by internal memory paging and the instruction set allows for calls and jumps to any destination with no penalty. But you should still endeavor to keep functions as small as possible.

Interrupt functions must be written so that they do not exceed the size of a memory page. They cannot be split to occupy more than one page.

With all devices, the smaller the function, the easier it is for the linker to allocate it to memory without errors.

2.4.5.2 HOW DO I STOP AN UNUSED FUNCTION BEING REMOVED?

If a C function's symbol is referenced in hand-written assembly code, the function will never be removed, even if it is not called or has never had its address taken in C code.

Create an assembly source file and add this file to your project. You only have to reference the symbol in this file; so the file can contain the following

```
GLOBAL _myFunc
```

where `myFunc` is the C name of the function in question (note the leading underscore in the assembly name, see Section 4.12.3.1 "Equivalent Assembly Symbols"). This is sufficient to prevent the function removal optimization from being performed.

2.4.5.3 HOW DO I MAKE A FUNCTION INLINE?

You can ask the compiler to inline a function by using the `inline` specifier (see Section 4.8.1.2 "Inline Specifier") or `#pragma inline`. This is only a suggestion to the compiler and cannot always be obeyed. Do not confuse this specifier/pragma with the `intrinsic` pragma[1] (see Section 4.14.3.4 "The #pragma Intrinsic Directive"), which is for functions that have no corresponding source code and which will be specifically expanded by the code generator during compilation.

2.4.6 Interrupts

Interrupt and interrupt service routine questions are discussed in this section.

How Do I Use Interrupts in C?

See also the following linked information in other sections.

- *How Can I Make My Interrupt Routine Faster?*
- *How Do I Share Data Between Interrupt and Main-line Code?*

2.4.6.1 HOW DO I USE INTERRUPTS IN C?

Be aware of what sort of interrupt hardware is available on your target device. Most baseline PIC devices do not implement interrupts at all; baseline devices with interrupts and mid-range devices utilize a single interrupt vector. PIC18 devices implement two separate interrupt vector locations and use a simple priority scheme. Some PIC18 devices use an interrupt controller macro module that can use a vector table to invoke multiple interrupt functions.

In C source code, a function can be written to act as the interrupt service routine (see Section 4.9.1 "Writing an Interrupt Service Routine"). Such functions save and/or restore program context before and/or after executing the function body code and a different return instruction is used (see Section 4.9.4 "Context Switching").

Code inside the interrupt function can do anything you like, but see Section 2.6.7 "How Can I Make My Interrupt Routine Faster?" for suggestions to enhance real-time performance.

Prior to any interrupt occurring, your program must ensure that peripherals are correctly configured and that interrupts are enabled (see Section 4.9.5 "Enabling Interrupts"). On PIC18 devices, you must specify the priority of interrupt sources by writing the appropriate SFRs.

1. This specifier was originally named in-line but was changed to avoid confusion.

© 2012-2018 Microchip Technology Inc.

2.4.7 Assembly Code

This section examines questions that arise when writing assembly code as part of a C project.

- *How Should I Combine Assembly and C Code?*
- *What Do I Need Other than Instructions in an Assembly Source File?*
- *How Do I Access C Objects from Assembly Code?*
- *How Can I Access SFRs from Within Assembly Code?*
- *What Things Must I Manage When Writing Assembly Code?*

2.4.7.1 HOW SHOULD I COMBINE ASSEMBLY AND C CODE?

Ideally, any hand-written assembly should be written as separate routines that can be called. This offers some degree of protection from interaction between compiler-generated and hand-written assembly code. Such code can be placed into a separate assembly module that can be added to your project (see Section 4.12.1 "Integrating Assembly Language Modules").

If necessary, assembly code can be added in-line with C code using either of two methods (see Section 4.12.2 "Inline Assembly"). The code added in-line should ideally be limited to instructions such as `NOP`, `SLEEP` or `CLRWDT`. Macros are already provided which in-line all these instructions (see Appendix A. Library Functions). More complex in-line assembly that changes register contents and the device state can cause code failure if precautions are not taken and should be used with caution. See Section 4.7 "Register Usage" for those registers used by the compiler.

2.4.7.2 WHAT DO I NEED OTHER THAN INSTRUCTIONS IN AN ASSEMBLY SOURCE FILE?

Assembly code typically needs assembler directives as well as the instructions themselves. The operation of all the directives are described in the subsections of Section 5.2.9 "Assembler Directives". Common directives required are mentioned below.

All assembly code must be placed in a psect so it can be manipulated as a whole by the linker and placed in memory. See Section 4.15.1 "Compiler-Generated Psects" for general information on psects; see Section 5.2.9.3 "PSECT" for information on the directive used to create and specify psects.

The other commonly used directive is `GLOBAL`, defined in Section 5.2.9.1 "GLOBAL" which is used to make symbols accessible across multiple source files.

2.4.7.3 HOW DO I ACCESS C OBJECTS FROM ASSEMBLY CODE?

Most C objects are accessible from assembly code. There is a mapping between the symbols used in the C source and those used in the assembly code generated from this source. Your assembly should access the assembly-equivalent symbols which are detailed in Section 4.12.3 "Interaction between Assembly and C Code".

Instruct the assembler that the symbol is defined elsewhere by using the `GLOBAL` assembler directive (see Section 5.2.9.1 "GLOBAL"). This is the assembly equivalent of a C declaration, although no type information is present. This directive is not needed and should not be used if the symbol is defined in the same module as your assembly code.

Any C variable accessed from assembly code will be treated as if it were qualified `volatile` (see Section 4.4.8.2 "Volatile Type Qualifier"). Specifically specifying the `volatile` qualifier in C code is preferred as it makes it clear that external code can access the object.

2.4.7.4 HOW CAN I ACCESS SFRS FROM WITHIN ASSEMBLY CODE?

The safest way to gain access to SFRs in assembly code is to have symbols defined in your assembly code that equate to the corresponding SFR address. Header files are provided with the compiler so that you do not need to define these yourselves (detailed in Section 4.12.3.2 "Accessing Registers from Assembly Code").

There is no guarantee that you will be able to access symbols generated by the compilation of C code, even the code that accesses the SFR that you require.

2.4.7.5 WHAT THINGS MUST I MANAGE WHEN WRITING ASSEMBLY CODE?

When writing assembly code by hand, you assume responsibility for managing certain features of the device and formatting your assembly instructions and operands. The following list describes some of the actions you must take.

- Whenever you access a RAM variable, you must ensure that the bank of the variable is selected before you read or write the location. This is done by one or more assembly instructions. The exact code is based on the device you are using and the location of the variable. Bank selection is not be required if the object is in common memory, (which is called the access bank on PIC18 devices) or if you are using an instruction that takes a full address (such as the `movff` instruction on PIC18 devices). Check your device data sheet to see the memory architecture of your device, as well as the instructions and registers which control bank selection. Failure to select the correct bank will lead to code failure.
  The `BANKSEL` pseudo instruction can be used to simplify this process (see Section 5.2.1.2 "Bank and Page Selection").
- You must ensure that the address of the RAM variable you are accessing has been masked so that only the bank offset is being used as the instruction's file register operand. This should not be done if you are using an instruction that takes a full address (such as the `movff` instruction on PIC18 devices). Check your device data sheet to see what address operand instructions requires. Failure to mask an address can lead to a fixup error (see Section 2.7.8 "How Do I Fix a Fixup Overflow Error?") or code failure.
  The `BANKMASK` macro can truncate the address for you (see Section 4.12.3.2 "Accessing Registers from Assembly Code").
- Before you call or jump to any routine, you must ensure that you have selected the program memory page of this routine using the appropriate instructions. You can either use the `PAGESEL` pseudo instruction (see Section 5.2.1.2 "Bank and Page Selection"), or the `fcall` or `LJMP` pseudo instructions (not required on PIC18 devices) (see Section 5.2.1.8 "Long Jumps and Calls") which will automatically add page selection instructions, if required.
- You must ensure that any RAM used for storage has memory reserved. If you are only accessing variables defined in C code, then reservation is already done by the compiler. You must reserve memory for any variables you only use in the assembly code using an appropriate directive such as `DS` or `DABS` (see Section 5.2.9.11 "DS" or Section 5.2.9.12 "DABS"). It is often easier to define objects in C code rather than in assembly code.

© 2012-2018 Microchip Technology Inc.

- You must place any assembly code you write in a psect (see Section 5.2.9.3 "PSECT" for the directive to do this, and Section 4.15.1 "Compiler-Generated Psects" for general information about psects). A psect you define may need flags (options) to be specified. Take particular notice of the `delta`, `space`, `reloc` and `class` flags (see Section 5.2.9.3.4 "Delta" and Section 5.2.9.3.17 "Space" Section 5.2.9.3.15 "Reloc" and Section 5.2.9.3.3 "Class"). If these are not set correctly, compile errors or code failure will almost certainly result. If the psect specifies a class and you are happy with it being placed anywhere in the memory range defined by that class (see Section 6.2.1 "-Aclass =low-high,..."), it does not need any additional options to be linked; otherwise, you will need to link the psect using a linker option (see Section 6.2.18 "-Pspec" for the usual way to link psects and Section 3.7.12 "Mapped Linker Options" which indicates how you can specify this option without running the linker directly).
  Assembly code that is placed in-line with C code will be placed in the same psect as the compiler-generated assembly and you should not place this into a separate psect.
- You must ensure that any registers you write to in assembly code are not already in used by compiler-generated code. If you write assembly in a separate module, then this is less of an issue because the compiler will, by default, assume that all registers are used by these routines (see Section 4.7 "Register Usage"). No assumptions are made for in-line assembly (although the compiler will assume that the selected bank was changed by the assembly, see Section 4.12.2 "Inline Assembly") and you must be careful to save and restore any resources that you use (modify) and which are already in use by the surrounding compiler-generated code.

2.5 GETTING MY APPLICATION TO DO WHAT I WANT

This section provides programming techniques, applications and examples. It also examines questions that relate to making an application perform a specific task.

- *What Can Cause Glitches on Output Ports?*
- *Where Am I Allowed To Manually Link Psects?*
- *How Do I Link Bootloaders and Downloadable Applications?*
- *What Do I Need to Do When Compiling to Use a Debugger?*
- *How Can I Have Code Executed Straight After Reset?*
- *How Do I Share Data Between Interrupt and Main-line Code?*
- *How Can I Prevent Misuse of My Code?*
- *How Do I Use Printf to Send Text to a Peripheral?*
- *How Do I Setup the Oscillator in My Code?*
- *How Do I Place Variables in the PIC18 Device's External Program Memory?*
- *How Can I Implement a Delay in My Code?*
- *How Can I Rotate a Variable?*
- *How Can I Stop Variables Being Cleared at Startup?*
- *How Do I Use High-Endurance Flash for Data, Not Code?*

2.5.1 What Can Cause Glitches on Output Ports?

In most cases, this is caused by using ordinary variables to access port bits or the entire port itself. These variables should be qualified `volatile`.

The value stored in a variable mapped over a port (hence the actual value written to the port) directly translates to an electrical signal. It is vital that the values held by these variables only change when the code intends them to and that they change from their current state to their new value in a single transition (see Section 4.4.8.2 "Volatile Type Qualifier"). The compiler attempts to write to volatile variables in one operation.

2.5.2 Where Am I Allowed To Manually Link Psects?

It is recommended that the linker options for compiler-generated psects (sections) are not modified. If these must be changed or if there are user-defined psects that need special allocation, there might be device- or compiler-imposed restrictions on where these can be placed in memory.

Try to link psects in a suitable compiler linker class (as shown in Section 4.15.2 "Default Linker Classes") as the definitions for these memory ranges take into consideration any restrictions. Define your own linker class, if necessary (see Section 2.4.3.3 "How Do I Position a Variable Into an Address Range?"). Refer to Section 4.15.1 "Compiler-Generated Psects" to see the memory placement restrictions that apply to compiler-generated psects which hold similar content to your psect.

Most limitations relate to psects straddling some memory boundary, such as a data bank or program memory page. One typical limitation is that all psects holding executable code cannot straddle a device page boundary. Compiler-generated psects holding variables must also be typically linked within the data bank for which they were created. These boundaries, therefore, impose limits on the size to which the psect can grow.

© 2012-2018 Microchip Technology Inc.

2.5.3 How Do I Link Bootloaders and Downloadable Applications?

Exactly how this is done depends on the device you are using and your project requirements, but the general approach when compiling applications that use a bootloader is to allocate discrete program memory space to the bootloader and application so they have their own dedicated memory. In this way the operation of one cannot affect the other. This will require that either the bootloader or the application is offset in memory. That is, the Reset and interrupt location are offset from address 0 and all program code is offset by the same amount.

On PIC18 devices, the application code is typically offset and the bootloader is linked with no offset so that it populates the Reset and interrupt code locations. The bootloader Reset and interrupt code merely contains code which redirects control to the real Reset and interrupt code defined by the application and which is offset.

On mid-range devices, this is not normally possible to perform when interrupts are being used. Consider offsetting all of the bootloader with the exception of the code associated with Reset, which must always be defined by the bootloader. The application code can define the code linked at the interrupt location. The bootloader will need to remap any application code that attempts to overwrite the Reset code defined by the bootloader.

The option `-mcodeoffset`, (see Section 3.7.1.3 "codeoffset"), allows the program code (Reset and vectors included) to be moved by a specified amount. The option also restricts the program from using any program memory from address 0 (Reset vector) to the offset address. Always check the map file (see Section 3.7.12 "Mapped Linker Options"), to ensure that nothing remains in reserved areas.

The contents of the HEX file for the bootloader can be merged with the code of the application by adding the HEX file as a project file, either on the command line, or in MPLAB X IDE. This results in a single HEX file that contains the bootloader and application code in the one image. HEX files are merged by the HEXMATE application (see Section 7.3 "HEXMATE"). Check for warnings from this application about overlap, which can indicate that memory is in use by both bootloader and the downloadable application.

2.5.4 What Do I Need to Do When Compiling to Use a Debugger?

You can use debuggers, such as the MPLAB ICD4 or REAL ICE, to debug code built with the MPLAB XC8 compiler. These debuggers use some of the data and program memory of the device for its own use, so it is important that your code does not also use these resources.

There is a command-line option (see Section 3.7.1.6 "debugger"), that can be used to tell the compiler which debugger is to be used. The compiler can then reserve the memory used by the debugger so that your code will not be located in these locations.

In the MPLAB X IDE, the appropriate debugger option is specified if you perform a debug build. It will not be specified if you perform a regular Build Project or Clean and Build.

Since some device memory is being used up by the debugger, there is less available for your program and it is possible that your code or data might not fit in the device when a debugger is selected.

Note that which specific memory locations used by the debuggers is an attribute of MPLAB X IDE, not the device. If you move a project to a new version of the IDE, the resources required can change. For this reason, you should not manually reserve memory for the debugger, or make any assumptions in your code as to what memory is used. A summary of the debugger requirements is available in the MPLAB X IDE help files.

To verify that the resources reserved by the compiler match those required by the debugger, do the following. Compile your code with and without the debugger selected and keep a copy of the map file produced for both builds. Compare the linker options in the map files and look for changes in the `-A` options (see Section 6.2.1 "-Aclass =low-high,..."). For example, the memory defined for the `CODE` class with no debugger might be specified by this option:

```
-ACODE=00h-0FFh,0100h-07FFh,0800h-0FFFhx3
```

and with the ICD3 selected as the debugger, it becomes:

```
-ACODE=00h-0FFh,0100h-07FFh,0800h-0FFFhx2,01800h-01EFFh
```

This shows that a memory range from 1F00 to 1FFF has been removed by the compiler and cannot be used by your program (See also Section 2.6.16 "Why Are Some Objects Positioned Into Memory That I Reserved?").

2.5.5 How Can I Have Code Executed Straight After Reset?

A special hook has been provided so you can easily add special "powerup" assembly code that will be linked to the Reset vector (see Section 4.10.3 "The Powerup Routine"). This code will be executed before the runtime startup code, which in turn is executed before the `main()` function (see Section 4.10 "Main, Runtime Startup and Reset").

2.5.6 How Do I Share Data Between Interrupt and Main-line Code?

Variables accessed from both interrupt and main-line code can easily become corrupted or mis-read by the program. The `volatile` qualifier (see Section 4.4.8.2 "Volatile Type Qualifier") tells the compiler to avoid performing optimizations on such variables. This will fix some of the issues associated with this problem.

The other issues relates to whether the compiler/device can access the data atomically. With 8-bit PIC devices, this is rarely the case. An atomic access is one where the entire variable is accessed in only one instruction. Such access is uninterruptible. You can determine if a variable is being accessed atomically by looking at the assembly code the compiler produces in the assembly list file (see Section 5.4 "Assembly List Files"). If the variable is accessed in one instruction, it is atomic. Since the way variables are accessed can vary from statement to statement it is usually best to avoid these issues entirely by disabling interrupts prior to the variable being accessed in main-line code, then re-enable the interrupts afterwards (see Section 4.9.5 "Enabling Interrupts").

2.5.7 How Can I Prevent Misuse of My Code?

First, many devices with flash program memory allow all or part of this memory to be write protected. The device Configuration bits need to be set correctly for this to take place; see Section 4.3.5 "Configuration Bit Access" and your device data sheet.

Second, you can prevent third-party code being programmed at unused locations in the program memory by filling these locations with a value rather than leaving them in an unprogrammed state. You can chose a fill value that corresponds to an instruction or set all the bits so as the values cannot be further modified. (Consider what will happen if your program somehow reaches and starts executing from these filled values.)

The compiler's HEXMATE utility (see Section 7.3 "HEXMATE") has the capability to fill unused locations and this operation can be requested using a command-line driver option (see Section 3.7.11.8 "fill"). As HEXMATE only works with HEX files, this feature is only available when producing HEX/COF file outputs (as opposed to binary, for example), which is the default operation.

And last, if you wish to make your library files or intermediate p-code files available to others but do not want the original source code to be viewable, then you can obfuscate the files using the `-mshroud`option (see Section 3.7.1.20 "shroud").

© 2012-2018 Microchip Technology Inc.

2.5.8 How Do I Use Printf to Send Text to a Peripheral?

The `printf` function does two things: it formats text based on the format string and placeholders you specify, and sends (prints) this formatted text to a destination (or stream); see Appendix A. Library Functions. The `printf` function performs all the formatting; then it calls a helper function, called `putch`, to send each byte of the formatted text. By customizing the `putch` function you can have `printf` send data to any peripheral or location (see Section 4.12 “Mixing C and Assembly Code”). You can choose the `printf` output go to an LCD, SPI module or USART, for example.

A stub for the `putch` function can be found in the compiler’s `sources` directory. Copy it into your project then modify it to send the single byte parameter passed to it to the required destination. Before you can use `printf`, peripherals that you use will need to be initialized in the usual way. Here is an example of putch for a USART on a mid-range device.

```
void putch(char data) {
  while( ! TXIF)  // check buffer
    continue;     // wait till ready
  TXREG = data;   // send data
}
```

You can get `printf` to send to one of several destinations by using a global variable to indicate your choice. Have the `putch` function send the byte to one of several destinations based on the contents of this variable.

2.5.9 How Do I Setup the Oscillator in My Code?

All PIC devices have several oscillator modes that must be selected by programming the device’s configuration bits in your project. See your device data sheet for information on the modes and Section 4.3.5 “Configuration Bit Access” for assistance with programming the configuration bits.

Some devices have an OSCCON register, which further controls such runtime attributes as clock sources and internal clock frequencies. In C source, this register can be written to in the usual way, based on information in your device data sheet.

Some devices allow the internal oscillator to be tuned at runtime via the OSCTUNE register. Other devices allow for calibration of their internal oscillators using values pre-programmed into the device. The runtime startup code generated by the compiler, (see Section 4.10.2 “Runtime Startup Code”), will by default provide code that performs oscillator calibration. This can be disabled, if required, using an option (see Section 3.7.1.14 “osccal”).

If you intend to use some of the compiler’s built-in delay functions, you will need to set the `_XTAL_FREQ` macro, which indicates the system frequency to the compiler. This macro in no way affects the operating frequency of the device (see Section “__DELAY_MS, __DELAY_US, __delaywdt_us, __delaywdt_Ms”).

2.5.10 How Do I Place Variables in the PIC18 Device’s External Program Memory?

If all you mean to do is place read-only variables in program memory, qualify them as `const` (see Section 4.5.2 “Objects in Data Memory”). If you intend the variables to be located in the external program memory then use the `__far` qualifier and specify the memory using the `-mram` option (see Section 3.7.1.16 “ram”). The compiler will allow `__far`-qualified variables to be modified. Note that the time to access these variables will be longer than for variables in the internal data memory. The access mode to external memory can be specified with an option (see Section 3.7.1.9 “emi”).

2.5.11 How Can I Implement a Delay in My Code?

If an accurate delay is required, or if there are other tasks that can be performed during the delay, then using a timer to generate an interrupt is the best way to proceed.

If these are not issues in your code, then you can use the compiler's in-built delay pseudo-functions: `_delay`, `__delay_ms` or `__delay_us`; see Appendix A. Library Functions. These all expand into in-line assembly instructions or a (nested) loop of instructions that will consume the specified number of cycles or time. The delay argument must be a constant and less than 50,463,240.

Note that these code sequences will only use the `nop` instruction and/or instructions which form a loop. The alternate versions of these pseudo-functions, e.g., `_delaywdt`, can use the `clrwdt` instruction as well.

2.5.12 How Can I Rotate a Variable?

The C language does not have a rotate operator, but rotations can be performed using the shift and bitwise OR operators. Since the PIC devices have a rotate instruction, the compiler will look for code expressions that implement rotates (using shifts and ORs) and use the rotate instruction in the generated output wherever possible (see Section 4.6.2 "Rotation").

2.5.13 How Can I Stop Variables Being Cleared at Startup?

Use the `__persistent` qualifier (see Section 4.4.9.5 "__persistent Type Qualifier"), which will place the variables in a different psect that is not cleared by the runtime startup code.

2.5.14 How Do I Use High-Endurance Flash for Data, Not Code?

For devices that implement this Flash in the program memory space, it will need to be reserved so that the compiler does not use it for executable code (see Section 2.4.3.8 "How Do I Stop the Compiler From Using Certain Memory Locations?").

© 2012-2018 Microchip Technology Inc.

2.6 UNDERSTANDING THE COMPILATION PROCESS

This section tells you how to find out what the compiler did during the build process, how it encoded output code, where it placed objects, etc. It also discusses the features that are supported by the compiler.

- *What's the Difference Between the Free, Standard and PRO Modes?*
- *How Can I Make My Code Smaller?*
- *How Can I Reduce RAM Usage?*
- *How Can I Make My Code Faster?*
- *How Can I Speed Up Programming Times*
- *How Does the Compiler Place Everything in Memory?*
- *How Can I Make My Interrupt Routine Faster?*
- *How Big Can C Variables Be?*
- *How Do I Utilize/Allocate the RAM Banks on My Device?*
- *How Do I Utilize the Linear Memory on Enhanced Mid-range PIC Devices?*
- *What Devices are Supported by the Compiler?*
- *How Do I Know What Code the Compiler Is Producing?*
- *How Can I Tell How Big a Function Is?*
- *How Do I Know Which Resources Are Being Used by Each Function?*
- *How Do I Find Out Where Variables and Functions Have Been Positioned?*
- *Why Are Some Objects Positioned Into Memory That I Reserved?*
- *How Do I Know How Much Memory Is Still Available?*
- *How Do I Use Library Files in My Project?*
- *What Optimizations Are Employed by the Compiler?*
- *Why Do I Get Out-of-memory Errors When I Select a Debugger?*
- *How Do I Know Which Stack Model the Compiler Has Assigned to a Function?*
- *How Do I Know What Value Has Been Programmed in the Configuration Bits or ID Location?*

See also the following linked information in other sections.

- *How Do I Find Out What an Warning/Error Message Means?*
- *What is Different About an MPLAB X IDE Debug Build?*
- *How Do I Stop An Unused Function Being Removed?*
- *How Do I Build Libraries?*

2.6.1 What's the Difference Between the Free, Standard and PRO Modes?

These modes (see Section 1.2 "Compiler Description and Documentation") mainly differ in the optimizations that are performed when compiling. Compilers operating in Free (formerly called Lite) and Standard mode can compile for all the same devices as supported by the Pro mode. The code compiled in Free and Standard mode can use all the available memory for the selected device. What will be different is the size and speed of the generated compiler output. Free mode output will be much less efficient when compared to that produced in Standard mode, which in turn will be less efficient than that produce when in Pro mode.

All these modes use the OCG compiler framework, so the entire C program is compiled in one step and the source code does not need many non-standard extensions.

2.6.2 How Can I Make My Code Smaller?

There are a number of ways that this can be done, but results vary from one project to the next. Use the assembly list file, (see Section 5.4 "Assembly List Files"), to observe the assembly code produced by the compiler to verify that the following tips are relevant to your code.

Use the smallest data types possible as less code is needed to access these. (This also reduces RAM usage.) Note that a `bit` type and non-standard 24-bit integer type (`short long`) exists for this compiler. Avoid multi-bit fields whenever possible. The code used to access these can be very large. See Section 4.4 "Supported Data Types and Variables" for all data types and sizes.

There are two sizes of floating-point type, as well, and these are discussed in the same section. Avoid floating-point if at all possible. Consider writing fixed-point arithmetic code.

Use unsigned types, if possible, instead of signed types; particularly if they are used in expressions with a mix of types and sizes. Try to avoid an operator acting on operands with mixed sizes whenever possible.

Whenever you have a loop or condition code, use a "strong" stop condition, i.e., the following:

```
for(i=0; i!=10; i++)
```

is preferable to:

```
for(i=0; i<10; i++)
```

A check for equality (== or `!=`) is usually more efficient to implement than the weaker < comparison.

In some situations, using a loop counter that decrements to zero is more efficient than one that starts at zero and counts up by the same number of iterations. This is more likely to be the case if the loop index is a byte-wide type. So you might be able to rewrite the above as:

```
for(i=10; i!=0; i--)
```

There might be a small advantage in changing the order of function parameters so that the first parameter is byte sized. A register is used if the first parameter is byte-sized. For example consider:

```
char calc(char mode, int value);
```

over

```
char calc(int value, char mode);
```

Ensure that all optimizations are enabled (see Section 3.7.6 "Options for Controlling Optimization"). Be aware of what optimizations the compiler performs (see Section 4.13 "Optimizations" and Section 5.3 "Assembly-Level Optimizations") so you can take advantage of them and don't waste your time manually performing optimizations in C code that the compiler already handles, e.g., don't turn a multiply-by-4 operation into a shift-by-2 operation as this sort of optimization is already detected.

© 2012-2018 Microchip Technology Inc.

2.6.3 How Can I Reduce RAM Usage?

Use the smallest data types possible. (This also reduces code size as less code is needed to access these.) Note that a `__bit` type and non-standard 24-bit integer type (`__int24` and `__uint24`) exists for this compiler. See Section 4.4 "Supported Data Types and Variables" for all data types and sizes. There are two sizes of floating-point type, as well, and these are discussed in the same section.

Consider using `auto` variables over global or `static` variables as there is the potential that these can share memory allocated to other `auto` variables that are not active at the same time. Memory allocation of auto variables is made on a compiled stack (described in Section 4.5.2.2 "Automatic Storage Duration Objects").

Rather than pass large objects to or from, functions pass pointers which reference these objects. This is particularly true when larger structures are being passed, but there might be RAM savings to be made even when passing `long` variables.

Objects that do not need to change throughout the program can be located in program memory using the `const` qualifier (see Section 4.4.8.1 "Const Type Qualifier" and Section 4.5.2 "Objects in Data Memory"). This frees up precious RAM, but slows execution.

Ensure that all optimizations are enabled (see Section 3.7.6 "Options for Controlling Optimization"). Be aware of which optimizations the compiler performs (see Section 4.13 "Optimizations"), so that you can take advantage of them and don't waste your time manually performing optimizations in C code that the compiler already handles.

2.6.4 How Can I Make My Code Faster?

To a large degree, smaller code is faster code, so efforts to reduce code size often decrease execution time (see Section 2.6.2 "How Can I Make My Code Smaller?" and Section 2.6.7 "How Can I Make My Interrupt Routine Faster?"). However, there are ways some sequences can be sped up at the expense of increased code size.

One of the compiler optimization settings is for speed (the alternate setting is for space), so ensure this is selected (see Section 3.7.6 "Options for Controlling Optimization"). This will use alternate output in some instances that is faster, but larger.

Some library multiplication routines operate faster when one of their operands is a smaller value. See Section 4.3.9 "Multiplication" for more information on how to take advantage of this.

Generally, the biggest gains to be made in terms of speed of execution come from the algorithm used in a project. Identify which sections of your program need to be fast. Look for loops that might be linearly searching arrays and choose an alternate search method such as a hash table and function. Where results are being recalculated, consider if they can be cached.

2.6.5 How Can I Speed Up Programming Times

The linker can allocate sections to both ends of program memory: some sections initially placed at a low address and built up through memory; other sections assembled at a high address and extended down. This does not affect code operation and makes linking easier, but it can produce a HEX file covering the entire device memory space. Programming this HEX file into the device may take a long time.

To reduce programming times in this situation, instruct the linker to not use all the device's program memory. Use the `-mreserve` option to reserve the upper part of program memory (see Section 3.7.1.17 "reserve").

2.6.6 How Does the Compiler Place Everything in Memory?

In most situations, assembly instructions and directives associated with both code and data are grouped into sections, called psects, and these are then positioned into containers that represent the device memory. An introductory explanation into this process is given in Section 4.15.1 "Compiler-Generated Psects". The exception is for absolute variables (see Section 4.5.4 "Absolute Variables"), which are placed at a specific address when they are defined and which are not placed in a psect.

2.6.7 How Can I Make My Interrupt Routine Faster?

Consider suggestions made in Section 2.6.2 "How Can I Make My Code Smaller?" (code size) for any interrupt code. Smaller code is often faster code.

In addition to the code you write in the ISR there is the code the compiler produces to switch context. This is executed immediately after an interrupt occurs and immediately before the interrupt returns, so must be included in the time taken to process an interrupt (see Section 4.9.4 "Context Switching"). When the compiler is operating in Pro mode, this code is optimal, in that only registers used in the ISR will be saved by this code. Thus, the fewer registers that are used in your ISR means that potentially less context switch code will be executed. Register use increases with the complexity of code, so avoid complex statements and calls to functions that might also contain complex code. Use the assembly list file to see which registers are being used by the compiler in the interrupt code (see Section 5.4 "Assembly List Files").

Mid-range devices have only a few registers that are used by the compiler, and there is little context switch code. Some devices save context automatically into shadow registers, which further reduces (or eliminates entirely) the compiler-generated switch code (see Section 4.7 "Register Usage").

Consider having the ISR simply set a flag and return. The flag can then be checked in main-line code to handle the interrupt. This has the advantage of moving the complicated interrupt-processing code out of the ISR so that it no longer contributes to its register usage. Always use the `volatile` qualifier (see Section 4.4.8.2 "Volatile Type Qualifier" for variables shared by the interrupt and main-line code; see Section 2.5.6 "How Do I Share Data Between Interrupt and Main-line Code?").

2.6.8 How Big Can C Variables Be?

This question specifically relates to the size of individual C objects, such as arrays or structures. The total size of all variables is another matter.

To answer this question you need to know in which memory space the variable will be located. Objects qualified `const` will be located in program memory; other objects will be placed in data memory. Program memory object sizes are discussed in Section 4.5.3.1 "Object Size Limitations". Objects in data memory are broadly grouped into autos and non-autos and the size limitations of these objects (see Section 4.5.2.2.1 "Object Size Limits" and Section 4.5.2.1.2 "Object Size Limits").

2.6.9 How Do I Utilize/Allocate the RAM Banks on My Device?

The compiler will automatically use all the available RAM banks on the device you are programming. It is only if you wish to alter the default memory allocation that you need take any action. Special bank qualifiers (see Section 4.4.9.1 "__bank() Type Qualifier"), and an option (see Section 3.7.1.1 "addrqual") to indicate how these qualifiers are interpreted are used to manually allocate variables.

Note that there is no guarantee that all the memory on a device can be utilized as data and code is packed in sections, or psects.

© 2012-2018 Microchip Technology Inc.

2.6.10 How Do I Utilize the Linear Memory on Enhanced Mid-range PIC Devices?

The linear addressing mode is a means of accessing the banked data memory as one contiguous and linear block (see Section 4.5.1 "Address Spaces"). Use of the linear memory is fully automatic. Objects that are larger than a data bank can be defined in the usual way and will be accessed using the linear addressing mode (see Section 4.5.2.2.1 "Object Size Limits"). If you define absolute objects at a particular location in memory, you can use a linear address if you prefer, or the regular banked address (see Section 4.5.4.1 "Absolute Objects in Data Memory").

2.6.11 What Devices are Supported by the Compiler?

Support for new devices usually takes place with each compiler release. To find whether a device is supported by your compiler, you can do several things (see also, Section 4.3.1 "Device Support").

- HTML listings are provided in the compiler's `docs` directory. Open these in your favorite web browser. They are called `pic_chipinfo.html` and `pic18_chipinfo.html`.
- Run the compiler driver on the command line (see Section 3.2 "Invoking the Compiler") with the `-target-help` option; (see Section 3.7.2.8 "print-devices"). A full list of all devices is printed to the screen.

2.6.12 How Do I Know What Code the Compiler Is Producing?

The assembly list file (see Section 5.4 "Assembly List Files") shows the assembly output for almost the entire program, including library routines linked in to your program, as well a large amount of the runtime startup code (see Section 4.10.2 "Runtime Startup Code"). The list file is produced by default if you are using MPLAB X IDE. If you are using the command-line, the option `-Wa,-a` will produce this file for you (see Section 3.7.10 "Mapped Assembler Options"). The assembly list file will have a `.lst` extension.

The list file shows assembly instructions, some assembly directives and information about the program, such as the call graph (see Section 5.4.6 "Call Graph"), pointer reference graph (see Section 5.4.5 "Pointer Reference Graph"), and information for every function. Not all assembly directives are shown in the list file if the assembly optimizers are enabled (they are produced in the intermediate assembly file). Temporarily disable the assembly optimizers (see Section 3.7.6 "Options for Controlling Optimization"), if you wish to see all the assembly directives produced by the compiler.

2.6.13 How Can I Tell How Big a Function Is?

Information that includes the size of functions is presented in the map file. Look for the header "MODULE INFORMATION" near the bottom of the file. This information is discussed in Section 6.4.2.8 "Module Information".

2.6.14 How Do I Know Which Resources Are Being Used by Each Function?

In the assembly list file there is information printed for every C function, including library functions (see Section 5.4 "Assembly List Files"). This information indicates what registers the function used, what functions it calls (this is also found in the call graph; see Section 5.4.6 "Call Graph" and how many bytes of data memory it requires. Note that auto, parameter and temporary variables used by a function can overlap with those from other functions as these are placed in a compiled stack by the compiler (see Section 4.5.2.2 "Automatic Storage Duration Objects").

2.6.15 How Do I Find Out Where Variables and Functions Have Been Positioned?

You can determine where variables and functions have been positioned from either the assembly list file (see Section 5.4 "Assembly List Files"), or the map file (see Section 6.4 "Map Files"). Only symbols associated with objects with static storage duration are shown in the map file; all symbols (including those with automatic storage duration) are listed in the assembly list file, but only for the code represented by that list file. Each assembly module has its own list file.

There is a mapping between C identifiers and the symbols used in assembly code, which are the symbols shown in both of these files (see Section 4.12.3.1 "Equivalent Assembly Symbols"). The symbol associated with a variable is assigned the address of the lowest byte of the variable; for functions it is the address of the first instruction generated for that function.

2.6.16 Why Are Some Objects Positioned Into Memory That I Reserved?

The memory reservation options (see Section 2.4.3.6 "How Do I Place a Function Into a Unique Section?") will adjust the range of addresses associated with classes used by the linker. Most variables and function are placed into sections (see Section 4.15.1 "Compiler-Generated Psects") that are linked anywhere inside these class ranges and so are affected by these reservation options.

Some sections are explicitly placed at an address rather than being linked anywhere in an address range, e.g., the sections that holds the code to be executed at Reset is always linked to address 0 because that is where the Reset location is defined to be for 8-bit devices. Such a section will not be affected by the `-mrom` option, even if you use it to reserve memory address 0. Sections that hold code associated with Reset and interrupts can be shifted using the `-mcodeoffset` option (see Section 3.7.1.3 "codeoffset").

Check the assembly list file (see Section 5.4 "Assembly List Files") to determine the names of sections that hold objects and code. Check the linker options in the map file (see Section 6.4 "Map Files"), to see if psects have been linked explicitly or if they are linked anywhere in a class. See also, the linker options `-p` (Section 6.2.18 "-Pspec") and `-A` (Section 6.2.1 "-Aclass =low-high,...").

© 2012-2018 Microchip Technology Inc.

2.6.17 How Do I Know How Much Memory Is Still Available?

Although the memory summary printed by the compiler after compilation (see Section 3.7.12 "Mapped Linker Options" options), or the memory display available in MPLAB X IDE both indicate the amount of memory used and the amount still available, neither of these features indicate whether this memory is one contiguous block or broken into many small chunks. Small blocks of free memory cannot be used for larger objects and so out-of-memory errors can be produced even though the total amount of memory free is apparently sufficient for the objects to be positioned (see Section 2.7.6 "How Do I Fix a "Can't find space..." Error?").

The "UNUSED ADDRESS RANGES" section (see Section 6.4.2.5 "Unused Address Ranges") in the map file indicates exactly what memory is still available in each linker class. It also indicated the largest contiguous block in that class if there are memory bank or page divisions.

2.6.18 How Do I Use Library Files in My Project?

See Section 2.3.5 "How Do I Build Libraries?" for information on how you build your own library files. The compiler will automatically include any applicable standard library into the build process when you compile, so you never need to control these files.

To use one or more library files that were built by yourself or a colleague, include them in the list of files being compiled on the command line. The library files can be specified in any position in the file list relative to the source files, but if there is more than one library file, they will be searched in the order specified in the command line. For example:

```
xc8-cc -mcpu=16f1937 main.c int.c lcd.a
```

If you are using MPLAB X IDE to build a project, add the library file(s) to the Libraries folder that will shown in your project, in the order in which they should be searched. The IDE will ensure that they are passed to the compiler at the appropriate point in the build sequence.

2.6.19 What Optimizations Are Employed by the Compiler?

Optimizations are employed at both the C and assembly level of compilation. This is described in Section 4.13 "Optimizations" and Section 5.3 "Assembly-Level Optimizations" respectively. The options that control optimization are described in Section 3.7.6 "Options for Controlling Optimization".

2.6.20 Why Do I Get Out-of-memory Errors When I Select a Debugger?

If you use a hardware tool debugger, such as the REAL ICE or ICD3, these require memory for the on-board debug executive. When you select a debugger using the compiler's `-mdebugger` option (Section 3.7.1.6 "debugger"), or the IDE equivalent, the memory required for debugging is removed from that available to your project (see Section 2.5.4 "What Do I Need to Do When Compiling to Use a Debugger?").

2.6.21 How Do I Know Which Stack Model the Compiler Has Assigned to a Function?

Look in the function information section in the assembly list file (see Section 5.4.3 "Function Information"). The last line of this block will indicate whether the function uses a reentrant or non-reentrant model.

2.6.22 How Do I Know What Value Has Been Programmed in the Configuration Bits or ID Location?

Check the file `startup.s` (see Section 3.4.2 "Startup and Initialization"). This contains the output of the `#pragma config` directive. You will see the numerical value programmed to the appropriate locations. In the following example, the configuration value programmed is 0xFFBF. A breakdown of what this value means is also printed.

```
; Config register CONFIG @ 0x2007
;       BOREN = OFF, BOR disabled
; ...
;       PWRTE = 0x1, unprogrammed default

        psect   config
                org 0x0
                dw 0xFFBF
```

© 2012-2018 Microchip Technology Inc.

2.7 FIXING CODE THAT DOES NOT WORK

This section examines issues relating to projects that do not build due to compiler errors, or those that build, but do not work as expected.

- *How Do I Find Out What an Warning/Error Message Means?*
- *How Do I Find the Code that Caused Compiler Errors or Warnings in My Program?*
- *How Can I Stop Spurious Warnings From Being Produced?*
- *Why Can't I Even Blink an LED?*
- *How Do I Know If the Hardware Stack Has Overflowed?*
- *How Do I Fix a "Can't find space..." Error?*
- *How Do I Fix a "Can't generate code..." Error?*
- *How Do I Fix a Fixup Overflow Error?*
- *What Can Cause Corrupted Variables and Code Failure When Using Interrupts?*

2.7.1 How Do I Find Out What an Warning/Error Message Means?

Each warning or error message has a description and possibly sample code that might trigger such an error, listed in the messages chapter (see Appendix B. Error and Warning Messages).

2.7.2 How Do I Find the Code that Caused Compiler Errors or Warnings in My Program?

In most instances, where the error is a syntax error relating to the source code, the message produced by the compiler indicates the offending line of code (see Section 3.6 "Compiler Messages"). If you are compiling in MPLAB X IDE, then you can double-click the message and have the editor take you to the offending line. But identifying the offending code is not always so easy.

In some instances, the error is reported on the line of code following the line that needs attention. This is because a C statement is allowed to extend over multiple lines of the source file. It is possible that the compiler cannot be able to determine that there is an error until it has started to scan to statement following. So in the following code

```
input = PORTB   // oops - forgot the semicolon
if(input>6)
  // ...
```

The missing semicolon on the assignment statement will be flagged on the following line that contains the `if()` statement.

In other cases, the error might come from the assembler, not the code generator. If the assembly code was derived from a C source file then the compiler will try to indicate the line in the C source file that corresponds to the assembly that is at fault. If the source being compiled is an assembly module, the error directly indicates the line of assembly that triggered the error. In either case, remember that the information in the error relates to some problem is the assembly code, not the C code.

Finally, there are errors that do not relate to any particular line of code at all. An error in a compiler option or a linker error are examples of these. If the program defines too many variables, there is no one particular line of code that is at fault; the program as a whole uses too much data. Note that the name and line number of the last processed file and source can be printed in some situations even though that code is not the direct source of the error.

To determine the application that generated the error or warning, check the message section of the manual, see Appendix B. Error and Warning Messages. At the top of each message description, on the right in brackets, is the name of the application that produced this message. Knowing the application that produced the error makes it easier to track down the problem. The compiler application names are indicated in Section 3.3 "The Compilation Sequence". If you need to see the assembly code generated by the compiler, look in the assembly list file (see Section 5.4 "Assembly List Files"). For information on where the linker attempted to position objects, see the map file discussed in Section 6.4 "Map Files".

2.7.3 How Can I Stop Spurious Warnings From Being Produced?

Warnings indicate situations that could possibly lead to code failure. In many situations the code is valid and the warning is superfluous. Always check your code to confirm that it is not a possible source of error and in cases where this is so, there are several ways that warnings can be hidden.

- The warning level threshold can be adjusted so that only warnings of a certain importance are printed (see Section 3.6.4.1 "Disabling Messages").
- All warnings with a specified ID can be inhibited.
- In some situations, a pragma can be used to inhibit a warning with a specified ID for certain lines of source code (see Section 4.14.3.11 "The #pragma warning Directive").

2.7.4 Why Can't I Even Blink an LED?

Even if you have set up the TRIS register and written a value to the port, there are several things that can prevent such a seemingly simple program from working.

- Make sure that the device's Configuration registers are set up correctly (see Section 4.3.5 "Configuration Bit Access"). Make sure that you explicitly specify every bit in these registers and don't just leave them in their default state. All the configuration features are described in your device data sheet. If the Configuration bits that specify the oscillator source are wrong, for example, the device clock cannot even be running.
- If the internal oscillator is being used, in addition to Configuration bits there can be SFRs you need to initialize to set the oscillator frequency and modes, see Section 4.3.7 "Using SFRs From C Code" and your device data sheet.
- Either turn off the Watch Dog Timer in the Configuration bits or clear the Watch Dog Timer in your code (see Section Appendix A. "Library Functions") so that the device does not reset. If the device is resetting, it can never reach the lines of code in your program that blink the LED. Turn off any other features that can cause device Reset until your test program is working.
- The device pins used by the port bits are often multiplexed with other peripherals. A pin might be connected to a bit in a port, or it might be an analog input, or it might the output of a comparator, for example. If the pin connected to your LED is not internally connected to the port you are using, then your LED will never operate as expected. The port function tables shown in your device data sheets will show other uses for each pin that will help you identify peripherals to investigate.

© 2012-2018 Microchip Technology Inc.

- Make sure you do not have a "read-modify-write" problem. If the device you are using does not have a separate "latch" register (as is the case with mid-range PIC devices) this problem can occur, particularly if the port outputs are driving large loads, such as an LED. You can see that setting one bit turns off another or other unusual events. Create your own latch by using a temporary variable. Rather than read and write the port directly, make modifications to the latch variable. After modifications are complete, copy the latch as a whole to the port. This means you are never reading the port to modify it. Check the device literature for more detailed information.

2.7.5 How Do I Know If the Hardware Stack Has Overflowed?

An 8-bit PIC device has a limited hardware stack that is used only for function (and interrupt function) return addresses (see Section 4.3.4 "Stacks"). If the nesting of function calls and interrupts is too deep, the stack will overflow (wraps around and overwrites previous entries). Code will then fail at a later point – sometimes much later in the call sequence – when it accesses the corrupted return address.

The compiler attempts to track stack depth and, when required, swap to a method of calling that does not need the hardware stack (PIC10/12/16 devices only). You have some degree of control over what happens when the stack depth has apparently overflowed, see Section 3.7.1.22 "stackcall" for the `-mstackcall` option.

A call graph shows the call hierarchy and depth that the compiler has determined. This graph is shown in the assembly list file. To understand the information in this graph, see Section 5.4.6 "Call Graph".

Since the runtime behavior of the program cannot be determined by the compiler, it can only assume the worst case and can report that overflow is possible even though it is not. However, no overflow should go undetected if the program is written entirely in C. Assembly code that uses the stack is not considered by the compiler and this must be taken into account.

2.7.6 How Do I Fix a "Can't find space..." Error?

There are a number of different variants of this message, but all essentially imply a similar situation. They all relate to there being no free space large enough to place a block of data or instructions. Due to memory paging, banking or other fragmentation, this message can be issued when seemingly there is enough memory remaining. See Appendix B. Error and Warning Messages for more information on your particular error number.

2.7.7 How Do I Fix a "Can't generate code..." Error?

This is a catch-all message which is generated if the compiler has exhausted all possible means of compiling a C expression, see Appendix B. Error and Warning Messages. It does not usually indicate a fault in your code. The inability to compile the code can be a deficiency in the compiler, or an expression that requires more registers or resources than are available at that point in the code. This is more likely to occur on baseline devices. In any case, simplifying the offending expression, or splitting a statement into several smaller statements, usually allows the compilation to continue. You may need to use another variable to hold the intermediate results of complicated expressions.

2.7.8 How Do I Fix a Fixup Overflow Error?

Fixup – the linker action of replacing a symbolic reference with an actual address – can overflow if the address assigned to the symbol is too large to fit in the address field of an assembly instruction. Most 8-bit PIC assembly instructions specify a file address that is an offset into the currently selected memory bank. If a full unmasked address is specified with these instructions, the linker will be unable to encode the large address value into the instruction and this error will be generated. For example, a mid-range device instruction only allows for file addresses in the range of 0 to 0x7F. However, if such a device has 4 data banks of RAM, the addresses of variables can range from 0 to 0x1FF.

For example, if the symbol of a variable that will be located at address 0x1D0 has been specified with one of these instructions, then when the symbol is replaced with its final value, this value will not fit in the address field of the instruction.

Many of the jump and call instructions also take a destination operand that is a truncated address. (The PIC18 call and goto instructions work with a full address, but the branch and relative call instructions do not.) If the destination label to any of these instructions is not masked, a fixup error can result.

The fixup process applies to the operands of assembler directives, as well as instructions; so if the operand to a directive overflows, a fixup error can also result. For example, if the symbol `error` is resolved by the linker to be the value 0x238, the directive:

```
DB error
```

which expects a byte value, will generate a fixup overflow error.

In most cases, fixup errors are caused by hand-written assembly code. When writing assembly, it is the programmer's responsibility to add instructions to select the destination bank or page, and then mask the address being used in the instruction (see Section 2.4.7.5 "What Things Must I Manage When Writing Assembly Code?").

In some situations assembly code generated from C code can produce a fixup overflow message. Typically this will be related to jumps that are out of range. C `switch` statements that have become too large can trigger such a message. Changing how a compiler-generated psect is linked can also cause fixup overflow, as the new psect location may break an assumption made by the compiler.

It is important to remember that this is an issue with an assembly instruction, and that you need to find the instruction at fault before you can proceed. See the relevant error number in Appendix B. Error and Warning Messages for specific details about how to track down the offending instruction.

2.7.9 What Can Cause Corrupted Variables and Code Failure When Using Interrupts?

This is usually caused by having variables used by both interrupt and main-line code. If the compiler optimizes access to a variable or access is interrupted by an interrupt routine, then corruption can occur. See Section 2.5.6 "How Do I Share Data Between Interrupt and Main-line Code?" for more information.

© 2012-2018 Microchip Technology Inc.

Chapter 3. XC8-CC Command-line Driver

3.1 INTRODUCTION

The name of the MPLAB XC8 command-line driver is `xc8-cc`. This driver can be invoked to perform all aspects of compilation, including C code generation, assembly, and link steps, and is the recommended way to use the compiler, as it hides the complexity of all the internal applications and provides a consistent interface for all compilation steps. Even if an IDE is used to assist with compilation, the IDE will ultimately call `xc8-cc`.

If you are building a legacy project or would prefer to use the old command-line driver and its command-line options, you may instead run the `xc8` driver application. It's use is described in its own user's guide, MPLAB® XC8 C Compiler User's Guide, which also covers the C90 aspect of compilation.

This chapter describes the steps that the driver takes during compilation, the files that the driver can accept and produce, as well as the command-line options that control the compiler's operation.

The following topics are examined in this chapter of the MPLAB XC8 C Compiler User's Guide:

- Invoking the Compiler
- The Compilation Sequence
- Runtime Files
- Compiler Output
- Compiler Messages
- Option Descriptions

3.2 INVOKING THE COMPILER

This section explains how to invoke `xc8-cc` on the command line, as well as the files that it can read.

3.2.1 Driver Command-line Format

The `xc8-cc` driver has the following basic command format:

```
xc8-cc [options] files [libraries]
```

Throughout this manual, it is assumed that the compiler applications are in the console's search path (see Section 3.2.2 "Driver Environment Variables") or that the full path is specified when executing an application.

It is customary to declare *`options`* (identified by a leading dash "`-`" or double dash "`--`") before the files' names. However, this is not mandatory.

The formats of the options are supplied in Section 3.7 "Option Descriptions" along with corresponding descriptions of the options.

The *`files`* can be an assortment of C and assembler source files and precompiled intermediate files. While the order in which these files are listed is not important, it can affect the allocation of code or data and can affect the names of some of the output files.

`Libraries` is a list of user-defined library files that will be searched by the compiler, in addition to the standard C libraries. The order of these files will determine the order in which they are searched. It is customary to insert the *`Libraries`* list after the list of source file names. However, this is not mandatory.

If you are building code using a make system, familiarity with the unique intermediate p-code file format (described in Section 3.3.3 "Multi-Step Compilation"), is recommended. Object files are seldom used with the MPLAB XC8 C Compiler, unless assembly source modules are in the project.

3.2.1.1 LONG COMMAND LINES

The `xc8-cc` driver can be passed a command-line file containing driver options and arguments to circumvent any operating-system-imposed limitation on command line length.

A command file is specified by the `@` symbol, which should be immediately followed (i.e., no intermediate space character) by the name of the file containing the arguments. This same system of argument passing can be used by most of the internal applications called by the compiler driver.

Inside the file, each argument must be separated by one or more spaces and can extend over several lines. The file can contain blank lines, which will be ignored.

The following is the content of a command file, `xyz.xc8` for example, that was constructed in a text editor and that contains the options and the file names required to compile a project.

```
-mcpu=16F877A -Wl,-Map=proj.map -Wa,-a \
-O2 main.c isr.c
```

After this file is saved, the compiler can be invoked with the following command:

```
xc8-cc @xyz.xc8
```

Command files can be used as a simple alternative to a make file and utility, and can conveniently store compiler options and source file names.

3.2.2 Driver Environment Variables

No environment variables are defined or required by the compiler for it to execute.

© 2012-2018 Microchip Technology Inc.

Adjusting the PATH environment variable allows you to run the compiler driver without having to specify the full compiler path.

This variable can be automatically updated when installing the compiler by selecting the *Add xc8 to the path environment variable* checkbox in the appropriate dialog.

Note that the directories specified by the PATH variable are only used to locate the compiler driver. Once the driver is running, it will manage access to the internal compiler applications, such as the assembler and linker, etc.

The MPLAB X IDE allows the compiler to be selected via the Project properties dialog without the need for the PATH variable.

3.2.3 Input File Types

The `xc8-cc` driver accepts a number of input file types, which are distinguished by the file's extension. Recognized input file extensions are listed in Table 3-1.

TABLE 3-1: INPUT FILE TYPES

Extension	File format
`.c`	C source file
`.i`	Preprocessed C source file
`.p1`	p-code file
`.s`	Assembler source file
`.S` or `.sx`	Assembly source file requiring preprocessing
`.o`	Relocatable object code file
`.a`	Relocatable p-code or object library file
`.hex`	Intel HEX file
other	A file to be passed to the linker

There are no compiler restrictions imposed on the names of source files, but be aware of case, name-length, and other restrictions that are imposed by your operating system.

Avoid using the same base name for assembly and C source files, even if they are located in different directories, and avoid having source files with the same basename as the MPLAB X IDE project name.

3.3 THE COMPILATION SEQUENCE

When you compile a project, many internal applications are called to do the work. This section looks at when these internal applications are executed, and how this relates to the build process of multiple source files. This section should be of particular interest if you are using a make system to build projects.

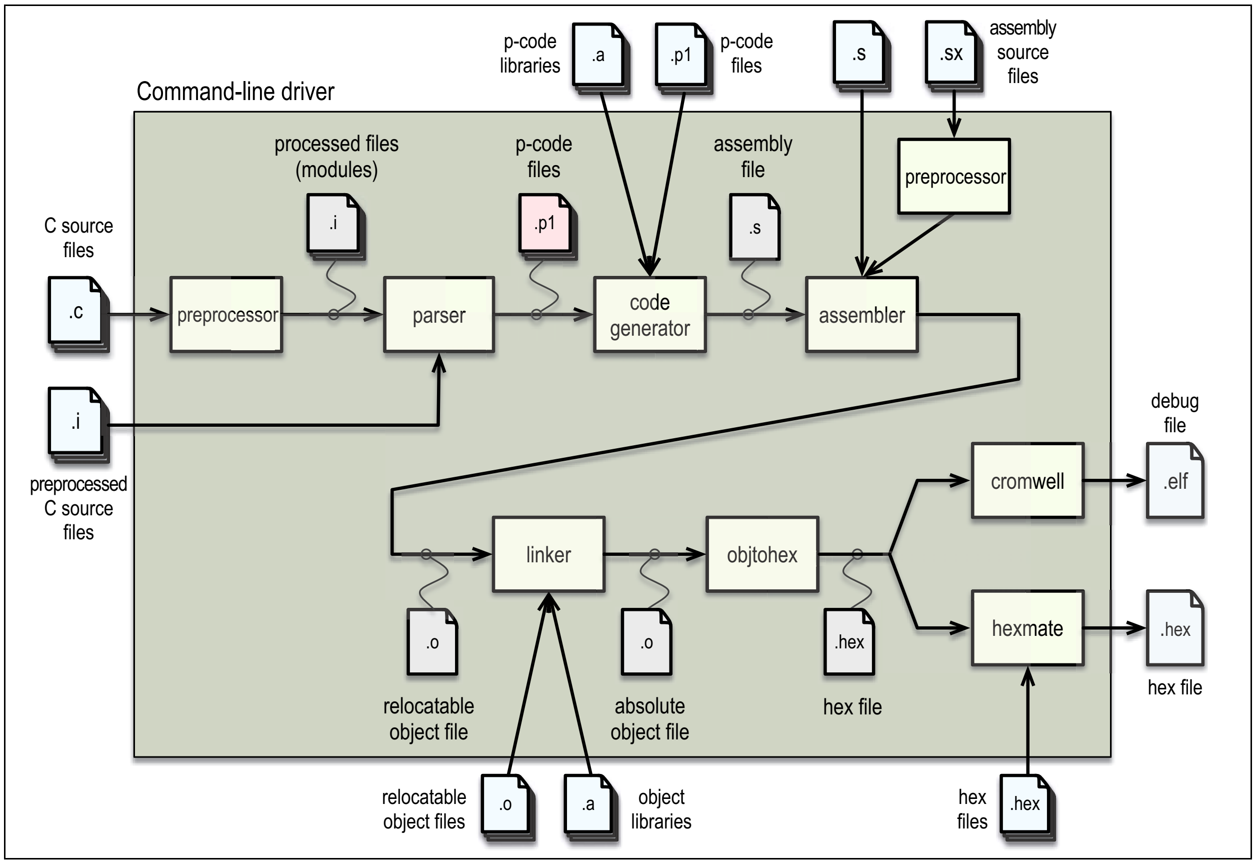
3.3.1 The Compiler Applications

The main internal compiler applications and files are illustrated in Figure 3-1.

The large shaded box represents the compiler, which is controlled by the command line driver, `xc8-cc`. You might be satisfied just knowing that C source files (shown on the far left) are passed to the compiler and the resulting output files (shown here as a HEX and ELF debug file on the far right) are produced; however, internally there are many applications and temporary files being produced. An understanding of the internal operation of the compiler, while not necessary, does assist with using the tool.

The driver will call the required compiler applications when required. These applications are located in the compiler's bin directories and are shown in the diagram as the smaller boxes inside the driver. The temporary files produced by each application can also be seen in this diagram and are marked at the point in the compilation sequence where they are generated. The intermediate files for C source are shaded in red. Some of these temporary files remain after compilation has concluded. There are also driver options to request that the compilation sequence halt after execution of a particular application so that the output of that application remains in a file and can be examined.

FIGURE 3-1: COMPILER APPLICATIONS AND FILES



It is recommended that only the hexmate (`hexmate`) and librarian (`xc8-ar`) internal applications be executed directly. Their command-line options are described in Chapter 7. Utilities.

© 2012-2018 Microchip Technology Inc.

3.3.2 Single-Step Compilation

Compilation of one or more source files can be performed in just one step using the `xc8-cc` driver.

The following command will build both the C source files and the assembly source file listed, passing these files to the appropriate internal applications, then link the generated code to form the final output.

```
xc8-cc -mcpu=16F877A main.c io.c mdef.s
```

The driver will compile all source files, regardless of whether they have changed since the last build. Development environments (such as MPLAB® X IDE) and make utilities must be employed to achieve incremental builds (see Section 3.3.3 "Multi-Step Compilation").

Unless otherwise specified, a HEX file and ELF file are produced as the final output. The intermediate files remain after compilation has completed, but most other temporary files are deleted, unless you use the `-save_temps` option (see Section 3.7.5.3 "save-temps") which preserves all generated files except the run-time start-up file. Note that some generated files can be in a different directory than your project source files (see also Section 3.7.2.3 "o: Specify Output File").

3.3.3 Multi-Step Compilation

A multi-step compilation method can be employed to achieve an incremental build of your project. Make utilities take note of which source files have changed since the last build and only rebuild these files to speed up compilation. From within MPLAB X IDE, you can select an incremental build (Build Project icon), or fully rebuild a project (Clean and Build Project icon).

Make utilities typically call the compiler multiple times: once for each source file to generate an intermediate file and once to perform the second stage compilation.

The option `-c` (see Section 3.7.2.1 "c: Compile to Intermediate File") is used to create an intermediate file. The option stops compilation after the parser has executed, and the resulting p-code output file will have a `.p1` extension. Always use p-code files as the intermediate file format if you are using a make system to build projects.

The intermediate files are then specified to the driver during the second stage of compilation, when they will be passed to the code generator and linked.

The first two of the following command lines build an intermediate file for each C source file, then these intermediate files are passed to the driver again to complete the compilation in the last command.

```
xc8-cc -mcpu=16F877A -c main.c
xc8-cc -mcpu=16F877A -c io.c
xc8-cc -mcpu=16F877A  main.p1 io.p1
```

As with any compiler, all the files that constitute the project must be present when performing the second stage of compilation.

You might also wish to generate intermediate files to construct your own library files. See Section 7.2 "Librarian" for more information on library creation.

3.3.4 Compilation of Assembly Source

Assembly files are compiled in a similar way to C source files; however these files are built first so that information contained in the assembly code can be subsequently passed to the code generator, see Section 4.12.3 "Interaction between Assembly and C Code".

If you wish to use the C preprocessor to parser an assembly source file for preprocessor directives, ensure the source file uses a `.S` or `.sx` extension, for example `init.sx`.

The intermediate file format associated with assembly source files is an object file (`.o` extension). The `-c` option (see Section 3.7.2.1 "c: Compile to Intermediate File") will halt compilation after the assembly step when building assembly source files, generating the object file.

© 2012-2018 Microchip Technology Inc.

3.4 RUNTIME FILES

In addition to the C and assembly source files specified on the command line, there are also compiler-generated source files and pre-compiled library files that the compiler can link into your project. These files are discussed in the following sections.

3.4.1 Library Files

The names of the C standard library files appropriate for the selected target device are determined by the driver and passed to the code generator and linker. You do not need to manually include library files into your project.

Most library routines are derived from p-code library files, which the compiler will search for in the `pic/lib/c99` or `pic/lib/c90` directory under the compiler installation directory, based on your language standard selection.

The standard libraries are named *`family-type-options`*`.a`, where the following apply.

- *`family`* can be `pic18` for PIC18 devices, or `pic` for all other 8-bit PIC devices
- *`type`* indicates the sort of library functionality provided and can be `stdlib` for the standard library functions, or `trace`, etc.
- *`options`* indicates hyphen-separated names to indicate variants of the library to accommodate different compiler options or modes, e.g., `htc` for the default flavor of C used by MPLAB XC8, `d32` for 32-bit doubles, `sp` for space optimizations etc.

For example, the standard library for baseline and midrange devices using 24-bit `double` types is `pic-stdlib-d24-sz.a`.

For more information on libraries, see Section 4.11 “Libraries”.

3.4.2 Startup and Initialization

A file containing the runtime startup code is generated by the compiler each time you build, and it is automatically linked into your project. Section 4.10.2 “Runtime Startup Code” details the specific actions taken by this code and how it interacts with programs you write.

Rather than the traditional method of linking in a generic, precompiled routine, the MPLAB XC8 C Compiler determines what runtime startup code is required from the user’s program and then generates this code each time you build.

The default operation of the driver is to keep the startup module; however, you can ask that it be deleted by using the option `-mno-keep-startup` (see Section 3.7.1.13 “no-keep-startup”). If you are using the MPLAB X IDE to build, the file will be deleted unless you indicate otherwise in the Project Properties dialog.

If the startup module is kept, it will be called `startup.s` and will be located in the current working directory. If you are using an IDE to perform the compilation, the destination directory will be dictated by the IDE. MPLAB X IDE stores this file in the `dist/default/production|debug` directory in your project directory.

Generation of the runtime startup code is an automatic process that does not require any user interaction; however, some aspects of the runtime code can be controlled, if required, using the `-Wl,-no-data-init` option. Section 3.7.12 “Mapped Linker Options” describes the use of this option.

The runtime startup code is executed before `main()`. However, if you require any special initialization to be performed immediately after Reset, you should use the powerup feature described later in Section 4.10.3 “The Powerup Routine”.

3.5 COMPILER OUTPUT

There are many files created by the compiler during the compilation. A large number of these are temporary files. Many are deleted after compilation is complete, but same remain and are used for programming the device, or for debugging purposes.

Note: Throughout this manual, the term *project name* will refer to either the name of the project created in the IDE, or the base name (file name without extension) of the first C source file specified on the command line.

3.5.1 Output Files

The default behavior of `xc8-cc` is to produce an ELF and Intel HEX output. Unless changed by the `-o` option (see Section 3.7.2.3 "o: Specify Output File"), the base names of these files will be the project name. The common output file types are shown inTable 3-2.

TABLE 3-2: COMMON OUTPUT FILES

Extension	Type and option to create
`.hex`	Intel HEX file
`.elf`	ELF/Dwarf, generated by default or by `-gdwarf-3`
`.cof`	COFF, generated by `-gcoff`
`.o`	Relocatable object file, produced by `-c`
`.s`	Assembly file, produced by `-S`
`.i`	Preprocessed C file, produced by `-E`

The default output file types can be explicitly controlled by the `-gcoff` and `-gdwarf-3` options, which generate a COFF and ELF file format as output, respectively (described in Section 3.7.5.2 "g: Produce debugging information").The ELF/DWARF file is used by debuggers to obtain debugging information about the project and allows for more accurate debugging compared to the COFF format. The IDE will typically request the compiler to produce an ELF file.

The default names of temporary files use the same base name as the source file from which they were derived. For example, the source file `input.c` will create a p-code file called `input.p1`.

3.5.2 Diagnostic Files

Two valuable files produced by the compiler are the assembly list file generated by the assembler, and the map file generated by the linker. These are generated by options, shown in Table 3-3.

TABLE 3-3: DIAGNOSTIC FILES

File format	Type and option used
`file.lst`	Assembly list file, produced by `-Wa,-a=file.lst`
`file.map`	Map file, produced by `-Wl,-Map=file.map`

© 2012-2018 Microchip Technology Inc.

3.6 COMPILER MESSAGES

All compiler applications use textual messages to report feedback during the compilation process. A centralized messaging system is used by most applications to produce the messages; however the Clang front end, used when compiling for C99 projects, currently bypasses this system and is not controlled by the features described in the following sections.

A list of warning and error messages can be found in Appendix B. Error and Warning Messages.

3.6.1 Messaging Overview

Messages produced by applications (excluding Clang) are referenced by a unique number. The messaging system takes the message number requested by the application that needs to convoy the information and determines the corresponding message type and string from one of several Message Description Files (MDF), which are stored in the `pic/dat` directory in the compiler's installation directory.

A message is referenced by a unique number that is passed to the messaging system by the compiler application that needs to convey the information. The message string corresponding to this number is obtained from Message Description Files (MDF), which are stored in the `dat` directory in the compiler's installation directory.

When a message is requested by a compiler application, its number is looked up in the MDF that corresponds to the currently selected language. The language of messages can be altered (see Section 3.6.2 "Message Type").

Once found, the alert system can read the message type and the string to be displayed from the MDF. Several different message types are described in
Section 3.6.2 "Message Type" and the type can be overridden by the user, as described in that same section.

The user is also able to set a threshold for warning message importance, so that only those that the user considers significant will be displayed. In addition, messages with a particular number can be disabled. A pragma can also be used to disable a particular message number within specific lines of code. These methods are explained in Section 3.6.4.1 "Disabling Messages".

Provided the message is enabled and it is not a warning message whose level is below the current warning threshold, the message string obtained from the MDF will be displayed.

In addition to the actual message string, there are several other pieces of information that can be displayed, such as the message number, the name of the file for which the message is applicable, the file's line number and the application that issued the message, etc.

If a message is an error, a counter is incremented. After a specific amount of errors has been reached, compilation of the current module will cease. The default number of errors that will cause this termination can be adjusted by using the `-fmax-errors` option, (see Section 3.7.4.1 "max-errors"). This counter is reset for each internal compiler application, thus specifying a maximum of five errors will allow up to five errors from the parser, five from the code generator, five from the linker, five from the driver, etc.

Although the information in the MDF can be modified with any text editor, this is not recommended. Message behavior should only be altered using the options and pragmas described in the following sections.

3.6.2 Message Type

There are four types of messages. These are described below. The behavior of the compiler when encountering a message of each type is also listed.

Advisory Messages	convey information regarding a situation the compiler has encountered or some action the compiler is about to take. The information is being displayed "for your interest," and typically requires no action to be taken. Compilation will continue as normal after such a message is issued.
Warning Messages	indicate source code or some other situation that can be compiled, but is unusual and may lead to runtime failures of the code. The code or situation that triggered the warning should be investigated; however, compilation of the current module will continue, as will compilation of any remaining modules.
Error Messages	indicate source code that is illegal or that compilation of this code cannot take place. Compilation will be attempted for the remaining source code in the current module, but no additional modules will be compiled and the compilation process will then conclude.
Fatal Error Messages	indicate a situation in which the compilation cannot proceed and requires that the compilation process to stop immediately.

3.6.3 Message Format

By default, messages are printed in a human-readable format. This format can vary from one internal application to another, since each application reports information about different file formats.

Some applications (for example, the parser) are typically able to pinpoint the area of interest down to a position on a particular line of C source code, whereas other applications, such as the linker, can at best only indicate a module name and record number, which is less directly associated with any particular line of code. Some messages relate to issues in driver options that are in no way associated with the source code.

The format of messages produced by the Clang front end cannot be changed, but the following information is still relevant for the other compiler applications.

The compiler can use environment variables to whose values are used as a template for all messages produced by all compiler applications. The names of these environment variables are given in Table 3-4.

TABLE 3-4: MESSAGING ENVIRONMENT VARIABLES

Variable	Effect
`HTC_MSG_FORMAT`	All advisory messages
`HTC_WARN_FORMAT`	All warning messages
`HTC_ERR_FORMAT`	All error and fatal error messages

© 2012-2018 Microchip Technology Inc.

The value of these environment variables are strings that are used as templates for the message format. Printf-like placeholders can be placed within the string to allow the message format to be customized. The placeholders, and what they represent, are presented in Table 3-5.

TABLE 3-5: MESSAGING PLACEHOLDERS

Placeholder	Replacement
`%a`	Application name
`%c`	Column number
`%f`	Filename
`%l`	Line number
`%n`	Message number
`%s`	Message string (from MDF)

If these options are used in a DOS batch file, two percent characters will need to be used to specify the placeholders, as DOS interprets a single percent character as an argument and will not pass this on to the compiler. For example:

```
SET HTC_ERR_FORMAT="file %%f: line %%l"
```

3.6.4 Changing Message Behavior

The attributes of messages produced by the Clang front end cannot be changed, but the following driver options and C pragmas are still relevant for the other compiler applications.

3.6.4.1 DISABLING MESSAGES

Each numbered warning message has a default number indicating a level of importance. This number is specified in the MDF and ranges from -9 to 9. The higher the number, the more important the warning.

Warning messages can be disabled by adjusting the warning level threshold using the `-mwarn` driver option, (see Section 3.7.4.2 “warn”). Any warnings whose level is below that of the current threshold are not displayed. Warnings from Clang cannot be disabled.

The default threshold is 0 which implies that only warnings with a warning level of 0 or higher will be displayed by default. The information in this option is propagated to all compiler applications, so its effect will be observed during all stages of the compilation process.

All warnings can be disabled using the `-w` option.

Note: Disabling error or warning messages in no way fixes the condition that triggered the message. Always use extreme caution when exercising these options.

3.6.4.2 CHANGING MESSAGE TYPES

It is also possible to change the type of some messages. This can only be done for messages generated by the parser or code generator. See Section 4.14.3.11 “The #pragma warning Directive” for more information on this pragma.

3.7 OPTION DESCRIPTIONS

Most aspects of the compilation can be controlled using the command-line driver, `xc8-cc`. The driver will configure and execute all required applications, such as the code generator, assembler and linker.

Many options follow a GCC style; however, the compiler is not based on GCC and you cannot use any other GCC options that are not documented here. Many of the old-style `xc8` driver options (described in the MPLAB® XC8 C Compiler User's Guide Ds50002053) can be used with the `xc8-cc` if there is no GCC-style option equivalent listed.

All options are identified by single or double leading dash character, e.g. `-c` or `--version`.

Use the `--help` option, Section 3.7.2.7 "help", to obtain a brief description of accepted options on the command line.

If you are compiling from within the MPLAB X IDE, it will by default issue explicit options to the compiler specified by the default selections in the Project Properties dialog, and these options can be different to those used by the compiler when running on the command line with no options specified.

If you are compiling the same project from the command line and from the MPLAB X IDE, always check that you explicitly specify each option.

The following categories of options are described.

- Options Specific to PIC Devices
- Options for Controlling the Kind of Output
- Options for Controlling the C Dialect
- Options for Controlling Warnings and Errors
- Options for Debugging
- Options for Controlling Optimization
- Options for Controlling the Preprocessor
- Options for Assembling
- Options for Linking
- Options for Directory Search
- Options for Code Generation Conventions

© 2012-2018 Microchip Technology Inc.

3.7.1 Options Specific to PIC Devices

The options shown in Table 3-6 are useful when compiling for 8-bit Microchip PIC devices with the MPLAB XC8 compiler and are discussed in the sections that follow.

TABLE 3-6: MACHINE-SPECIFIC OPTIONS

Option	Controls
`-maddrqual=`*`action`*	How the compiler will respond to storage qualifiers
`-mchecksum=`*`specs`*	The generation and placement of a checksum or hash
`-mcodeoffset=`*`offset`*	The offset applied to reset and interrupt vectors
`-m[no-]config`	Whether the device will be programmed with default configuration bit values
`-mcpu=`*`device`*	The target device that code will be built for
`-mdebugger=`*`type`*	Which debugger will be in use when executing the code
`-mdfp=`*`path`*	Which device family pack to use
`-m[no-]download`	How the final HEX file is conditioned
`-memi=`*`mode`*	The external memory interface that will be used
`-merrata=`*`type`*	Which workarounds to errata will be applied by the compiler
`-m[no-]ivt=`*`address`*	The interrupt vector table selected at startup
`-mmaxichip`	Use of a hypothetical device with full memory
`-mno-keep-startup`	Whether the runtime startup source is deleted after compilation
`-m[no-]osccal`	Whether the oscillator will be calibrated
`-moscval=`*`value`*	The oscillator calibration value
`-mram=`*`ranges`*	Data memory that is available for the program
`-mreserve=`*`ranges`*	What memory should be reserved
`-m[no-]resetbits`	Whether the device status bits should be preserved
`-mrom=`*`ranges`*	Program memory that is available for the program
`-mshroud`	Whether the output file should obfuscate the source code
`-mstack=`*`model`*`[:`*`size`*`]`	Which data stack will be used by default
`-m[no-]stackcall`	Whether functions can be called via lookup tables
`-msummary=`*`types`*	What memory summary information is produced
`-mundefints=`*`action`*	How the compiler completes unimplemented interrupts
`-m[no-]use-ivt`	see `-m[no-]ivt`

3.7.1.1 ADDRQUAL

The `-maddrqual=`*`action`* option indicates the compiler's response to non-standard memory qualifiers in C source code, as shown in Table 3-7.

TABLE 3-7: COMPILER RESPONSES TO MEMORY QUALIFIERS

Action	Response
`require`	The qualifiers will be honored. If they cannot be met, an error will be issued.
`request`	The qualifiers will be honored, if possible. No error will be generated if they cannot be followed.
`ignore`	The qualifiers will be ignored and code compiled as if they were not used.
`reject`	If the qualifiers are encountered, an error will be immediately generated.

The `__near` qualifier is affected by this option. On PIC18 devices, this option affects the `__far` qualifier; and for other 8-bit devices, the `__bank(`*`x`*`)` qualifier. By default, these qualifiers are ignored; i.e., they are accepted without error, but have no effect. Using this option allows these qualifiers to be interpreted differently by the compiler.

For example, when using the option `-maddrqual=request`, the compiler will try to honor any non-standard qualifiers, but silently ignore them if they cannot be met.

3.7.1.2 CHECKSUM

The `-mchecksum=`*`specs`* option will calculate a hash value (for example checksum or CRC) over the address range specified and stores the result at the indicated destination address. The general form of this option is as follows.

`-mchecksum=`*`start`*`-`*`end`*`@`*`destination`*`[,`*`specifications`*`]`

The following specifications are appended as a *comma*-separated list to this option.

TABLE 3-8: CHECKSUM ARGUMENTS

Argument	Description
`width=n`	Selects the width of the hash result in bytes for non-Fletcher algorithms. A negative width will store the result in little-endian byte order; positive widths in big-endian order. Result widths from one to four bytes are permitted.
`offset=nnnn`	Specifies an initial value or offset added to the checksum.
`algorithm=n`	Selects one of the hash algorithms implemented in `HEXMATE`. The selectable algorithms are described in Table 7-3.
`polynomial=nn`	Selects the polynomial value when using CRC algorithms
`code=nn`	Specifies a hexadecimal code that will trail each byte in the result. This can allow each byte of the result to be embedded within an instruction, for example `code=34` will embed the result in a `retlw` instruction on mid-range devices.

The *`start`*, *`end`* and *`destination`* attributes are, by default, hexadecimal constants. The addresses defining the input range are typically made multiples of the algorithm width. If this is not the case, zero bytes will pad any missing input word locations.

If an accompanying `--fill` option (Section 3.7.11.8 "fill") has not been specified, unused locations within the specified address range will be automatically filled with 0xFFF for baseline devices, 0x3FFF for mid-range devices, or 0xFFFF for PIC18 devices. This is to remove any unknown values from the calculations and ensure the accuracy of the result.

For example:

```
-mchecksum=800-fff@20,width=1,algorithm=2
```

© 2012-2018 Microchip Technology Inc.

will calculate a 1-byte checksum from address 0x800 to 0xfff and store this at address 0x20. A 16-bit addition algorithm will be used. Table 3-9 shows the available algorithms and Section 7.3.2 "Hash Functions" describes these in detail.

TABLE 3-9: CHECKSUM ALGORITHM SELECTION

Selector	Algorithm description
`-5`	Reflected cyclic redundancy check (CRC)
`-4`	Subtraction of 32 bit values from initial value
`-3`	Subtraction of 24 bit values from initial value
`-2`	Subtraction of 16 bit values from initial value
`-1`	Subtraction of 8 bit values from initial value
`1`	Addition of 8 bit values from initial value
2	Addition of 16 bit values from initial value
3	Addition of 24 bit values from initial value
4	Addition of 32 bit values from initial value
5	Cyclic redundancy check (CRC)
7	Fletcher's checksum (8 bit calculation, 2-byte result width)
8	Fletcher's checksum (16 bit calculation, 4-byte result width)

The hash calculations are performed by the HEXMATE application. The information in this driver option is passed to the HEXMATE application when it is executed.

3.7.1.3 CODEOFFSET

The `-mcodeoffset=`*`offset`* option shifts the reset and interrupt vector locations up in memory by the specified offset, and prevents code and data from using memory up to this offset address. This operation is commonly required when writing bootloaders.

The address is assumed to be a hexadecimal constant. A leading `0x`, or a trailing h hexadecimal specifier can be used but is not necessary.

For example, the option `-mcodeoffset=600` will move the reset vector from address 0 to 0x600; and move the interrupt vector from address 4 to 0x604, in the case of mid-range PIC devices, or to the addresses 0x608 and 0x618 for PIC18 devices. No code or data will be placed at the addresses 0 thru 0x5FF.

As the reset and interrupt vector locations are at fixed addresses in the PIC device, it is the programmer's responsibility to provide code that can redirect control from the actual vector locations to the reset and interrupt routines in there offset location.

This option differs from the `-mreserve` option in that it will also move the code associated with the reset and interrupt vectors (see Section 3.7.1.17 "reserve").

3.7.1.4 CONFIG

The `-mconfig` option can be used to have the compiler program default values for those configuration bits that have not been specified in the code using the `config` pragma. This option can only be used when programming PIC18 devices. The alternate form of this option is `-mdefault-config-bits`.

The default operation is to not program unspecified bits, and this can be made explicit using the option `-mno-config` (`-mno-default-config-bits`).

3.7.1.5 CPU

The `-mcpu=device` option must be used to specify the target device for the compilation. This is the only option that is mandatory when compiling code.

For example `-mcpu=18f6722` will select the PIC18F6722 device. To see a list of supported devices that can be used with this option, use the `--mprint-devices` option (Section 3.7.2.8 "print-devices").

3.7.1.6 DEBUGGER

The `--mdebugger=type` option is intended for use for compatibility with development tools that can act as a debugger. `xc8-cc` supports several debuggers and these are defined in Table 3-10.

TABLE 3-10: SELECTABLE DEBUGGERS

Type	Debugger selected
`none`	No debugger (default)
`icd2`	MPLAB® ICD 2
`icd3`	MPLAB ICD 3
`pickit2`	PICkit™ 2
`pickit3`	PICkit 3
`realice`	MPLAB REAL ICE™ in-circuit emulator

For example:

```
xc8-cc -mcpu=16F877AA -mdebugger=icd3 main.c
```

will ensure that none of the source code is allocated resourced that would be used by the debug executive for an MPLAB ICD 3.

Failing to select the appropriate debugger can lead to runtime failure.

If the debugging features of the development tool are not to be used (for example, if the MPLAB ICD 3 is only being used as a programmer), then the debugger option can be set to `none`, because memory resources are not being used by the tool.

MPLAB X IDE will automatically apply this option for debug builds once you have indicated the hardware tool in the Project Preferences.

3.7.1.7 DFP

The `-mdfp=path` option specifies an alternate the path to use for the device family pack. This option is required if you have installed new device family packs on your host machine.

3.7.1.8 DOWNLOAD

The `-mdownload` option conditions the Intel HEX for use by bootloader. The `-mdownload-hex` option is equivalent in effect.

When used, this option will pad data records in the Intel HEX file to 16-byte lengths and will align them on 16-byte boundaries. The compiler-generated startup code will not assume that certain registers hold their reset values.

The default operation is to not modify the HEX file, and this can be made explicit using the option `-mno-download`. (`-mno-download-hex`)

© 2012-2018 Microchip Technology Inc.

3.7.1.9 EMI

The `-memi=`*`mode`* option allows you to select the mode used by the external memory interface available on some PIC18 devices.

The interface can operate in a 16-bit word-write or byte-select mode; or in an 8-bit byte-write mode, and which are represented in Table 3-11.

TABLE 3-11: EXTERNAL MEMORY INTERFACE MODES

Mode	Operation
`wordwrite`	16-bit word-write mode (default)
`byteselect`	16-bit byte-select mode
`bytewrite`	8-bit byte-write mode

For example, the option `-memi=bytewrite` will select the 8-bit byte-write mode.

The selected mode will affect the code generated when writing to the external data interface. In word write mode, dummy reads and writes can be added to ensure that an even number of bytes are always written. In byte-select or byte-write modes, dummy reads and writes are not generated and can result in more efficient code.

Note that this option does not pre-configure the device for the selected mode. Your device data sheet will indicate the settings required in your code.

3.7.1.10 ERRATA

The `-merrata=`*`type`* option allows specification of software workarounds to documented silicon errata issues. A default set of errata apply to each device, but this set can be adjusted by using this option and the arguments presented in Table 3-12.

TABLE 3-12: ERRATA WORKAROUNDS

Type	#	Workaround
`4000`	`0`	Program memory accesses/jumps across 4000h address boundary
`fastints`	`1`	Fast interrupt shadow registers corruption
`lfsr`	`2`	Broken LFSR instruction
`minus40`	`3`	Program memory reads at -40 degrees
`reset`	`4`	goto instruction cannot exist at Reset vector
`bsr15`	`5`	Flag problems when BSR holds value 15
`daw`	`6`	Broken DAW instruction
`eedatard`	`7`	Read EEDAT in immediate instruction after RD set
`eeadr`	`8`	Don't set RD bit immediately after loading EEADR
`ee_lvd`	`9`	LVD must stabilize before writing EEPROM
`fl_lvd`	`10`	LVD must stabilize before writing Flash
`tblwtint`	`11`	Clear interrupt registers before tblwt instruction
`fw4000`	`12`	Flash write exe must act on opposite side of 4000h boundary
`resetram`	`13`	RAM contents can corrupt if async. Reset occurs during write access
`fetch`	`14`	Corruptible instruction fetch. – applies FFFFh (NOP) at required locations
`clocksw`	`15`	Code corruption if switching to external oscillator clock source – applies switch to HFINTOSC high-power mode first
`branch`	`16`	The PC might become invalid when restoring from an interrupt during a BRA or BRW instruction — avoids branch instructions
`brknop2`	`17`	Hardware breakpoints might be affected by BRA instruction — avoids branching to the following location
`nvmreg`	`18`	The program will access data flash rather than program flash memory after a reset — adjusts the NVMCON register

At present, workarounds are mainly employed for PIC18 devices, but the `clocksw` and `branch` errata are only applicable for some enhanced mid-range devices.

To disable all software workarounds, use the following.

```
-merrata=none
```

To maintain all the default workarounds but disable the jump across 4000 errata, for example, use the following:

```
-merrata=default,-4000
```

The value assigned to the preprocessor macro `_ERRATA_TYPES` (see Section 4.14.2 "Predefined Macros") indicates the errata applied. Each errata listed in Table 3-12 represents one bit position in the macro's value, with the topmost errata in the table being the least significant. That bit position in the `_ERRATA_TYPES` macro is set if the corresponding errata is applied. The header file `<errata.h>` contains definitions for each errata value, for example `ERRATA_4000` and `ERRATA_FETCH`, which can be compared with the compiler-defined `_ERRATA_TYPES` macro.

3.7.1.11 IVT

The `-mivt=`*`address`* option selects the interrupt vector table that will be used at the beginning of program execution for those PIC18 devices that implement interrupt vector tables.

The address argument specified is written to the `IVTBASE` register during startup, for example, `-mivt=0x200` will select the interrupt vector table whose base address is at 200h. This table would need to have been populated with vectors by the interrupt routine definitions in your source code (see Section 4.9.1 "Writing an Interrupt Service Routine"). The default operation is to leave the vector table at address 0x8 and this can be made explicit using the option `-mno-ivt`.

3.7.1.12 MAXICHIP

The `-mmaxichip` option tells the compiler to build for a hypothetical device with the same physical core and peripherals as the selected device, but with the maximum allowable memory resources permitted by the device family. You might use this option if your program does not fit in your intended target device and you wish to get an indication of the code or data size reductions needed to be able to program that device.

The compiler will normally terminate compilation if the selected device runs out of program memory, data memory, or EEPROM. When using this option, the program memory of PIC18 and mid-range devices will be maximized to extend from address 0 to either the bottom of external memory or the maximum address permitted by the PC register, whichever is lower. The program memory of baseline parts is maximized from address 0 to the lower address of the Configuration Words.

The number of data memory banks is expanded to the maximum number of selectable banks as defined by the BSR register (for PIC18 devices), RP bits in the STATUS register (for mid-range devices), or the bank select bits in the FSR register (for baseline devices). The amount of RAM in each additional bank is equal to the size of the largest contiguous memory area within the physically implemented banks.

EEPROM is only maximized if the device implements this memory. If present, EEPROM is maximized to a size dictated by the number of bits in the EEADR register.

If required, check the map file (see Section 6.4 "Map Files") to see the size and arrangement of the memory available when using this option with your device.

Note: When using the `-mmaxichip` option, you are *not* compiling for a real device. The generated code may not load or execute in simulators or the selected device. This option will not allow you to fit extra code into a device.

© 2012-2018 Microchip Technology Inc.

3.7.1.13 NO-KEEP-STARTUP

The `-mno-keep-startup` option deletes the startup assembly module remains after compilation. By default, this file is not deleted.

3.7.1.14 OSCCAL

The `-mosccal` option can be used to calibrate the oscillator for some PIC10/12/16 devices.

When using this option, the compiler will generate code which will calibrate the oscillator using the calibration constant preprogrammed in the device. The option `-mno-osccal` will omit the code that performs this initialization from the runtime startup code.

3.7.1.15 OSCVAL

The `-moscval=`*`value`* option allows you to specify the value that will be used to calibrate the oscillator for some PIC10/12/16 devices.

The calibration value is usually preprogrammed into your device; however this option allows you to specify an alternate value, or the original value if has been erased from the device. The option `-moscval=55` would ensure that the value 55h is loaded to the oscillator calibration register at startup (see Section 4.3.11 “Oscillator Calibration Constants”).

3.7.1.16 RAM

The `-mram=`*`ranges`* option is used to adjust the data memory that is specified for the target device. Without this option, all the on-chip RAM implemented by the device is available, thus this option only needs be used if there are special memory requirements. Specifying additional memory that is not in the target device might result in a successful compilation, but can lead to code failures at runtime.

For example, to specify an additional range of memory to that already present on-chip, use:

```
-mram=default,+100-1ff
```

This will add the range from 100h to 1ffh to the on-chip memory. To only use an external range and ignore any on-chip memory, use:

```
-mram=0-ff
```

This option can also be used to reserve memory ranges already defined as on-chip memory in the chipinfo file. To do this, supply a range prefixed with a minus character, `-`, for example:

```
-mram=default,-100-103
```

will use all the defined on-chip memory, but not use the addresses in the range from 100h to 103h for allocation of RAM objects.

This option will adjust the memory ranges used by linker classes (see Section 6.2.1 “-Aclass =low-high,...”) . Any objects contained in a psect that do not use the classes affected by this option might be linked outside the memory specified by this option.

This option is also used to specify RAM for `far` objects on PIC18 devices. These objects are stored in the PIC18 extended memory. Any additional memory specified with this option whose address is above the on-chip program memory is assumed to be extended memory implemented as RAM.

For example, to indicate that RAM has been implemented in the extended memory space at addresses 0x20000 to 0x20fff, use the following option.

```
-mram=default,+20000-20fff
```

3.7.1.17 RESERVE

The `-mreserve=`*`ranges`* option allows you to reserve memory normally used by the program. This option has the general form:

`-mreserve=`*`space`*`@`*`start`*`:`*`end`*

where *`space`* can be either of `ram` or `rom`, denoting the data and program memory spaces, respectively; and *`start`* and *`end`* are addresses, denoting the range to be excluded. For example, `-mreserve=ram@0x100:0x101` will reserve two bytes starting at address 100h from the data memory.

This option performs a similar task to the `-mram` and `-mrom` options, but it cannot be used to add additional memory to that available for the program.

3.7.1.18 RESETBITS

The `-mresetbits` option allows you to have the content of the status register preserved by the runtime startup code for PIC10/12/16 devices (described in Section 4.10.2.4 "STATUS Register Preservation"). The `-m[no-]save-resetbits` option is equivalent in effect.

When this option is in effect, the saved registers can be accessed in your program. The compiler can detect references to the saved STATUS register symbols an will automatically enable this option.

3.7.1.19 ROM

The `-mrom=`*`ranges`* option is used to change the default program memory that is specified for the target device. Without this option, all the on-chip program memory implemented by the device is available, thus this option only needs be used if there are special memory requirements. Specifying additional memory that is not in the target device might result in a successful compilation, but can lead to code failures at runtime.

For example, to specify an additional range of memory to that on-chip, use:

```
-mrom=default,+100-2ff
```

This will add the range from 100h to 2ffh to the on-chip memory. To only use an external range and ignore any on-chip memory, use:

```
-mrom=100-2ff
```

This option can also be used to reserve memory ranges already defined as on-chip memory in the chip configuration file. To do this supply a range prefixed with a minus character, `-`, for example:

```
-mrom=default,-100-1ff
```

will use all the defined on-chip memory, but not use the addresses in the range from 100h to 1ffh for allocation of ROM objects.

This option will adjust the memory ranges used by linker classes (see Section 6.2.1 "-Aclass =low-high,...") . Any code or objects contained in a psect that do not use the classes affected by this option might be linked outside the memory specified by this option.

Note that some psects must be linked above a threshold address, most notably some psects that hold `const`-qualified data. Using this option to remove the upper memory ranges can make it impossible to place these psects.

3.7.1.20 SHROUD

The `-mshroud` option should be used in situations where either intermediate or library files are built from confidential source code and are to be distributed.

© 2012-2018 Microchip Technology Inc.

When using this option, C comments, which are normally included into these files, as well as line numbers and variable names will be removed, or obfuscated, so that the original source code cannot be reconstructed from the distributed files.

3.7.1.21 STACK

The `-mstack=`*`model`*`[:`*`size`*`]` option allows selection of the stack model to be used by a program's stack-based variables.

The data stacks available are called a compiled stack and a software stack (described in Section 4.3.4.2 "Data Stacks"). The stack models that can be used with this option are described in Table 3-13.

TABLE 3-13: --STACK SUBOPTIONS

Model	Default Allocation for Stack-based Variables
`compiled` or `nonreentrant`	Use the compiled stack for all functions; functions are non-reentrant (default).
`software` or `reentrant`	Use the software stack for eligible functions and devices; such functions are reentrant.
`hybrid`	Use the compiled stack for functions not called reentrantly; use the software stack for all other eligible functions and devices; functions are only reentrant if required.

The `software` (or `reentrant`) or `hybrid` models have no effect on projects targeting baseline and mid-range devices, as they do not support a software stack. In addition, interrupt functions must use the compiled stack, but functions they call may use the software stack.

The hybrid model (`-mstack=hybrid`) will let the compiler choose how to encode each function based on how it is called. A function is compiled to use the software stack if it is called reentrantly in the program; otherwise, it will use a compiled stack. This model allows for reentrancy, when required, but takes advantage of the efficiency of the compiled stack for the majority of the program's functions.

Any of these option settings can be overridden for individual functions by using function specifiers (described in Section 4.8.1.3 "Reentrant and nonreentrant Specifiers").

Note: Use the `software` (`reentrant`) setting with caution. The maximum runtime size of the software stack is not accurately known at compile time, so the compiler cannot predict an overflow, which could corrupt objects or registers. When all functions are forced to use the software stack, the stack size will increase substantially.

In addition to the stack model, this option can be used to specify the maximum size of memory reserved by the compiler for the software stack. This option configuration only affects the software stack; there are no controls for the size of the compiled stack.

Distinct memory areas are allocated for the software stack that is used by main-line code and each interrupt function, but this is transparent at the program level. The compiler automatically manages the allocation of memory to each stack. If your program does not define any interrupt functions, all the available memory is made available to the software stack used by main-line code.

You can manually specify the maximum space allocated for each area of the stack by following the stack type with a colon-separated list of decimal values, each value being the maximum size, in bytes, of the memory to be reserved. The sizes specified correspond to the main-line code, the lowest priority interrupt through the highest priority interrupt. (PIC18 devices have two separate interrupts; other devices have only one.) Alternatively, you can explicitly state that you have no size preference by using a size of `auto`. For PIC18 devices, the following example:

```
-mstack=reentrant:auto:30:50
```

will arrange the stack starting locations so that the low-priority interrupt stack can grow to at most 30 bytes (before overflow); the high-priority interrupt stack can grow to at most 50 bytes (before overflow); and the main-line code stack can consume the remainder of the free memory that can be allocated to the stack (before overflow). If you are compiling for a PIC18 device and only one interrupt is used, it is recommended that you explicitly set the unused interrupt stack size to zero using this option.

If you do specify the stack sizes using this option, each size must be specified numerically or you can use the `auto` token. Do not leave a size field empty. If you try to use this option to allocate more stack memory than is available, a warning is issued and only the available memory will be utilized.

3.7.1.22 STACKCALL

The `-mstackcall` option allows the compiler to use a table look-up method of calling functions.

Once the hardware function return address stack (Section 4.3.4.1 "Function Return Address Stack") has been filled, no further function nesting can take place without corrupting function return values. If this option is enabled, the compiler will revert to using a look-up table method of calling functions once the stack is full (see Section 4.8.8 "Calling Functions").

3.7.1.23 SUMMARY

The `-msummary=`*`type`* option selects the type of information that is included in the summary that is displayed after compilation. By default, or if the `mem` type is selected, a memory summary is shown. This shows the total memory usage for all memory spaces.

A psect summary can be shown by enabling the `psect` type. This shows individual psects after they have been grouped by the linker and the memory ranges they cover. Table 4-20 shows what summary types are available. The output printed when compiling normally corresponds to the mem setting.

TABLE 3-14: SUMMARY TYPES

Type	Controls
`psect`	A summary of psect names and the addresses where they were linked will be shown.
`mem`	A concise summary of memory used will be shown. (default)
`class`	A summary of all classes in each memory space will be shown.
`hex`	A summary of addresses and HEX files that make up the final output file will be shown.
`file`	Summary information will be shown on screen and saved to a file.
`xml`	Summary information will be shown on the screen, and usage information for the main memory spaces will be saved in an XML file
`xmlfull`	Summary information will be shown on the screen, and usage information for all memory spaces will be saved in an XML file

If produced, the XML files contain information about memory spaces on the selected device, consisting of the space's name, addressable unit, size, amount used and amount free.

© 2012-2018 Microchip Technology Inc.

3.7.1.24 UNDEFINTS

The `-mundefints=`*`action`* option allows you to control how the compiler responds to uninitialized interrupt vectors, including undefined legacy low- and high-priority vectors, and entries in the interrupt vector table.

A warning is generated if any uninitialized vectors are detected, except if the `ignore` action is specified.

The actions are shown in Table 3-15 for projects that are using the Interrupt Controller Macro (ICM) module and for all other projects (which are those projects using devices that do not have the ICM, or those projects in which the vector tables are disabled and the device is running in legacy mode).

For example, to have a software breakpoint executed by any vector location that is not linked to an interrupt function, use the option `-mundefints:swbp`.

The default action for projects using the ICM is to program the address of a `reset` instruction (which will be located immediately after the vector table) into each unassigned vector location; for all other devices, it is to leave the locations unprogrammed and available for other use.

If the target device does not implement a `reset` instruction or software breakpoint instruction and execution of these instructions have been requested for unused vectors, an instruction that can jump to itself will be programmed instead.

TABLE 3-15: UNUSED INTERRUPT SUBOPTIONS

Action	Devices using the ICM	All other devices
`ignore`	No action; vector location available for program code.	No action; vector location available for program code (default).
`reset`	Program each unassigned vector with the address of a `reset` instruction (default).	Program a `reset` instruction at each unassigned vector.
`swbp`	Program each unassigned vector with the address of a software breakpoint instruction.	Program a software breakpoint instruction at each unassigned vector.

An interrupt function can be assigned to any otherwise unassigned vector location by using the `default` interrupt source when defining that function (see Section 4.9.1 “Writing an Interrupt Service Routine”).

The `-mundefints` option is ignored if the target device does not support interrupts.

3.7.2 Options for Controlling the Kind of Output

The options shown in Table 3-16 control the kind of output produced by the compiler and are discussed in the sections that follow.

TABLE 3-16: KIND-OF-OUTPUT CONTROL OPTIONS

Option	Produces
`-c`	An intermediate file
`-E`	A preprocessed file
`-o file`	An output file with the specified name
`-S`	An assembly file
`-v`	Verbose compilation
`-xassembler-with-cpp`	Output after preprocessing all source files
`--help`	Help information only
`-mprint-devices`	Chip information only
`--version`	Compiler version information

3.7.2.1 C: COMPILE TO INTERMEDIATE FILE

The `-c` option is used to generate an intermediate file for each source file listed on the command line. In the case of C source files, compilation will halt after the parsing stage, leaving behind a p-code file with a `.p1` extension. For assembly source files, compilation will terminate after executing the assembler, leaving a relocatable object file with a `.o` extension.

This option is often used when using a make utility (see Section 3.3.3 "Multi-Step Compilation"), for more information on using intermediate files.

3.7.2.2 E: PREPROCESS ONLY

The `-E` option is used to generate preprocessed C source files (also called modules or translation units).

When this option is used, the compilation sequence will terminate after the preprocessing stage, leaving behind files with the same basename as the corresponding source file and with a `.i` extension.

You might check the preprocessed source files to ensure that preprocessor macros have expanded to what you think they should. The option can also be used to create C source files that do not require any separate header files. This is useful when sending files to a colleague or to obtain technical support without sending all the header files, which can reside in many directories.

3.7.2.3 O: SPECIFY OUTPUT FILE

The `-o` option specifies the name and directory of the output file.

The option `-o main.elf`, for example, will place the compiler output in a file called `main.elf`. The name of an existing directory can be specified with the file name, for example `-o build/main.elf`, so that the file will appear in that directory.

© 2012-2018 Microchip Technology Inc.

3.7.2.4 S: COMPILE TO ASSEMBLY

The `-S` option stops compilation after generating an assembly output file.

When this option is used, the compilation sequence will terminate early, leaving behind files with the same basename as the corresponding source file and with a `.s` extension. If the assembler optimizers are enabled, the resulting output file is optimized by the assembler; otherwise the output is the raw code generator output. Optimized assembly files have many of the assembler directives removed.

This option might be useful for checking assembly code output by the compiler without the distraction of line number and opcode information that will be present in an assembly list file.

3.7.2.5 V: VERBOSE COMPILATION

The `-v` option specifies verbose compilation.

When this option is used, the name and path of the executed compiler applications will be displayed, followed by the command-line arguments to this application, for example:

```
/Applications/microchip/XC8/v2.00/bin/hexmate
@/tmp/hexmate_xcf8oco6H.cmd [
--edf=/Applications/dev/XC8/v2.00/dat/en_msgs.txt main.hex -E1
-Omain.hex -logfile=main.hxl -addressing=1 -break=300000 ]
```

3.7.2.6 X: SPECIFY SOURCE LANGUAGE

The `-xassembler-with-cpp` option allows you to specify that all assembly source files need to be preprocessed, irrespective of the source file's extension. For example:

```
xc8-cc -mcpu=18f4520 -xassembler-with-cpp proj.c init.s
```

will tell the compiler to run the C preprocessor over the assembly source file, even though it does not use a `.S` or `.sx` extension.

3.7.2.7 HELP

The `--help` option displays information on the `xc8-cc` compiler options, then the driver will terminate.

3.7.2.8 PRINT-DEVICES

The `--mprint-devices` option displays a list of devices the compiler supports. The names listed are those chips that are defined in the chipinfo file and which can be used with the `-mcpu` option. Compiler execution will terminate after this list has been printed.

3.7.2.9 VERSION

The `--version` option prints compiler version information then exits.

3.7.3 Options for Controlling the C Dialect

The options shown in Table 3-17 define the kind of C dialect used by the compiler and are discussed in the sections that follow.

TABLE 3-17: C DIALECT CONTROL OPTIONS

Option	Controls
`-ansi`	The C language standard

`-f[no-]signed-char`
`-f[no-]unsigned-char`
	The signedness of a plain `char` type

`-mext=`*`extension`*	Which language extensions is in effect
`-std=`*`standard`*	The C language standard

3.7.3.1 ANSI

The `-ansi` option is equivalent to `-std=c90`, and controls the C standard used.

3.7.3.2 SIGNED-CHAR/UNSIGNED-CHAR

The `-fsigned-char` and `-funsigned-char` options enforce the signedness of a plain `char` type.

By default, the plain `char` type is equivalent to `unsigned char`. These options specify the exact type that will be used by the compiler. Use the `-funsigned-char` or `-fno-signed-char` option to force a plain `char` to be unsigned, and the `-fsigned-char` or `-fno-unsigned-char` option to force a plain `char` to be signed.

Consider explicitly stating the signedness of `char` objects when they are defined, rather than relying on the type assigned to a plain `char` type by the compiler.

3.7.3.3 EXT

The `-mext=`*`extension`* option controls the language extension used during compilation and those extensions allowed are shown in Table 4-13.

TABLE 3-18: ACCEPTABLE C LANGUAGE EXTENSIONS

Extension	C Language Description
`xc8`	The native XC8 extensions (default)
`cci`	A common C interface acceptable by all MPLAB XC compilers

Enabling the `cci` extension requests the compiler to check all source code and compiler options for compliance with the Common C Interface (CCI). Code that complies with this interface can be more easily ported across all MPLAB XC compilers. Code or options that do not conform to the CCI will be flagged by compiler warnings.

3.7.3.4 STD

The `-std=`*`standard`* option specifies the C standard to which the compiler assumes source code will conform. Allowable standards and devices are shown in Table 3-19.

Note that a different compiler front end will be used for these two standards, thus you might see a change in compiler behavior when swapping between standards. Floating-point sizes of 24-bits are not permitted with building for C99 compliance (see Section 4.4.4 “Floating-Point Data Types”).

TABLE 3-19: ACCEPTABLE C LANGUAGE STANDARDS

Standard	Supports
`c89` or `c90`	ISO C90 programs using P1 front end for all devices
`c99`	ISO C99 programs using Clang front end for PIC18 and Enhanced mid-range

© 2012-2018 Microchip Technology Inc.

3.7.4 Options for Controlling Warnings and Errors

Warnings are diagnostic messages that report constructions that are not inherently erroneous, but that are risky or suggest there may have been an error.

The options shown in Table 3-20 control the messages produced by the compiler and are discussed in the sections that follow.

TABLE 3-20: WARNING AND ERROR OPTIONS IMPLIED BY ALL WARNINGS

Option	Controls
`-fmax-errors=`*`n`*	How many errors are output before terminating compilation
`-mwarn=level`	The threshold at which warnings are output
`-w`	The suppression of all warning messages
`-Wpedantic`	The acceptance of non-standard language extensions

3.7.4.1 MAX-ERRORS

The `-fmax-errors=`*`n`* option sets the maximum number of errors each compiler application (excluding Clang), as well as the driver, will display before execution is terminated.

By default, up to 20 error messages will be displayed by each application before the application terminates. The option `-fmax-errors=10`, for example, would ensure the applications terminate after only 10 errors.

See Section 3.6 “Compiler Messages” for full details of the messaging system employed by `xc8-cc`.

3.7.4.2 WARN

The `-mwarn=`*`level`* option is used to set the compiler warning level threshold. Allowable warning levels range from -9 to 9. The warning level determines how pedantic the compiler is about dubious type conversions and constructs. Each compiler warning has a designated warning level; the higher the warning level, the more important the warning message. If the warning message’s warning level exceeds the set threshold, the warning is printed by the compiler. The default warning level threshold is 0 and will allow all normal warning messages.

Use this option with care as some warning messages indicate code that is likely to fail during execution, or compromise portability. The warnings from the Clang front end are not controlled by this option.

Section 3.6 “Compiler Messages”has full information on the compiler’s messaging system.

3.7.4.3 W: DISABLE ALL WARNINGS

The `-w` option inhibits all warning messages. Use this option with care as some warning messages indicate code that is likely to fail during execution, or compromise portability.

3.7.4.4 PEDANTIC

The `-Wpedantic` option is used to enable strict ANSI C conformance of all special, non-standard keywords when building C89/90 conforming programs.

If this option is used, non-standard keywords must include two leading underscore characters (for example, `__persistent`) so as to strictly conform to the C standard.

3.7.5 Options for Debugging

The options shown in Table 3-21 control the debugging output produced by the compiler and are discussed in the sections that follow.

TABLE 3-21: DEBUGGING OPTIONS

Option	Controls
`-f[no-]instrumented-functions`	Inclusion of function profiling code in the file output
`-g`*`format`*	The type of debugging information generated
`-save-temps`	Whether intermediate files should be kept after compilation

3.7.5.1 INSTRUMENT-FUNCTIONS

The `-finstrument-functions` option embeds diagnostic code into the output to allow for function profiling with the appropriate hardware. See Section 4.3.13 "Function profiling" for more information.

3.7.5.2 G: PRODUCE DEBUGGING INFORMATION

The `-g`*`format`* option instructs the compiler to produce additional information, which can be used by hardware tools to debug your program.

The support formats are shown in Table 3-22.

TABLE 3-22: SUPPORTED DEBUGGING FILE FORMATS

Format	Debugging file format
`-gcoff`	COFF
`-gdwarf-3`	ELF/Dwarf release 3
`-ginhx32`	Intel HEX with extended linear address records, allowing use of addresses beyond 64kB
`-ginhx032`	INHX32 with initialization of upper address to zero

The compiler supports the use of this option with the optimizers enabled, making it possible to debug optimized code; however, the shortcuts taken by optimized code may occasionally produce surprising results, such as variables that do not exist and flow control that changes unexpectedly.

3.7.5.3 SAVE-TEMPS

The `-save-temps` option instructs the compiler to keep temporary files after compilation has finished.

© 2012-2018 Microchip Technology Inc.

3.7.6 Options for Controlling Optimization

The options shown in Table 3-23 control compiler optimizations and are described in the sections that follow. The table also indicates the compiler edition (license) required to be able to select the optimization level. See Section 4.13 "Optimizations" for a description of the sorts of optimizations possible.

TABLE 3-23: GENERAL OPTIMIZATION OPTIONS

Option	Edition	Builds with
`-O0`	All	No optimizations (default)
`-O` `-O1`	All	Optimization level 1
`-O2`	Standard or PRO	Optimization level 2
`-O3`	PRO only	Optimization level 3
`-Og`	All	Better debugging
`-Os`	PRO only	Size orientated optimizations
`-fasmfile`	All	Optimizations applied to assembly source files
`-f[no-]local`	All	Local optimizations
`--nofallback`	All	Only the selected optimization level and with no license-imposed fall back to a lesser level

3.7.6.1 O0: LEVEL OPTIMIZATIONS

The `-O0` option disables optimization.

Without no optimizations, the compiler's goal is to reduce the cost of compilation and to make debugging produce the expected results.

3.7.6.2 O1: LEVEL OPTIMIZATIONS

The `-O` or `-O1` options request level 1 optimizations.

The optimizations performed when using `-O1` aims to reduce code size and execution time, but still allows a reasonable level of debugability. This level is available for all compiler licenses.

O2: LEVEL OPTIMIZATIONS

The `-O2` option requests level 2 optimizations.

At this level, the compiler performs nearly all supported optimizations. This level is not available when using a Free license.

O3: LEVEL OPTIMIZATIONS

The `-O3` option requests level 2 optimizations.

This option requests all supported optimizations, including procedural abstraction, that reduces execution time but which might increase program size. This level is available only for PRO licensed compilers.

3.7.6.3 OG: BETTER DEBUGGING

The `-Og` option enables optimizations that do not severely interfere with debugging, offering a reasonable level of optimization while maintaining fast compilation and a good debugging experience.

3.7.6.4 OS: LEVEL OPTIMIZATIONS

The `-Os` option requests level 2 optimizations.

This option requests all supported optimizations that decrease program size. This level is available only for PRO licensed compilers.

3.7.6.5 ASMFILE

The `-fasmfile` option enables assembler optimizations on hand-written assembly source files. By default assembly source is not optimized.

3.7.6.6 LOCAL

The `-flocal` option limits the extent to which some optimizations are applied to the program.

This option will use omniscient code generation (OCG) optimizations with libraries or individual program modules but have the scope of those optimizations restricted to code within those libraries or modules. Normally optimizations in one module can be affected by code in other modules or libraries, and there are situations where you want to prevent this from occurring. The output of source compiled with this setting enabled with typically be larger but will change little from build to build, even if other project code that does not use this setting is modified. Such changes in the output might be undesirable if you have validated code that is to be distributed and used in many different applications.

All the source code specified with a build command that uses local optimizations constitutes one group and you can create as many groups as required by building source code with separate build commands. Any code built without local optimizations becomes part of the default (unrestricted) group. The standard libraries that are supplied with the compiler are built with local optimizations disabled and are always part of this default group.

Enabling local optimizations restricts the scope of many optimizations, but does not necessarily disable the optimizations themselves. Optimizations can still be performed within each group, but those optimizations will not be made if they depend on code that is contained in another group. For example, abstraction of common code sequences will not be made if the sequences are contained in different groups, but would be made if the sequences are from the same group. Since a group can be limited to just a few modules of source code (which you can build into a library in the usual way if you prefer), this still allows you to fully optimize the bulk of a project.

By default this option is disabled. It can be enabled when building for enhanced mid-range and PIC18 devices and an error message will be emitted if the optimization is selected with an incompatible device.

When code is built with local optimizations, all variables defined in that group are allocated to banked memory unless they are qualified with `near`. Bank selection instructions are often output when they might normally have been emitted. Page selection instructions before and after function calls are always output, constant propagation is disabled, floating-point type sizes are fixed at 32 bits for both `float` and `double` types (and this will be enforced for the entire program) and pointer sizes can be fixed based on their definition (see Section 4.4.6.2 "Pointer-Target Qualifiers"). Some assembly optimizations are also restricted, such as procedural abstraction, routine inlining, psect merging, and peephole optimizations.

© 2012-2018 Microchip Technology Inc.

3.7.6.7 NOFALLBACK

The `--nofallback` option can be used to ensure that the compiler is not inadvertently executed with optimizations below the that specified by the `-O` option.

For example, if an apparently unlicensed compiler was requested to run with level 2 optimizations, it would normally revert to a lower optimization level. With this option, the compiler will instead issue an error and compilation will terminate. Thus, this option can ensure that build are performed with a properly licensed compiler.

3.7.7 Options for Controlling the Preprocessor

The options shown in Table 3-24 control the preprocessor and are discussed in the sections that follow.

TABLE 3-24: PREPROCESSOR OPTIONS

Option	Controls

`-D`*`macro`*
`-D`*`macro=text`*
	The definition of preprocessor macros

`-M`	Generation of dependencies
`-MD`	Generation of dependencies
`-MF`	Where dependency information is written
`-MM`	Generation of dependencies
`-MMD`	Generation of dependencies
`-U`*`macro`*	The undefinition of preprocessor macros
`-Wp,`*`option`*	Options passed to the preprocessor
`-Xpreprocessor` *`option`*	Options passed to the preprocessor

3.7.7.1 D: DEFINE A MACRO

The `-D`*`macro=text`* option allows you to define preprocessor macros. A space may be present between the option and macro name.

With no `=`*`text`* specified in the option, this option defines a preprocessor macro called *`macro`* that will be considered to have been defined by any preprocessor directive that checks for such a definition (e.g. the `#ifdef` directive) and that will expand to be the value 1 if it is used in a context where it will be replaced. For example, when using the option, `-DMY_MACRO` (or `-D MY_MACRO`) and supplying the following code:

```
#ifdef MY_MACRO
int input = MY_MACRO;
#endif
```

the definition of `input` will be compiled, and the variable assigned the value `1`.

When the replacement, *`text`*, is specified with the option, the macro will subsequently expand to be the replacement specified. So if the above example code was compiled with the option `-DMY_MACRO=0x100`, then the definition would read: `int input = 0x100;` See Section 4.14.1.1 "Preprocessor Arithmetic" for clarification of how the replacement text might be used.

Defining macros as C string literals requires bypassing any interpretation issues in the operating system that is being used. To pass the C string, `"hello world"`, (including the *quote* characters) in the Windows environment, use: `"-DMY_STRING=\\\"hello world\\\""` (you must include the *quote* characters around the entire option, as there is a *space* character in the macro definition). Under Linux or Mac OS X, use: `-DMY_STRING=\"hello\ world\"`.

All instances of `-D` on the command line are processed before any `-U` options.

3.7.7.2 M: GENERATE MAKE RULE

The `-M` option tells the preprocessor to output a file describing the dependencies of each source file.

Both system and user headers are listed in the output. The dependencies is printed to a file with a `.d` extension and compilation will terminate after preprocessing.

© 2012-2018 Microchip Technology Inc.

3.7.7.3 MD: WRITE DEPENDENCY INFORMATION TO FILE

The `-MD` option is similar to `-M` but compilation will not be terminated after preprocessing.

3.7.7.4 MF: SPECIFY DEPENDENCY FILE

The `-MF` *`file`* option, when used with `-M` or `-MM`, specifies the file to which dependencies should be written.

3.7.7.5 MM: GENERATE MAKE RULE FOR QUOTED HEADERS

The `-MM` option is like `-M`, but system headers are not included in the output.

3.7.7.6 MMD: GENERATE MAKE RULE FOR USER HEADERS

The `-MMD` option is like `-MD`, but only user header files are included in the output.

3.7.7.7 U: UNDEFINE MACROS

The `-U`*`macro`* option undefines the macro *`macro`* if it was defined via `-D` option or by the compiler. All `-U` options are evaluated after all `-D` options (Section 3.7.7.1 “D: Define a Macro”).

3.7.7.8 WP: PREPROCESSOR OPTION

The `-Wp,`*`option`* option pass *`option`* to the preprocessor where it will be interpreted as a preprocessor option. If option contains commas, it is split into multiple options at the commas.

3.7.7.9 XPREPROCESSOR PREPROCESSOR OPTION

The `-Xpreprocessor,`*`option`* option pass *`option`* to the preprocessor where it will be interpreted as a preprocessor option. You can use this to supply system-specific preprocessor options that the compiler does not know how to recognize.

3.7.8 Options for Parsing

The options shown in Table 3-26 control parser operations and are discussed in the sections that follow.

TABLE 3-25: PARSER OPTIONS

Option	Controls
`-Xparser` *`option`*	Options to passed to the parser

3.7.8.1 XPARSER

The `-Xparser` *`option`* option passes its *`option`* argument directly to the parser. For example, `-Xparser -v` runs the parser in verbose mode. The options `-Xp1` and `-Xclang` are alternate forms of this option.

3.7.9 Options for Assembling

The options shown in Table 3-26 control assembler operations and are discussed in the sections that follow.

TABLE 3-26: ASSEMBLY OPTIONS

Option	Controls
`-Wa,`*`option`*	Options to passed to the assembler
`-Xassembler` *`option`*	Options to passed to the assembler

3.7.9.1 WA: PASS OPTION TO THE ASSEMBLER

The `-Wa,`*`option`* option passes its *`option`* argument directly to the assembler. If *`option`* contains commas, it is split into multiple options at the commas. For example `-Wa,-a` will request that the assembly produce an assembly list file.

3.7.9.2 XASSEMBLER ASSEMBLER OPTION

The `-Xassembler,`*`option`* option pass *`option`* to the assembler where it will be interpreted as an assembler option. You can use this to supply system-specific assembler options that the compiler does not know how to recognize.

3.7.10 Mapped Assembler Options

The following GCC-style option shown in Table 3-27 has been mapped to XC8 assembler equivalents.

TABLE 3-27: MAPPED ASSEMBLER OPTIONS

Option	Controls
`-Wa,-a`	The generation of an assembly list file

3.7.11 Options for Linking

The options shown in Table 3-28 control linker operations and are discussed in the sections that follow. If any of the options `-c`, `-S` or `-E` are used, the linker is not run.

TABLE 3-28: LINKING OPTIONS

Option	Controls
`-l`*`library`*	Which library files are scanned
`-mserial=`*`options`*	The insertion of a serial number in the output
`-nodefaultlibs`	Whether library code is linked with the project
`-nostartfiles`	Whether the runtime startup module is linked in
`-nostdlib`	Whether the library and startup code is linked with the project
`-Wl,option`	Options to passed to the linker
`-Xlinker option`	System-specific options to passed to the linker
`--fill=`*`options`*	Filling of unused memory

3.7.11.1 L: SPECIFY LIBRARY FILE

The `-l`*`library`* option search the library named *`library`* for unresolved symbols when linking. The linker then uses this file as if it had been specified precisely by name.

The directories searched include several standard system directories, plus any that you specify with `-L`.

© 2012-2018 Microchip Technology Inc.

The only difference between using an `-l` option (e.g., `-lmylib`) and specifying a file name (e.g., `mylib.a`) is that the compiler will search for a library specified using `-l` in several directories, as specified by the `-L` option.

3.7.11.2 SERIAL

The `-mserial=`*`options`* option allows a hexadecimal code to be stored at a particular address in program memory. A typical task for this option might be to position a serial number in program memory.

The byte-width of data to store is determined by the byte-width of the hexcode parameter in the option. For example, to store a one-byte value, 0, at program memory address 1000h, use `-mserial=00@1000`. To store the same value as a four byte quantity use `-mserial=00000000@1000`.

This option is functionally identical to the corresponding HEXMATE option. For more detailed information and advanced controls that can be used with this option (refer to Section 7.3.1.20 "-SERIAL").

The driver will also define a label at the location where the value was stored and can be referenced from C code as `_serial0`. To enable access to this symbol, remember to declare it, for example:

```
extern const int _serial0;
```

3.7.11.3 NODEFAULTLIBS

The `-nodefaultlibs` option will prevent the standard system libraries being linked into the project. Only the libraries you specify are passed to the linker.

3.7.11.4 NOSTARTFILES

The `-nostartfiles` option will prevent the runtime startup modules from being linked into the project.

3.7.11.5 NOSTDLIB

The `-nostdlib` option will prevent the standard system start-up files and libraries being linked into the project. No start-up files and only the libraries you specify are passed to the linker.

3.7.11.6 WL: LINKER OPTION

The `-Wl,`*`option`* option pass *`option`* to the linker where it will be interpreted as a linker option. If option contains commas, it is split into multiple options at the commas.

3.7.11.7 XL: LINKER OPTION

The `-Xl,`*`option`* option pass *`option`* to the linker where it will be interpreted as a linker option. You can use this to supply system-specific linker options that the compiler does not know how to recognize.

3.7.11.8 FILL

The `--fill=`*`options`* option allows you to fill unused memory with specified values in a variety of ways.

3.7.12 Mapped Linker Options

The following GCC-style options shown in Table 3-29 have been mapped to XC8 linker equivalents.

TABLE 3-29: MAPPED LINKER OPTIONS

Option	Controls
`-Wl,-[no-]data-init`	Clearing and initialization of C objects at runtime startup
`-Wl,-Map=`*`mapfile`*	The generation of a linker map file

© 2012-2018 Microchip Technology Inc.

3.7.13 Options for Directory Search

The options shown in Table 3-30 control directories searched operations and are discussed in the sections that follow.

TABLE 3-30: LINKING OPTIONS

Option	Controls
`-I`*`dir`*	The directories searched for preprocessor include files
`-L`*`dir`*	Directories searched for libraries
`-nostdinc`	Directories searched for headers

3.7.13.1 I: SPECIFY INCLUDE FILE SEARCH PATH

The `-I`*`dir`* option adds the directory *`dir`* to the head of the list of directories to be searched for header files. A space may be present between the option and directory name.

The option can specify either an absolute or relative path and it can be used more than once if multiple additional directories are to be searched, in which case they are scanned from left to right.The standard system directories are searched after scanning the directories specified with this option.

Under the Windows OS, the use of the directory backslash character may unintentionally form an escape sequence. To specify an include file path that ends with a directory separator character and which is quoted, use `-I "E:\\"`, for example, instead of `-I "E:\"`, to avoid the escape sequence `\"`. Note that MPLAB X IDE will quote any include file path you specify in the project properties and that search paths are relative to the output directory, not the project directory.

3.7.13.2 L: SPECIFY LIBRARY SEARCH PATH

The `-L`*`dir`* option allows you to specify an additional directory to be searched for library files. The compiler will automatically search standard library locations, so you only need to use this option if you are linking in your own libraries.

3.7.13.3 NOSTDINC

The `-nostdinc` option prevents the standard system directories for header files being searched by the preprocessor. Only the directories you have specified with `-I` options (and the current directory, if appropriate) are searched.

3.7.14 Options for Code Generation Conventions

The options shown in Table 3-31 control machine-independent conventions used when generating code and are discussed in he sections that follow.

TABLE 3-31: CODE GENERATION CONVENTION OPTIONS

Option	Controls
`-f[no-]short-double`	The size of the `double` type
`-f[no-]short-float`	The size of the `float` type

3.7.14.1 SHORT-DOUBLE

The `-fshort-double` option controls the size of the `double` type.

By default, the compiler will choose the truncated IEEE754 24-bit format for `double` types, or this can be explicitly requested by using this option. When using the `-fno-short-double` form of the option, the `double` type can be changed to the full 32-bit IEEE754 format. The selection of this option must be consistent across all modules of the program and a 32-bit `double` size should be selected when you require C99 compliance.

3.7.14.2 SHORT-FLOAT

The `-fshort-float` option controls the size of the `float` type.

By default, the compiler will choose the truncated IEEE754 24-bit format for `float` types, or this can be explicitly requested by using this option. When using the `-fno-short-float` form of the option, the `float` type can be changed to the full 32-bit IEEE754 format. The selection of this option must be consistent across all modules of the program and a 32-bit `float` size should be selected when you require C99 compliance.

© 2012-2018 Microchip Technology Inc.

Chapter 4. C Language Features

4.1 INTRODUCTION

MPLAB XC8 C Compiler supports a number of special features and extensions to the C language which are designed to ease the task of producing ROM-based applications for 8-bit PIC devices. This chapter documents the special language features that are specific to these devices.

- C Standard Compliance
- Device-Related Features
- Supported Data Types and Variables
- Memory Allocation and Access
- Operators and Statements
- Register Usage
- Functions
- Interrupts
- Main, Runtime Startup and Reset
- Libraries
- Mixing C and Assembly Code
- Optimizations
- Preprocessing
- Linking Programs

4.2 C STANDARD COMPLIANCE

This compiler is a freestanding implementation that conforms to the ISO/IEC 9899:1990 Standard (referred to as the C90 standard) as well the ISO/IEC 9899:1999 Standard (C99) for programming languages. The program standard can be selected using the `-std` option (see Section 3.7.3.4 "std").

This implementation makes no assumptions about any underlying operating system and does not provide support for streams, files, or threads. Aspects of the compiler that diverge from the standards are discussed in this section.

4.2.1 Common C Interface Standard

This compiler conforms to the Microchip XC compiler Common C Interface standard (CCI), and can verify that C source code is compliant with CCI.

CCI is a further refinement of the C standards that attempts to standardize implementation-defined behavior and non-standard extensions across the entire MPLAB XC compiler family.

CCI can be enforced by using the `-mext=cci` option (see Section 3.7.3.3 "ext").

4.2.2 Divergence from the C90 Standard

The C language implemented on MPLAB XC8 C Compiler can diverge from the C90 Standard in several areas detailed in the sections below.

4.2.2.1 REENTRANCY

One divergence is due to limited device memory and no hardware implementation of a data stack. For this reason, recursion is not supported and functions are not reentrant on Baseline and some Mid-range devices. Functions can be encoded reentrantly for Enhanced Mid-range and PIC18 devices. See Section 4.3.4 "Stacks" for more information on the stack models used by the compiler for each device family.

For those devices that do not support reentrancy, the compiler can make functions called from main-line and interrupt code appear to be reentrant via a duplication feature. See Section 4.9.7 "Function Duplication" for more about duplication.

4.2.2.2 SIZE OF OPERATOR WITH POINTER TYPES

Another divergence from both standards is that you cannot reliably use the C `sizeof` operator with pointer types or structure or array types that contain a pointer. This operator, however, may be used with pointer (or structure or array) variable identifiers. This is a result of the dynamic size of pointers assigned by the compiler.

So, for the following code:

```
char * cp;
size_t size;
size = sizeof(char *);
size = sizeof(cp);
```

`size` in the first example will be assigned the maximum size a pointer can be for the particular target device you have chosen. In the second example, `size` will be assigned the actual size of the pointer variable, `cp`. The `sizeof` operator using a pointer variable operand cannot be used as the number-of-elements expression in an array declaration. For example, the size of the following array is unpredictable:

```
unsigned buffer[sizeof(cp) * 10];
```

4.2.2.3 EMPTY FUNCTION PARAMETER LIST

According to the C standard, functions *defined* with an empty parameter list, as in the following example:

```
int range()
{ ... }
```

are assumed to take no arguments, as if `void` was specified in the brackets. A similar prototype in a *declaration*, as in the following example:

```
extern int range();
```

should specify that no information is supplied for the function's parameters.

When building for C90, the compiler assumes that a function *declared* with an empty parameter list has no parameters. This limitation is not present when you are compiling using the C99 standard, where such a declaration would be correctly interpreted to mean that no information is specified regarding the function's parameters.

4.2.3 Divergence from the C99 Standard

4.2.3.1 LIBRARY SUPPORT

The C99-compliant C libraries have not been shipped with this product but will become available in a subsequent release. As a result, some compiler features which are fully or partially implemented by library code are not available. These features include wide character support, type-generic math macros, universal character names, and hexadecimal floating-point support in `printf()`.

© 2012-2018 Microchip Technology Inc.

4.2.3.2 INLINED FUNCTIONS

There are several areas where the inlining of functions deviates from the C standard.

The standard states that an `inline` function should only be inlined in the translation unit in which it is defined. With MPLAB XC8, inlining can occur in any module.

The standard indicates that if no `extern` declaration is provided in the same translation unit as an `inline` function, then the definition is an *inlined definition*, does not provide an external definition of that function and poses as an alternative to an external definition. With this implementation, an external definition *is* implied by an `inline` function.

The standard states that if an external definition is provided in addition to an inline definition, then it is unspecified which definition the compiler should use in the translation unit of the inlined definition. With MPLAB XC8, a function redefinition error will be emitted if both inline and external definitions are encountered.

4.2.3.3 ALIASING USING EFFECTIVE TYPE

The compiler does not check for aliased types, but nor does it perform any optimizations that could fail as a result of aliased types.

4.2.3.4 RESTRICT WITH POINTERS

The `restrict` pointer type qualifier is allowed in programs, but will be ignored by the compiler.

4.2.3.5 VARIABLE LENGTH ARRAYS

The size of arrays must be known at compile time. Thus the dimensions of arrays must be constant expressions. Function prototypes cannot use the `[*]` syntax with an array to indicate a variable length array type.

4.2.3.6 FLEXIBLE ARRAY MEMBERS

The compiler will not accept an incomplete type array as the last member in a structure. All array members of a structure must specify a number of elements.

4.2.3.7 COMPLEX NUMBER SUPPORT

Complex types are not supported and use of the `_Complex` and `_Imaginary` and related types will trigger a warning and will be ignored. The `<complex.h>` header is also not supported.

4.2.3.8 EXTENDED IDENTIFIERS

C identifiers cannot currently use extended characters.

4.2.4 Implementation-Defined behavior

Certain features of the ANSI C standard have implementation-defined behavior. This means that the exact behavior of some C code can vary from compiler to compiler. The exact behavior of the compiler is detailed throughout this manual, and is fully summarized in Appendix C. Implementation-Defined Behavior.

4.3 DEVICE-RELATED FEATURES

MPLAB XC8 has several features which relate directly to the 8-bit PIC architectures and instruction sets. These are detailed in the following sections.

4.3.1 Device Support

The MPLAB XC8 C Compiler aims to support all 8-bit PIC and AVR devices. This user's guide should be consulted when you are programming PIC devices; when programming AVR targets, see the MPLAB® XC8 C Compiler User's Guide for AVR® MCU.

New PIC devices are frequently released. There are several ways you can check whether the compiler you are using supports a particular device.

From the command line, run the compiler you wish to use and pass it the option `--mprint-devices` (See Section 3.7.2.8 "print-devices"). A list of all devices will be printed.

You can also see the supported devices in your favorite web browser. Open the files `pic_chipinfo.html` for a list of all supported Baseline or Mid-range device, or `pic18_chipinfo.html` for all PIC18 devices. Both these files are located in the `docs` directory under your compiler's installation directory.

4.3.2 Instruction Set Support

The compiler supports all instruction sets for PIC10/12/16 devices as well as the standard (legacy) PIC18 instruction set. The extended instruction mode available on some PIC18 devices is not currently supported and setting the configuration bit (typically `XINST`) to enable this instruction set will trigger an error from the compiler.

4.3.3 Device Header Files

There is one header file that is typically included into each C source file you write. The file is `<xc.h>` and is a generic header file that will include other device- and architecture-specific header files when you build your project.

Inclusion of this file will allow access to SFRs via special variables, as well as macros which allow special memory access or inclusion of special instructions, like `CLRWDT()`.

Do *not* include chip-specific header files in your code as this will reduce portability, and these headers may not contain all the required definitions for the successful compilation of your code.

The header files shipped with the compiler are specific to that compiler version. Future compiler versions may ship with modified header files. Avoid including header files that have been copied into you project. Such projects might no longer be compatible with future versions of the compiler.

For information about assembly include files (`.inc`) (see Section 4.12.3.2 "Accessing Registers from Assembly Code").

© 2012-2018 Microchip Technology Inc.

4.3.4 Stacks

Stacks are used for two different purposes by programs running on 8-bit PIC devices: one stack is for storing function return addresses and one or two other stacks are used for data allocation.

4.3.4.1 FUNCTION RETURN ADDRESS STACK

The 8-bit PIC devices use a hardware stack for function return addresses. This stack cannot be manipulated directly and has a limited depth, which is indicated in your device data sheet and the compiler's chipinfo file.

Nesting functions too deeply can exceed the maximum hardware stack depth and lead to program failure. Remember that interrupts and implicitly called library functions also use this stack.

The compiler can be made to manage stack usage for some devices using the `-mstackcall` option (see Section 3.7.1.22 "stackcall"). This enables an alternate means of calling functions to allow function nesting deeper than the stack alone would otherwise allow.

A call graph is provided by the code generator in the assembler list file (see Section 5.4.6 "Call Graph"). This will indicate the stack levels at each function call and can be used as a guide to stack depth. The code generator can also produce warnings if the maximum stack depth is exceeded.

The warnings and call graphs are *guides* to stack usage. Optimizations and the use of interrupts can decrease or increase the program's stack depth over that determined by the compiler.

4.3.4.2 DATA STACKS

The compiler can implement two types of data stack: a compiled stack and a software stack. Both these stacks are for storing stack-based variables which have automatic storage duration, such as auto, parameter, and temporary variables.

Either one or both of these types of stacks may be used by a program. Compiler options, specifiers, and how the functions are called will dictate which stacks are used. See Section 4.5.2.2 "Automatic Storage Duration Objects" for more information on how the compiler allocates a function's stack-based objects.

A section, called `stack`, is used to reserve the memory used by the stack.

4.3.4.2.1 Compiled Stack Operation

A compiled stack is one or more areas of memory that are designated for automatic storage duration objects. Objects allocated space in the compiled stack are assigned a static address which can be accessed via a compiler-allocated symbol. This is the most efficient way of accessing stack-based objects, since it does not use a stack pointer.

Functions which allocate their stack-based objects in the compiled stack will not be reentrant, since each instance of the functions' objects will be accessed via the same symbols (see Section 4.12.3 "Interaction between Assembly and C Code"). Memory in a compiled stack can be reused, just like that in a conventional software stack. If two functions are never active at the same time, then their stack-based objects can overlap in memory with no corruption of data. The compiler can determine which functions could be active at the same time and will automatically reuse memory when possible. The compiler takes into account that interrupt functions, and functions they call, need their own dedicated memory (see also Section 4.9.7 "Function Duplication").

The size of the compiled stack can be determined at compile time, so available space can be confirmed by the compiler.

4.3.4.2.2 Software Stack Operation

A software stack is a dynamic allocation of memory this is used for automatic storage duration objects and which is indirectly accessed via a stack pointer. Although access of objects on a software stack can be slower, functions which use a software stack are reentrant. This form of stack is available only for Enhanced Mid-range and PIC18 devices.

As functions are called, they allocate a chunk of memory for their stack-based objects and the stack grows in memory. When the function exits, the memory it claimed is released and made available to other functions. Thus, a software stack has a size that is dynamic and varies as the program is executed. The stack grows up in memory, toward larger addresses when objects are allocated to the stack; it decreases in size when a function returns and its stack-based objects are no longer required.

A register, known as the stack pointer, is permanently assigned to hold the address of the "top" of the stack. MPLAB XC8 uses the `FSR1` register as the stack pointer, and it holds the address of the next free location in the software stack. The register contents are increased when variables are allocated (pushed) to the stack and decreased when a function returns and variables are removed (popped) from the stack. There is no register assigned to hold a frame pointer. All access to the stack must use an offset to the stack pointer.

Note that if there are *any* functions in the program that use the software stack, the `FSR1` register is reserved as the stack pointer for the duration of the entire program, even when executing functions that do not use the software stack. With this register unavailable for general use, the code generated may be less efficient or “Can't generate code” errors may result.

The maximum size of the stack is not exactly known at compile time and the compiler typically reserves as much space as possible for the stack to grow during program execution. The stack is always allocated a single memory range, which may cross bank boundaries, but within this range it may be segregated into one area for main-line code and an area for each interrupt routine, if required. The maximum size of each area can be specified using the `-mstack` option (see Section 3.7.1.21 “stack”). The stack pointer is reloaded when an interrupt occurs so it will access the separate stack area used by interrupt code. It is restored by the interrupt context switch code when the interrupt routine is complete.

The compiler cannot detect for overflow of the memory reserved for the stack as a whole, nor are any runtime checks made for stack overflow. If the software stack overflows, data corruption and code failure can result.

4.3.5 Configuration Bit Access

Configuration bits or fuses are used to set up fundamental device operation, such as the oscillator mode, watchdog timer, programming mode and code protection. These bits must be correctly set to ensure your program executes correctly.

Use the configuration pragma, which has the following forms, to set up your device.

```
#pragma config setting = state|value
#pragma config register = value
```

Here, *`setting`* is a configuration setting descriptor, e.g., `WDT`, and *`state`* is a textual description of the desired state, e.g., `OFF`.

The settings and states associated with each device can be determined from an HTML guide. Open the `pic_chipinfo.html` file (or the `pic18_chipinfo.html` file) that is located in the `pic/docs` directory of your compiler installation. Click the link to your target device and the page will show you the settings and values that are appropriate with this pragma. Review your device data sheet for more information.

© 2012-2018 Microchip Technology Inc.

The *value* field is a numerical value that can be used in preference to a descriptor. Numerical values can only be specified in decimal or in hexadecimal, the latter radix indicated by the usual `0x` prefix. Values must never be specified in binary (i.e., using the `0b` prefix).

Consider the following examples.

```
#pragma config WDT = ON      // turn on watchdog timer
#pragma config WDTPS = 0x1A  // specify the timer postscale value
```

One pragma can be used to program several settings by separating each setting-value pair with a comma. For example, the above could be specified with one pragma, as in the following.

```
#pragma config WDT=ON, WDTPS = 0x1A
```

It is recommended that the setting-value pairs be quoted to ensure that the preprocessor does not perform substitution of these tokens, for example:

```
#pragma config "BOREN=OFF"
```

You should never assume that the `OFF` and `ON` tokens used in configuration macros equate to 0 and 1, respectively, as that is often not the case.

Rather than specify individual settings, each half of the configuration register can be programmed with one numerical value, for example:

```
#pragma config CONFIG1L = 0x8F
```

Neither the `config` pragma nor the `__CONFIG` macro produce executable code, and ideally they should both be placed outside function definitions.

All the bits in the Configuration Words should be programmed to prevent erratic program behavior. Do not leave them in their default/unprogrammed state. Not all Configuration bits have a default state of logic high; some have a logic low default state. Consult your device data sheet for more information.

If you are using MPLAB X IDE, take advantage of its built-in tools to generate the required pragmas, so that you can copy and paste them into your source code.

4.3.6 ID Locations

The 8-bit PIC devices have locations outside the addressable memory area that can be used for storing program information, such as an ID number. The `config` pragma is also used to place data into these locations by using a special register name. The pragma is used as follows:

```
#pragma config IDLOCx = value
```

where *x* is the number (position) of the ID location, and *value* is the nibble or byte that is to be positioned into that ID location. The value can only be specified in decimal or in hexadecimal, the latter radix indicated by the usual `0x` prefix. Values must never be specified in binary (i.e., using the `0b` prefix). If *value* is larger than the maximum value allowable for each location on the target device, the value will be truncated and a warning message is issued. The size of each ID location varies from device to device. See your device data sheet for more information. For example:

```
#pragma config IDLOC0 = 1
#pragma config IDLOC1 = 4
```

will attempt fill the first two ID locations with 1 and 4. One pragma can be used to program several locations by separating each register-value pair with a comma. For example, the above could also be specified as shown below.

```
#pragma config IDLOC0 = 1, IDLOC1 = 4
```

The config pragma does not produce executable code and so should ideally be placed outside function definitions.

4.3.7 Using SFRs From C Code

The Special Function Registers (SFRs) are typically memory mapped registers and are accessed by absolute C structure variables that are placed at the register's address. These structures can be accessed in the usual way so that no special syntax is required to access SFRs.

The SFRs control aspects of the MCU and peripheral module operation. Some registers are read-only; some are write-only. Always check your device data sheet for complete information regarding the registers.

The SFR structures are predefined in header files and are accessible once you have included `<xc.h>` (see Section 4.3.3 "Device Header Files") into your source files. Structures are mapped over the entire register and bit-fields within those structures allow access to specific SFR bits. The names of the structures will typically be the same as the corresponding register, as specified in the device data sheet, followed by `bits` (see Section 2.4.2.5 "How Do I Find The Names Used to Represent SFRs and Bits?"). For example, the following shows code that includes the generic header file, clears PORTA as a whole and sets bit 2 of PORTA using the bit-field definition.

```
#include <xc.h>
void main(void)
{
   PORTA = 0x00;
   PORTAbits.RA2 = 1;
}
```

Care should be taken when accessing some SFRs from C code or from in-line assembly. Some registers are used by the compiler to hold intermediate values of calculations, and writing to these registers directly can result in code failure. A list of registers used by the compiler and can be found in Section 4.7 "Register Usage".

4.3.7.1 SPECIAL PIC18 REGISTER ISSUES

Some of the SFRs used by PIC18 devices can be grouped to form multi-byte values, e.g., the `TMR`*x*`H` and `TMR`*x*`L` register combine to form a 16-bit timer count value. Depending on the device and mode of operation, there can be hardware requirements to read these registers in certain ways, e.g., often the `TMR`*x*`L` register must be read before trying to read the `TMR`*x*`H` register to obtain a valid 16-bit result.

It is not recommended that you read a multi-byte variable mapped over these registers as there is no guarantee of the order in which the bytes will be read. It is recommended that each byte of the SFR should be accessed directly, and in the required order, as dictated by the device data sheet. This results in a much higher degree of portability.

The following code copies the two timer registers into a C `unsigned` variable `count` for subsequent use.

```
count = TMR0L;
count += TMR0H << 8;
```

Macros are also provided to perform reading and writing of the more common timer registers. See the macros `READTIMER`*x* and `WRITETIMER`*x* in Appendix A. Library Functions. These guarantee the correct byte order is used.

4.3.8 Bit Instructions

Wherever possible, the MPLAB XC8 C Compiler will attempt to use bit instructions, even on non-bit integer values. For example, when using a bitwise operator and a mask to alter a bit within an integral type, the compiler will check the mask value to determine if a bit instruction can achieve the same functionality.

```
unsigned int foo;
foo |= 0x40;
```

© 2012-2018 Microchip Technology Inc.

will produce the instruction:

```
bsf _foo,6
```

To set or clear individual bits within integral type, the following macros could be used:

```
#define bitset(var, bitno)    ((var) |= 1UL << (bitno))
#define bitclr(var, bitno)    ((var) &= ~(1UL << (bitno)))
```

To perform the same operation on `foo` as above, the `bitset` macro could be employed as follows:

```
bitset(foo, 6);
```

4.3.9 Multiplication

The PIC18 instruction set includes several 8-bit by 8-bit hardware multiple instructions, and these are used by the compiler in many situations. Non-PIC18 targets always use a library routine for multiplication operations.

There are three ways that 8x8-bit integer multiplication can be implemented by the compiler:

Hardware Multiply Instructions (HMI)	These assembly instructions are the most efficient method of multiplication, but they are only available on PIC18 devices.
A bitwise iteration (8loop)	Where dedicated multiplication instructions are not available, this implementation produces the smallest amount of code – a loop cycles through the bit pattern in the operands and constructs the result bit-by-bit. The speed of this implementation varies and is dependent on the operand values; however, this is typically the slowest method of performing multiplication.
An unrolled bitwise sequence (8seq)	This implementation performs a sequence of instructions that is identical to the bitwise iteration (above), but the loop is unrolled. The generated code is larger, but execution is faster than the loop version.

Multiplication of operands larger than 8 bits can be performed one of the following two ways:

A bitwise iteration (*x*loop)	This is the same algorithm used by 8-bit multiplication (above) but the loop runs over all (*x*) bits of the operands. Like its 8-bit counterpart, this implementation produces the smallest amount of code but is typically the slowest method of performing multiplication.
A bytewise decomposition (bytdec)	This is a decomposition of the multiplication into a summation of many 8-bit multiplications. The 8-bit multiplications can then be performed using any of the methods described above. This decomposition is advantageous for PIC18 devices, which can then use hardware multiply instructions. For other devices, this method is still fast, but the code size can become impractical.

Multiplication of floating-point operands operates in a similar way – the integer mantissas can be multiplied using either a bitwise loop (*x*fploop) or by a bytewise decomposition.

The following tables indicate which of the multiplication methods are chosen by the compiler when performing multiplication of both integer and floating point operands. The method is dependent on the size of the operands, the type of optimizations enabled, and the target device.

Table 4-1 shows the methods chosen when speed optimizations are enabled (see Section 3.7.6 "Options for Controlling Optimization").

TABLE 4-1: MULTIPLICATION WITH SPEED OPTIMIZATIONS

Device	8-bit	16-bit	24-bit	32-bit	24-bit FP	32-bit FP
PIC18	HMI	bytdec+HMI	bytdec+HMI	bytdec+HMI	bytdec+HMI	bytdec+HMI
Enhanced Mid-range	8seq	bytdec+8seq	bytdec+8seq	bytdec+8seq	bytdec+8seq	bytdec+8seq
Mid-range/ Baseline	8seq	16loop	24loop	32loop	24fploop	32fploop

Table 4-2 shows the method chosen when space optimizations are enabled or when no C-level optimizations are enabled.

TABLE 4-2: MULTIPLICATION WITH NO OR SPACE OPTIMIZATIONS

Device	8-bit	16-bit	24-bit	32-bit	24-bit FP	32-bit FP
PIC18	HMI	bytdec+HMI	24loop	32loop	24fploop	32fploop
Enhanced Mid-range	8loop	bytdec+8loop	24loop	32loop	24fploop	32fploop
Mid-range/Baseline	8loop	16loop	24loop	32loop	24fploop	32fploop

The source code for the multiplication routines (documented with the algorithms employed) is available in the `pic/c99/sources` directory, located in the compiler's installation directory. Look for files whose name has the form `Umul`*`x`*`.c`. where *x* is the size of the operation in bits.

If your device and optimization settings dictate the use of a bitwise multiplication loop you can sometimes arrange the multiplication operands in your C code to improve the operation's speed. Where possible, ensure that the left operand to the multiplication is the smallest of the operands.

For example, in the code:

```
x = 10;
y = 200;
result = x * y;  // first multiply
result = y * x;  // second multiply
```

the variable `result` will be assigned the same value in both statements, but the first multiplication expression will be performed faster than the second.

4.3.10 Baseline PIC MCU Special Instructions

Baseline devices can use the `OPTION` and `TRIS` SFRs, which are not memory mapped.

The definition of these registers use a special qualifier, `__control`, to indicate that the registers are write-only, outside the normal address space, and must be accessed using special instructions.

When these SFRs are written in C code, the compiler will use the appropriate instruction to store the value. So, for example, to set the TRIS register, the following code:

```
TRIS = 0xFF;
```

would be encoded by the compiler as:

© 2012-2018 Microchip Technology Inc.

```
movlw 0ffh
TRIS
```

Those Baseline PIC devices which have more than one output port can have `__control` definitions for objects: `TRISA`, `TRISB` and `TRISC`, and which are used in the same manner as described above.

Any register that uses the `__control` qualifier must be accessed as a full byte. If you need to access bits within the register, copy the register to a temporary variable first, then access that temporary variable as required.

4.3.11 Oscillator Calibration Constants

Some Baseline and Mid-range devices have an oscillator calibration constant pre-programmed into their program memory. This constant can be read and written to the `OSCCAL` register to calibrate the internal RC oscillator.

On some Baseline PIC devices, the calibration constant is stored as a `movlw` instruction at the top of program memory, e.g., the PIC10F509 device. On Reset, the program counter is made to point to this instruction and it is executed first before the program counter wraps around to 0x0000, which is the effective Reset vector for the device. The default runtime startup routine (see Section 4.10.2 “Runtime Startup Code”) will automatically include code to load the OSCCAL register with the value contained in the W register after Reset on such devices. No other code is required.

For other chips, such as PIC12F629 device, the oscillator constant is also stored at the top of program memory, but as a `retlw` instruction. The compiler’s startup code will automatically generate code to retrieve this value and perform the configuration. This value can also be read at runtime by calling `__osccal_val()`, whose prototype is provided in `<xc.h>`. For example:

```
unsigned char calVal;
calVal = __osccal_val();
```

Loading of the calibration value at startup can be turned off via the `-mosccal` option (see Section 3.7.1.14 “osccal”).

> **Note:** The location that stores the calibration constant is never code protected and will be lost if you reprogram the device. Thus, the calibration constant must be saved before the device is erased. The constant must then be reprogrammed at the same location along with the new program and data. If you are using an in-circuit emulator (ICE), the location used by the calibration `retlw` instruction cannot be programmed and subsequent calls to `__osccal_val()` will not work. If you wish to test code that calls this function on an ICE, you must program a `retlw` instruction at the appropriate location. Remember to remove this instruction when programming the actual part so you do not destroy the calibration value.

Legacy projects can use the macro `_READ_OSCCAL_DATA()`, which maps to the `__osccal_val()` function.

4.3.12 MPLAB REAL ICE In-Circuit Emulator Support

The compiler supports log and trace functions (instrumented trace) when using a Microchip MPLAB REAL ICE In-Circuit Emulator. See the emulator’s documentation for more information on the instrumented trace features.

Not all devices support instrumented trace and only native trace is currently supported by the compiler.

The log and trace macro calls need to be either added by hand to your source code or inserted by right-clicking on the appropriate location in MPLAB X IDE editor, as described by the emulator documentation. The `<xc.h>` header must be included in any modules that use these macros. The macros have the following form.

```
__TRACE(id);
__LOG(id, expression);
```

MPLAB X IDE will automatically substitute an appropriate value for `id` when you compile; however, you can specify these by hand if required. The trace `id` should be a constant in the range of 0x40 to 0x7F and the log `id` is a constant in the range of 0x0 to 0x7F. Each macro should be given a unique number so that it can be properly identified. The same number can be used for both trace and log macros.

Trace macros should be inserted in the C source code at the locations you wish to track. They will trigger information to be sent to the debugger and IDE when they are executed, recording that execution reached that location in the program.

The log *`expression`* can be any integer or 32-bit floating-point expression whose value will be recorded along with the program location. Typically, this expression is simply a variable name so the variable's contents are logged.

Adding trace and log macros will increase the size of your code as they contribute to the program image that is downloaded to the device.

Here is an example of these macros that you might add.

```
#include <xc.h>

inpStatus = readUser();
if(inpStatus == 0) {
    __TRACE(id);
    recovery();
}
__LOG(id, inpStatus);
```

4.3.13 Function profiling

The compiler can generate function registration code for the MPLAB REAL ICE In-Circuit Emulator to provide function profiling. To obtain profiling results, you must also use a Power Monitor Board and MPLAB X IDE and power monitor plugin that support code profiling for the MPLAB XC8 C Compiler.

The `-finstrument-functions` option (see Section 3.7.5.1 "instrument-functions") enables this feature and inserts assembly code into the prologue and epilogue of each function. This code communicates runtime information to the debugger to signal when a function is being entered and when it exits. This information, along with further measurements made by a Microchip Power Monitor Board, can determine how much energy each function is using. This feature is transparent, but note the following points when profiling is enabled:

- The program will increase in size and run slower due to the profiling code
- One extra level of hardware stack is used
- Some additional RAM memory is consumed
- Inlining of functions will not take place for any profiled function

If a function cannot be profiled (due to hardware stack constraints) but is qualified `inline`, the compiler might inline the function. See Section 4.8.1.2 "Inline Specifier" for more information on inlining functions.

© 2012-2018 Microchip Technology Inc.

4.4 SUPPORTED DATA TYPES AND VARIABLES

4.4.1 Identifiers

Identifiers are used to represent C objects and functions and must conform to strict rules.

A C identifier is a sequence of letters and digits where the underscore character “_” counts as a letter. Identifiers cannot start with a digit. Although they can start with an underscore, such identifiers are reserved for the compiler’s use and should not be defined by your programs. Such is not the case for assembly-domain identifiers, which often begin with an underscore (see Section 4.12.3.1 “Equivalent Assembly Symbols”).

Identifiers are case sensitive, so `main` is different to `Main`.

Up to 255 characters are significant in an identifier. If two identifiers differ only after the maximum number of significant characters, then the compiler will consider them to be the same symbol.

4.4.2 Integer Data Types

The MPLAB XC8 compiler supports integer data types with 1, 2, 3 and 4 byte sizes as well as a single bit type. Table 4-3 shows the data types and their corresponding size and arithmetic type. The default type for each type is underlined.

TABLE 4-3: INTEGER DATA TYPES

Type	Size (bits)	Arithmetic Type
`__bit`	1	Unsigned integer
`signed char`	8	Signed integer
`unsigned char`	8	Unsigned integer
`signed short`	16	Signed integer
`unsigned short`	16	Unsigned integer
`signed int`	16	Signed integer
`unsigned int`	16	Unsigned integer
`__int24`	24	Signed integer
`__uint24`	24	Unsigned integer
`signed long`	32	Signed integer
`unsigned long`	32	Unsigned integer
`signed long long`	32/64	Signed integer
`unsigned long long`	32/64	Unsigned integer

The `__bit` and `__int24` types are non-standard types available in this implementation. The `long long` types are 64-bit C99 standard types when building for PIC18 devices, but this implementation limits their size to only 32 bits for projects conforming to the C90 Standard or any project targeting any other device.

All integer values are represented in little endian format with the Least Significant Byte (LSB) at the lower address.

If no signedness is specified in the type, then the type will be `signed` except for the `char` and `__bit` types which are always `unsigned`. The concept of a signed bit is meaningless.

Signed values are stored as a two’s complement integer value.

The range of values capable of being held by these types is summarized in Table A-7.

The symbols in this table are preprocessor macros which are available after including <limits.h> in your source code. As the size of data types are not fully specified by the C Standard, these macros allow for more portable code which can check the limits of the range of values held by the type on this implementation. The macros associated with the __int24 type are non-standard macros available in this implementation. The values associated with the long long macros are dependent on the C standard being used

Macros are also available in <stdint.h> which define values associated with fixed-width types, such as int8_t, uint32_t etc.

4.4.2.1 BIT DATA TYPES AND VARIABLES

The MPLAB XC8 C Compiler supports a single-bit integer type via the __bit type specifier.

Bit variables behave in most respects like normal unsigned char variables, but they can only contain the values 0 and 1. They provide a convenient and efficient method of storing flags, since eight bit objects are packed into each byte of memory storage. Operations on bit variables are performed using the single bit instructions (bsf and bcf) wherever possible.

```
__bit init_flag;
```

These variables cannot be auto or parameters to a function, but can be qualified static, allowing them to be defined locally within a function. For example:

```
int func(void) {
    static __bit flame_on;
    // ...
}
```

A function can return a bit by using the __bit keyword in the function's prototype in the usual way. The returned value will be stored in the STATUS register carry flag.

It is not possible to declare a pointer to bit types or assign the address of a bit object to any pointer. Nor is it possible to statically initialize bit variables so they must be assigned any non-zero starting value (i.e., 1) in the code itself. Bit objects will be cleared on startup, unless the bit is qualified __persistent.

When assigning a larger integral type to a bit variable, only the least significant bit is used. For example, in the following code:

```
int data = 0x54;
__bit bitvar;
bitvar = data;
```

bitvar will be cleared by the assignment since the LSb of data is zero. This sets the __bit type apart from _Bool, which is a boolean type (See Section 4.4.3 "Boolean Types").

All addresses assigned to bit objects and the sections that hold them will be bit addresses. For absolute bit variables (see Section 4.5.4 "Absolute Variables"), the address specified in code must be a bit address. Take care when comparing these addresses to byte addresses used by all other variables.

4.4.3 Boolean Types

The compiler supports _Bool, a type used for holding true and false values. The values held by variables of this type are not integers and behave differently in expressions compared to similar expressions involving integers of type bit (See Section 4.4.2.1 "Bit Data Types and Variables"). Values converted to a _Bool type result in 0 (false) if the value is 0; otherwise, they result in 1 (true).

© 2012-2018 Microchip Technology Inc.

The <stdbool.h> header defines true and false macros that can be used with _Bool types, and the bool macro, which expands to the _Bool type. For example:

```
#include <stdbool.h>
_Bool motorOn;
motorOn = false;
```

If you are compiling with the C90 standard, _Bool is not available, but there is a bool type available if you include <stdbool.h>, but which is merely a typedef for unsigned char.

4.4.4 Floating-Point Data Types

The MPLAB XC8 compiler supports 32- and 24-bit floating-point types, being an IEEE 754 32-bit format, or a truncated, 24-bit form of this, respectively. Floating-point sizes of 32-bits will be automatically set when you select C99 compliance. If 24-bit floating-point types are explicitly selected, the compiler will use the C90 libraries. Table 4-4 shows the data types and their corresponding size and arithmetic type.

TABLE 4-4: FLOATING-POINT DATA TYPES

Type	Size (bits)	Arithmetic Type
`float`	24 / 32	Real
`double`	24 / 32	Real
`long double`	same size as `double`	Real

For both float and double values, the 24-bit format is the default. The options -fshort-float and -fshort-double can also be used to specify this explicitly. The 32-bit format is used for double values if -fno-short-double option is used and for float values if -fno-short-float is used.

Variables can be declared using the float and double keywords, respectively, to hold values of these types. Floating-point types are always signed and the unsigned keyword is illegal when specifying a floating-point type. Types declared as long double will use the same format as types declared as double. All floating-point values are represented in little endian format with the LSB at the lower address.

The 32-bit floating-point type supports "relaxed" semantics when compared to the full IEEE implementation, which means the following rules are observed.

Tiny (sub-normal) arguments to floating-point routines are interpreted as zeros. There are no representable floating-point values possible between -1.17549435E-38 and 1.17549435E-38, except for 0.0. This range is called the denormal range. Sub-normal results of routines are flushed to zero. There are no negative 0 results produced.

Not-a-number (NaN) arguments to routines are interpreted as infinities. NaN results are never created in addition, subtraction, multiplication, or division routines where a NaN would be normally expected—an infinity of the proper sign is created instead. The square root of a negative number will return the “distinguished” NaN (default NaN used for error return).

Infinities are legal arguments for all operations and behave as the largest representable number with that sign. For example, +inf + -inf yields the value 0.

The format for both floating-point types is described in Table 4-5, where:

- *Sign* is the sign bit, which indicates if the number is positive or negative
- The *Biased Exponent* is 8 bits wide and is stored as excess 127 (i.e., an exponent of 0 is stored as 127).
- *Mantissa* is the mantissa, which is to the right of the radix point. There is an implied bit to the left of the radix point which is always 1 except for a zero value, where the implied bit is zero. A zero value is indicated by a zero exponent.

The value of this number is $(-1)^{sign} \times 2^{(exponent-127)} \times 1.$ mantissa.

TABLE 4-5: FLOATING-POINT FORMATS

Format	Sign	Biased Exponent	Mantissa
IEEE 754 32-bit	x	xxxx xxxx	xxx xxxx xxxx xxxx xxxx xxxx
modified IEEE 754 24-bit	x	xxxx xxxx	xxx xxxx xxxx xxxx

Here are some examples of the IEEE 754 32-bit formats shown in Table 4-6. Note that the most significant bit (MSb) of the mantissa column (i.e., the bit to the left of the radix point) is the implied bit, which is assumed to be 1 unless the exponent is zero.

TABLE 4-6: FLOATING-POINT FORMAT EXAMPLE IEEE 754

Format	Value	Biased Exponent	1.mantissa	Decimal
32-bit	7DA6B69Bh	11111011b	1.0100110101101101 0011011b	2.77000e+37
		(251)	(1.302447676659)	—
24-bit	42123Ah	10000100b	1.001001000111010b	36.557
		(132)	(1.142395019531)	—

Use the following process to manually calculate the 32-bit example in Table 4-6.

The sign bit is zero; the biased exponent is 251, so the exponent is 251-127=124. Take the binary number to the right of the decimal point in the mantissa. Convert this to decimal and divide it by 223 where 23 is the size of the mantissa, to give 0.302447676659. Add 1 to this fraction. The floating-point number is then given by:

-10´2124´1.302447676659

which is approximately equal to:

2.77000e+37

Binary floating-point values are sometimes misunderstood. It is important to remember that not every floating-point value can be represented by a finite sized floating-point number. The size of the exponent in the number dictates the range of values that the number can hold and the size of the mantissa relates to the spacing of each value that can be represented exactly. Thus the 24-bit format allows for values with approximately the same range of values representable by the 32-bit format, but the values that can be exactly represented by this format are more widely spaced.

So, for example, if you are using a 24-bit wide floating-point type, it can exactly store the value 95000.0. However, the next highest number it can represent is 95002.0 and it is impossible to represent any value in between these two in such a type as it will be rounded. This implies that C code which compares floating-point values might not behave as expected.

For example:

```
volatile float myFloat;
myFloat = 95002.0;
if(myFloat == 95001.0)     // value will be rounded
   PORTA++;                // this line will be executed!
```

in which the result of the `if` expression will be true, even though it appears the two values being compared are different.

Compare this to a 32-bit floating-point type, which has a higher precision. It also can exactly store 95000.0 as a value. The next highest value which can be represented is (approximately) 95000.00781.

© 2012-2018 Microchip Technology Inc.

The characteristics of the floating-point formats are summarized in Table A-4, where *XXX* can be either FLT or DBL, representing float and double types, respectively.

The symbols in this table are preprocessor macros that are available after including <float.h> in your source code. As the size and format of floating-point data types are not fully specified by the C Standard, these macros allow for more portable code which can check the limits of the range of values held by the type on this implementation.

4.4.5 Structures and Unions

MPLAB XC8 C Compiler supports struct and union types. Structures and unions only differ in the memory offset applied to each member.

These types will be at least 1 byte wide. The members of structures and unions cannot be objects of type __bit, but bit-fields and _Bool objects are fully supported.

Structures and unions can be passed freely as function arguments and function return values. Pointers to structures and unions are fully supported.

4.4.5.1 STRUCTURE AND UNION QUALIFIERS

The compiler supports the use of type qualifiers on structures. When a qualifier is applied to a structure, all of its members will inherit this qualification. In the following example the structure is qualified const.

```
const struct {
        int number;
        int *ptr;
} record = { 0x55, &i };
```

In this case, the entire structure will be placed into the program space and each member will be read-only. Remember that all members are usually initialized if a structure is const as they cannot be initialized at runtime.

If the members of the structure were individually qualified const, but the structure was not, then the structure would be positioned into RAM, but each member would be read-only. Compare the following structure with the above.

```
struct {
        const int number;
        int * const ptr;
} record = { 0x55, &i };
```

4.4.5.2 BIT-FIELDS IN STRUCTURES

MPLAB XC8 C Compiler fully supports bit-fields in structures.

Bit-fields are always allocated within 8-bit words, even though it is usual to use the type unsigned int in the definition. The first bit defined will be the LSb of the word in which it will be stored. When a bit-field is declared, it is allocated within the current 8-bit unit if it will fit; otherwise, a new byte is allocated within the structure. Bit-fields can never cross the boundary between 8-bit allocation units. Bit-fields of type _Bool are also supported; however, they can only be one bit in size.

For example, the declaration:

```
struct {
        unsigned        lo : 1;
        unsigned        dummy : 6;
        unsigned        hi : 1;
} foo;
```

will produce a structure occupying 1 byte. If `foo` was ultimately linked at address 0x10, the field `lo` will be bit 0 of address 0x10 and field `hi` will be bit 7 of address 0x10. The LSb of `dummy` will be bit 1 of address 0x10.

Note: Accessing bit-fields larger than a single bit can be very inefficient. If code size and execution speed are critical, consider using a `char` type or a `char` structure member, instead. Be aware that some SFRs are defined as bit-fields. Most are single bits, but some can be multi-bit objects.

Unnamed bit-fields can be declared to pad out unused space between active bits in control registers. For example, if `dummy` is never referenced, the structure above could have been declared as:

```
struct {
        unsigned        lo : 1;
        unsigned           : 6;
        unsigned        hi : 1;
} foo;
```

A structure with bit-fields can be initialized by supplying a *comma*-separated list of initial values for each field. For example:

```
struct {
        unsigned        lo  : 1;
        unsigned        mid : 6;
        unsigned        hi  : 1;
} foo = {1, 8, 0};
```

Structures with unnamed bit-fields can be initialized. No initial value should be supplied for the unnamed members, for example:

```
struct {
        unsigned        lo  : 1;
        unsigned            : 6;
        unsigned        hi  : 1;
} foo = {1, 0};
```

will initialize the members `lo` and `hi` correctly.

A bit-field that has a size of 0 is a special case. The Standard indicates that no further bit-field is to be packed into the allocation unit in which the previous bit-field, if any, was placed.

4.4.5.3 ANONYMOUS STRUCTURES AND UNIONS

The MPLAB XC8 compiler supports anonymous structures and unions. These are C11 constructs with no identifier and whose members can be accessed without referencing the identifier of the construct. Anonymous structures and unions must be placed inside other structures or unions. For example:

```
struct {
       union {
       int x;
       double y;
   };
} aaa;

aaa.x = 99;
```

Here, the union is not named and its members are accessed as if they are part of the structure.

Objects defined with anonymous structures or unions can only be initialized if you are using the C99 Standard.

© 2012-2018 Microchip Technology Inc.

4.4.6 Pointer Types

There are two basic pointer types supported by the MPLAB XC8 C Compiler: data pointers and function pointers. Data pointers hold the addresses of objects which can be read, and possibly written, by the program. Function pointers hold the address of an executable function which can be called via the pointer. Data pointers (even generic `void *` pointers) should never be used to hold the address of functions, and function pointers should never be used to hold the address of objects.

The MPLAB XC8 compiler records *all* assignments of addresses to each pointer the program contains, and as a result, non-standard qualifiers are not required when defining pointer variables. The standard qualifiers `const` and `volatile` can still be used and have their usual meaning.

The size and format of the address held by each pointer is based on the set of all possible targets the pointer can address. This information is specific to each pointer defined in the program, thus two pointers with the same C type can hold addresses of different sizes and formats due to the way the pointers were used in the program.

The compiler tracks the memory location of all targets, as well as the size of all targets to determine the size and scope of a pointer. The size of a target is important as well, particularly with arrays or structures. It must be possible to increment a pointer so it can access all the elements of an array, for example.

4.4.6.1 COMBINING TYPE QUALIFIERS AND POINTERS

It is helpful to first review the C conventions for definitions of pointer types.

Pointers can be qualified like any other C object, but care must be taken when doing so as there are two quantities associated with pointers. The first is the actual pointer itself, which is treated like any ordinary C variable and has memory reserved for it. The second is the target, or targets, that the pointer references, or to which the pointer points. The general form of a pointer definition looks like the following:

`target_type_&_qualifiers * pointer’s_qualifiers pointer’s_name``;`

Any qualifiers to the right of the `*` (i.e., next to the pointer’s name) relate to the pointer variable itself. The type and any qualifiers to the left of the `*` relate to the pointer’s targets. This makes sense since it is also the `*` operator that dereferences a pointer, which allows you to get from the pointer variable to its current target.

Here are three examples of pointer definitions using the `volatile` qualifier. The fields in the definitions have been highlighted with spacing:

```
volatile int *           vip ;
int          * volatile  ivp ;
volatile int * volatile  vivp ;
```

The first example is a pointer called `vip`. The pointer itself – the variable that holds the address – is *not* `volatile`; however, the objects that are accessed when the pointer is dereferenced are treated as being `volatile`. In other words, the target objects accessible via the pointer can be externally modified.

In the second example, the pointer called `ivp` is `volatile`, that is, the address the pointer contains can be externally modified; however, the objects that can be accessed when dereferencing the pointer are not `volatile`.

The last example is of a pointer called `vivp` which is itself qualified `volatile`, and which also holds the address of `volatile` objects.

Bear in mind that one pointer can be assigned the addresses of many objects; for example, a pointer that is a parameter to a function is assigned a new object address every time the function is called. The definition of the pointer must be valid for every target address assigned.

Note: Care must be taken when describing pointers. Is a "const pointer" a pointer that points to `const` objects, or a pointer that is `const` itself? You can talk about "pointers to const" and "const pointers" to help clarify the definition, but such terms might not be universally understood.

4.4.6.2 POINTER-TARGET QUALIFIERS

The `__rom` and `__ram` pointer-target qualifiers can be used if you would like the compiler to confirm that targets assigned to a pointer are in a particular memory space.

These qualifiers can be used only when declaring or defining pointers. They cannot be used with ordinary variables and they have no effect on the placement of the pointers themselves. These qualifiers are always enforced by the compiler and they are not affected by the `-maddrqual` option (see Section 3.7.1.1 "addrqual") or `#pragma addrqual`.

The assignment of an incompatible target to a pointer that uses one of these qualifiers will trigger an error, so in the following example:

```
const int __rom * in_ptr;
```

an error would be generated if your program assigned to `in_ptr` the address of an object that was in data memory. Use of `__rom` implies the `const` qualifier, but it is recommended that `const` is explicitly used to ensure the meaning of your code is clear.

The use of these qualifiers must be consistent across all declarations of a pointer and it is illegal to use both qualifiers with the same pointer variable.

4.4.6.3 DATA POINTERS

There are several pointer classifications used with the MPLAB XC8 C Compiler, such as those indicated below. Those classification marked with (local) are the only classifications considered when local OCG optimizations have been selected (see Section 4.4.6.3.2 "Pointer Classifications with Local Optimization").

For Baseline and Mid-range devices:

- 8-bit pointer capable of accessing common memory and two consecutive (even-odd) banks, e.g., banks 0 and 1, or banks 6 and 7, etc.
- 16-bit pointer capable of accessing the entire data memory space (local)
- 8-bit pointer capable of accessing up to 256 bytes of program space data
- 16-bit pointer capable of accessing up to 64 Kbytes of program space data (local)
- 16-bit mixed target space pointer capable of accessing the entire data space memory and up to 64 Kbytes of program space data (local)

For PIC18 devices:

- 8-bit pointer capable of accessing the access bank
- 16-bit pointer capable of accessing the entire data memory space (local)
- 8-bit pointer capable of accessing up to 256 bytes of program space data
- 16-bit pointer capable of accessing up to 64 Kbytes of program space data (local)
- 24-bit pointer capable of accessing the entire program space (local)
- 16-bit mixed target space pointer capable of accessing the entire data space memory and up to 64 Kbytes of program space data
- 24-bit mixed target space pointer capable of accessing the entire data space memory and the entire program space (local)

© 2012-2018 Microchip Technology Inc.

Each data pointer will be allocated one of the available classifications after preliminary scans of the source code. There is no mechanism by which the programmer can specify the style of pointer required (other than by the assignments to the pointer). The C code must convey the required information to the compiler.

Information about the pointers and their targets are shown in the pointer reference graph, (described in Section 5.4.5 "Pointer Reference Graph"). This graph is printed in the assembly list file.

4.4.6.3.1 Pointers to Both Memory Spaces

When a data pointer is assigned the address of one or more objects that have been allocated memory in the data space and also assigned the address of one or more objects that have been allocated memory in the program memory space, the pointer is said to have targets with mixed memory spaces. Such pointers fall into one of the mixed target space pointer classifications (listed in Section 4.4.6.3 "Data Pointers") and the address will be encoded so that the target memory space can be determined at runtime. The encoding of these pointer types are as follows.

For the Baseline/Mid-range 16-bit mixed target space pointer, the MSb of the address (i.e., bit number 15) indicates the memory space that the address references. If this bit is set, it indicates that the address is of something in program memory; clear indicates an object in the data memory. The remainder of this address represents the full address in the indicated memory space.

For the PIC18 16-bit mixed target space pointer, any address above the highest data space address is that of an object in the program space memory; otherwise, the address is of a data space memory object.

For the PIC18 24-bit mixed target space pointer, bit number 21 indicates the memory space that the address references. If this bit is set, it indicates that the address is of an object residing in data memory; if it is clear, it indicates an object in the program memory. The remainder of this address represents the full address in the indicated memory space. Note that for efficiency reasons, the meaning of the memory space bit is the opposite to that for Baseline and Mid-range devices.

If assembly code references a C pointer, the compiler will force that pointer to become a 16-bit mixed target space pointer, in the case of Baseline or Mid-range programs, or a 24-bit mixed target space pointer, for PIC18 programs. These pointer types have unrestricted access to all memory areas and will operate correctly, even if assignments (of a correctly formatted address) are made to the pointer in the assembly code.

4.4.6.3.2 Pointer Classifications with Local Optimization

Where local optimizations have been enabled, pointers can have a size and classification based purely on their definition, not on the targets assigned to them by the program.

The pointer-target specifiers, `__ram` and `__rom`, (see Section 4.4.6.2 "Pointer-Target Qualifiers") can be used to ensure that addresses assigned to a pointer during the program's execution are within an intended memory space. Together with a restricted range of pointer classifications, this ensures that pointers will have a size that is predictable.

Pointers defined in code built with local optimizations and which have the indicated targets will have the following sizes, where *type* is a valid, unqualified C type, and [bracketed tokens] are optional.

`const` *`type`* `*` pointers can be assigned the address of any object in data or program memory. These pointers will be 3 bytes wide if the program is being built for a PIC18 device that has more than 64kB of program memory; they will be 2 bytes wide, otherwise.

`[const] __rom` *`type`* `*` pointers can be assigned the address of any object in program memory, and attempts to assign the address of a data memory object will result in an error. These pointers will be 3 bytes wide if the program is being built for a PIC18 device that has more than 64kB of program memory; they will be 2 bytes wide, otherwise.

`type` `*` pointers can be assigned the address of any object in data memory. As per normal operation, the compiler will issue a warning if the address of a `const` object is assigned to such pointers. These pointers are always 2 bytes in size.

`[const] __ram` *`type`* `*` pointers can be assigned the address of any object in data memory and attempts to assign the address of a program memory object will result in an error. These pointers will always be 2 bytes in size. The presence of the `const` specifier indicates only that the target objects must be treated as read-only.

The size and operation of pointers to `__far`, pointers to `eeprom`, and function pointers are not affected by the local optimization setting.

4.4.6.4 FUNCTION POINTERS

The MPLAB XC8 compiler fully supports pointers to functions. These are often used to call one of several function addresses stored in a user-defined C array, which acts like a lookup table.

For Baseline and Mid-range devices, function pointers are always one byte in size and hold an offset into a jump table that is output by the compiler. This jump table contains jumps to the destination functions.

For Enhanced Mid-range devices, function pointers are always 16-bits wide and can hold the full address of any function.

For PIC18 devices, function pointers are either 16 or 24 bits wide. The pointer size is purely based on the amount of program memory available on the target device.

As with data pointers, the target assigned to function pointers is tracked. This is an easier process to undertake compared to that associated with data pointers as all function instructions must reside in program memory. The pointer reference graph (described in Section 5.4.5 “Pointer Reference Graph”) will show function pointers, in addition to data pointers, as well as all their targets. The targets will be names of functions that could possibly be called via the pointer.

One notable runtime feature for Baseline and Mid-range devices is that a function pointer which contains null (the value 0) and is used to call a function indirectly will cause the code to become stuck in a loop which branches to itself. This endless loop can be used to detect this erroneous situation. Typically calling a function via a null function would result in the code crashing or some other unexpected behavior. The label to which the endless loop will jump is called `fpbase`.

© 2012-2018 Microchip Technology Inc.

4.4.6.5 SPECIAL POINTER TARGETS

Pointers and integers are not interchangeable. Assigning an integer to a pointer will generate a warning to this effect. For example:

```
const char * cp = 0x123;  // the compiler will flag this as bad code
```

There is no information in the integer constant, 0x123, relating to the type, size or memory location of the destination. There is a very good chance of code failure when dereferencing pointers that have been assigned integer addresses, particularly for PIC devices that have more than one memory space.

Always take the address of a C object when assigning an address to a pointer. If there is no C object defined at the destination address, then define or declare an object at this address which can be used for this purpose. Make sure the size of the object matches the range of the memory locations that are to be accessed by the pointer.

For example, a checksum for 1000 memory locations starting at address 0x900 in program memory is to be generated. A pointer is used to read this data. You can be tempted to write code such as:

```
const char * cp;
cp = 0x900;  // what resides at 0x900???
```

and increment the pointer over the data.

However, a much better solution is this:

```
const char * cp;
extern const char inputData[1000] __at(0x900);
cp = &inputData;
// cp is incremented over inputData and used to read values there
```

In this case, the compiler can determine the size of the target and the memory space. The array size and type indicates the size of the pointer target, the `const` qualifier on the object (not the pointer) indicates the target is located in program memory space. Note that the `const` array does not need initial values to be specified in this instance, see Section 4.4.8.1 “Const Type Qualifier” and can reside over the top of other objects at these addresses.

If the pointer has to access objects in data memory, you need to define a different object to act as a dummy target. For example, if the checksum was to be calculated over 10 bytes starting at address 0x90 in data memory, the following code could be used.

```
const char * cp;
extern char inputData[10] __at(0x90);
cp = &inputData;
// cp is incremented over inputData and used to read values there
```

No memory is consumed by the `extern` declaration, and this can be mapped over the top of existing objects.

User-defined absolute objects will not be cleared by the runtime startup code and can be placed over the top of other absolute variables.

Take care when comparing (subtracting) pointers. For example:

```
if(cp1 == cp2)
  ; // take appropriate action
```

The C standard only allows pointer comparisons when the two pointers’ addresses are of the same object. One exception is that the address can extend to one element past the end of an array.

Never compare pointers with integer constants as that is even more risky, for example:

```
if(cp1 == 0x246)
  ; // take appropriate action
```

A null pointer is the one instance where a constant value can be assigned to a pointer and this is handled correctly by the compiler. A null pointer is numerically equal to 0 (zero), but this is a special case imposed by the C standard. Comparisons with the macro `NULL` are also allowed.

4.4.7 Constant Types and Formats

Constant in C are an immediate value that can be specified in several formats and that are assigned a type.

4.4.7.1 INTEGRAL CONSTANTS

The format of integral constants specifies their radix. MPLAB XC8 supports the standard radix specifiers, as well as ones which enables binary constants to be specified in C code.

The formats used to specify the radices are given in Table 4-7. The letters used to specify binary or hexadecimal radices are case insensitive, as are the letters used to specify the hexadecimal digits.

TABLE 4-7: RADIX FORMATS

Radix	Format	Example
binary	`0b`*number* or `0B`*number*	0b10011010
octal	`0`*number*	0763
decimal	*number*	129
hexadecimal	`0x`*number* or `0X`*number*	0x2F

Any integral constant will have a type of `int`, `long int` or `long long int`, so that the type can hold the value without overflow. Constants specified in octal or hexadecimal can also be assigned a type of `unsigned int`, `unsigned long int` or `unsigned long long int` if their signed counterparts are too small to hold the value.

The default types of constants can be changed by the addition of a suffix after the digits; e.g., `23U`, where `U` is the suffix. Table 4-8 shows the possible combination of suffixes and the types that are considered when assigning a type. So, for example, if the suffix `l` is specified and the value is a decimal constant, the compiler will assign the type `long int`, if that type will hold the constant; otherwise, it will assigned `long long int`. If the constant was specified as an octal or hexadecimal constant, then unsigned types are also considered.

TABLE 4-8: SUFFIXES AND ASSIGNED TYPES

Suffix	Decimal	Octal or Hexadecimal

`u` or `U`	`unsigned int`
	`unsigned long int`
	`unsigned long long int`
		`unsigned int`
		`unsigned long int`
		`unsigned long long int`

`l` or `L`	`long int`
	`long long int`
		`long int`
		`unsigned long int`
		`long long int`
		`unsigned long long int`

`u` or `U`, and `l` or `L`	`unsigned long int`
	`unsigned long long int`
		`unsigned long int`
		`unsigned long long int`

`ll` or `LL`	`long long int`	`long long int`
		`unsigned long long int`

`u` or `U`, and `ll` or `LL`	`unsigned long long int`	`unsigned long long int`

© 2012-2018 Microchip Technology Inc.

Here is an example of code that can fail because the default type assigned to a constant is not appropriate:

```
unsigned long int result;
unsigned char shifter;

shifter = 20;
result = 1 << shifter;   // oops!
```

The constant `1` (one) will be assigned an `int` type, hence the value 1 shifted left 20 bits will yield the result 0, not 0x100000.

The following uses a suffix to change the type of the constant, hence ensure the shift result has an `unsigned long` type.

```
result = 1UL << shifter;
```

4.4.7.2 FLOATING-POINT CONSTANT

Floating-point constants have `double` type unless suffixed by `f` or `F`, in which case it is a `float` constant. The suffixes `l` or `L` specify a `long double` type which is considered an identical type to `double` by MPLAB XC8.

Floating point constants can be specified as decimal digits with a decimal point and/or an exponent. If you are using C99, they can be expressed as hexadecimal digits and a binary exponent, initiated with either p or P. So for example:

```
myFloat = -123.98E12;
myFloat = 0xFFEp-22;  // C99 float representation
```

4.4.7.3 CHARACTER AND STRING CONSTANTS

Character constants are enclosed by single quote characters, `’`, for example `’a’`. A character constant has `int` type, although this can be later optimized to a `char` type by the compiler.

To comply with the C standard, the compiler does not support the extended character set in characters or character arrays. Instead, they need to be escaped using the backslash character, as in the following example.

```
const char name[] = "Bj\370rk";
printf("%s's Resum\351", name);     \\ prints "Bjørk's Resumé"
```

Multi-byte character constants are not supported by this implementation.

String constants, or string literals, are enclosed by double quote characters “, for example “`hello world`”. The type of string constants is `const char *` and the characters that make up the string are stored in program memory, as are all objects qualified `const`.

A common warning relates to assigning a string literal, which cannot be modified, to a pointer that does not specify a `const` target, for example:

```
char * cp = "hello world\n";
```

See Section 4.4.6.1 “Combining Type Qualifiers and Pointers” and qualify the pointer as follows.

```
const char * cp = "hello world\n";
```

Defining and initializing an array (i.e., not a pointer) with a string is an exception. For example:

```
char ca[]= "hello world\n";
```

will actually copy the string characters into the RAM array, rather than assign the address of the characters to a pointer, as in the previous examples. The string literal remains read-only, but the array is both readable and writable.

The MPLAB XC8 compiler will use the same storage location and label for strings that have identical character sequences, except where the strings are used to initialize an array residing in the data space. For example, in the code snippet

```
if(strncmp(scp, "hello", 6) == 0)
    fred = 0;
if(strcmp(scp, "world") == 0)
    fred--;
if(strcmp(scp, "hello world") == 0)
    fred++;
```

the characters in the string "`world`" and the last 6 characters of the string "`hello world`" (the last character is the null terminator character) would be represented by the same characters in memory. The string "`hello`" would not overlap with the same characters in the string "`hello world`" as they differ in terms of the placement of the null character.

4.4.8 Standard Type Qualifiers

The compiler supports the standard qualifiers `const` and `volatile`, and additional qualifiers that allow programs take advantage of the 8-bit PIC MCU architecture.

4.4.8.1 CONST TYPE QUALIFIER

The `const` type qualifier is used to tell the compiler that an object is read only and will not be modified. If any attempt is made to modify an object declared `const`, the compiler will issue a warning or error.

User-defined objects (excluding autos and parameters) declared `const` are placed in a special psect linked into the program space. Objects qualified `const` can be absolute. The `__at(`*`address`*`)` construct is used to place the object at the specified address in program memory, as in the following example which places the object `tableDef` at address 0x100.

```
const int tableDef[] __at(0x100) = { 0, 1, 2, 3, 4};
```

Usually a `const` object must be initialized when it is declared, as it cannot be assigned a value at any point at runtime. For example:

```
const int version = 3;
```

will define `version` as being a read-only `int` variable, holding the value 3. However, uninitialized absolute `extern const` objects can be defined and are useful if you need to place an object in program memory over the top of other objects at a particular location, as in the following example.

```
extern const char checksumRange[0x100] __at(0x800);
```

will define `checksumRange` as an array of 0x100 characters located at address 0x800 in program memory. This definition will not place any data in the HEX file.

© 2012-2018 Microchip Technology Inc.

4.4.8.2 VOLATILE TYPE QUALIFIER

The `volatile` type qualifier indicates to the compiler that an object cannot be guaranteed to retain its value between successive accesses. This information prevents the optimizer from eliminating apparently redundant references to objects declared `volatile` because these references might alter the behavior of the program.

Any SFR which can be modified by hardware or which drives hardware is qualified as `volatile`, and any variables which can be modified by interrupt routines should use this qualifier as well. For example:

```
volatile static unsigned int  TACTL __at(0x160);
```

The `volatile` qualifier does not guarantee that any access will be atomic, which is often not the case since the 8-bit PIC MCU architecture can only access a maximum of 1 byte of data per instruction.

The code produced by the compiler, used to access `volatile` objects can be different to that of ordinary variables and typically the code will be longer and slower for `volatile` objects, so only use this qualifier if it is necessary. However, failure to use this qualifier when it is required can lead to code failure.

A common use of the `volatile` keyword is to prevent unused global variables being removed. If a non-`volatile` variable is never used, or used in a way that has no effect, then it can be removed before code is generated by the compiler.

A C statement that consists only of a `volatile` variable identifier will produce code that reads the variable's memory location and discards the result. For example, the entire statement, `PORTB;` will produce assembly code the reads `PORTB`. This is useful for some peripheral registers that require reading to reset the state of interrupt flags.

Some variables are treated as being `volatile` even though they are not qualified. See Section 4.12.3.5 "Undefined Symbols" if you have assembly code in your project.

4.4.9 Special Type Qualifiers

The MPLAB XC8 C Compiler supports special type qualifiers to allow the user to control placement of objects with static storage duration into particular address spaces.

4.4.9.1 __BANK() TYPE QUALIFIER

The `__bank(`*`n`*`)` type qualifier and the `-maddrqual` compiler option are used to place objects in a particular memory bank.

The data memory on PIC devices is arranged into memory banks. The compiler automatically allocates objects to one of the available banks, but there are times when you might require the object to be located in a particular bank, as might be the case if assembly code selects that bank prior accessing the object. They can be used to place objects in banks 0 through 3 (higher bank selection is not currently available).

This qualifier can be used with any variable with static storage duration, for example to following places `playMode` into bank 1:

```
__bank(1) unsigned char playMode;
```

These qualifiers are controlled by the compiler option `-maddrqual`, which determines their effect (see Section 3.7.1.1 "addrqual"). Based on this option's settings, these qualifiers can be binding or ignored (which is the default operation). Qualifiers which are ignored will not produce an error or warning, but will have no effect.

4.4.9.2 __EEPROM TYPE QUALIFIER

The `__eeprom` type qualifier is used to place objects in EEPROM memory for Baseline and Mid-range devices that implement this memory. A warning is produced if the qualifier is not supported for the selected device. Check your device data sheet to see the memory available with your device.

This qualifier can be used with any object with static storage duration, for example to place the inputData array into EEPROM, use:

```
eeprom unsigned char inputData[3];
```

See Section 4.5.5 "Variables in EEPROM" for other ways of accessing the EEPROM.

4.4.9.3 __FAR TYPE QUALIFIER

The `__far` type qualifier and the `-maddrqual` compiler option are used to place variables into external memory.

Some PIC18 devices can support external memory. If you hardware supports this, you must first specify this memory with the `-mram` option (see Section 3.7.1.16 "ram"). For example, to map additional data memory from 20000h to 2FFFFh use

```
--RAM=default,+20000-2FFFF.
```

Memory added to the RAM ranges is exclusively used by variables that are qualified `__far`. Access of external memory is less efficient than that of ordinary data memory and will be slower to execute and use more code. Here is an example of an `unsigned int` object placed into the device's external program memory space:

```
__far unsigned int farvar;
```

This qualifier is controlled by the compiler option `-maddrqual`, which determines its effect on PIC18 devices (see Section 3.7.1.1 "addrqual"). Based on this option's settings, this qualifier can be binding or ignored (which is the default operation). Qualifiers which are ignored will not produce an error or warning, but will have no effect.

Note that this qualifier will be ignored when compiling for PIC10/12/16 targets and that not all PIC18 devices support external memory.

4.4.9.4 __NEAR TYPE QUALIFIER

The `__near` type qualifier and the `-maddrqual` compiler option are used to place variables in common memory.

Some of the 8-bit PIC architectures implement data memory which can be always accessed regardless of the currently selected bank. This *common memory* can be used to reduce code size and execution times as the bank selection instructions that are normally required to access data in banked memory are not required when accessing the common memory. PIC18 devices refer to this memory as the access bank memory. Mid-range and Baseline devices have very small amounts of this memory, if it is present at all. PIC18 devices have substantially more common memory, but the amount differs between devices. See your device data sheet for more information.

This qualifier can be used with any variable with static storage duration, for example:

```
__near unsigned char fred;
```

This qualifier is controlled by the compiler option `-maddrqual`, which determines its effect (see Section 3.7.1.1 "addrqual"). Based on this option's settings, this qualifier can be binding or ignored (which is the default operation). Qualifiers which are ignored will not produce an error or warning, but will have no effect.

The compiler must use common memory for some temporary objects. Any remaining space is available for general use. The compiler automatically places frequently accessed user-defined objects in common memory, so this qualifier is only needed for special memory placement of objects.

© 2012-2018 Microchip Technology Inc.

4.4.9.5 __PERSISTENT TYPE QUALIFIER

The `__persistent` type qualifier is used to indicate that variables should not be cleared by the runtime startup code by having them stored in a different area of memory to other variables.

By default, C variables with static storage duration that are not explicitly initialized are cleared on startup. This is consistent with the definition of the C language. However, there are occasions where it is desired for some data to be preserved across a Reset.

For example, the following ensures that the static local object, `intvar`, is not cleared at startup:

```
void test(void)
{
    static __persistent int intvar;  /* must be static */
    // ...
}
```

4.4.9.6 __RAM AND __ROM POINTER-TARGET QUALIFIERS

The `__ram` and `rom` qualifiers ensure that pointers access targets only in a desired memory space. They do not affect the placement of pointers with which they are used. See Section 4.4.6.3 “Data Pointers” for more information.

4.4.9.7 __SECTION QUALIFIER

The `__section()` qualifier allocates the object to a user-nominated section rather than allowing the compiler to place it in a default section. See Section 4.15.3 “Changing and Linking the Allocated Section” for full information on the use of this qualifier.

4.5 MEMORY ALLOCATION AND ACCESS

Objects you define are automatically allocated to an area of memory. In some instances, it is possible to alter this allocation. Memory areas and allocation are discussed in the following sections.

4.5.1 Address Spaces

All 8-bit PIC devices have a Harvard architecture, which has a separate data memory (RAM) and program memory space. Some devices also implement EEPROM.

The data memory (referred to in the data sheets as the *general purpose register file*) is banked to reduce the assembly instruction width. A bank is "selected" by one or more instructions that sets one or more bits in an SFR. Consult your device data sheet for the exact operation of the device you are using.

Both the general purpose RAM and SFRs both share the same data space and can appear in all available memory banks. PIC18 devices have all SFRs in the one data bank, but Mid-range and Baseline devices have SFRs at the lower addresses of each bank. Due to the location of SFRs in these devices, the general purpose memory becomes fragmented and this limits the size of most C objects.

The Enhanced Mid-range devices overcome this fragmentation by allowing a linear addressing mode, which allows the general purpose memory to be accessed as one contiguous chunk. Thus, when compiling for these devices, the maximum allowable size of objects typically increases. Objects defined when using PIC18 devices can also typically use the entire data memory.

Many devices have several bytes which can be accessed regardless of which bank is currently selected. This memory is called *common memory*. The PIC18 data sheets refer to the bank in which this memory is stored as the access bank, and hence it is often referred to as the access bank memory. Since no code is required to select a bank before accessing these locations, access to objects in this memory is typically faster and produces smaller code. The compiler always tries to use this memory if possible.

The program memory space is primarily for executable code, but data can also be located here. There are several ways the different device families locate and read data from this memory, but all objects located here will be read-only.

4.5.2 Objects in Data Memory

Most variables are ultimately positioned into the data memory. Due to the fundamentally different way in which automatic and static storage duration objects are allocated memory, they are discussed separately.

4.5.2.1 STATIC STORAGE DURATION OBJECTS

Objects which are allocated a memory location that remains fixed for the duration of the program (i.e. not allocated space on a stack) are said to have static storage duration and are located by the compiler into any of the available data banks.

Allocation is performed in two steps. The code generator places each object into a specific section, then the linker places these sections into their predetermined memory areas. See Section 4.15.1 "Compiler-Generated Psects" for an introductory guide to sections. Thus, during compilation, the code generator can determine the bank in which each object will reside, so that it can efficiently handle bank selection, but it will not know the object's exact address.

© 2012-2018 Microchip Technology Inc.

The compiler considers three broad categories of object, which relate to the value the object should contain at the time the program begins. Each object category has a corresponding family of sections (see Section 4.15.1 “Compiler-Generated Psects”), which are tabulated below.

`nv`	These sections are used to store objects qualified `__persistent`, whose values are not cleared by the runtime startup code.
`bss`	These sections contain any uninitialized objects, which will be cleared by the runtime startup code.
`data`	These sections contain the RAM image of initialized objects, whose non-zero value is copied to them by the runtime startup code.

Section 4.10 “Main, Runtime Startup and Reset” has information on how the runtime startup code operates.

4.5.2.1.1 Static Objects

All `static` objects have static storage duration, even local static objects, defined inside a function and which have a scope limited to that function. Thus, even local static objects can be referenced by a pointer, and are guaranteed to retain their value between calls to the function in which they are defined, unless explicitly modified via a pointer.

Objects which are `static` only have their initial value assigned once during the program’s execution. Thus, they can be preferable over initialized `auto` objects which are assigned a value every time the block in they are defined begins execution.

All `static` variables which are also specified as `const` will be stored in program memory.

4.5.2.1.2 Object Size Limits

An object with static storage duration cannot be made larger than the available device memory size, but there can be other restrictions as to how large each object can be.

When compiling for Enhanced Mid-range PIC devices, the size of an object is typically limited only by the total available data memory. Objects that will not fit into any one of the available data banks will be allocated across several banks and accessed using the device’s linear data memory feature. Linear memory access is typically slower than accessing the object directly.

When compiling for PIC18 devices, the size of an object is also typically limited only by the data memory available. The instruction set allows any object to span several data banks; however, the code to access such objects will typically be larger and slower.

On Baseline and other Mid-range devices, the object must entirely fit in one bank and so objects are limited in size to the largest of the available spaces in the data banks.

4.5.2.1.3 Changing the Default Allocation

You can change the default memory allocation of objects with static storage duration by either:

- Reserving memory locations
- Using specifiers
- Making the objects absolute; or
- Placing objects in their own section and linking that section

If you wish to prevent objects from using one or more data memory locations so that these locations can be used for some other purpose, you are best reserving the memory using the memory adjust options. See Section 3.7.1.17 “reserve” for information on how to do this.

Objects can be placed in specific memory banks using the `__bank()` specifier (see Section 4.4.9.1 "__bank() Type Qualifier").

If only a few objects are to be located at specific addresses in data space memory, then those objects can be made absolute (described in Section 4.5.4 "Absolute Variables"). Since absolute objects have a known address, they do not follow the normal memory allocation procedure.

Objects can also be placed in their own section by using the `__section()` specifier, allowing this section to be linked at the required location (see Section 4.15.3 "Changing and Linking the Allocated Section").

4.5.2.2 AUTOMATIC STORAGE DURATION OBJECTS

Objects with automatic storage duration, such as `auto`, parameter objects, and temporary variables, are allocated space on a stack implemented by the compiler.

MPLAB XC8 has two stack implementations: a compiled stack and a software stack[1] (described in Section 4.3.4 "Stacks"). Each C function is compiled to use exactly one of these stacks for its automatic storage duration objects and Table 4-9 summarizes how the choice of stack affects a function's reentrancy.

TABLE 4-9: FUNCTION MODELS IMPLEMENTATION

Data Stack Used	Function Model	Supported Device Families
Compiled stack	Non-reentrant	All devices
Software stack	Reentrant	Enhanced Mid-range and PIC18 devices

When compiling for those devices that do not support the reentrant function model, all functions are encoded to use the compiled stack, which are non-reentrant functions.

For the Enhanced Mid-range and PIC18 devices, by default the compiler will use the non-reentrant model for all functions. The `-mstack` option (see Section 3.7.1.21 "stack") can be used to change the compiler's default behavior when assigning function models. Select the `software` argument with this option so that the compiler will always choose the reentrant model (software stack) for each function. Set this option to `hybrid` to allow the compiler to decide how each function should be encoded. If the function is not reentrantly called, then it will be encoded to use the non-reentrant model and the compiled stack. If the function appears in more than one call graph (i.e., it is called from main-line and interrupt code), or it appears in a loop in a call graph (i.e., it is called recursively), then the compiler will use the reentrant model. The hybrid mode allows the program to use recursion but still take advantage of the more efficient compiled stack.

Alternatively you can change the function model for *individual* functions by using function specifiers when you define the function. Use either the `__compiled` or `__nonreentrant` specifier (identical meanings) to indicate that the specified function must use the compiled stack, without affecting any other function. Alternatively, use either the `__software` or `__reentrant` specifier to indicate a function must be encoded to use the software stack.

The function specifiers have precedence over the `-mstack` option setting. If, for example, the option `-mstack=compiled` has been used, but one function uses the `__software` (or `__reentrant`) specifier, then the specified function will use the software stack and all the remaining functions will use the compiled stack. These functions specifiers also override any choice made by the compiler in hybrid mode.

1. What is referred to as a software stack in this user's guide is the typical dynamic stack arrangement employed by most computers. It is ordinary data memory accessed by some sort of push and pop instructions, and a stack pointer register.

© 2012-2018 Microchip Technology Inc.

If the `-mstack=compiled` option has been issued or a function has been specified as `__compiled` (or `__nonreentrant`) and that function appears in more than one call graph in the program, then a function duplication feature automatically comes into effect (see Section 4.9.7 “Function Duplication”). Duplicating a non-reentrant function allows it to be called from multiple call graphs, but cannot allow the function to be called recursively.

The `auto` objects defined in a function will not necessarily be allocated memory in the order declared, in contrast to parameters which are always allocated memory based on their lexical order. In fact, `auto` objects for one function can be allocated in many RAM banks.

The standard `const` qualifier can be used with `auto` objects and these do not affect how they are positioned in memory. This implies that a local `const`-qualified object is still an `auto` object and, as such, will be allocated memory in the stack in the data space memory, not in the program memory as with other `const` objects. If you want to define a local-scope object that is placed in program memory, specify it as `static const`.

4.5.2.2.1 Object Size Limits

The compiled stack can be built up in more than one block, each located in a different data bank, thus the total size of the stack is roughly limited only by the available memory on the device; however, individual objects in the stack are limited in size to the largest of the available spaces in the data banks.

The software stack is always allocated one block of memory; however, this memory may cross bank boundaries. The maximum size of the software stack is typically limited by the amount of free data space remaining. There are no compile-time or runtime checks made for stack overflow.

There are instruction-set-imposed limitations on the amount of stack data that each function can define and the compiler can detect if these data allocations will be exceeded. The limits are 127 bytes for PIC18 devices and typically 31 bytes for Enhanced Mid-range devices.

When reentrant functions call other reentrant functions, the stack pointer is incremented as any parameters to the called function are loaded. This increases the offset from the new top-of-stack position to the stack-based objects defined by the calling function. If this offset becomes too large, a warning (1488) or error might result when trying to access stack-based objects in the calling function. A similar situation exists if the called reentrant function returns a value, as this might also be located on the stack. For these reasons, the entire stack depth might not be usable for every function.

4.5.2.2.2 Changing the Default Allocation

All objects with automatic storage duration are located on a stack, thus there is no means to individually move them. They cannot be made absolute, nor can they be assigned a unique section using the `__section()` specifier.

4.5.3 Objects in Program Space

Only `const` objects that have static storage duration are placed in program memory.

Enhanced Mid-range devices can directly read their program memory, although the compiler will still usually store data as `retlw` instructions. This way the compiler can either produce code that can call these instructions to obtain the program memory data as with the ordinary Mid-range devices, or directly read the operand to the instruction (the LSB of the `retlw` instruction). The most efficient access method can be selected by the compiler when the data needs to be read.

Data can be stored as individual bytes in the program memory of PIC18 devices. This can be read using table read instructions.

For other 8-bit PIC devices, the program space is not directly readable by the device. For these devices, the compiler stores data in the program memory by means of `retlw` instructions which can be called and will return a byte of data in the `W` register. The compiler will generate the code necessary to make it appear that program memory is being read directly.

Accessing data located in program memory is much slower than accessing objects in the data memory. The code associated with the access is also larger.

4.5.3.1 OBJECT SIZE LIMITATIONS

A `const`-qualified object cannot be made larger than the available device memory size, but there can be other restrictions as to how large each object can be.

For Baseline PIC devices, the maximum size of a single `const` object is 255 bytes. However, you can define as many `const` objects as required provided the total size does not exceed the available program memory size of the device.

For all other 8-bit devices, the maximum size of a `const`-qualified object is limited mainly by the available program memory, however for PIC18 devices, program memory from address 0 up to an address equal to the highest data memory address is typically not used to hold this data.

Note that in addition to the data itself, there is also a small amount of code required to access data in program memory. This additional code is included only once, regardless of the amount or number of `const`-qualified objects.

4.5.3.2 CHANGING THE DEFAULT ALLOCATION

You can change the default memory allocation of const-specified objects by either:

- Reserving memory locations
- Making the objects absolute; or
- Placing objects in their own section and linking that section

If you wish to prevent variables from using one or more program memory locations so the locations can be used for some other purpose, it is recommended to reserve the memory using the memory adjust options. See Section 3.7.1.17 "reserve" for information on how to do this.

If only a few `const` objects are to be located at specific addresses in program space memory, then the objects can be made absolute. Absolute variables are described in Section 4.5.4 "Absolute Variables".

Objects in program memory can also be placed in their own section by using the `__section()` specifier, allowing this section to be linked at the required location (see Section 4.15.3 "Changing and Linking the Allocated Section").

4.5.4 Absolute Variables

Objects can be located at a specific address by following their declaration with the construct `__at(`*`address`*`)`, where *`address`* is an integer constant that represents the location in memory where the variable is to be positioned. Such a variable is known as an absolute variable.

Making a variable absolute is the easiest method to place an object at a user-defined location, but it only allows placement at an address which must be known prior to compilation and must be specified for each object to be relocated.

4.5.4.1 ABSOLUTE OBJECTS IN DATA MEMORY

Any object which has static storage duration and which has file scope can be placed at an absolute address in data memory, thus all but `static` objects defined inside a function and stack-based objects can be made absolute.

For example:

```
volatile unsigned char Portvar __at(0x06);
```

will declare a variable called `Portvar` located at 06h in the data memory.

Note:	Defining absolute objects can fragment memory and can make it impossible for the linker to position other objects. If absolute objects must be defined, try to place them at either end of a memory bank so that the remaining free memory is not fragmented into smaller chunks.

The compiler will mark storage for absolute objects as being used (if the address is within general-purpose RAM), but does not make any checks for overlap of absolute variables with other absolute variables. There is no harm in defining more than one absolute variable to live at the same address if this is what you require. No warning will be issued if the address of an absolute object lies outside the memory of the device or outside the memory defined by the linker classes.

Absolute variables in RAM cannot be initialized when they are defined, and they are not cleared by the runtime startup code. After defining absolute variables, assign them an initial value at a suitable point in your main-line code, if required.

Objects should not be made absolute to force them into common (unbanked) memory. Always use the `__near` qualifier for this purpose (see Section 4.4.9.4 "__Near Type Qualifier").

When defining absolute bit variables (see Section 4.4.2.1 "Bit Data Types and Variables"), the address specified must be a bit address. A bit address is obtained by multiplying the byte address by 8, then adding the bit offset within that bit. For example, to place a bit variable called `mode` at bit position #2 at address 0x50, use the following:

```
bit mode __at(0x282);
```

When compiling for an Enhanced Mid-range PIC device, the address specified for absolute objects can be either a conventional banked memory address or a linear address. As the linear addresses start above the largest banked address, it is clear which type of address has been specified. In the following example:

```
int input[100] __at(0x2000);
```

it is clear that `input` should placed at address 0x2000 in the linear address space, which is address 0x20 in bank 0 RAM in the conventional banked address space.

4.5.4.2 ABSOLUTE OBJECTS IN PROGRAM MEMORY

Any `const`-qualified object which has static storage duration and which has file scope can be placed at an absolute address in program memory.

For example:

```
const int settings[] __at(0x200) = { 1, 5, 10, 50, 100 };
```

will place the array `settings` at address 0x200 in the program memory.

An uninitialized `extern const` object can be made absolute and is useful when you want to define a placeholder object that does not make a contribution to the output file.

4.5.5 Variables in EEPROM

For devices with on-chip EEPROM, the compiler offers several methods of accessing this memory as described in the following sections.

4.5.5.1 EEPROM VARIABLES

When compiling for Baseline and Mid-range parts, the `__eeprom` qualifier allows you to create named C objects that reside in the EEPROM space (see Section 4.4.9.2 "__eeprom Type Qualifier").

Objects qualified `__eeprom` are cleared or initialized, as required, just like ordinary RAM-based objects; however, the initialization process is not carried out by the runtime startup code. Initial values are placed into the HEX file and are burnt into the EEPROM when you program the device. Thus, if you modify the EEPROM during program execution and then reset the device, these objects will not contain the initial values specified in your code at startup up.

The following example defines two arrays in EEPROM.

```
__eeprom char regNumber[10] = "A93213";
__eeprom int lastValues[3];
```

For both these objects, their initial values will appear in the HEX file. Zeros will be used as the initial values for `lastValues`.

The generated code to access `__eeprom`-qualified objects will be much longer and slower than code to access RAM-based objects. Consider copying values from EEPROM to regular RAM-based objects and using these in complicated expressions to avoid can't generator code error messages.

4.5.5.2 EEPROM INITIALIZATION

For those devices that support external programming of their EEPROM data area, the `__EEPROM_DATA()` macro can be used to place values into the HEX file ready for programming into the EEPROM. This macro cannot used to write to EEPROM locations during runtime.

The macro is used as follows.

```
#include <xc.h>
__EEPROM_DATA(0, 1, 2, 3, 4, 5, 6, 7);
```

The macro has eight parameters, representing eight data values. Each value should be a byte in size. Unused values should be specified with zero.

The `__EEPROM_DATA()` macro arguments expand into assembly code. Ensure that any operators or tokens in argument expressions are written in assembly code (see Section 5.2 "MPLAB XC8 Assembly Language").

The macro can be called multiple times to define the required amount of EEPROM data. It is recommended that the macro be placed outside any function definition.

The values defined by this macro share the EEPROM space with `__eeprom`-qualified objects, but cannot be used to initialize such objects. The section used by this macro to hold the data values is different to those used by `__eeprom`-qualified objects. The link order of these sections can be adjusted, if required (see Section 3.7.12 "Mapped Linker Options").

For convenience, the macro `_EEPROMSIZE` represents the number of bytes of EEPROM available on the target device.

© 2012-2018 Microchip Technology Inc.

4.5.5.3 EEPROM ACCESS FUNCTIONS

The library functions `eeprom_read()` and `eeprom_write()`, can be called to read from, and write to, the EEPROM during program execution.

These functions are available for all Mid-range devices that implement EEPROM (described in Section “eeprom_read” and Section “eeprom_write”).

For convenience, the macro `_EEPROMSIZE` represents the number of bytes of EEPROM available on the target device.

4.5.5.4 EEPROM ACCESS MACROS

Macro versions of the EEPROM access functions are also provided (described in Section “EEPROM_READ (macro)” and Section “EEPROM_WRITE (macro)”).

4.5.6 Variables in Registers

With MPLAB XC8, there is no direct control of placement of variables in registers. The `register` keyword (which can only be used with `auto` variables) is silently ignored and has no effect on the allocation of variables.

Some arguments are passed to functions in the W register rather than in a memory location; however, these values will typically be stored back to memory by code inside the function so that W can be used by code associated with that function. See Section 4.8.6 “Function Parameters” for more information as to which parameter variables can use registers.

4.5.7 Dynamic Memory Allocation

Dynamic memory allocation, (heap-based allocation using `malloc`, etc.) is not supported on any 8-bit device. This is due to the limited amount of data memory available, the memory banks which divide the memory, and the wasteful nature of dynamic memory allocation.

4.5.8 Memory Models

MPLAB XC8 C Compiler does not use fixed memory models to alter allocation of variables to memory. Memory allocation is fully automatic and there are no memory model controls.

4.6 OPERATORS AND STATEMENTS

The MPLAB XC8 C Compiler supports all the ANSI operators, some of which behave in an implementation defined way, see Appendix C. Implementation-Defined Behavior. The following sections illustrate code operations that are often misunderstood as well as additional operations that the compiler is capable of performing.

4.6.1 Integral Promotion

Integral promotion is always applied in accordance with the C standard, but it can confuse those who are not expecting such behavior.

When there is more than one operand to an operator, they typically must be of exactly the same type. The compiler will automatically convert the operands, if necessary, so they do have the same type. The conversion is to a "larger" type so there is no loss of information; however, the change in type can cause different code behavior to what is sometimes expected. These form the standard type conversions.

Prior to these type conversions, some operands are unconditionally converted to a larger type, even if both operands to an operator have the same type. This conversion is called *integral promotion*. The compiler performs these integral promotions where required, and there are no options that can control or disable this operation.

Integral promotion is the implicit conversion of enumerated types, `signed` or `unsigned` varieties of `char`, `short int` or bit-field types to either `signed int` or `unsigned int`. If the result of the conversion can be represented by an `signed int`, then that is the destination type, otherwise the conversion is to `unsigned int`.

Consider the following example.

```
unsigned char count, a=0, b=50;
if(a - b < 10)
  count++;
```

The `unsigned char` result of `a - b` is 206 (which is not less than 10), but both a and b are converted to `signed int` via integral promotion before the subtraction takes place. The result of the subtraction with these data types is -50 (which *is* less than 10) and hence the body of the `if()` statement is executed.

If the result of the subtraction is to be an `unsigned` quantity, then apply a cast, as in the following example, which forces the comparison to be done as `unsigned int` types:

```
if((unsigned int)(a - b) < 10)
  count++;
```

Another problem that frequently occurs is with the bitwise complement operator, ~. This operator toggles each bit within a value. Consider the following code.

```
unsigned char count, c;
c = 0x55;
if( ~c == 0xAA)
  count++;
```

If c contains the value 0x55, it often assumed that ~c will produce 0xAA; however, the result is 0xFFAA and so the comparison in the above example would fail. The compiler can be able to issue a mismatched comparison error to this effect in some circumstances. Again, a cast could be used to change this behavior.

© 2012-2018 Microchip Technology Inc.

The consequence of integral promotion as illustrated above is that operations are not performed with `char`-type operands, but with `int`-type operands. However, there are circumstances when the result of an operation is identical regardless of whether the operands are of type `char` or `int`. In these cases, the compiler will not perform the integral promotion so as to increase the code efficiency. Consider this example.

```
unsigned char a, b, c;
a = b + c;
```

Strictly speaking, this statement requires that the values of b and c are promoted to `unsigned int`, the addition is performed, the result of the addition is cast to the type of a, and then that result is assigned. In this case, the value assigned to a will be the same whether the addition is performed as an `int` or `char`, and so the compiler will encode the former.

If in the above example, the type of a was `unsigned int,` then integral promotion would have to be performed to comply with the C Standard.

4.6.2 Rotation

The C language does not specify a rotate operator; however, it does allow shifts. The compiler will detect expressions that implement rotate operations using shift and logical operators and compile them efficiently.

For the following code:

```
c = (c << 1) | (c >> 7);
```

if `c` is `unsigned` and non-`volatile`, the compiler will detect that the intended operation is a rotate left of 1 bit and will encode the output using the PIC MCU rotate instructions. A rotate left of 2 bits would be implemented with code like:

```
c = (c << 2) | (c >> 6);
```

This code optimization will also work for integral types larger than a `char`. If the optimization cannot be applied, or this code is ported to another compiler, the rotate will be implemented, but typically with shifts and a bitwise OR operation.

4.6.3 Switch Statements

The compiler can encode `switch` statements using one of several strategies. By default, the compiler chooses a strategy based on the case values that are used inside the `switch` statement. Each `switch` statement is assigned its strategy independently.

The type of strategy can be indicated by using the `#pragma switch` directive (see Section 4.14.3.10 "The #pragma switch Directive"), which also lists the available strategy types. There can be more than one strategy associated with each type.

There is information printed in the assembly list file for each `switch` statement detailing the value being switched and the case values listed (see Section 5.4.4 "Switch Statement Information").

4.7 REGISTER USAGE

The assembly generated from C source code by the compiler will use certain registers in the PIC MCU register set. Most importantly, the compiler assumes that nothing other than code it generates can alter the contents of these registers.

The registers that are special and which are used by the compiler are listed in Table 4-10.

TABLE 4-10: REGISTERS USED BY THE COMPILER

Register name	Applicable devices
`W`	All 8-bit devices
`STATUS`	All 8-bit devices
`PCLATH`	All Mid-range devices
`PCLATH, PCLATU`	All PIC18 devices
`BSR`	Enhanced Mid-range and PIC18 devices
`FSR`	Non-Enhanced Mid-range devices
`FSR0L, FSR0H, FSR1L, FSR1H`	Enhanced Mid-range and PIC18 devices
`FSR2L, FSR2H`	All PIC18 devices
`TBLPTRL, TBLPTRH, TBLPTRU, TABLAT`	All PIC18 devices
`PRODL, PRODH`	All PIC18 devices
`btemp, wtemp, ttemp, ltemp, lltemp`	Enhanced Mid-range and PIC18 devices

The `xtemp` registers are variables that the compiler treats as registers. These are saved like any other register if they are used in interrupt code. The `lltemp` register is only available on PIC18 devices.

The compiler will not be aware of changes to a register's value when the register itself is a C lvalue (assignment destination). For example, if the statement `WREG = 0;` was encoded using the `clrf` instruction, the compiler would not consider this as modifying the `W` register. Nor should these registers be changed directly by in-line assembly code, as shown in the following example which modifies the ZERO bit in the STATUS register.

```
#include <xc.h>

void getInput(void)
{
#asm
   bcf ZERO  ; do not write using inline assembly code
#endasm
   process(c);
}
```

If any of the applicable registers listed in the table are used by interrupt code, they will be saved and restored when an interrupt occurs, either in hardware or software (see Section 4.9.4 "Context Switching").

© 2012-2018 Microchip Technology Inc.

4.8 FUNCTIONS

Functions are written in the usual way, in accordance with the C language. Implementation-specific features associated with functions are discussed in following sections.

4.8.1 Function Specifiers

Aside from the standard C specifier, `static`, which affects the linkage of the function, there are several non-standard function specifiers, which are described in the following sections.

4.8.1.1 __INTERRUPT() SPECIFIER

The `__interrupt()` specifier indicates that the function is an interrupt service routine and that it is to be encoded specially to suit this task. Interrupt functions are described in detail in 4.9.1 Writing an Interrupt Service Routine.

4.8.1.2 INLINE SPECIFIER

The `inline` function specifier is a recommendation that the compiler replace calls to the specified function with the function's body, if possible.

The following is an example of a function which has been made a candidate for inlining.

```
inline int combine(int x, int y) {
    return 2*x-y;
}
```

All function calls to a function that was inlined by the compiler will be encoded as if the call was replaced with the body of the called function. This is performed at the assembly code level. Inlining will only take place if the assembly optimizers are enabled and the compiler is not operating in Free mode. The function itself might still be encoded normally by the compiler even if it is inlined.

If inlining takes place, this will increase the program's execution speed, since the call and return sequences associated with the call will be eliminated. It will also reduce the hardware stack usage as no call instruction is executed; however, this stack-size reduction is not reflected in the call graphs, as these graphs are generated before inlining takes place.

Code size can be reduced if the assembly code associated with the body of the inlined function is very small, but code size can increase if the body of the inlined function is larger than the call/return sequence it replaces. You should only consider this specifier for functions which generate small amounts of assembly code. Note that the amount of C code in the body of a function is not a good indicator of the size of the assembly code that it generates (see Section 2.6.13 "How Can I Tell How Big a Function Is?").

A function containing in-line assembly will not be inlined. Some generated assembly code sequences will also prevent inlining of a function. A warning will be generated if the `inline` function references `static` objects (to comply with the C Standard) or is not inlined successfully. Your code should not make any assumptions about whether inlining took place.

This specifier performs the same task as the `#pragma inline` directive (see Section 4.14.3.4 "The #pragma Intrinsic Directive"). Note that the optimizers can also implicitly inline small called-only-once routines (see Section 5.3 "Assembly-Level Optimizations").

If the `xc8-cc` flag `-Wpedantic` is used, the `inline` keyword becomes unavailable, but you can use the `__inline` keyword.

4.8.1.3 REENTRANT AND NONREENTRANT SPECIFIERS

The `__reentrant` and `__nonreentrant` function specifiers indicate the function model (stack) that should be used for that function's stack-based variables (`auto` and parameters), as shown in Table 4-11. The aliases `__software` and `__compiled`, respectively, can be used if you prefer. You would only use these specifiers if the default allocation is unacceptable.

TABLE 4-11: STACK RELATED FUNCTION SPECIFIERS

Specifier	Allocation for Stack-based variables
`__compiled`, `__nonreentrant`	Always use the compiled stack; functions are nonreentrant
`__software`, `__reentrant`	Use the software stack, if available; functions are reentrant

The following shows an example of a function that will always be encoded as reentrant.

```
__reentrant int setWriteMode(int mode)
{
    accessMode = (mode!=0);
    reutrn mode;
}
```

These specifiers override any setting indicated using the `-mstack` option (see Section 3.7.1.21 "stack"). If neither function specifier is used with a function and the `-mstack` option is not specified (or specified as `hybrid`), then the compiler will choose the stack to be used by that function for its stack-based variables.

The `__reentrant` specifier only has an effect if the target device supports a software stack. In addition, not all functions allow reentrancy. Interrupt functions must always use the compiled stack, but functions they call may use the software stack. Functions encoded for Baseline and Mid-range devices always use the nonreentrant model and the compiled stack.

Repeated use of the `__software` (`__reentrant`) specifier will increase substantially the size of the software stack leading to possible overflow. The size of the software stack is not accurately known at compile time, so the compiler cannot issue a warning if it is likely to overwrite memory used for some other purpose.

See Section 4.3.4.2 "Data Stacks" for device specific information relating to the data stacks available on each device.

4.8.2 External Functions

Functions that are defined outside the project's C source files (e.g., a function defined in a separate bootloader project or in an assembly module) will require declarations so that the compiler knows how to encode calls to those functions. You might also need to define a symbol to represent the memory locations used to store parameter or the return value.

A function declaration will look similar to the following example. Note that the extern specifier is optional, but makes it clear this is a declaration.

```
extern int clockMode(int);
```

If the external function uses the compiled stack and it takes arguments or returns a value you might need to define a symbol that represents the base address of the functions parameter block (which is also used as the base address of the return value). This would not be necessary if parameters and the return value are passed in registers. See Section 4.8.6 "Function Parameters" and Section 4.8.7 "Function Return Values" to

© 2012-2018 Microchip Technology Inc.

determine if a register or memory locations by your function. If this symbol is not defined, the compiler will issue an undefined symbol error. This error can be used to verify the name being used by the compiler to encode the call, if required.

The required value can be determined from the map file of the external build. Look for the symbol `?_`*`funcName`*, where *`funcName`* is the name of the function defined externally. Define this symbol in your code that makes the call via a simple `EQU` directive in assembler. For example, the following snippet of code could be placed in your C source to allow you to call the function `extReadFn()` defined in another project:

```
#asm
GLOBAL ?_extReadFn
?_extReadFn EQU 0x20
#endasm
```

This defines the base address of the parameter area for `extReadFn()` to be 0x20.

If an external function uses the reentrant model, it will never use the W register for parameter passing, and all arguments will be stored on the stack.

4.8.3 Allocation of Executable Code

Code associated with functions is always placed in program memory.

On Baseline and Mid-range devices, the program memory is paged. Program memory addresses are still sequential across a page boundary, but the paging means that calls or jumps from code in one page to a label in another must use a longer sequence of instructions. Your device data sheet has more information on the program memory and instruction set for your device.

PIC18 devices do not implement any program memory paging. The `call` and `goto` instruction are two-word instructions and their destinations are not limited.

The generated code associated with each function is initially placed in sections by the compiler (see Section 4.15.1 “Compiler-Generated Psects”). When the program memory is paged, the optimizer tries to allocate several functions to the same section so they can use the shorter form of call and jump. These sections are linked anywhere in the program memory (see 4.10 Main, Runtime Startup and Reset), although Baseline devices restrict the entry point of functions to within the first 256 location in each page.

The base name of each section is tabulated below. See Section 4.15.1.1 “Program Space Psects” for a full list of all program-memory section names.

`maintext`	The generated code associated with the special function, `main`, is placed in this section. Some optimizations and features are not applied to this psect.
`textn`	These sections (where *n* is a decimal number) contain all other executable code that does not require a special link location.

4.8.4 Changing the Default Function Allocation

You can change the default memory allocation of functions by either:

- Reserving memory locations
- Making functions absolute
- Placing functions in their own section and linking that section

If you wish to prevent functions from using one or more program memory locations so that these locations can be used for some other purpose, it is recommended to reserve the memory using the memory adjust options (see Section 3.7.1.17 "reserve").

The easiest method to explicitly place individual functions at a known address is to make them absolute by using the `__at(`*`address`*`)` construct in a similar fashion to that used with absolute variables.

The compiler will issue a warning if code associated with an absolute function overlaps with code from other absolute functions. No warning will be issued if the address of an absolute object lies outside the memory of the device or outside the memory defined by the linker classes. The compiler will not locate code associated with ordinary functions over the top of absolute functions.

The following example of an absolute function will place the function at address 400h:

```
int mach_status(int mode) __at(0x400)
{
  /* function body */
}
```

If this construct is used with interrupt functions, it will only affect the position of the code associated with the interrupt function body. The interrupt context switch code associated with the interrupt vector will not be relocated. See Section 3.7.1.3 "codeoffset" for information on how to move Reset and interrupt vector locations (which can be useful for designing applications such as bootloaders).

The code generated for absolute functions is placed in a section dedicated only to that function. The section name has the form shown below (see Section 4.15.1 "Compiler-Generated Psects" for a full list of all section names.

`xxx_text` Defines the section for a function that has been made absolute. *xxx* will be the assembly symbol associated with the function, e.g., the absolute function `rv()` would appear in the psect called `_rv_text`.

Functions can be allocated to a user-defined psect using the `__section()` specifier (see Section 4.15.3 "Changing and Linking the Allocated Section") so that this new section can then be linked at the required location. This method is the most flexible and allows functions to be placed at a fixed address, after other section, or anywhere in an address range. As with absolute functions, when used with interrupt functions, it will only affect the position of the interrupt function body. Never place functions into a section that is also used to hold non-executable objects, such as `const` objects, as this might affect the ability to debug the functions.

Regardless of *how* a function is located, take care choosing its address. If possible, place functions at either end of a program memory page (if relevant) to avoid fragmenting memory and increasing the possibility of linker errors. Place functions in the first page, which contains the reset and interrupt code, rather than in pages higher in memory, as this will assist the optimizations that merge psects.

© 2012-2018 Microchip Technology Inc.

4.8.5 Function Size Limits

For all devices, the code generated for a regular function is limited only by the available program memory; however the longer jump sequences within a function if it is located across more than one page will decrease efficiency. See 4.8.3 Allocation of Executable Code for more details.

Interrupt functions (see Section 4.9.1 “Writing an Interrupt Service Routine”) however, are limited to one page in size and cannot be split over multiple pages.

4.8.6 Function Parameters

MPLAB XC8 uses a fixed convention to pass arguments to a function. The method used to pass the arguments depends on the size and number of arguments involved, and on which stack model is used with the function.

Note: The names “argument” and “parameter” are often used interchangeably, but typically an argument is the value that is passed to the function and a parameter is the variable defined by the function to store the argument.

4.8.6.1 COMPILED STACK PARAMETERS

For non-reentrant functions using the compiled stack, the compiler will pass arguments in the W register, or in the called function’s parameter memory.

If the first parameter is one byte in size, it is passed in the W register. All other parameters are passed in the parameter memory. The parameter memory will be located in the compiled stack (see Section 4.3.4.2.1 “Compiled Stack Operation”).

Parameters are referenced as an offset from the symbol `?_`*`function`*, where *`function`* is the name of the function in which the parameter is defined (i.e., the function that is to be called).

Unlike `auto` variables, parameter variables are allocated memory strictly in the order in which they appear in the function’s prototype. This means that a function’s parameters will always be placed in the same memory bank; whereas `auto` variables for a function can be allocated across multiple banks and in any order.

The arguments for unnamed parameters in functions that take a variable argument list (defined using an *ellipsis* in the prototype), are placed in the parameter memory, along with named parameters.

Take, for example, the following prototyped function.

```
void test(char a, int b);
```

The function `test()` will receive the parameter b in parameter memory (using the two bytes `?_test` and `?_test+1`) and a in the `W` register.

The compiler needs to take special action if more than one function using the compiled stack can be indirectly called via the same function pointer. Such would be the case in the following example, where any of `sp_ad`, `sp_sub` or `sp_null` could be called via the pointer, `fp`.

```
int (*funcs[])(int, int) = {sp_add, sp_sub, sp_null};
int (*fp)(int, int);
fp = funcs[getOperation()];
result = fp(37, input);
```

In such a case, the compiler treats all three functions in the array as being “buddies”.

The parameter(s) to all buddy functions will be aligned in memory, i.e., they will all reside at the same address(es). This way the compiler does not need to know exactly which function is being called. The implication of this is that a function cannot call (either directly or indirectly) any of its buddies. To do so would corrupt the caller function's parameters. An error will be issued if such a call is attempted.

4.8.6.2 SOFTWARE STACK PARAMETERS

When a function uses the software stack, most arguments to that function will be passed on the stack (see Section 4.3.4.2.2 "Software Stack Operation").

Arguments are pushed onto the stack by the calling function, in a reverse order to that in which the corresponding parameters appear in the function's prototype. Subsequently, and if required, the called function will increase the value stored in the stack pointer to allocate storage for any `auto` or temporary variables it needs to allocate.

The `W` register is sometimes used for the first function argument if it is byte-sized. This will only take place for Enhanced Mid-range devices and provided the function does not take a variable number of arguments. If a reentrant function is external (see Section 4.8.2 "External Functions"), the W register will never be used to hold any function arguments. The `W` register is never used by reentrant function arguments when compiling for PIC18 devices.

The arguments for unnamed parameters in functions that take a variable argument list (defined using an *ellipsis* in the prototype), are placed on the software stack, before those for the named parameters. After all the function's arguments have been pushed, the total size of the unnamed parameters is pushed on to the stack. A maximum of 256 bytes of non-prototyped parameters are permitted per function.

As there is no frame pointer, accessing function parameters (or other stack-based objects) is not recommended in hand-written assembly code.

4.8.7 Function Return Values

Values returned from functions are loaded into a register or placed on the stack used by that function. The mechanism will depend on the function model used by the function.

4.8.7.1 COMPILED STACK RETURN VALUES

For functions that use the compiled stack, return values are passed to the calling function using the `W` register, or the function's parameter memory. The memory assigned to the function's parameters (which is no longer needed when the function is ready to return) is reused to reduce the function's code and data requirements.

Single-byte values are returned from a function in the `W` register. Values larger than a byte are returned in the function's parameter memory area.

For example, the function:

```
int returnWord(void)
{
    return 0x1234;
}
```

will return with the value 0x34 in `?_returnWord`, and 0x12 in `?_returnWord+1`.

For PIC18 targets returning values greater than 4 bytes but less than 8 bytes in size, the address of the parameter area is also placed in the `FSR0` register.

Functions that return a value of type `__bit` do so using the carry bit in the `STATUS` register.

© 2012-2018 Microchip Technology Inc.

4.8.7.2 SOFTWARE STACK RETURN VALUES

Functions that use the software stack will pass values back to the calling function via `btemp` variables, provided the value is 4 bytes or less in size. The `W` register will be used to return byte-sized values for Enhanced Mid-range device functions that do not have a variable number of arguments. For objects larger than 4 bytes in size, they are returned on the stack. Reentrant PIC18 functions that return a value of type `__bit` do so using bit #0 in `btemp0`; other devices use the carry bit in the `STATUS` register.

As there is no frame pointer, accessing the return value location, or other stack-based objects, is not recommended in hand-written assembly code.

4.8.8 Calling Functions

All 8-bit devices use a hardware stack for function return addresses. The maximum depth of this stack varies from device to device.

Typically, call assembly instructions are used to transfer control to a C function when it is called. A call uses one level of hardware stack that is freed after the called routine executes a `return` or `retlw` instruction. Nested function calls will increase the stack usage of a program. If the hardware stack overflows, function return addresses will be overwritten and the code will eventually fail.

For PIC18 devices, a call instruction is the only way in which function calls are made, but for other 8-bit devices, the `-mstackcall` option, (see Section 3.7.1.22 “stackcall”), can controls how the compiler behaves when the compiler detects that the hardware stack might overflow due to too many nested calls. When this option is enabled, the compiler will, instead of issuing a warning, automatically swap to using a managed stack that involves the use of a lookup table and which does not require use of the hardware stack.

When the lookup method is being employed, a function is reached by a jump (not a call) directly to its address. Before this is done the address of a special “return” instruction (implemented as a jump instruction) is stored in a temporary location inside the called function. This return instruction will be able to return control back to the calling function.

This means of calling functions allows functions to be nested deeply without overflowing the limited stack available on Baseline and Mid-range devices; however, it does come at the expense of memory and program speed.

4.8.8.1 INDIRECT CALLS

When functions are called indirectly using a pointer, the compiler employs a variety of techniques to call the intended function.

The PIC18 and Enhanced Mid-range devices all use the value in the function pointer to load the program counter with the appropriate address. For PIC18 devices, the code loads the TOS registers and executes a `return` to perform the call. For Enhanced Mid-range devices, the `callw` instruction is used. The number of functions that can be called indirectly is limited only by the available memory of the device.

The Baseline and Mid-range devices all use a lookup table which is loaded with jump instructions. The lookup table code is called and an offset is used to execute the appropriate jump in the table. The table increases in size as more functions are called indirectly, but cannot grow beyond 0xFF bytes in size. This places a limit on the number of functions that can be called indirectly, and typically this limit is approximately 120 functions. Note that this limit does not affect the number of function pointers a program can define, which are subject to the normal limitations of available memory on the device.

Indirect calls are not affected by the `-mstackcall` option and the depth of indirect calls on Baseline and Mid-range devices are limited by the hardware stack depth.

© 2012-2018 Microchip Technology Inc.

4.9 INTERRUPTS

The MPLAB XC8 compiler incorporates features allowing interrupts to be fully handled from C code. Interrupt functions are often called Interrupt Service Routines, or ISRs.

The operation of interrupts is handled differently by the different device families. Most Baseline devices do not implement interrupts at all; Mid-range devices have one vector location which is linked to all interrupt sources; some PIC18 devices have two independent interrupt vectors, one assigned to low-priority interrupt sources, the other to high-priority sources; and, finally, some PIC18 devices implement a vectored interrupt controller (VIC) module with support for one or more interrupt vector tables (IVTs), which can be populated with the addresses of high- or low-priority interrupt functions.

The operation of the IVT on devices with a VIC module can be disabled by clearing the `MVECEN` configuration bit. The device is then said to be operating in *legacy mode*, operating with dual priorities and dual vector locations. This bit is also used by the compiler to determine how interrupt functions should be programmed. Although the vector table is disabled in this mode, the vector locations are still relocatable. By default the vector location will be 0x8 and 0x18, the same for regular PIC18 devices without the VIC module.

The priority scheme implemented by PIC18 devices can also be disabled by clearing the `IPEN` SFR bit. Such devices are then said to be operating in *Mid-range compatibility mode* and utilize only one interrupt vector, located at address 0x8.

The following are the general steps you need to follow to use interrupts. More detail about these steps is provided in the sections that follow.

For Enhanced Baseline devices with interrupts, Mid-range devices, or PIC18 devices operating in Mid-range compatibility mode:

- Write one interrupt function to process all interrupt sources.
- At the appropriate point in your main-line code, unmask the interrupt sources required by setting their interrupt enable bit in the corresponding SFR.
- At the appropriate point in your code, enable the global interrupt enable to allow interrupts to be generated.

For PIC18 devices without the VIC module, or PIC18 devices operating in legacy mode:

- Plan the priorities to be assigned to each interrupt source. If the device is operating in legacy mode, determine the number of sets of dual interrupt vectors you require.
- Program the `MVECEN` configuration bit if appropriate.
- Write one interrupt function to process each priority being used. You can define at most two interrupt functions, or two interrupt functions per vector set for devices operating in legacy mode. Consider implementing both interrupt functions to handle accidental triggering of unused interrupts, or use the `-mundefints` option to provide a default action (see Section 3.7.1.24 “undefints”).
- Write code to assign the required priority to each interrupt source by writing the appropriate bits in the SFRs.
- If the device is operating in legacy mode and if required, at the appropriate points in your code, select the required set of dual vectors by writing to the `IVTBASE` registers. Never write the `IVTBASE` registers if interrupts are enabled. The initial vectors can also be selected by using the `-mivt` option (see Section 3.7.1.11 “ivt”).
- At the appropriate point in your code, enable the interrupt sources required.
- At the appropriate point in your code, enable the global interrupt enable.

For devices using the VIC module:

- Plan the priorities associated with each interrupt source and determine the number of interrupt vector tables you require.
- Write as many interrupt functions as required. For fast interrupt response times, write a dedicated function for each interrupt source, although multiple sources can be processed by one function, if desired. Consider one or more additional functions to handle accidental triggering of unused interrupt sources, or use the `-mundefints` option to provide a default action (see Section 3.7.1.24 "undefints").
- Write code to assign the required priority to each interrupt source by writing the appropriate bits in the SFRs.
- If you are using more than one interrupt vector table, at the appropriate points in your code, select the required IVT by writing to the `IVTBASE` registers. Never write the `IVTBASE` registers if interrupts are enabled. The initial IVT can also be selected by using the `-mivt` option (see Section 3.7.1.11 "ivt").
- At the appropriate point in your code, enable the interrupt sources required.
- At the appropriate point in your code, enable the global interrupt enable.

Interrupt functions must not be called directly from C code (due to the different return instruction that is used), but interrupt functions can call other functions, both user-defined and library functions.

Interrupt code is the name given to any code that executes as a result of an interrupt occurring, including functions called from the ISR and library code. Interrupt code completes at the point where the corresponding return from interrupt instruction is executed. This contrasts with *main-line code*, which, for a freestanding application, is usually the main part of the program that executes after Reset.

4.9.1 Writing an Interrupt Service Routine

The prototype and content of an ISR will vary based on the target device and the project being compiled. Observe the following guidelines when writing an ISR.

For devices that do not have the VIC module:

- Write each ISR prototype using the `__interrupt()`specifier.
- Use `void` as the return type and for the parameter specification.
- If your device supports interrupt priorities, with each function use the `low_priority` or `high_priority` arguments to `__interrupt()`.
- Inside the ISR body, determine the source of the interrupt by checking the interrupt flag and the interrupt enable for each source that is to be processed, and make the relevant interrupt code conditional on those being set.

© 2012-2018 Microchip Technology Inc.

For devices operating in legacy mode:

- Write each ISR prototype using either the `__interrupt()` specifier.
- Use `void` as the return type, and specify a parameter list of either `void` or one `char` argument if you need to identify the interrupt source.[1]
- As arguments to the `__interrupt()` specifier in the ISR prototype, specify the interrupt priority assigned to the function's source, using `low_priority` or `high_priority`; and optionally, specify the base address of the IVT in which to place the function's address, using `base()`.[2]
- If the ISR processes more than one source, determine the source of the interrupt from the function's parameter, if specified, or by checking the interrupt flag and the interrupt enable for each source that is to be processed.

For devices which are using the VIC module:

- Write each ISR prototype using only the `__interrupt()` specifier.
- Use `void` as the return type, and specify a parameter list of either `void` or one `char` argument if you need to identify the interrupt source.
- As arguments to the `__interrupt()` specifier in the ISR prototype, specify which sources each interrupt function should handle, using `irq()`; specify the interrupt priority assigned to the function's source, using `low_priority` or `high_priority`; and optionally, specify the base address of the IVT in which to place the function's address, using `base()`.
- If the ISR processes more than one source, determine the source of the interrupt from the function's parameter, if specified, or by checking the interrupt flag and the interrupt enable for each source that is to be processed.

For all devices:

- Inside the ISR body, clear the relevant interrupt flag once the source has been processed.
- Do not re-enable interrupts inside the ISR body. This is performed automatically when the ISR returns.
- Keep the ISR as short and as simple as possible. Complex code will typically use more registers that will increase the size of the context switch code.

If interrupt priorities are being used but an ISR does not specify a priority, it will default to being high priority. It is recommended that you always specify the ISR priority to ensure your code is readable.

If you supply an `irq()` or `base()` argument to the `__interrupt()` specifier with a device that does not have the VIC module, an error will be issued by the compiler. If you use this specifier with a device that is configured for legacy mode, supplying an `irq()` argument will result in an error from the compiler; however, you may continue to use the `base()` argument if required.

Devices that have the VIC module identify each interrupt with a number. This number can be specified with the `irq()` argument to `__interrupt()` if the vector table is enabled, or you can use a compiler-defined symbol that equates to that number. You can see a list of all interrupt numbers, symbols and descriptions by opening the files `pic_chipinfo.html` or `pic18_chipinfo.html` in your favorite web browser, and selecting your target device. Both these files are located in the `docs` directory under your compiler's installation directory.

1. It is recommended that the parameter list be set to `void` if you want to ensure portability with devices that do not have the VIC module.
2. It is recommended that the base address be left as the default if you want to ensure portability with devices that do not have the VIC module.

Interrupt functions always use the non-reentrant function model. These functions ignore any option or function specifier that might otherwise specify reentrancy.

The compiler processes interrupt functions differently to other functions, generating code to save and restore any registers used by the function and a special return instruction.

An example of an interrupt function written for code not using the IVT is shown below. Notice that the interrupt function checks for the source of the interrupt by looking at the interrupt enable bit (e.g., `TMR0IE`) and the interrupt flag bit (e.g., `TMR0IF`). Checking the interrupt enable flag is required since interrupt flags associated with a peripheral can be asserted even if the peripheral is not configured to generate an interrupt.

```
int tick_count;

void __interrupt(high_priority) tcInt(void)
{
    if (TMR0IE && TMR0IF) {  // any timer 0 interrupts?
        TMR0IF=0;
        ++tick_count;
    }
    if (TMR1IE && TMR1IF) {  // any timer 1 interrupts?
        TMR1IF=0;
        tick_count += 100;
    }
    // process other interrupt sources here, if required
    return;
}
```

Here is the same function code, split and modified for a device using vector tables. Note that since only one source is associated each ISR, the interrupt code does not need to determine the source of the interrupt and is therefor faster.

```
void __interrupt(irq(TMR0),high_priority) tc0Int(void)
{
    TMR0IF=0;
    ++tick_count;
    return;
}

void __interrupt(irq(TMR1),high_priority) tc1Int(void)
{
    TMR1IF=0;
    tick_count += 100;
    return;
}
```

© 2012-2018 Microchip Technology Inc.

If you prefer to process multiple interrupt sources in one function, that can be done by specifying more than one interrupt source in the `irq()` argument and using a function parameter to hold the source number, such as in the following example.

```
void __interrupt(irq(TMR0,TMR1),high_priority) tInt(unsigned char src)
{
    switch(src) {
    case IRQ_TMR0:
        TMR0IF=0;
        ++tick_count;
        break;
    case IRQ_TMR1:
        TMR1IF=0;
        tick_count += 100;
        break;
    }
    return;
}
```

The VIC module will load the parameter, in this example, `src`, with the interrupt source number when the interrupt occurs.

The special interrupt source symbol, `default`, can be used to indicate that the ISR will be linked to any interrupt vector not already explicitly specified using `irq()`. You can also populate unused vector locations by using the `-mundefints` option (see Section 3.7.1.24 "undefints").

By default, the interrupt vector table will be located at an address equal to the reset value of the IVTBASE register, which is the legacy address of 0x8. The `base()` argument to `__interrupt()` can be used to specify a different table base address for that function. This argument can take one or more comma-separated addresses. The base address cannot be set to an address lower than the reset value of the IVTBASE register.

By default and if required, the compiler will initialize the IVTBASE register in the runtime startup code. You can disable this functionality by turning off the `-mivt` option (see Section 3.7.1.11 "ivt"). This option also allows you to specify an initial address for this register, for the initial vector table that will be used. If vectored interrupts are enabled but you do not specify an address using this option, the vector table location will be set to the lowest table address used in the program, as specified by the `base()` arguments to `__interrupt()`.

If you use the `base()` argument to implement more than one table of interrupt vectors, you must ensure that you allocate sufficient memory for each table. The compiler will emit an error message if it detects an overlap of any interrupt vectors.

The following examples show the interrupt function prototypes for two ISRs which handle the timer 0 and 1 interrupt sources. These are configured to reside in independent vector tables whose base addresses are 0x100 and 0x200. All other interrupt sources are handled by a low-priority ISR, `defIsr()`, which appears in both vector tables. For these ISRs to become active, the IVTBASE register must first be loaded either 0x100 or 0x200. Changing the address in this register allows you to select which vector table is active.

```
void __interrupt(irq(TMR0,TMR1),base(0x100)) timerIsr(void)
{...}
void __interrupt(irq(TMR0,TMR1),base(0x200)) altTimerIsr(void)
{...}
void __interrupt(irq(default),base(0x100,0x200),low_priority)
defIsr(void)
{...}
```

4.9.2 Changing the Default Interrupt Function Allocation

Moving the code associated with interrupt functions is more difficult than that for ordinary functions, as interrupt routines have entry points strictly defined by the device.

You can use the `__section()` specifier (see Section 4.15.3 "Changing and Linking the Allocated Section") if you want to move the interrupt function, but leave the interrupt entry point at the default vector location.

To move the vector location, see the following section.

4.9.3 Specifying the Interrupt Vector

For devices that do not have the VIC module, the process of populating the interrupt vector locations is fully automatic. The compiler links the interrupt code entry point to the fixed vector locations. Typically the entry point code will be all or part of the code that performs the interrupt context switch, and the body of the interrupt function will be located elsewhere.

The location of these interrupt vectors cannot be changed at runtime, nor can you change the code linked to the vector. That is, you cannot have alternate interrupt functions and select which will be active during program execution. An error will result if there are more interrupt functions than interrupt vectors in a program.

For devices that have the VIC module, you have more freedom in how interrupt functions can be executed at runtime. When the IVT is enabled, these devices employ a table of interrupt vectors. Each table entry can hold an address, which is read when the corresponding interrupt is triggered, and the device will jump to that address. The vector table entry corresponding to an interrupt function is automatically completed by the compiler, based on the information in the `irq()` and `base()` arguments to `__interrupt()`, see Section 4.9.1 "Writing an Interrupt Service Routine".

Although the addresses in the vector table cannot be changed at runtime, it is possible to construct more than one table and have the device swap from one table to another. Changing the active vector table is performed by changing the vector table base address, which is stored in the IVTBASE registers. Since these registers cannot be modified atomically, you must disable all interrupts before changing their content. The following example shows how this might be performed in C code.

```
di();    // disable all interrupts
IVTBASEU = 0x0;
IVTBASEH = 0x2;
IVTBASEL = 0x0;
ei();    // re-enable interrupts
```

For devices with the VIC module operating in legacy mode, the vector table is disabled and the dual-priority vectors employed by regular PIC18 devices are used. These vector locations will then hold an instruction, not an address, but unlike regular PIC18 devices, the program can use the IVTBASE register to map the vector locations to any address and you can define two interrupt functions for each base address.

Do not confuse the function of the IVTBASE register with the `-mcodeoffset` option (see Section 3.7.1.3 "codeoffset"). The option moves the entry point of the code associated with each interrupt but does not move the vector location. When using this option, your program will not execute correctly until you provide code which maps the vector locations to the shifted interrupt entry points. By comparison, adjusting the IVTBASE registers does not move the location of the interrupt functions, but changes the vector locations. Your unmodified project will operate normally after adjusting this register.

© 2012-2018 Microchip Technology Inc.

Interrupt vectors that have not been specified explicitly in the project can be assigned a default function address by defining an interrupt function that uses `default` as its `irq()` interrupt source, or assigned a default instruction by using the `-mundefints` option (see Section 3.7.1.24 “undefints”).

4.9.4 Context Switching

The compiler will automatically link code into your project which saves the current status when an interrupt occurs and then restores this status when the interrupt returns.

4.9.4.1 CONTEXT SAVING ON INTERRUPTS

Some registers are automatically saved by the hardware when an interrupt occurs. Any registers or compiler temporary objects used by the interrupt function, other than those saved by the hardware, will be saved in code generated by the compiler. This is the *context save* or *context switch* code.

See Section 4.7 "Register Usage" for the registers that must be saved and restored either by hardware or software when an interrupt occurs.

Enhanced Mid-range PIC devices save the WREG, STATUS, BSR and FSR*x* registers in hardware (using special shadow registers) and hence these registers do not need to be saved by software. The registers that might need to be saved by software are the BTEMP registers[1], compiler temporary locations that act like registers.

Other Mid-range PIC processors only save the entire PC (excluding the PCLATH register) when an interrupt occurs. The WREG, STATUS, FSR and PCLATH registers and any BTEMP registers must be saved by code produced by the compiler, if required.

By default, the PIC18 high-priority interrupt function will utilize its internal shadow register to save the W, STATUS and BSR registers. For the low priority PIC18 interrupts, or when the shadow registers cannot be used, all registers that has been used by the interrupt code will be saved by software.

If the PIC18 device has the Vectored Interrupt Controller module, it additionally saves the FSRx, PCLATHx, and PRODx registers to shadow registers. All other used registers are saved by software. Separate shadow registers are available for low- and high-priority interrupts.

Note that for some older devices, the compiler will not use the shadow registers if compiling for the MPLAB ICD debugger, as the debugger itself utilizes these shadow registers. Some errata workarounds also prevent the use of the shadow registers (see Section 3.7.1.10 "errata").

The compiler determines exactly which registers and objects are used by an interrupt function, or any of the functions that it calls and saves these appropriately.

Assembly code placed in-line within the interrupt function is *not* scanned for register usage. Thus, if you include in-line assembly code into an interrupt function (or functions called by the interrupt function), you may have to add extra assembly code to save and restore any registers used.

If the software stack is in use, the context switch code will also initialize the stack pointer register so it is accessing the area of the stack reserved for the interrupt. See Section 4.5.2.2.1 "Object Size Limits" for more information on the software stack.

4.9.4.2 CONTEXT RESTORATION

Any objects saved by software are automatically restored by software before the interrupt function returns. The order of restoration is the reverse of that used when context is saved.

If the software stack is in use, the context restoration code will also restore the stack pointer register so that it is accessing the area of the stack used before the interrupt occurred. See Section 4.5.2.2.1 "Object Size Limits" for more information on the software stack.

1. These registers are memory locations allocated by the compiler, but are treated like registers for code generation purposes. They are typically used when generating reentrant code.

© 2012-2018 Microchip Technology Inc.

4.9.5 Enabling Interrupts

Two macros are available, once you have included `<xc.h>`, that control the masking of all available interrupts. These macros are `ei()`, which enable or unmask all interrupts, and `di()`, which disable or mask all interrupts.

On all devices, they affect the GIE bit in the INTCON or INTCON0 register. These macros should be used once the appropriate interrupt enable bits for the interrupts that are required in a program have been enabled.

For example:

```
ADIE = 1;  // A/D interrupts will be used
PEIE = 1;  // all peripheral interrupts are enabled
ei();      // enable all interrupts
// ...
di();      // disable all interrupts
```

> **Note:** Never re-enable interrupts inside the interrupt function itself. Interrupts are automatically re-enabled by hardware on execution of the `retfie` instruction. Re-enabling interrupts inside an interrupt function can result in code failure.

4.9.6 Accessing Objects From Interrupt Routines

Reading or writing objects from interrupt routines can be unsafe if other functions access these same objects.

The compiler will automatically treat as `volatile` any variables that are referenced in an interrupt routine; however, it is recommended that you explicitly mark these variables using the `volatile` specifier to ensure your code is portable (see Section 4.4.8.2 “Volatile Type Qualifier”). The compiler will restrict the optimizations performed on volatile objects (see Section 4.13 “Optimizations”).

Even when objects are marked as `volatile`, the compiler cannot guarantee that they will be accessed atomically. This is particularly true of operations on multi-byte objects, but, indeed, many operations on single-byte or bit objects cannot be performed in one instruction.

Interrupts should be disabled around any main-line code that modifies an object that is used by interrupt functions, unless you can guarantee that the access is atomic. Check the assembler list file to see the code generated for a statement, but remember that the instructions can change as the program is developed, particularly if the optimizers are enabled.

4.9.7 Function Duplication

It is assumed by the compiler that an interrupt can occur at any time. Functions encoded to use the compiled stack are not reentrant (see Section 4.5.2.2.1 "Object Size Limits"), so if such a function is called by an interrupt function and by main-line code, this could lead to code failure.

MPLAB XC8 compiler has a feature which will duplicate the generated code associated with any function that uses the non-reentrant function model and which is called from more than one call graph. There is one call graph associated with main-line code, and one for each interrupt function, if defined. It is assumed by the compiler that an interrupt may occur at any time. This allows reentrancy, but recursion is still not possible, even if the function is duplicated.

Any function compiled using the non-reentrant function model may fail if it is called from an interrupt function and by main-line code. Although the compiler can compile functions using a reentrant model, this feature is not available with all devices; it can also be disabled using the `-mstack` option or the `__nonreentrant` specifier. The compiler will duplicate the output for any function using the nonreentrant model if it has been called from both call trees. See Section 4.5.2.2 "Automatic Storage Duration Objects" for information on which function model is chosen for a function.

If a function is duplicated, main-line code will call the code generated for the original function, and the interrupt will call that for the duplicated function. The duplication takes place only in the generated code; there is no duplication of the C source code itself.

The duplicated code and objects defined by the function use unique identifiers. A duplicate identifier is identical to that used by the original code, but is prefixed with `i1`. Duplicated PIC18 functions use the prefixes `i1` and `i2` for the low- and high-priority interrupts, respectively.

To illustrate, in a program the function `main` calls a function called `input` which is also called by an interrupt function. The generated assembly code for the C function `input()` will use the assembly label `_input`. The corresponding label used by the duplicated function output will be `i1_input`. If this function makes reference to a temporary variable, the generated code will use the symbol `??_input`, compared to `??i1_input` for the duplicate. Even local labels within the function's generated code will be duplicated in the same way. The call graph, in the assembly list file, will show the calls made to both of these functions as if they were independently written. These symbols will also be seen in the map file symbol table.

Code associated with library functions are duplicated in the same way. This also applies to implicitly-called library routines, such as those that perform division or floating-point operations associated with C operators.

© 2012-2018 Microchip Technology Inc.

4.9.7.1 DISABLING DUPLICATION

The automatic duplication of non-reentrant functions called from more than one call graph can be inhibited by the use of a special pragma.

Duplication should only be disabled if the source code guarantees that an interrupt cannot occur while the function is being called from any main-line code. Typically this would be achieved by disabling interrupts before calling the function. It is not sufficient to disable the interrupts inside the function after it has been called; if an interrupt occurs when executing the function, the code can fail. See Section 4.9.5 "Enabling Interrupts" for more information on how interrupts can be disabled.

The pragma is:

```
#pragma interrupt_level 1
```

The pragma should be placed before the definition of the function that is not to be duplicated. The pragma will only affect the first function whose definition follows.

For example, if the function `read` is only ever called from main-line code when the interrupts are disabled, then duplication of the function can be prevented if it is also called from an interrupt function as follows.

```
#pragma interrupt_level 1
int read(char device)
{
    // ...
}
```

In main-line code, this function would typically be called as follows:

```
di();  // turn off interrupts
read(IN_CH1);
ei();  // re-enable interrupts
```

The value specified with the pragma indicates for which interrupt the function will not be duplicated. For Mid-range devices, the level should always be 1; for PIC18 devices it can be 1 or 2 for the low- or high-priority interrupt functions, respectively. To disable duplication for both interrupt priorities, use the pragma twice to specify both levels 1 and 2. The following function will not be duplicated if it is also called from the low- and high-priority interrupt functions.

```
#pragma interrupt_level 1
#pragma interrupt_level 2
int timestwo(int a) {
   return a * 2;
}
```

4.10 MAIN, RUNTIME STARTUP AND RESET

Coming out of Reset, your program will first execute runtime startup code added by the compiler, then control is transfered to the function `main()`. This sequence is described in the following sections.

4.10.1 The main Function

The identifier `main` is special. You must always have one, and only one, function called `main()` in your programs. This is the first C function to execute in your program.

Since your program is not called by a host, the compiler inserts special code at the end of `main()`, which is executed if this function ends, i.e., a `return` statement inside `main()` is executed, or code execution reaches the `main()`'s terminating right brace. This special code causes execution to jump to address 0, the Reset vector for all 8-bit PIC devices. This essentially performs a software Reset. Note that the state of registers after a software Reset can be different to that after a hardware Reset.

It is recommended that the `main()` function does not end. Add a loop construct (such as a `while(1)`) that will never terminate either around your code in `main()` or at the end of your code, so that execution of the function will never terminate. For example,

```
void main(void)
{
    // your code goes here
    // finished that, now just wait for interrupts
    while(1)
        continue;
}
```

4.10.2 Runtime Startup Code

A C program requires certain objects to be initialized and the device to be in a particular state before it can begin execution of its function `main()`. It is the job of the *runtime startup* code to perform these tasks, specifically (and in no particular order):

- Initialization of global variables assigned a value when defined
- Clearing of non-initialized global variables
- General set up of registers or device state

Rather than the traditional method of linking in a generic, precompiled routine, MPLAB XC8 determines what runtime startup code is required from the user's program. Details of the files used and how the process can be controlled are described in Section 3.4.2 "Startup and Initialization". The following sections detail the tasks performed by the runtime startup code.

The runtime startup code assumes that the device has just come out of Reset and that registers will be holding their power-on-reset value. If your program is an application invoked by a bootloader that will have already executed, you might need to ensure that data bank 0 is selected so that the runtime startup code executes correctly. This can be achieved by placing the appropriate code sequence towards the end of the bootloader as in-line assembly.

© 2012-2018 Microchip Technology Inc.

The following table lists the significant assembly labels used by the startup and powerup code.

TABLE 4-12: SIGNIFICANT ASSEMBLY LABELS

Label	Location
`reset_vec`	at the Reset vector location (0x0)
`powerup`	the beginning of the powerup routine, if used
`start`	the beginning of the runtime startup code, in `startup.s`
`start_initialization`	the beginning of the C initialization startup code, in the C output code

4.10.2.1 INITIALIZATION OF OBJECTS

One task of the runtime startup code is to ensure that any static storage duration objects contain their initial value before the program begins execution. A case in point would be `input` in the following example.

```
int input = 88;
```

In the above, the initial value, 0x88, will be stored as data in program memory, and will be copied to the memory reserved for `input` by the runtime startup code. For efficiency, initial values are stored as blocks of data and copied by loops. Absolute variables, see Section 4.5.4 "Absolute Variables" are never initialized and must be explicitly assigned a value if that is required for correct program execution.

This feature can be disabled using `-Wl,-no-data-init`; however, code that relies on objects containing their initial value will fail.

Since `auto` objects are dynamically created, they require code to be positioned in the function in which they are defined to perform their initialization and are not considered by the runtime startup code.

Note: Initialized `auto` variables can impact on code performance, particularly if the objects are large in size. Consider using `static` local objects instead.

Objects whose content should be preserved over a Reset should be marked with the `__persistent` qualifier (see Section 4.4.9.5 "__persistent Type Qualifier"). Such objects are linked in a different area of memory and are not altered by the runtime startup code.

The runtime startup code that initializes objects will clobber the content of the STATUS register. If you need to determine the cause of reset from this register, the register content can be preserved (see Section 4.10.2.4 "STATUS Register Preservation").

4.10.2.2 CLEARING OBJECTS

Those objects with static storage duration which are not assigned a value must be cleared before the `main()` function begins by the runtime startup code, for example.

```
int output;
```

The runtime startup code will clear all the memory locations occupied by uninitialized objects so they will contain zero before `main()` is executed. Absolute variables, see Section 4.5.4 “Absolute Variables” are never cleared and must be explicitly assigned a value of zero if that is required for correct program execution.

This feature can be disabled using `-Wl,-no-data-init`; however, code that relies on objects containing their initial value will fail.

Objects whose contents should be preserved over a Reset should be qualified with `__persistent` (see Section 4.4.9.1 “__bank() Type Qualifier”). Such objects are linked at a different area of memory and are not altered by the runtime startup code.

The runtime startup code that clears objects will clobber the content of the STATUS register. If you need to determine the cause of reset from this register, the register content can be preserved (see Section 4.10.2.4 “STATUS Register Preservation”).

4.10.2.3 SETUP OF DEVICE STATE

Some PIC devices come with an oscillator calibration constant which is pre-programmed into the device’s program memory. Code is automatically placed in the runtime startup code to load this calibration value (see Section 4.3.11 “Oscillator Calibration Constants”).

If the software stack is being used by the program, the stack pointer (FSR1) is also initialized by the runtime startup code (see Section 4.5.2.2.1 “Object Size Limits”).

© 2012-2018 Microchip Technology Inc.

4.10.2.4 STATUS REGISTER PRESERVATION

The `-mresetbits` option (see 3.7.1.18 resetbits) preserves some of the bits in the STATUS register before they are clobbered by the remainder of the runtime startup code. The state of these bits can be examined after recovering from a Reset condition to determine the cause of the Reset. This option is not available when compiling for PIC18 devices.

The entire STATUS register is saved to an assembly variable `___resetbits`. The compiler also defines the assembly symbols `___powerdown` and `___timeout` to represent the bit address of the Power-down and Time-out bits within the STATUS register and can be used if required.

These locations can be accessed from C code once `<xc.h>` has been included, noting that the equivalent C identifiers will use just two leading underscore characters, e.g. `__resetbits`. See Section 4.12.3.1 "Equivalent Assembly Symbols" for more details of symbol mapping.

The compiler will detect the usage of the above symbols in your code and automatically enable the `-mresetbits` option, if they are present. You may choose to enable this feature manually, if desired.

4.10.3 The Powerup Routine

Some hardware configurations require special initialization, often within the first few instruction cycles after Reset. To achieve this there is a hook to the Reset vector provided via the *powerup* routine.

This routine can be supplied in a user-defined assembler module. A template powerup routine is provided in the file `powerup.S` which is located in the `pic/sources` directory of your compiler distribution. Refer to comments in this file for more details.

The file should be copied to your working directory, modified, and included into your project as a source file. No special linker options or other code is required. The compiler will detect if you have defined a powerup routine and will automatically execute this code after reset, provided the code is contained in a psect (section) called `powerup`.

For correct operation, the code must end with a `goto` instruction that jumps to the label called `start`. As with all user-defined assembly code, any code inside this file must take into consideration program memory paging and/or data memory banking, as well as any applicable errata issues for the device you are using.

4.11 LIBRARIES

4.11.1 Standard Libraries

The C standard libraries contain a standardized collection of functions, such as string, and math routines. These functions are listed in Appendix A. Library Functions.

The libraries also contain C routines that are implicitly called by programs to perform tasks such as floating-point operations and integer division. These routines do not directly correspond to a function call in the source code.

And finally, there are several library functions, such as functions relating to function-level profiling, mid-range EEPROM access, REALICE trace and log etc., that are built with the program as required. These will not be found in any library file.

4.11.1.1 THE PRINTF ROUTINE

The code associated with the `printf()` function is not precompiled into the library files. The `printf()` function is generated from a special C template file that is customized after analysis of the user’s C code.

Template files are shipped with the compiler and contain a full implementation of the `printf()`function, but these features are conditionally included based on how you use `printf()` in your project.

The compiler analyzes the C source code, searching for calls to the `printf()` function and collates the format string placeholders that were used in those calls.

For example, if a program contains one call to `printf()`, which looks like:

```
printf(”input is: %d”);
```

The compiler will note that only the `%d` placeholder is used and the `printf()` function that is linked into the program might not include code to handle printing of types other than an `int`.

If the format string in a call to `printf()` is a pointer to a string, not a string literal as above, then the compiler will not be able to detect how `printf()` is used. A more complete version of `printf()` will be generated; however, the compiler can still make certain assumptions. In particular, the compiler can look at the number and type of the arguments to `printf()` following the format string expression to determine which placeholders could be valid. This enables the size and complexity of the generated `printf()` routine to be kept to a minimum even in this case.

For example, if `printf()` was called as follows:

```
printf(myFormatString, 4, 6);
```

the compiler could determine that, for example, no floating-point placeholders are required.

No aspect of this operation is user-controllable (other than by adjusting the calls to `printf()`); however, the final `printf()` code can be observed by opening the pre-processed output of the printf modules.

© 2012-2018 Microchip Technology Inc.

4.11.2 User-Defined Libraries

User-defined libraries can be created and linked in with your program. Library files are easier to manage than many source files, and can result in faster compilation times. Libraries must, however, be compatible with the target device and options for a particular project. Several versions of a library might need to be created and maintained to allow it to be used for different projects.

Libraries can be created using the librarian, `xc8-ar`, (see Section 7.2 “Librarian”).

Once built, user-defined libraries can be used on the command line along with the source files or added to the Libraries folder in your MPLAB X IDE project.

Library files specified on the command line are scanned first for unresolved symbols; so, their content can redefine anything that is defined in the C standard libraries (see Section 4.15.4 “Replacing Library Modules”).

4.11.3 Using Library Routines

Library functions and objects that have been referenced will be automatically linked into your program, provided the library file is part of your project. The use of a function from one library file will not include any other functions from that library.

Your program will require declarations for any library functions or symbols it uses. Standard libraries come with standard C headers (`.h` files), which can be included into your source files. See your favorite C text book or Appendix A. Library Functions for the header that corresponds to each library function. Typically you would write library headers if you create your own library files.

Header files are not library files. Library files contain precompiled code, typically functions and variable definitions; header files provide declarations (as opposed to definitions) for those functions, variables and types in the library. Headers can also define preprocessor macros.

4.12 MIXING C AND ASSEMBLY CODE

Assembly language can be mixed with C code using two different techniques: writing assembly code and placing it into a separate assembler module, or including it as in-line assembly in a C module.

Note: The more assembly code a project contains, the more difficult and time consuming will be its maintenance. Assembly code might need revision if the compiler is updated due to differences in the way the updated compiler may work. These factors do not affect code written in C.
If assembly must be added, it is preferable to write this as a self-contained routine in a separate assembly module, rather than in-lining it in C code.

4.12.1 Integrating Assembly Language Modules

Entire functions can be coded in assembly language as separate source files included into your project. They will be assembled and combined into the output image by the linker. Use a `.s` extension for source files containing plain assembly code, or `.S` or `.sx` for files that contain preprocessor directives that must be processed by the preprocessor.

By default, such modules are not optimized by the assembler optimizer. Optimization can be enabled by using the `-fasmfile` option (see Section 3.7.6.5 "asmfile").

The following are guidelines that must be adhered to when writing a C-callable assembly routine.

- Include the `<xc.inc>` assembly header file if you need to use SFRs in your code. (If this is included using `#include`, ensure the source file uses `.sx` or `.S` as its extension.)
- Select, or define, a suitable psect for the executable assembly code (see Section 4.15.1 "Compiler-Generated Psects" for an introductory guide.)
- Select a name (label) for the routine using a leading underscore character
- Ensure that the routine's label is globally accessible from other modules
- Select an appropriate C-equivalent prototype for the routine on which argument passing can be modeled
- If values need to be passed to or returned from the routine, write a reentrant routine if possible (see Section 4.12.3.3 "Writing Reentrant Assembly Routines With Parameters"); otherwise use ordinary variables for value passing.
- Optionally, use a signature value to enable type checking when the function is called
- Use bank selection instructions and mask addresses of any variable symbols

© 2012-2018 Microchip Technology Inc.

The following example shows a Mid-range device assembly routine that can add an 8-bit argument with the contents of PORTB and return this as an 8-bit quantity. The code is similar for other devices.

```
#include <xc.inc>

GLOBAL _add        ; make _add globally accessible
SIGNAT _add,4217   ; tell the linker how it should be called

; everything following will be placed into the mytext psect
PSECT mytext,local,class=CODE,delta=2
; our routine to add to ints and return the result
_add:
   ; W is loaded by the calling function;
   BANKSEL   (PORTB)            ; select the bank of this object
   addwf     BANKMASK(PORTB),w   ; add parameter to port
   ; the result is already in the required location (W)so we can
   ; just return immediately
   return
```

The code has been placed in a user-defined psect, `myText`, but this section is part of the `CODE` linker class, so it will be automatically placed in the area of memory set aside for code without you having to adjust the default linker options.

The `delta` flag used with this section indicates that the memory space in which the psect will be placed is word addressable (value of 2), which is true for PIC10/12/16 devices. For PIC18 devices, program memory is byte addressable, but instructions must be word-aligned, so you would instead use code such as the following, which uses a `delta` value is 1 (which is the default setting), but the `reloc` (alignment) flag is set to 2, to ensure that the section starts on a word-aligned address.

```
PSECT text0,class=CODE,reloc=2
```

See Section 5.2.9.3 "PSECT" for detailed information on the flags used with the `PSECT` assembler directive.

The mapping between C identifiers and those used by assembly are described in Section 4.12.3 "Interaction between Assembly and C Code". In assembly domain we must choose the routine name `_add` as this then maps to the C identifier `add`. Since this routine will be called from other modules, the label is made globally accessible, by using the `GLOBAL` assembler directive (Section 5.2.9.1 "GLOBAL").

A `SIGNAT` directive (Section 5.2.9.22 "SIGNAT") was used so that the linker can check that the routine is correctly called.

The W register will be used for passing in the argument. See Section 4.8.6 "Function Parameters" for the convention used to pass parameters.

The `BANKSEL` directive and `BANKMASK` macro have been used to ensure that the correct bank was selected and that all addresses are masked to the appropriate size.

To call an assembly routine from C code, a declaration for the routine must be provided. Here is a C code snippet that declares the operation of the assembler routine, then calls the routine.

```
// declare the assembly routine so it can be correctly called
extern unsigned char add(unsigned char a);

void main(void) {
  volatile unsigned char result;

  result = add(5);  // call the assembly routine
}
```

4.12.2 Inline Assembly

Assembly instructions can be directly embedded in-line into C code using the statement `asm();`.

The instructions are placed in a string inside what look like function call brackets, although no actual call takes place. Typically one instruction is placed in the string, but you can specify more than one assembly instruction by separating the instructions with a `\n` character, e.g., `asm("movlw 55\nmovwf _x");`, Code will be more readable if you place one instruction in each statement and use multiple statements.

You can use the `asm()` form of in-line assembly at any point in the C source code as it will correctly interact with all C flow-of-control structures, as shown below.

```
unsigned int var;

void main(void)
{
    var = 1;
    asm("bcf 0,3");
    asm("BANKSEL _var");
    asm("rlf (_var)&07fh");
    asm("rlf (_var+1)&07fh");
}
```

In-line assembly code is never optimized by the assembler optimizer.

When using in-line assembler code, it is extremely important that you do not interact with compiler-generated code. The code generator cannot scan the assembler code for register usage; so, it will remain unaware if registers are clobbered or used by the assembly code. However, the compiler will reset all bank tracking once it encounters in-line assembly, so any SFRs or bits within SFRs that specify the current bank do not need to be preserved by in-line assembly.

The registers used by the compiler are explained in Section 4.7 "Register Usage". If you are in doubt as to which registers are being used in surrounding code, compile your program with the `-Wa,-a` option (see Section 3.7.10 "Mapped Assembler Options") and examine the assembler code generated by the compiler. Remember that as the rest of the program changes, the registers and code strategy used by the compiler will change as well.

If a C function is called from main-line and interrupt code, it can be duplicated (see Section 4.9.7 "Function Duplication"). Although a special prefix is used to ensure that labels generated by the compiler are not duplicated, this does not apply to labels defined in hand-written, in-line assembly code in C functions. Thus, you should not define assembly labels for in-lined assembly if the containing function might be duplicated.

4.12.3 Interaction between Assembly and C Code

MPLAB XC8 C Compiler incorporates several features designed to allow C code to obey requirements of user-defined assembly code. There are also precautions that must be followed to ensure that assembly code does not interfere with the assembly generated from C code.

4.12.3.1 EQUIVALENT ASSEMBLY SYMBOLS

Most C symbols map to an corresponding assembly equivalent.

This mapping is such that an "ordinary" symbol defined in the assembly domain cannot interfere with an "ordinary" symbol in the C domain. So for example, if the symbol `main` is defined in the assembly domain, it is quite distinct to the `main` symbol used in C code and they refer to different locations.

© 2012-2018 Microchip Technology Inc.

The name of a C function maps to an assembly label that will have the same name, but with an *underscore* prepended. So the function `main()` will define an assembly label `_main`.

Baseline PIC devices can use alternate assembly domain symbols for functions. The destinations of call instructions on these devices are limited to the first half of a program memory page. The compiler, thus, encodes functions in two parts, as illustrated in the following example of a C function, `add()`, compiled for a Baseline device.

```
entry__add:
    ljmp    _add
```

The label `entry__add` is the function's entry point and will always be located in the first half of a program memory page. The code associated with this label is simply a long jump (see Section 5.2.1.8 "Long Jumps and Calls") to the actual function body located elsewhere and identified by the label `_add`.

If you plan to call routines from assembly code, you must be aware of this limitation in the device and the way the compiler works around it for C functions. Hand-written assembly code should always call the `entry__funcName` label rather than the usual assembly-equivalent function label.

If a C function is qualified `static` and there is more than one `static` function in the program with exactly the same name, the name of the first function will map to the usual assembly symbol and the subsequent functions will map to a special symbol with the form: *`fileName@functionName`*, where *`fileName`* is the name of the file that contains the function, and *`functionName`* is the name of the function.

For example, a program contains the definition for two `static` functions, both called `add`. One lives in the file `main.c` and the other in `lcd.c`. The first function will generate an assembly label `_add`. The second will generate the label `lcd@add`.

The name of a C variable with static storage duration also maps to an assembler label that will have the same name, but with an *underscore* prepended. So the variable `result` will define an assembly label: `_result`.

If the C variable is qualified `static`, there is a chance that there could be more than one variable in the program with exactly the same C name. The same rules apply to these `static` variables as to `static` functions. The name of the first variable will map to a symbol prepended with an underscore; the subsequent symbols will have the form: *`fileName@variableName`*, where *`fileName`* is the name of the file that contains the variable, and *`variableName`* is the name of the variable.

If there is more than one local `static` variable (i.e., it is defined inside a function definition) then all the variables will have an assembly name of the form: *`functionName@variableName`*.

If there is a `static` variable called `output` in the function `read` and another `static` variable with the same name defined in the function `update`, then the symbols in the assembly can be accessed using the symbols `read@output` and `update@output`, respectively.

If there is more than one `static` function with the same name and they contain definitions for `static` variables of the same name, then the assembly symbol used for these variables will be of the form:

`fileName@functionName@variableName`.

Having two `static` variables or functions with the same name is legal, but not recommended as is easy to write code that accesses the wrong variable or calls the wrong function.

Functions that use the reentrant model do not define any symbols that allow you to access `auto` and parameter variables. You should not attempt to access these in assembly code. Special symbols for these variables are defined, however, by functions that use the nonreentrant model. These symbols are described in the following paragraphs.

To allow easy access to parameter and `auto` variables on the compiled stack, special equates are defined which map a unique symbol to each variable. The symbol has the form: *`functionName@variableName`*. Thus, if the function `main` defines an `auto` variable called `foobar`, the symbol `main@foobar` can be used in assembly code to access this C variable.

Function parameters use the same symbol mapping as `auto` variables. If a function called `read` has a parameter called `channel`, then the assembly symbol for that parameter is `read@channel`.

Function return values have no C identifier associated with them. The return value for a function shares the same memory as that function's parameter variables, if they are present. The assembly symbol used for return values has the form `?_`*`funcName`*, where *`funcName`* is the name of the function returning the value. Thus, if a function, `getPort` returns a value, it will be located the address held by the assembly symbol `?_getPort`. If this return value is more than one byte in size, then an offset is added to the symbol to access each byte, e.g., `?_getPort+1`.

If the compiler creates temporary variables to hold intermediate results, these will behave like `auto` variables. As there is no corresponding C variable, the assembly symbol is based on the symbol that represents the `auto` block for the function plus an offset. That symbol is `??_`*`funcName`*, where *`funcName`* is the function in which the symbol is being used. So for example, if the function `main` uses temporary variables, they will be accessed as an offset from the symbol `??_main`.

4.12.3.2 ACCESSING REGISTERS FROM ASSEMBLY CODE

In separate assembly modules, SFR definitions are not automatically accessible. The assembly header file `<xc.inc>` can be used to gain access to these register definitions. Do not use this file for assembly in-line with C code as it will clash with definitions in `<xc.h>`.

Include the file using the assembler's `INCLUDE` directive, (see Section 5.2.10.5 "INCLUDE") or use the C preprocessor's `#include` directive. If you are using the latter method, make sure you use a `.S` or `.sx` extension for the assembly source file.

The symbols for registers in this header file look similar to the identifiers used in the C domain when including `<xc.h>`, e.g., `PORTA`, `EECON1`, etc. They are different symbols in different domains, but will map to the same memory location.

Names of bits within registers are defined as *`registerName,bitNumber`*. So, for example, `RA0` is defined as `PORTA,0`.

Here is an example of a Mid-range assembly module that uses SFRs.

```
#include <xc.inc>
GLOBAL _setports

PSECT text,class=CODE,local,delta=2
_setports:
   movlw     0xAA
   BANKSEL   (PORTA)
   movwf     BANKMASK(PORTA)
   BANKSEL   (PORTB)
   bsf       RB1
```

© 2012-2018 Microchip Technology Inc.

If you wish to access register definitions from assembly that is in-line with C code, ensure that the `<xc.h>` header is included into the C module. Information included by this header will define in-line assembly symbols as well as the usual symbols accessible from C code.

The symbols used for register names will be the same as those defined by `<xc.inc>`. So for example, the example given previously could be rewritten as in-line assembly as follows.

```
asm("movlw0xAA);
asm("BANKSEL(PORTA));
asm("movwfBANKMASK(PORTA));
asm("BANKSEL(PORTB));
asm("bsf  RB1);
```

The code generator does not detect when SFRs have been written to in in-line assembly, so these must be preserved. The list of registers used by the compiler and further information can be found in Section 4.7 "Register Usage".

4.12.3.3 WRITING REENTRANT ASSEMBLY ROUTINES WITH PARAMETERS

Hand-written assembly routines for Enhanced Mid-range and PIC18 devices can be written to use the software stack and be reentrantly called from C code. Such routines can take parameters, return values, and define their own local objects, if required.

The following are the steps that need to be followed to create such routines.

- Declare the C prototype for the routine in C source code, choosing appropriate parameter and return value types.
- Include the `<xc.inc>` assembly header file. (If this is included using `#include`, ensure the source file uses `.sx` or `.S` as its extension.)
- If required, define each auto-like variable using the `stack_auto` *`name`*`,size` macro, where *`name`* can be any valid assembler identifier and *`size`* is the variable's size in bytes.
- If required, define each parameter using the macro `stack_param` *`name`*`,`*`size`*, where *`name`* can be any valid assembly identifier and *`size`* is the variable's size in bytes. Parameters must be defined after autos and their order must match the order in which they appear in the C prototype.
- Initialize the stack *once* using the macro `alloc_stack` before any instructions in the routine.
- Immediately before *each* return instruction, restore the stack using the macro `restore_stack`.

Write the routine in assembly in the usual way, taking note of the points in Section 4.12.1 "Integrating Assembly Language Modules".

Each auto and parameter variable will be located at a unique offset to the stack pointer (FSR1). If you follow the above guidelines, you can use the symbol *`name`*`_offset`, which will be assigned the stack-pointer offset for the variable with *`name`*. These macros will exist for both auto and parameter variables.

If the routine returns a value, this must be placed into the location expected by the code that calls the routine (for full details of C-callable routines, see Section 4.8.7.2 "Software Stack Return Values"). To summarize, for objects 1 to 4 bytes in size, these must be loaded to temporary variables referenced as `btemp`, plus an offset. This symbol is automatically linked into your routine if you use the macros described above.

It is recommended that you do not arbitrarily adjust the stack pointer during the routine. The symbols that define the offset for each auto and parameter variable assume that the stack pointer has not been modified. However, if your assembly routine calls other reentrant routines (regardless of whether they are defined in C or assembly code), you must write the assembly code that pushes the arguments onto the stack, calls the function, and then removes any return value from the stack.

The following is an example of a reentrant assembly routine, `_inc`, written for a PIC16F1xxx device. Its arguments and return value are described by the C prototype:

```
extern reentrant int inc(int foo);
```

This routine returns an `int` value that is one higher than the `int` argument that is passed to it. It uses an auto variable, `x`, strictly for illustrative purposes.

```
#include <xc.inc>

PSECT  text2,local,class=CODE,delta=2

GLOBAL _inc
_inc:
    stack_auto x,2      ;an auto called 'x'; 2 bytes wide
    stack_param foo,2   ;a parameter called 'foo'; 2 bytes wide
    alloc_stack

;x = foo + 1;
   moviw  [foo_offset+0]FSR1
   addlw  low(01h)
   movwf  btemp+0
   moviw  [foo_offset+1]FSR1
   movwf  btemp+1
   movlw  high(01h)
   addwfc btemp+1,f
   movf   btemp+0,w
   movwi  [x_offset+0]FSR1
   movf   btemp+1,w
   movwi  [x_offset+1]FSR1

;return x;
   moviw  [x_offset+0]FSR1
   movwf  btemp+0
   moviw  [x_offset+1]FSR1
   movwf  btemp+1

   restore_stack
   return
```

© 2012-2018 Microchip Technology Inc.

The following is an example of a reentrant assembly routine, `_add`, written for a PIC18 device. Its arguments and return value are described by the C prototype:

```
extern reentrant int add(int base, int index);
```

This routine returns an `int` value that is one higher than the `int` sum of the `base` and `index` arguments that are passed to it. It uses the auto variables, `tmp` and `result`, strictly for illustrative purposes.

```
#include <xc.inc>

psect  text1,class=CODE,space=0,reloc=2

GLOBAL _add
_add:
   stack_auto tmp,2      ;an auto called 'tmp'; 2 bytes wide
   stack_auto result,2   ;an auto called 'result'; 2 bytes wide
   stack_param base,2    ;a parameter called 'base'; 2 bytes wide
   stack_param index,2   ;a parameter called 'index'; 2 bytes wide
   alloc_stack

;tmp = base + index;
   movlw  base_offset
   movff  PLUSW1,btemp+0
   movlw  base_offset+1
   movff  PLUSW1,btemp+1
   movlw  index_offset
   movf   PLUSW1,w,c
   addwf  btemp+0,f,c
   movlw  index_offset+1
   movf   PLUSW1,w,c
   addwfc btemp+1,f,c
   movlw  tmp_offset
   movff  btemp+0,PLUSW1
   movlw  tmp_offset+1
   movff  btemp+1,PLUSW1

;result = tmp + 1;
   movlw  tmp_offset
   movf   PLUSW1,w,c
   addlw  1
   movwf  btemp+0,c
   movlw  tmp_offset+1
   movff  PLUSW1,btemp+1
   movlw  0
   addwfc btemp+1,f,c
   movlw  result_offset
   movff  btemp+0,PLUSW1
   movlw  result_offset+1
   movff  btemp+1,PLUSW1

;return result;
   movlw  result_offset
   movff  PLUSW1,btemp+0
   movlw  result_offset+1
   movff  PLUSW1,btemp+1

   restore_stack
   return
```

4.12.3.4 ABSOLUTE PSECTS

MPLAB XC8 is able to determine the address bounds of absolute psects (defined using the `abs` and `ovrld`, `PSECT` flags) and reserves that data memory prior to the compilation stage so it is not used by C source. Any data memory required by assembly code must use an absolute psect, but these do not need to be used for psects to be located in program memory.

The following example code contained in an assembly code file defines a table that must be located at address 0x110 in the data space.

```
PSECT lkuptbl,class=RAM,space=1,abs,ovrld
ORG 110h
lookup:
    DS 20h
```

When the project is compiled, the memory range from address 0x110 to 0x12F in memory space 1 (data memory) is recorded as being used and is reserved before compiling the C source. An absolute psect always starts at address 0. For such psects, you can specify a non-zero starting address by using the `ORG` directive. See Section 5.2.9.4 "ORG" for important information on this directive.

4.12.3.5 UNDEFINED SYMBOLS

If an object is defined in C source code, but is only accessed in assembly code, the compiler might ordinarily remove the object believing it is unused, resulting in an undefined symbol error.

To work around this issue, MPLAB XC8 searches for symbols in assembly code that have no assembly definition (which would typically be a label). If these symbols are encountered in C source they are automatically treated as being `volatile` (see Section 4.4.8.2 "Volatile Type Qualifier"), which will prevent them from being removed.

For example, if a C program defines a variable as follows:

```
int input;
```

but this variable is never used in C code. The assembly module(s) can simply declare this symbol, with the leading underscore character (see Section 4.12.3 "Interaction between Assembly and C Code"), using the `GLOBAL` assembler directive and then use it as follows.

```
GLOBAL _input, _raster
PSECT text,local,class=CODE,reloc=2
_raster:
   movf   _input,w
```

© 2012-2018 Microchip Technology Inc.

4.13 OPTIMIZATIONS

The optimizations in the MPLAB XC8 compiler can be broadly grouped into C-level optimizations performed on the source code before conversion into assembly and assembly-level optimizations performed on the assembly code generated by the compiler.

The C-level optimizations are performed early during the code generation phase and so have flow-on benefits: performing one optimization might mean that another can then be applied. As these optimizations are applied before the debug information has been produced, there is less impact on source-level debugging of programs.

Some of these optimizations are integral to the code generation process and so cannot be disabled via an option. Suggestions as to how specific optimizations can be defeated are given in the sections below.

If your compiler is unlicensed, some of the optimization levels are disabled (see Section 3.7.6 “Options for Controlling Optimization”). Even if they are enabled, optimizations can only be applied if very specific conditions are met. As a result, you might see that some lines of code are optimized, but other similar lines are not.

The optimization level determines the available optimizations, which are listed in Table 4-13.

TABLE 4-13: OPERATING MODE OPTIMIZATION SETS

Level	Optimization sets available
01 (Free mode)	• Basic code generator and assembler optimizations
02 (Std mode)	• Basic code generator and assembler optimizations • Whole program assembly optimizations
03 (PRO mode)	• Basic code generator and assembler optimizations • Whole program assembly optimizations • Procedural abstraction (assembly optimization) • OCG C-level optimizations

Assembly-level optimizations are described in Section 5.3 “Assembly-Level Optimizations”.

The basic code generator optimizations consist of the following.

- **Whole-program analysis for object allocation** into data banks without having to use non-standard keywords or compiler directives.
- **Simplification and folding of constant expressions** to simplify expressions.
- **Expression tree optimizations** to ensure efficient assembly generation.

The following is a list of main OCG C-level optimizations, which simplify C expressions or code produced from C expressions. These are applied across the entire program, not just on a module-by-module basis.

- **Tracking of the current data bank** is performed by the compiler as it generates assembly code. This allows the compiler to reduce the number of bank-selection instructions generated.
- **Strength reductions and expression transformations** are applied to all expression trees before code is generated. This involves replacing expressions with equivalent, but less costly operations.

- **Unused variables in a program are removed**. This applies to all variables. Variables removed will not have memory reserved for them, will not appear in any list or map file, and will not be present in debug information (will not be observable in the debugger). A warning is produced if an unused variable is encountered. Global objects qualified `volatile` will never be removed (see Section 4.4.8.2 “Volatile Type Qualifier”). Taking the address of a variable or referencing its assembly-domain symbol in hand-written assembly code also constitutes use of the variable.
- **Redundant assignments to variables not subsequently used are removed**, unless the variable is `volatile`. The assignment statement is completely removed, as if it was never present in the original source code. No code will be produced for it and you will not be able to set a breakpoint on that line in the debugger.
- **Unused functions in a program are removed**. A function is considered unused if it is not called, directly or indirectly, nor has had its address taken. The entire function is removed, as if it was never present in the original source code. No code will be produced for it and you will not be able to set a breakpoint on any line in the function in the debugger. Referencing a function's assembly-domain symbol in a separate hand-written assembly module will prevent it being removed. The assembly code need only use the symbol in the `GLOBAL` directive.
- **Unused return expressions in a function are removed**. The return value is considered unused if the result of all calls to that function discard the return value. The code associated with calculation of the return value will be removed and the function will be encoded as if its return type was `void`.
- **Propagation of constants is performed** where the numerical contents of a variable can be determined. Variables which are not `volatile` and whose value can be exactly determined are replaced with the numerical value. Uninitialized global variables are assumed to contain zero prior to any assignment to them.
- **Variables assigned a value before being read are not cleared or initialized** by the runtime startup code. Only non-`auto` variables are considered and if they are assigned a value before other code can read their value, they are treated as being `__persistent` (see Section 4.4.9.1 “__bank() Type Qualifier”). All `__persistent` objects are not cleared by the runtime startup code, so this optimization will speed execution of the program startup.
- **Pointer sizes are optimized** to suit the target objects they can access. The compiler tracks all assignments to pointer variables and keeps a list of targets each pointer can access. As the memory space of each target is known, the size and dereference method used can be customized for each pointer.
- **Dereferencing pointers with only target can be replaced** with direct access of the target object. This applies to data and function pointers.
- **Unreachable code is removed**. C Statements that cannot be reached are removed before they generate assembly code. This allows subsequent optimizations to be applied at the C level.

MPLAB X IDE or other IDEs can indicate incorrect values when watching variables if optimizations hold a variable in a register. Try to use the ELF/DWARF debug file format to minimize such occurrences. Check the assembly list file to see if registers are used in the routine that is being debugged.

© 2012-2018 Microchip Technology Inc.

4.14 PREPROCESSING

All C source files are preprocessed before compilation. The preprocessed file is deleted after compilation, but you can examine this file by using the `-E` option (see Section 3.7.2.2 “E: Preprocess Only”).

Assembler source files are preprocessed if the file uses a `.S` or `.sx` extension.

4.14.1 Preprocessor Directives

MPLAB XC8 accepts several specialized preprocessor directives, in addition to the standard directives. All of these are listed in Table 4-14.

TABLE 4-14: PREPROCESSOR DIRECTIVES

Directive	Meaning	Example
`#`	preprocessor null directive, do nothing	`#`
`#assert`	generate error if condition false	`#assert SIZE > 10`

`#define`	define preprocessor macro	`#define SIZE (5)`
		`#define FLAG`
		`#define add(a,b) ((a)+(b))`

`#elif`	short for `#else #if`	`see #ifdef`
`#else`	conditionally include source lines	`see #if`
`#endif`	terminate conditional source inclusion	`see #if`
`#error`	generate an error message	`#error Size too big`

`#if`	include source lines if constant expression true	`#if SIZE < 10`
		`  c = process(10)`
		`#else`
		`  skip();`
		`#endif`

`#ifdef`	include source lines if preprocessor symbol defined	`#ifdef FLAG`
		`  do_loop();`
		`#elif SIZE == 5`
		`  skip_loop();`
		`#endif`

`#ifndef`	include source lines if preprocessor symbol not defined	`#ifndef FLAG`
		`  jump();`
		`#endif`

`#include`	include text file into source	`#include <stdio.h>`
		`#include “project.h”`

`#line`	specify line number and filename for listing	`#line 3 final`
`#`*nn*	(where *nn* is a number) short for `#line` *nn*	`#20`
`#pragma`	compiler specific options	See Section 4.14.3 “Pragma Directives”.
`#undef`	undefines preprocessor symbol	`#undef FLAG`
`#warning`	generate a warning message	`#warning Length not set`

Macro expansion using arguments can use the # character to convert an argument to a string, and the ## sequence to concatenate arguments. If two expressions are being concatenated, consider using two macros in case either expression requires substitution itself; for example

```
#define __paste1(a,b)   a##b
#define __paste(a,b)    __paste1(a,b)
```

lets you use the `paste` macro to concatenate two expressions that themselves can require further expansion. Remember, that once a macro identifier has been expanded, it will not be expanded again if it appears after concatenation.

4.14.1.1 PREPROCESSOR ARITHMETIC

Preprocessor macro replacement expressions are textual and do not utilize types. Unless they are part of the controlling expression to the inclusion directives (discussed below), macros are not evaluated by the preprocessor. Once macros have been textually expanded and preprocessing is complete, the expansion forms a C expression which is evaluated by the *code generator* along with other C code. Tokens within the expanded C expression inherit a type, and values are then subject to integral promotion and type conversion in the usual way.

If a macro is part of the controlling expression to a conditional inclusion directive (`#if` or `#elif`), the macro must be evaluated by the *preprocessor*. The result of this evaluation is often different to the C-domain result for the same sequence. The preprocessor assigns sizes to literal values in the controlling expression that are equal to the largest integer size accepted by the compiler, as specified by the size of `intmax_t` defined in `<stdint.h>`. For the MPLAB XC8 C compiler, this size is 32 bits, unless you are compiling for a PIC18 device with C99 in which case it is 64 bits.

The following code written for a Mid-range device does not work as you might expect it to work. The preprocessor will evaluate `MAX` to be the result of a 32-bit multiplication, 0xF4240. However, the definition of the `long int` variable, `max`, will be assigned the value 0x4240 (since the constant 1000 has a `signed int` type, and, therefore, the C-domain multiplication will also be performed using a 16-bit `signed int` type).

```
#define MAX 1000*1000
...
#if MAX > INT16_MAX   // evaluation of MAX by preprocessor
long int max = MAX;   // evaluation of MAX by code generator
#else
int max = MAX;        // evaluation of MAX by code generator
#endif
```

Overflow in the C domain can be avoided by using a constant suffix in the macro (see Section 4.4.7 “Constant Types and Formats”). For example, an `L` after a number in a macro expansion indicates it should be interpreted by the C compiler as a `long`, but this suffix does not affect how the preprocessor interprets the value, if it needs to evaluate it.

So, for example:

```
#define MAX 1000*1000L
```

will evaluate to 0xF4240 in C expressions.

© 2012-2018 Microchip Technology Inc.

4.14.2 Predefined Macros

The compiler drivers define certain symbols to the preprocessor, allowing conditional compilation based on chip type, etc. The symbols listed in Table 4-15 show the more common symbols defined by the drivers.

Each symbol, if defined, is equated to 1 (unless otherwise stated).

TABLE 4-15: PREDEFINED MACROS

Symbol	Set
`ERRATA_4000_BOUNDARY`	When the ERRATA_4000 applies
`HI_TECH_C`	When the C language variety is HI-TECH C compatible
`MPLAB_ICD`	When building for a non-PIC18 device and an MPLAB ICD debugger, and is assigned 2 to indicate an MPLAB ICD 2, assigned 3 for the MPLAB ICD 3
`_`*`CHIPNAME`*	When the specific chip type selected, e.g., `_16F877`
`_BANKBITS_`	When building for non-PIC18 devices, and is assigned 0, 1 or 2 to indicate 1, 2 or 4 available banks or RAM
`_BANKCOUNT_`	When building for non-PIC18 devices and indicates the number of banks of data memory implemented
`_COMMON_`	When common RAM is present
`_COMMON_ADDR_`	When common memory is present, and indicates common memory starting address
`_COMMON_SIZE_`	When common memory is present, and indicates the common memory size
`_EEPROMSIZE`	When building for non-PIC18 devices and indicates how many bytes of EEPROM are available
`_EEPROM_INT`	When building for non-PIC18 devices, and is assigned a value of 2 (_NVMREG_INT), 1 (_EEREG_INT), or 0 (_NOREG_INT) to indicate the device uses the NVMREG, EEREG, or no register interface to access EEPROM.
`_ERRATA_TYPES`	When the errata workaround is being applied, see `-merrata` option, Section 3.7.1.10 "errata"
`_`*`FAMILY`*`_FAMILY_` (1)	When building for PIC18 devices and indicates the PIC18 family
`_FLASH_ERASE_SIZE` (2)	Always, and indicates the size of the flash erase block
`_FLASH_WRITE_SIZE` (2)	Always, and indicates the size of the flash write block
`_GPRBITS_`	When building for non-PIC18 devices, and is assigned 0, 1 or 2 to indicate 1, 2 or 4 available banks or general purpose RAM.
`_GPRCOUNT_`	When building for non-PIC18 devices, and is assigned a value which indicates the number of banks that contain general-purpose RAM
`_HAS_FUNCTIONLEVELPROF_`	When `-finstrument-functions` is specified and target supports profiling
`_HAS_INT24`	Always
`_HAS_OSCVAL_`	When the target device has an oscillator calibration register
`_MPC_`	When compiling for Microchip PIC MCU family

Note 1: To determine the family macro relevant to your device, look for the `FAMILY` field in the `picc-18.ini` file in the compiler's `dat` directory.

2: These macros relate only to Flash program memory. They do not convey any information regarding Flash data memory.

TABLE 4-15: PREDEFINED MACROS (CONTINUED)

Symbol	Set
`_OMNI_CODE_`	When compiling using an OCG compiler
`_PIC12`	When building for a Baseline device (12-bit instruction)
`_PIC12E`	When building for an Enhanced Baseline device (12-bit instruction)
`_PIC12IE`	When building for am Enhanced Baseline device with interrupts
`_PIC14`	When building for an Mid-range device (14-bit instruction)
`_PIC14E`	When building for an Enhanced Mid-range device (14-bit instruction)
`_PIC14EX`	When building for an extended-bank Enhanced Mid-range PIC device (14-bit instruction)
`_PIC18`	When building for a PIC18 device (16-bit instruction)
`_PROGMEM_`	When building for a Mid-range device with flash memory, and indicates the type of flash memory employed by the target device: values 0xFF (unknown) 0xF0 (none) 0 (read-only) 1 (word write with auto erase) 2 (block write with auto erase) 3 (block write with manual erase)
`_`*`RAMSIZE`*	When building for a PIC18 device and to indicates how many bytes of data memory are available
`_ROMSIZE`	Always, and Indicates how much program memory is available (byte units for PIC18 devices; words for other devices)
`_XC8_MODE_`	Always, and indicates which compiler, PRO, Standard or Free, is in use Values of 2, 1 or 0 are assigned, respectively.
`__`*`CHIPNAME`* and `__`*`CHIPNAME`*`__`	When the specific chip type selected, e.g., `__16F877`
`__CLANG__`	When the Clang frontend is in use (`-std=c99`)
`__DATABANK`	When eeprom or flash memory is implemented, and identifies in which bank the EEDATA/PMDATA register is found
`__DATE__`	Always, and indicates the current date as a string literal, e.g., `"May 21 2004"`
`__EXTMEM`	When device has external memory, and indicates the size of this memory
`__FILE__`	Always, and indicates the source file being preprocessed
`__FLASHTYPE`	When building for non-PIC18 devices with flash memory, and indicates the type of flash memory employed by the target device, see `_PROGMEM` below
`__LINE__`	Always, and indicates this source line number
`__J_PART`	When building for a PIC18 'J' series part
`__MPLAB_ICD`*`X`*`__`	When compiling for an ICD debugger. *X* can be `2`, or `3` indicating a Microchip MPLAB ICD 2, or ICD 3, respectively

Note 1: To determine the family macro relevant to your device, look for the `FAMILY` field in the `picc-18.ini` file in the compiler's `dat` directory.

2: These macros relate only to Flash program memory. They do not convey any information regarding Flash data memory.

© 2012-2018 Microchip Technology Inc.

TABLE 4-15: PREDEFINED MACROS (CONTINUED)

Symbol	Set
`__MPLAB_PICKITX__`	When compiling for a PICkit™. x can be 2 or 3, indicating a Microchip MPLAB PICkit 2 or PICkit 3, respectively
`__MPLAB_REALICE__`	When compiling for a Microchip MPLAB REAL ICE™ In-Circuit Emulator
`__OPTIMIZE_SPEED__`	When using speed-orientated optimizations
`__OPTIMIZE_SPACE__` and `__OPTIMIZE_SIZE__`	When using space-orientated optimizations
`__OPTIMIZE_NONE__`	When no optimizations are in effect
`__OPTIM_FLAGS`	Always, and indicates the optimizations in effect (see text following this table)
`__PICCPRO__` and `__PICC__`	When building for any PIC10/12/14/16 device
`__PICC18__`	When not in C18 compatibility mode
`__RESETBITS_ADDR`	When the STATUS register will be preserved, and indicates the address at which this register will be saved
`__SIZEOF_`*`TYPE`*`__`	Always, and indicates the size in bytes of the specified type, e.g., `__SIZEOF_INT__` or `__SIZEOF___INT24__`
`__STACK`	Always, and assigned with `__STACK_COMPILED`(1), `__STACK_HYBRID`(2) or `__STACK_REENTRANT`(4) to indicate the global stack setting: compiled, hybrid or software, respectively
`__STRICT`	When the `-Wpedantic` option is enabled.
`__TIME__`	Always, and indicates the current time as a string literal, e.g., `"08:06:31"`
`__TRADITIONAL18__`	When building for a PIC18 device, and indicates the non-extended instruction set is selected
`__XC`	Always, and indicates MPLAB XC compiler for Microchip is in use
`__XC8`	Always, and indicates MPLAB XC compiler for Microchip 8-bit devices is in use
`__XC8_VERSION`	Always, and indicates the compiler's version number multiplied by 1000, e.g., v1.00 will be represented by 1000

Note 1: To determine the family macro relevant to your device, look for the `FAMILY` field in the `picc-18.ini` file in the compiler's `dat` directory.

2: These macros relate only to Flash program memory. They do not convey any information regarding Flash data memory.

The compiler-defined macros shown in Table 4-16 can be used as bitwise AND masks to determine the value held by `__OPTIM_FLAGS`, hence the optimizations used.

TABLE 4-16: OPTIMIZATION FLAGS

Macro	Value	Meaning
`__OPTIM_NONE`	0x0	no optimizations applied (on equality)
`__OPTIM_ASM`	0x1	assembler optimizations on C code
`__OPTIM_ASMFILE`	0x2	assembler optimizations on assembly source code
`__OPTIM_SPEED`	0x20000	optimized for speed
`__OPTIM_SPACE`	0x40000	optimized for size
`__OPTIM_SIZE`	0x40000	optimized for size
`__OPTIM_DEBUG`	0x80000	optimized for accurate debug
`__OPTIM_LOCAL`	0x200000	local optimizations applied

© 2012-2018 Microchip Technology Inc.

4.14.3 Pragma Directives

There are certain compile-time directives that can be used to modify the behavior of the compiler. These are implemented through the use of the C Standard's `#pragma` facility. The format of a pragma is:

`#pragma` *`keyword options`*

where *`keyword`* is one of a set of keywords, some of which are followed by certain *`options`*. A list of the keywords is given in Table 4-17. Those keywords not discussed elsewhere are detailed below.

TABLE 4-17: PRAGMA DIRECTIVES

Directive	Meaning	Example
`addrqual`	specify action of qualifiers	`#pragma addrqual require`
`config`	specify configuration bits	`#pragma config WDT=ON`
`inline`	inline function if possible	`#pragma inline(getPort)`
`intrinsic`	specify function is inline	`#pragma intrinsic(_delay)`
`interrupt_level`	allow call from interrupt and main-line code	`#pragma interrupt_level 1`
`pack`	specify structure packing	`#pragma pack 1`
`printf_check`	enable printf-style format string checking	`#pragma printf_check(printf) const`
`psect`	rename compiler-generated psect	`#pragma psect nvBANK0=my_nvram`
`regsused`	specify registers used by function	`#pragma regsused myFunc wreg,fsr`
`switch`	specify code generation for switch statements	`#pragma switch direct`
`warning`	control messaging parameters	`#pragma warning disable 299,407`

4.14.3.1 THE #PRAGMA ADDRQUAL DIRECTIVE

This directive allows you to control the compiler's response to non-standard memory qualifiers. This pragma is an in-code equivalent to the `-maddrqual` option and both use the same arguments (see Section 3.7.1.1 "addrqual").

The pragma has an effect over the entire C program and should be issued once, if required. If the pragma is issued more than once, the last pragma determines the compiler's response.

For example:

```
#pragma addrqual require
__bank(2) int foobar;
```

4.14.3.2 THE #PRAGMA CONFIG DIRECTIVE

This directive allows the device Configuration bits to be specified for PIC18 target devices. See Section 4.3.5 "Configuration Bit Access" for full details.

4.14.3.3 THE #PRAGMA INLINE DIRECTIVE

The `#pragma inline` directive indicates to the compiler that calls to the specified function should be as fast as possible. This pragma has the same effect as using the `inline` function specifier.

4.14.3.4 THE #PRAGMA INTRINSIC DIRECTIVE

The `#pragma intrinsic` directive is used to indicate to the compiler that a function will be inlined intrinsically by the compiler. This directive should never be used with user-defined code.

You should not attempt to redefine an existing library function that uses the `intrinsic` pragma. If you need to develop your own version of such a routine, it must not use the same name as the intrinsic function. For example, if you need to develop your own version of `memcpy()`, give this a unique name, such as `sp_memcpy()`. Check the standard header files to determine which library functions use this pragma.

4.14.3.5 THE #PRAGMA INTERRUPT_LEVEL DIRECTIVE

The `#pragma interrupt_level` directive can be used to prevent duplication of functions called from main-line and interrupt code (see Section 4.9.7.1 "Disabling Duplication").

4.14.3.6 THE #PRAGMA PACK DIRECTIVE

All 8-bit PIC devices can only perform byte accesses to memory and so do not require any alignment of memory objects within structures. This pragma will have no effect when used.

4.14.3.7 THE #PRAGMA PRINTF_CHECK DIRECTIVE

Certain library functions accept a format string followed by a variable number of arguments in the manner of `printf()`. Although the format string is interpreted at runtime, it can be compile-time checked for consistency with the remaining arguments.

This directive enables this checking for the named function, for example the system header file `<stdio.h>` includes the directive:

```
#pragma printf_check(printf) const
```

to enable this checking for `printf()`. You can also use this for any user-defined function that accepts `printf` -style format strings.

The qualifier following the function name is to allow automatic conversion of pointers in variable argument lists. The above example would cast any pointers to strings in RAM to be pointers of the type (`const char *`).

Note that the warning level must be set to -1 or below for this option to have any visible effect (see Section 3.7.4.2 "warn").

4.14.3.8 THE #PRAGMA PSECT DIRECTIVE

The `#pragma psect` was used to redirect objects and functions to a new psect (section). It has been replaced by the `__section()` specifier (see Section 4.15.3 "Changing and Linking the Allocated Section"), which not only performs the same task, but is easier to use, and has fewer restrictions as to where the psects can be linked. It is recommended you always use the `__section()` specifier to location variables and function in unique psects.

The general form of this pragma looks like:

```
#pragma psect standardPsect=newPsect
```

and instructs the code generator that anything that would normally appear in the standard psect `standardPsect`, will now appear in a new psect called `newPsect`. This psect will be identical to `standardPsect` in terms of its flags and attributes; however, it will have a unique name. Thus, you can explicitly position this new psect without affecting the placement of anything in the original psect.

If the name of the standard psect that is being redirected contains a counter (e.g., `text0`, `text1`, `text2`, etc.), the placeholder %%u should be used in the name of the psect at the position of the counter, e.g., `text%%u`.

© 2012-2018 Microchip Technology Inc.

4.14.3.9 THE #PRAGMA REGSUSED DIRECTIVE

The `#pragma regsused` directive allows the programmer to indicate register usage for functions that will not be “seen” by the code generator; for example, if they were written in assembly code. It has no effect when used with functions defined in C code, but in those cases the register usage of these functions can be accurately determined by the compiler and the pragma is not required. This pragma is not available in Free mode, and when used with devices that can save registers into shadow registers, it has no effect.

The general form of the pragma is:

```
#pragma regsused routineName registerList
```

where *`routineName`* is the C-equivalent name of the function or routine whose register usage is being defined, and *`registerList`* is a space-separated list of registers’ names, as shown in Table 4-10.

Those registers that are not listed are assumed to be unused by the function or routine. The code generator can use any of these registers to hold values across a function call. If the routine does in fact use these registers, unreliable program execution can happen.

The register names are not case sensitive and a warning will be produced if the register name is not recognized. An empty register list indicates that the specified function or routine uses no registers. If this pragma is not used, the compiler will assume that the external function uses all registers.

For example, a routine called `_search` is written in PIC18 assembly code. In the C source, we can write:

```
extern void search(void);
#pragma regsused search wreg status fsr0
```

to indicate that this routine used the W register, STATUS and FSR0. Here, FSR0 expands to both FSR0L and FSR0H. These could be listed individually, if required.

The compiler can determine those registers and objects that need to be saved by an interrupt function, so this pragma could be used, for example, to allow you to customize the context switch code in cases where an interrupt routine calls an assembly routine.

4.14.3.10 THE #PRAGMA SWITCH DIRECTIVE

Normally, the compiler encodes `switch` statements to produce the smallest possible code size. The `#pragma switch` directive can be used to force the compiler to use a different coding strategy.

The `switch` pragma affects all subsequent code, and has the general form:

```
#pragma switch switchType
```

where *`switchType`* is one of the available selections that are listed in Table 4-18. The only switch type currently implemented for PIC18 devices is `space`.

TABLE 4-18: SWITCH TYPES

Switch Type	Description
`speed`	use the fastest switch method
`space`	use the smallest code size method
`time`	use a fixed delay switch method
`auto`	use smallest code size method (default)
`direct` (deprecated)	use a fixed delay switch method
`simple` (deprecated)	sequential xor method

Specifying the `time` option to the `#pragma switch` directive forces the compiler to generate a table look-up style `switch` method. The time taken to execute each case is the same, so this is useful where timing is an issue, e.g., with state machines.

The `auto` option can be used to revert to the default behavior.

Information is printed in the assembly list file for each `switch` statement, showing the chosen strategy (see Section 5.4.4 "Switch Statement Information").

4.14.3.11 THE #PRAGMA WARNING DIRECTIVE

This pragma allows control over some of the compiler's messages, such as warnings and errors. The pragmas have no effect when the Clang front end is used to compile C99 projects. For full information on the messaging system employed by the compiler see Section 3.6 "Compiler Messages".

4.14.3.11.1 The Warning Disable Pragma

Some warning messages can be disabled by using the `warning disable` pragma.

This pragma will only affect warnings that are produced by the parser or the code generator; i.e., errors directly associated with C code. The position of the pragma is only significant for the parser; i.e., a parser warning number can be disabled for one section of the code to target specific instances of the warning. Specific instances of a warning produced by the code generator cannot be individually controlled and the pragma will remain in force during compilation of the entire C program, even across modules.

Those warnings that have been disabled can be preserved and recalled using the `warning push` and `warning pop` pragmas. The warning push and pop pragmas can be nested.

The following example normally produces the warning associated with assignment of a const object address to a pointer to non-`const` objects (359).

```
int readp(int * ip) {
    return *ip;
}

const int i = 'd';

void main(void) {
    unsigned char c;
#pragma warning disable 359
    readp(&i);
#pragma warning enable 359
}
```

This same effect would be observed using the following code.

```
#pragma warning push
#pragma warning disable 359
    readp(&i);
#pragma warning pop
```

Here, the state of the messaging system is saved by the `warning push` pragma. Warning 359 is disabled, then after the source code which triggers the warning, the state of the messaging system is retrieved by using the `warning pop` pragma.

© 2012-2018 Microchip Technology Inc.

4.14.3.11.2 The Warning Error/Warning Pragma

It is possible to change the types of some messages.

A message type can only be changed by using the `warning pragma` and this only affects messages generated by the parser or code generator. The position of the pragma is only significant for the parser; i.e., a parser message number can have its type changed for one section of the code to target specific instances of the message. Specific instances of a message produced by the code generator cannot be individually controlled and the pragma will remain in force during compilation of the entire program.

The following example shows the warning produced in the previous example being converted to an error for the instance in the function `main()`.

```
void main(void) {
    unsigned char c;
#pragma warning error 359
    readp(&i);
}
```

Building this code would result in an error, not the usual warning.

4.15 LINKING PROGRAMS

The compiler will automatically invoke the linker unless the compiler has been requested to stop earlier in the compilation sequence.

The linker will run with options that are obtained from the command-line driver. These options specify the memory of the device and how the sections should be placed in the memory. No linker scripts are used.

The linker options passed to the linker can be adjusted by the user, but this is only required in special circumstances (see Section 3.7.11.6 "Wl: Linker Option" for more information).

The linker creates a map file which details the memory assigned to sections and some objects within the code. The map file is the best place to look for memory information. See Section 6.4 "Map Files" for a more comprehensive explanation of the detailed information in this file.

4.15.1 Compiler-Generated Psects

The code generator places code and data into psects, or sections, with standard names, which are subsequent positioned by the default linker options. The linker does not treat these compiler-generated psects any differently to a psect that has been defined by yourself. A psect can be created in assembly code by using the `PSECT` assembler directive (see Section 5.2.9.3 "PSECT").

Some psects use special naming conventions, for example, the `bss` psect, which holds uninitialized objects. There may be uninitialized objects that will need to be located in bank 0 data memory; others may need to be located in bank 1 memory. As these two groups of objects will need to be placed into different memory banks, they will need to be in separate psects so they can be independently controlled by the linker.

The general form of data psect names is:

`[bit]`*`psectBaseNameCLASS`*`[`*`div`*`]`

where *`psectBaseName`* is the base name of the psect (listed in Section 4.15.1.2 "Data Space Psects"). The *`CLASS`* is a name derived from the linker class (see Section 4.15.2.2 "Data Memory Classes") in which the psect will be linked, e.g., `BANK0`. The prefix `bit` is used if the psect holds `__bit` variables. So there can be psects like: `bssBANK0`, `bssBANK1` and `bitbssBANK0` defined by the compiler to hold the uninitialized variables.

Note that `__eeprom`-qualified variables can define psects called `bssEEDATA` or `dataEEDATA`, for example, in the same way. Any psect using the class suffix `EEDATA` is placed in the HEX file and is burnt into the EEPROM space when you program the device.

If a data psect needs to be split around a reserved area, it will use the letters `l` and `h` (as *`div`* in the above form) in the psect name to indicate if it is the lower or higher division. Thus you might see `bssBANK0l` and `bssBANK0h` psects if a split took place.

If you are unsure which psect holds an object or code in your project, check the assembly list file (see Section 5.4.1 "General Format").

© 2012-2018 Microchip Technology Inc.

The contents of these psects are described below, listed by psect base name.

4.15.1.1 PROGRAM SPACE PSECTS

`checksum` –this is a psect that is used to mark the position of a checksum that has been requested using the `-mchecksum` option.
See Section 3.7.1.2 "checksum" for more information.
The checksum value is added after the linker has executed so you will not see the contents of this psect in the assembly list file, nor specific information in the map file.
Do not change the default linker options relating to this psect.

`cinit` –used by the C initialization runtime startup code.
Code in this psect is output by the code generator along with the generated code for the C program.
This psect can be linked anywhere within a program memory page, provided it does not interfere with the requirements of other psects.

`config` –used to store the Configuration Words.
This psect must be stored in a special location in the HEX file. Do not change the default linker options relating to this psect.

`const` –these PIC18-only psects hold objects that are declared `const` and string literals which are not modifiable.
Used when the total amount of `const` data in a program exceeds 64k.
This psect can be linked anywhere within a program memory page, provided it does not interfere with the requirements of other psects.

`eeprom` (PIC18: `eeprom_data`) – used to store initial values in EEPROM memory.
Do not change the default linker options relating to this psect.

`end_init` -used by the C initialization runtime startup code for Baseline and Mid-range devices.
This psect holds code which transfers control to the `main()` function.

`idata` –these psects contain the ROM image of any initialized variables.
The class name associated with these psects represents the class of the corresponding RAM-based data psects, to which the content of these psects will be copied.
These psects can be linked at any address within a program memory page, provided that they do not interfere with the requirements of other psects.

`idloc` –used to store the ID location words.
This psect must be stored in a special location in the HEX file.
Do not change the default linker options relating to this psect.

`init` – used by assembly code in the runtime startup assembly module.
The code in this and `cinit` define the runtime startup code. If no interrupt code is defined, the Reset vector code can "fall through" into this psect.
It is recommended that the linker options for this psect are not changed.

`intcode`, `intcodelo` – are the psects which contains the executable code for the high-priority (default) and low-priority interrupt service routines, respectively, linked to interrupt vector at address 0x8 and 0x18.
Do not change the default linker options relating to these psects. See Section 3.7.1.3 "codeoffset" if moving code when using a bootloader.

`intentry` –contains the entry code for the interrupt service routine which is linked to the interrupt vector.
This code saves the necessary registers and jumps to the main interrupt code in the case of Mid-range devices; for Enhanced Mid-range devices this

psect will contain the interrupt function body. (PIC18 devices use the `intcode` psects.)
This psect must be linked at the interrupt vector. Do not change the default linker options relating to this psect. See the `-mcodeoffset` option Section 3.7.1.3 "codeoffset" if you want to move code when using a bootloader.

`ivt0x`*n* –contains the vector table located at address *n* for devices that use interrupt vector tables or that are operating in legacy mode, see Section 4.9.1 "Writing an Interrupt Service Routine".

`jmp_tab` –only used for the Baseline processors, this is a psect used to store jump addresses and function return values.
Do not change the default linker options relating to this psect.

`maintext` –this psect will contain the assembly code for the `main()` function.
The code for `main()` is segregated as it contains the program entry point.
Do not change the default linker options relating to this psect as the runtime startup code can "fall through" into this psect.

`mediumconst` – these PIC18-only psects hold objects that are declared `const` and string literals. Used when the total amount of `const` data in a program exceeds 255 bytes, but is less than 64k.
This psect can be linked anywhere in the lower 64k of program memory, provided it does not interfere with the requirements of other psects. For PIC18 devices, the location of the psect must be above the highest RAM address.

`powerup` –contains executable code for a user-supplied powerup routine.
Do not change the default linker options relating to this psect.

`reset_vec` –this psect contains code associated with the Reset vector.
Do not change the default linker options relating to this psect. See the `-mcodeoffset` option Section 3.7.1.3 "codeoffset", if you want to move code when using a bootloader.

`reset_wrap` – for Baseline PIC devices, this psect contains code that is executed after the oscillator calibration location at the top of program memory has been loaded.
Do not change the default linker options relating to this psect.

`smallconst` – these psects hold objects that are declared `const` and string literals. Used when the total amount of `const` data in a program is less than 255 bytes.
This psect can be linked anywhere in the program memory, provided it does not cross a 0x100 boundary and it does not interfere with the requirements of other psects. For PIC18 devices, the location of the psect must be above the highest RAM address.

`strings` –the `strings` psect is used for `const` objects.
It also includes all unnamed string literals.
This psect can be linked anywhere in the program memory, provided it does not cross a 0x100 boundary or interfere with the requirements of other psects.

`stringtext`*n* – the `stringtext`*n* psects (where *n* is a decimal number) are used for `const` objects when compiling for Enhanced Mid-range devices.
These psects can be linked anywhere in the program memory, provided they do not interfere with the requirements of other psects.

© 2012-2018 Microchip Technology Inc.

`text`*n* –these psects (where *n* is a decimal number) contain all other executable code that does not require a special link location.
These psects can be linked anywhere within any program memory page, and provided they do not interfere with the requirements of other psects. Note that the compiler imposes pseudo page boundaries on some PIC18 devices to work around published errata. Check the default `CODE` linker class for the presence of pages, and their size, in the executable memory.

`temp` – this psect contains compiler-defined temporary variables.
This psect must be linked in common memory, but can be placed at any address in that memory, provided it does not interfere with other psects.

`xxx``_text` –defines the psect for a function that has been made absolute; i.e., placed at an address. *`xxx`* will be the assembly symbol associated with the function.
For example if the function `rv()` is made absolute, code associated with it will appear in the psect called `_rv_text`.
As these psects are already placed at the address indicated in the C source code, the linker options that position them should not be changed.

`xxx``_const` – used for `const` objects that has been made absolute; i.e., placed at an address. *`xxx`* will be the assembly symbol associated with the object.
For example, if the array `nba` is made absolute, values stored in this array will appear in the psect called `_nba_const`.
As these psects are already placed at the address indicated in the C source code, the linker options that position them should not be changed.

4.15.1.2 DATA SPACE PSECTS

`nv` – these psects are used to store variables qualified `__persistent`.
They are not cleared or otherwise modified at startup.
These psects can be linked anywhere in their targeted memory bank and should not overlap any common (unbanked memory) that the device supports if it is a banked psect.

`bss` – these psects contain any uninitialized variables.
These psects can be linked anywhere in their targeted memory bank and should not overlap any common (unbanked memory) that the device supports if it is a banked psect.

`data` – these psects contain the RAM image of any initialized variables.
These psects can be linked anywhere in their targeted memory bank and should not overlap any common (unbanked memory) that the device supports if it is a banked psect.

`cstack` –these psects contain the compiled stack.
On the stack are auto and parameter variables for the entire program. See Section 4.5.2.2.1 “Object Size Limits” for information on the compiled stack.
These psects can be linked anywhere in their targeted memory bank and should not overlap any common (unbanked memory) that the device supports if it is a banked psect.

`stack` –this psect is used as a placeholder for the software stack.
This stack is dynamic and its size is not known by the compiler. As described in 4.3.4.2 Data Stacks this psect is typically allocated the remainder of the free data space so that the stack may grow as large as possible.
This psect may be linked anywhere in the data memory, but adjusting the default linker options for this psect may limit the size of the software stack. Any overflow of the software stack may cause code failure.

4.15.2 Default Linker Classes

The linker uses classes to represent memory ranges. For an introductory guide to psects and linker classes (see Section 4.15.1 "Compiler-Generated Psects").

The classes are defined by linker options (see Section 6.2.1 "-Aclass =low-high,...") passed to the linker by the compiler driver. Psects are typically allocated space in the class they are associated with. The association is made using the `class` flag of the `PSECT` directive (see Section 5.2.9.3.3 "Class"). Alternatively, a psect can be explicitly placed into a class using a linker option (see Section 6.2.18 "-Pspec").

Classes can represent a single memory range, or multiple ranges. Even if two ranges are contiguous, the address where one range ends and the other begins forms a boundary and psects placed in the class can never cross such boundaries. You will see classes that cover the same addresses, but will be divided into different ranges and have different boundaries. This is to accommodate psects whose contents were compiled under assumptions about where they would be located in memory.

Memory allocated from one class will also be reserved from other classes that specify the same memory. To the linker, there is no significance to a class name or the memory it defines.

Memory can be subtracted from these classes if using the `-mreserve` option (see Section 3.7.1.17 "reserve"), or when subtracting memory ranges using the `-mram` and `-mrom` options (see Section 3.7.1.16 "ram" and Section 3.7.1.19 "rom"). When specifying a debugger, such as an ICD (see Section 3.7.1.6 "debugger"), memory can also be removed from the ranges associated with some classes so that this memory is not used by your program.

Although you can manually adjust the ranges associated with a class, this is not recommended. Never change or remove address boundaries specified by a class definition option.

The following are the linker classes that can be defined by the compiler. Not all classes can be present for each device.

4.15.2.1 PROGRAM MEMORY CLASSES

`CODE` – consists of ranges that map to the program memory pages on the target device and are used for psects containing executable code.
On Baseline devices, it can only be used by code that is accessed via a jump table.

`ENTRY` –is used by Baseline devices for psects containing executable code that is accessed via a `call` instruction (calls can only be to the first half of a page).
The class is defined in such a way that it is the size of a page, but psects it holds will be positioned so that they start in the first half of the page.
This class is also used in Mid-range devices and will consist of many 0x100 word-long ranges, aligned on a 0x100 boundary.

`STRING` –consists of ranges that are 0x100 words long and aligned on a 0x100 boundary. Thus, it is useful for psects whose contents cannot span a 0x100 word boundary.

`STRCODE` –defines a single memory range that covers the entire program memory. It is useful for psects whose content can appear in any page and can cross page boundaries.

`CONST` –consists of ranges that are 0x100 words long and aligned on a 0x100 boundary. Thus, it is useful for psects whose contents cannot span a 0x100 word boundary.

4.15.2.2 DATA MEMORY CLASSES

`RAM` – consist of ranges that cover all the general purpose RAM memory of the target device, but excluding any common (unbanked) memory.
Thus, it is useful for psects that must be placed within any general-purpose RAM bank.

`BIGRAM` –consists of a single memory range that is designed to cover the linear data memory of Enhanced Mid-range devices, or the entire available memory space of PIC18 devices.
It is suitable for any psect whose contents are accessed using linear addressing or which does not need to be contained in a single data bank.

`ABS1` – consist of ranges that cover all the general purpose RAM memory of the target device, including any common (unbanked) memory.
Thus, it is useful for psects that must be placed in general purpose RAM, but can be placed in any bank or the common memory,

`BANK`*x* (where *x* is a bank number) – each consist of a single range that covers the general purpose RAM in that bank, but excluding any common (unbanked) memory.

`COMMON` –consists of a single memory range that covers the common (unbanked) RAM, if present, for all Mid-range devices.

`COMRAM` –consists of a single memory range that covers the common (unbanked) RAM, if present, for all PIC18 devices.

`SFR`*x* (where *x* is a number) – each consists of a single range that covers the SFR memory in bank *x*.
These classes would not typically be used by programmers as they do not represent general purpose RAM.

4.15.2.3 MISCELLANEOUS CLASSES

`CONFIG` –consists of a single range that covers the memory reserved for configuration bit data.
This class would not typically be used by programmers as it does not represent general purpose RAM.

`IDLOC` –consists of a single range that covers the memory reserved for ID location data in the hex file.
This class would not typically be used by programmers as it does not represent general purpose RAM.

`EEDATA` –consists of a single range that covers the EEPROM memory of the target device, if present.
This class is used for psects that contain data that is to be programmed into the EEPROM.

4.15.3 Changing and Linking the Allocated Section

The `__section()` specifier allows you to have a object or function redirected into a user-define psect, or section.

Section 4.15.1 "Compiler-Generated Psects" lists the default sections the compiler uses to hold objects and code. The default section used by a function or object can be changed if the object has unique linking requirements that cannot be addressed by existing compiler features.

New sections created by the specifier for objects will have no linker class associated with them. In addition, the compiler will not make assumptions about the final location of the new section. You can link objects specified with `__section()` into any data bank. However, since the compiler cannot know where the new section will be placed until the linker has executed, the code to access the relocated object will be less efficient than the code used to access the object without the specifier.

Since the new section is linked after other objects have been allocated memory, you might also receive memory errors when using the `__section()` specifier. If this is the case, you will need to reserve memory for the new section (see Section 3.7.1.17 “reserve”).

New sections created by the specifier for functions will inherit the same flags. However, there are fewer linking restrictions relating to functions and this has minimal impact on the generated code.

The name of the new section you specify must be a valid assembly-domain identifier. The name must contain only alphabetic, numeric characters, or the underscore character, _. It cannot have a name which is the same as that of an assembler directive, control, or directive flag. If the new section contains executable code and you wish this code to be optimized by the assembler, ensure that the section name contains the substring “text”, e.g., `usb_text`. Sections named otherwise will not be modified by the assembler optimizer.

Objects that use the `__section()` specifier will be cleared or initialized in the usual way by the runtime startup code (see Section 3.4.2 “Startup and Initialization”). For the case of initialized objects, the compiler will automatically allocate an additional new section (whose name will be the same as the section specified, prefixed with the letter `i`), which will contain the initial values. This section must be stored in program memory, and you might need to locate this section explicitly with a linker option.

The following are examples of a object and function allocated to a non-default section.

```
int __section("myData") foobar;
int __section("myCode") helper(int mode) { /* ... */ }
```

Typically you locate new sections you create with an explicit linker option. So, for example, if you wanted to place the sections created in the above example, you could use the following driver options:

```
-Wl,-PmyData=0200h
-Wl,-AMYCODE=50h-3ffh
-Wl,-PmyCode=MYCODE
```

which will place the section `myData` at address 0x200, and the section `myCode` anywhere in the range 0x50 to 0x3ff represented by the linker class, `MYCODE`. See Section 6.2 “Operation” for linker options that can be passed using the `-Wl` driver option (Section 3.7.11.6 “Wl: Linker Option”).

If you are creating a new class for a memory range in program memory and your target is a Baseline or Mid-range PIC device, then you will need to inform the linker that this class defines memory that is word addressable. Do this by using the linker’s `-D` option, which indicates a delta value for a class. For example:

```
-Wl,-DMYCODE=2
```

Do not use this option for PIC18 devices, which have byte-addressable program memory.

© 2012-2018 Microchip Technology Inc.

If you would like to set special flags with the new section, you can do this by providing a definition of the new section in your source code. For example, if you wanted the `mycode` section to be placed at an address that is a multiple of 100h, then you can place the following in your source file:

```
asm("PSECT mycode,reloc=100h");
int __section("myCode") helper(int mode) { /* ... */ }
```

The `reloc`, `size` and `limit` psect flags (see for example Section 5.2.9.3.15 "Reloc") can all be redefined in this way. Redefinitions might trigger assembler warning messages; however, these can be ignored in this circumstance.

4.15.4 Replacing Library Modules

You can easily replace a library routine with your own without having to using the librarian, ,`xc8-ar` (see Section 7.2 "Librarian").

If a source file in your project contains the definition for a routine or object with the same name as a library routine or object, the definition from the source will replace the library definition. This is because the linker scans all the source modules for definitions before it search library files.

You cannot replace a C library function with an equivalent written in assembly code using the above method. If this is required, you will need to use the librarian to edit or create a new library file.

4.15.5 Signature Checking

A signature is a 16-bit value computed from a combination of the function's return type, the number of its parameters and other information affecting how the function is called. This signature is automatically generated and placed the output whenever a C function is referenced or defined. The linker will report any mismatch of signatures, which will indicate a discrepancy between how the function is defined and how it is called.

If it is necessary to write an assembly language routine, it is desirable to include a signature with that routine that is compatible with its equivalent C prototype. The simplest method of determining the correct signature for a function is to write a dummy C function with the same prototype and check the assembly list file using the `-Wa,-a` option (see Section 3.7.9.1 "Wa: Pass Option to the Assembler").

For example, suppose you have an assembly language routine called `_widget` whose equivalent C prototype takes a `char` argument and returns a `char`. To find the correct signature for such a function, write a test function, such as the following, and check the assembly list file after building this function as part of a test program.

```
char myTestFunction(char arg1) {
}
```

The resultant assembler code seen in the assembly list file includes the following line, indicating that the signature value is 4217:

```
SIGNAT  _myTestFunction,4217
```

Include a similar `SIGNAT` directive in your assembly source code that contains `_widget`.

If you mistakenly declare this assembly routine in a C source file as:

```
extern char widget(long);
```

then the signature generated by this declaration will differ to that specified in your assembly routine and trigger an error.

4.15.6 Linker-Defined Symbols

The linker defines special symbols that can be used to determine where some sections where linked in memory. These symbols can be used in your code, if required.

The link address of a section can be obtained from the value of a global symbol with name `__L`*`name`* (two leading underscores) where *`name`* is the name of the section. For example, `__LbssBANK0` is the low bound of the `bssBANK0` section. The highest address of a section (i.e., the link address plus the size) is represented by the symbol `__H`*`name`*. If the section has different load and link addresses, the load start address is represented by the symbol `__B`*`name`*.

Sections that are not placed in memory using a `-P` linker option. See Section 6.2.18 "-Pspec" are not assigned this type of symbol, and note that section names can change from one device to another.

Assembly code can use these symbol by globally declaring them, for example:

```
GLOBAL __Lidata
```

and C code could use them by declaring a symbol such as the following.

```
extern char * _Lidata;
```

Note that there is only one leading underscore in the C domain, two in the assembler domain. As the symbol represents an address, a pointer is the typical type choice.

© 2012-2018 Microchip Technology Inc.

Chapter 5. Macro Assembler

5.1 INTRODUCTION

An assembler is included with the MPLAB XC8 C Compiler to assemble source files for all 8-bit PIC devices. The assembler is automatically run by the compiler driver, `xc8-cc`, for any assembly source files in your project.

This chapter describes the directives (assembler pseudo-ops and controls) accepted by the assembler in the assembly source files or assembly inline with C code.

Although the term "assembler" is almost universally used to describe the tool that converts human-readable mnemonics into machine code, both "assembler" and "assembly" are used to describe the source code which such a tool reads. The latter is more common and is used in this manual to describe the language. Thus you will see the terms assembly language (or just assembly), assembly listing and other assembly terms, but also, assembler options, assembler directive and assembler optimizer.

The following topics are examined in this chapter of the user's guide:

- MPLAB XC8 Assembly Language
- Assembly-Level Optimizations
- Assembly List Files

5.2 MPLAB XC8 ASSEMBLY LANGUAGE

Information about the source language accepted by the macro assemblers is described in this section.

All opcode mnemonics and operand syntax are specific to the target device, and you should consult your device data sheet. Additional mnemonics, deviations from the instruction set, and assembler directives and controls are documented in this section.

The same assembler application is used for compiler-generated intermediate assembly and hand-written assembly source code, and for hand-written assembly modules and assembly inline with C code.

5.2.1 Assembly Instruction Deviations

The MPLAB XC8 assembler uses a slightly modified form of assembly language to that specified by the Microchip data sheets. The following information details changes to the instruction format, and pseudo instructions that can be used in addition to the device instruction set.

These deviations can be used in assembly code in-line with C code or in hand-written assembly modules.

5.2.1.1 DESTINATION LOCATION

The PIC device data sheets indicate that some instructions use the operands "`,0`" or "`,1`" to specify the destination for the result of that operation. The XC8 assemblers instead use the more-readable operands "`,w`" and "`,f`" to specify the destination.

The W register is selected as the destination when using the "`,w`" operand, and the file register is selected when using the "`,f`" operand. The case of the letter in the destination operand in not important. For example (ignoring bank selection and address masking for this example):

```
movf   _foo,w    ;move _foo into wreg
addwf  _foo,f    ;add wreg to _foo, updating the content of _foo
addwf  _foo,w    ;add wreg to _foo, leaving the result in wreg
```

It is highly recommended that the destination is always specified with each instruction that requires this operand. If the destination is omitted, it is assumed to be the file register. Never use the numeric destination operands.

In the same way, the PIC18 assembler also uses the RAM access operand "`,b`" (instead of "`,1`") to indicate that PIC18 instructions should use the bank select register (BSR) when accessing the specified file register address. The "`,c`" operand (instead of "`,0`") indicates that the address is in the common memory, which is known as the access bank on PIC18 devices. Alternatively, an instruction operand can be preceded by the characters "`c:`" to indicate that the address resides in common memory. These operands and prefix affect the RAM access bit in the instruction. For example:

```
addwf  _bar,f,c  ;add wreg to _bar in common memory
btfsc  c:_bar,3  ;test bit three in the common memory symbol _bar
```

These operands and prefix are not applicable with operands to the PIC18 `movff` instruction, which takes two untruncated addresses, and which always works independently of the BSR.

© 2012-2018 Microchip Technology Inc.

For example, the following instructions show the W register being moved to first, an absolute location; and, then, to an address represented by an identifier. Bank selection and masking has been used in this example. The PIC18 op codes for these instructions, assuming that the address assigned to `_foo` is 0x516 and to `_bar` is 0x55, are shown below.

```
6EE5  movwf 0FE5h              ;write to access bank location 0xFE5
6E55  movwf _bar,c             ;write to access bank location 0x55
0105  BANKSEL(_foo)            ;set up BSR to access _foo
6F16  movwf BANKMASK(_foo),b   ;write to _foo (banked)
6F16  movwf BANKMASK(_foo)     ;defaults to banked access
```

Notice that the first two instruction opcodes have the RAM access bit (bit 8 of the op-code) cleared, but that the bit is set in the last two instructions.

It is recommended that you always specify the RAM access operand or the common memory prefix. If these are not present, the instruction address is absolute, and the address is within the upper half of the access bank (which dictates that the address must not masked), the instruction will use the access bank RAM. In all other situations, the instruction will access banked memory.

The destination operand and the RAM access operand can be listed in any order for PIC18 instructions. For example, the following two instructions are identical:

```
addwf  _foo,f,c
addwf  _foo,c,f
```

5.2.1.2 BANK AND PAGE SELECTION

The `BANKSEL` pseudo instruction can be used to generate instructions to select the bank of the operand specified. The operand should be the symbol or address of an object that resides in the data memory.

Depending on the target device, the generated code will either contain one or more bit instructions to set/clear bits in the appropriate register, or use a `MOVLB` instruction (in the case of enhanced mid-range or PIC18 devices). As this pseudo instruction can expand to more than one instruction on mid-range or baseline parts, it should not immediately follow a `BTFS`*X* instruction on those devices.

For example:

```
movlw 20
BANKSEL(_foobar)    ;select bank for next file instruction
movwf BANKMASK(_foobar)  ;write data and mask address
```

In the same way, the `PAGESEL` pseudo instruction can be used to generate code to select the page of the address operand. For the current page, you can use the location counter, $, as the operand.

Depending on the target device, the generated code will either contain one or more instructions to set/clear bits in the appropriate register, or use a `MOVLP` instruction in the case of enhanced mid-range PIC devices. As the directive could expand to more than one instruction, it should not immediately follow a `BTFS`*X* instruction.

For example:

```
fcall _getInput
PAGESEL $        ;select this page
```

This directive is accepted when compiling for PIC18 targets but has no effect and does not generate any code. Support is purely to allow easy migration across the 8-bit devices.

5.2.1.3 ADDRESS MASKING

A macro, `BANKMASK()`, can be used with an identifier; so, it is usable as an operand to instructions that expect a file register address. The macro does this by ANDing out the bank information using a suitable mask. It is available once you include the `<xc.inc>` file. An example of this macro is given in Section 5.2.1.2 "Bank and Page Selection".

All MPLAB XC8 assembly identifiers represent a full address. This address includes the bank information for the object it represents. Virtually all instructions in the 8-bit PIC instruction sets that take a file register operand expect this operand value to be an offset into the currently selected bank. As the device families have different bank sizes, the width of this offset is different for each family. Use of this macro increases assembly code portability across Microchip devices, since it adjusts the mask to suit the bank size of the target device.

Do not use this macro with either operand to the PIC18's `movff` instruction, which requires two full, banked addresses to be specified, or with any other instruction that expects a full address.

5.2.1.4 MOVFW PSEUDO INSTRUCTION

The `movfw` pseudo instruction implemented by MPLAB C18 is *not* implemented in MPLAB XC8. You will need to use the standard PIC instruction that performs an identical function. Note that the MPLAB C18 instruction:

```
movfw foobar
```

maps directly to the standard PIC instruction:

```
movf foobar,w
```

5.2.1.5 MOVIW/MOVWI INSTRUCTIONS

Both the `moviw` and `movwi` instructions have operands which differ in syntax to that indicated in the data sheet. These instructions are only available with enhanced mid-range devices.

The indexed Indirect operands to these instructions have the FSR offset specified first in square brackets, followed by the FSR name, for example:

```
moviw [6]FSR0
movwi [0x10]FSR1
```

The pre/post increment/decrement form of these instructions use the name of the FSR register, not the indirection register (INDF), for example:

```
moviw ++FSR0
movwi FSR1++
movwi FSR0--
```

5.2.1.6 MOVFF/MOVFFL INSTRUCTIONS

The `movff` instruction is a physical device instruction, but for PIC18 devices that have extended data memory, it also serves as a placeholder for the `movffl` instruction.

For these devices, when generating output for the `movff` instruction, the assembler checks the psects that hold the operand symbols. If the psect containing the source operand is the same psect that contains the destination operand, then the instruction is encoded as a `movff` instruction. If the psects of both source and destination operands have the `lowdata` psect flag set, the instruction is also encoded as a `movff` instruction. In all other situations, the instruction is encoded as a `movffl` instruction.

Note that assembly list files will always show the `movff` placeholder regardless of how it is encoded.

© 2012-2018 Microchip Technology Inc.

5.2.1.7 INTERRUPT RETURN MODE

The `retfie` PIC18 instruction can be followed by “`f`” (no comma) to indicate that the shadow registers should be retrieved and copied to their corresponding registers on execution. Without this modifier, the registers are not updated from the shadow registers. This replaces the “`0`” and “`1`” operands indicated in the device data sheet.

The following examples show both forms and the opcodes they generate.

```
0011  retfie f    ;shadow registers copied
0010  retfie      ;return without copy
```

The baseline and mid-range devices do not allow such a syntax.

5.2.1.8 LONG JUMPS AND CALLS

The assembler recognizes several mnemonics that expand into regular PIC MCU assembly instructions. The mnemonics are `fcall` and `ljmp`. On baseline and mid-range parts, these instructions expand into regular `call` and `goto` instructions respectively, but also ensure the instructions necessary to set the bits in `PCLATH` (for mid-range devices) or `STATUS` (for baseline devices) will be generated when the destination is in another page of program memory. Whether the page selection instructions are generated, and exactly where they will be located, is dependent on the surrounding source code. Page selection instructions can appear immediately before the call or jump, or be generated as part of, and immediately after, a previous `fcall/ljmp` instruction.

On PIC18 devices, these mnemonics are present purely for compatibility with smaller 8-bit devices and are always expanded as regular PIC18 `call` and `goto` instructions.

These additional mnemonics should be used where possible as they make assembly code independent of the final position of the routines that are to be executed. If the call or jump is determined to be within the current page, the additional code to set the `PCLATH` bits can be optimized away. Note that assembly code that is added in-line with C code is never optimized and assembly modules require a specific option to enable optimization (see Section 3.7.6.5 “asmfile”). Unoptimized `fcall` and `LJMP` instruction will always generate page selection code.

The following mid-range PIC example shows an `fcall` instruction in the assembly list file. You can see that the `fcall` instruction has expanded to five instructions. In this example, there are two bit instructions that set/clear bits in the `PCLATH` register. Bits are also set/cleared in this register after the call to reselect the page that was selected before the `fcall`.

```
    13  0079  3021                        movlw   33
    14  007A  120A  158A  2000            fcall   _phantom
                120A  118A
    15  007F  3400                        retlw   0
```

Since `fcall` and `ljmp` instructions can expand into more than one instruction, they should never be preceded by an instruction that can skip, e.g., a `btfsc` instruction.

The `fcall` and `ljmp` instructions assume that the psect that contains them is smaller than a page. Do not use these instructions to transfer control to a label in the current psect if it is larger than a page. The default linker options will not permit code psects to be larger than a page.

On PIC18 devices, the regular `call` instruction can be followed by a “`,f`” to indicate that the W, STATUS and BSR registers should be pushed to their respective shadow registers. This replaces the “`,1`” syntax indicated on the device data sheet.

5.2.1.9 RELATIVE BRANCHES

The PIC18 devices implement conditional relative branch instructions, e.g., `bz`, `bnz`. These instructions have a limited jump range compared to the `goto` instruction.

Note that in some instance, the assembler can change a relative branch instruction to be a relative branch with the opposite condition over a `goto` instruction. For example:

```
    bz error
    ;next
```

can become:

```
    bnz l18
    goto error
l18:
    ;next
```

This is functionally identical and is performed so that the conditional branch can use the same destination range as the `goto` instruction.

5.2.2 Statement Formats

Legal statement formats are shown in Table 5-1: "ASPIC Statement Formats".

The *`label`* field is optional and, if present, should contain one identifier. A label can appear on a line of its own, or precede a mnemonic as shown in the second format.

The third format is only legal with certain assembler directives, such as `MACRO`, `SET` and `EQU`. The *`name`* field is mandatory and should contain one identifier.

If the assembly file is first processed by the C preprocessor (see Section 3.2.3 "Input File Types"), then it can also contain lines that form valid preprocessor directives. See Section 4.14.1 "Preprocessor Directives" for more information on the format for these directives.

There is no limitation on what column or part of the line in which any part of the statement should appear.

TABLE 5-1: ASPIC STATEMENT FORMATS

Format #	Field1	Field2	Field3	Field4
Format 1	*label:*			
Format 2	*label:*	*mnemonic*	*operands*	*; comment*
Format 3	*name*	*pseudo-op*	*operands*	*; comment*
Format 4	*; comment only*			
Format 5	*empty line*			

5.2.3 Characters

The character set used is standard 7 bit ASCII. Alphabetic case is significant for identifiers, but not mnemonics and reserved words. Tabs are equivalent to spaces.

5.2.3.1 DELIMITERS

All numbers and identifiers must be delimited by white space, non-alphanumeric characters or the end of a line.

5.2.3.2 SPECIAL CHARACTERS

There are a few characters that are special in certain contexts. Within a macro body, the character & is used for token concatenation. To use the bitwise & operator within a macro body, escape it by using && instead. In a macro argument list, the angle brackets < and > are used to quote macro arguments.

© 2012-2018 Microchip Technology Inc.

5.2.4 Comments

An assembly comment is initiated with a semicolon that is not part of a string or character constant.

If the assembly file is first processed by the C preprocessor (see Section 3.2.3 “Input File Types”), then the file can also contain C or C++ style comments using the standard `/* ... */` and `//` syntax.

5.2.4.1 SPECIAL COMMENT STRINGS

Several comment strings are appended to compiler-generated assembly instructions by the code generator. These comments are typically used by the assembler optimizer.

The comment string `;volatile` is used to indicate that the memory location being accessed in the instruction is associated with a variable that was declared as `volatile` in the C source code. Accesses to this location which appear to be redundant will not be removed by the assembler optimizer if this string is present.

This comment string can also be used in hand-written assembly source to achieve the same effect for locations defined and accessed in assembly code.

The comment string `;wreg free` is placed on some `call` instructions. The string indicates that the W register was not loaded with a function parameter; i.e., it is not in use. If this string is present, optimizations can be made to assembler instructions before the function call, which loads the W register redundantly.

5.2.5 Constants

5.2.5.1 NUMERIC CONSTANTS

The assembler performs all arithmetic with signed 32-bit precision.

The default radix for all numbers is 10. Other radices can be specified by a trailing base specifier, as given in Table 5-2.

TABLE 5-2: ASPIC NUMBERS AND BASES

Radix	Format
Binary	Digits 0 and 1 followed by B
Octal	Digits 0 to 7 followed by `O`, `Q`, `o` or `q`
Decimal	Digits 0 to 9 followed by `D`, `d` or nothing
Hexadecimal	Digits 0 to 9, A to F preceded by `0x` or followed by `H` *or* `h`

Hexadecimal numbers must have a leading digit (e.g., `0ffffh`) to differentiate them from identifiers. Hexadecimal digits are accepted in either upper or lower case.

Note that a binary constant must have an upper case `B` following it, as a lower case `b` is used for temporary (numeric) label backward references.

In expressions, real numbers are accepted in the usual format, and are interpreted as IEEE 32-bit format.

5.2.5.2 CHARACTER CONSTANTS AND STRINGS

A character constant is a single character enclosed in single quotes `'`.

Multi-character constants, or strings, are a sequence of characters, not including carriage return or newline characters, enclosed within matching quotes. Either single quotes `'` or double quotes `"` can be used, but the opening and closing quotes must be the same.

5.2.6 Identifiers

Assembly identifiers are user-defined symbols representing memory locations or numbers. A symbol can contain any number of characters drawn from the alphabetics, numerics, and the special characters: dollar, `$`; question mark, `?`; and underscore, `_`.

The first character of an identifier cannot be numeric. The case of alphabetics is significant, e.g., `Fred` is not the same symbol as `fred`. Some examples of identifiers are shown here:

```
An_identifier
an_identifier
an_identifier1
$
?$_12345
```

An identifier cannot be one of the assembler directives, keywords, or psect flags.

An identifier that begins with at least one underscore character can be accessed from C code. Care must be taken with such symbols that they do not interact with C code identifiers. Identifiers that do not begin with an underscore can only be accessed from the assembly domain. See Section 4.12.3.1 "Equivalent Assembly Symbols" for the mapping between the C and assembly domains.

5.2.6.1 SIGNIFICANCE OF IDENTIFIERS

Users of other assemblers that attempt to implement forms of data typing for identifiers should note that this assembler attaches no significance to any symbol, and places no restrictions or expectations on the usage of a symbol.

The names of psects (program sections) and ordinary symbols occupy separate, overlapping name spaces, but other than this, the assembler does not care whether a symbol is used to represent bytes, words or sports cars. No special syntax is needed or provided to define the addresses of bits or any other data type, nor will the assembler issue any warnings if a symbol is used in more than one context. The instruction and addressing mode syntax provide all the information necessary for the assembler to generate correct code.

5.2.6.2 ASSEMBLER-GENERATED IDENTIFIERS

Where a `LOCAL` directive is used in a macro block, the assembler will generate a unique symbol to replace each specified identifier in each expansion of that macro. These unique symbols will have the form `??`*nnnn* where *nnnn* is a 4-digit number. The user should avoid defining symbols with the same form.

5.2.6.3 LOCATION COUNTER

The current location within the active program section is accessible via the symbol `$`. This symbol expands to the address of the currently executing instruction (which is different than the address contained in the program counter (PC) register when executing this instruction). Thus:

```
goto $   ;endless loop
```

will represent code that will jump to itself and form an endless loop. By using this symbol and an offset, a relative jump destination can be specified.

Any address offset added to `$` has the native addressability of the target device. So, for baseline and mid-range devices, the offset is the number of instructions away from the current location, as these devices have word-addressable program memory. For PIC18 instructions, which use byte addressable program memory, the offset to this symbol represents the number of bytes from the current location. As PIC18 instructions must be word aligned, the offset to the location counter should be a multiple of 2. All offsets are rounded down to the nearest multiple of 2.

© 2012-2018 Microchip Technology Inc.

For example:

```
goto   $+2   ;skip...
movlw  8     ;to here for PIC18 devices, or
movwf  _foo  ;to here for baseline and mid-range devices
```

will skip the `movlw` instruction on baseline or mid-range devices. On PIC18 devices, `goto $+2` will jump to the following instruction; i.e., act like a `nop` instruction.

5.2.6.4 REGISTER SYMBOLS

Code in assembly modules can gain access to the special function registers by including pre-defined assembly header files. The appropriate file can be included by add the line:

```
#include <xc.inc>
```

to the assembler source file and using a `.S` or `.sx` extension with the source filename to ensure it is preprocessed.This header file contains appropriate commands to ensure that the header file specific for the target device is included into the source file.

These header files contain `EQU` declarations for all byte or multi-byte sized registers and `#define` macros for named bits within byte registers.

5.2.6.5 SYMBOLIC LABELS

A label is a symbolic alias that is assigned a value that is equal to the current address within the current psect. Labels are not assigned a value until link time.

A label definition consists of any valid assembly identifier followed by a *colon*, `:`. The definition can appear on a line by itself or it can be positioned before a statement. Here are two examples of legitimate labels interspersed with assembly code.

```
frank:
    movlw   1
    goto    fin
simon44: clrf _input
```

Here, the label `frank` will ultimately be assigned the address of the `movlw` instruction, and `simon44` the address of the `clrf` instruction. Regardless of how they are defined, the assembler list file produced by the assembler will always show labels on a line by themselves.

Note that the colon following the label is mandatory for PIC18 assembly, but is recommended in assembly for all other devices. Symbols that are not interpreted as instructions are assumed to be labels. Mistyped assembly instructions can sometimes be treated as labels without an error message being issued. Thus the code:

```
mistake:
    movlw 23h
    MOVWF 37h
    reutrn     ; oops
```

defines a symbol called `reutrn`, which was intended to be the `return` instruction. This does not occur with PIC18 assembly code, as the colon following a label is mandatory and the above code would flag an error.

Labels can be used (and are preferred) in assembly code, rather than using an absolute address with other instructions. In this way, they can be used as the target location for jump-type instructions or to load an address into a register.

Like variables, labels have scope. By default, they can be used anywhere in the module in which they are defined. They can be used by code located before their definition. To make a label accessible in other modules, use the `GLOBAL` directive. See Section 5.2.9.1 "GLOBAL" for more information.

5.2.7 Expressions

The operands to instructions and directives are comprised of expressions. Expressions can be made up of numbers, identifiers, strings and operators.

Operators can be unary (one operand, e.g., `not`) or binary (two operands, e.g., +). The operators allowable in expressions are listed in Table 5-3.

The usual rules governing the syntax of expressions apply.

The operators listed can all be freely combined in both constant and relocatable expressions. The linker permits relocation of complex expressions, so the results of expressions involving relocatable identifiers cannot be resolved until link time.

TABLE 5-3: ASPIC OPERATORS

Operator	Purpose	Example
`*`	multiplication	`movlw 4*33,w`
`+`	addition	`bra $+1`
`-`	subtraction	`DB 5-2`
`/`	division	`movlw 100/4`
= or `eq`	equality	`IF inp eq 66`
> or `gt`	signed greater than	`IF inp > 40`
>= or `ge`	signed greater than or equal to	`IF inp ge 66`
< or `lt`	signed less than	`IF inp < 40`
<= or `le`	signed less than or equal to	`IF inp le 66`
<> or `ne`	signed not equal to	`IF inp <> 40`
`low`	low byte of operand	`movlw low(inp)`
`high`	high byte of operand	`movlw high(1008h)`
`highword`	high 16 bits of operand	`DW highword(inp)`
`mod`	modulus	`movlw 77mod4`
& or `and`	bitwise AND	`clrf inp&0ffh`
^	bitwise XOR (exclusive or)	`movf inp^80,w`
`|`	bitwise OR	`movf inp|1,w`
`not`	bitwise complement	`movlw not 055h,w`
<< or `shl`	shift left	`DB inp>>8`
>> or `shr`	shift right	`movlw inp shr 2,w`
`rol`	rotate left	`DB inp rol 1`
`ror`	rotate right	`DB inp ror 1`
`float24`	24-bit version of real operand	`DW float24(3.3)`
`nul`	tests if macro argument is null	

© 2012-2018 Microchip Technology Inc.

5.2.8 Program Sections

Program sections, or psects, are simply a section of code or data. They are a way of grouping together parts of a program (via the psect's name) even though the source code cannot be physically adjacent in the source file, or even where spread over several modules. For an introductory guide to psects, see Section 4.15.1 "Compiler-Generated Psects".

A psect is identified by a name and has several attributes. The `PSECT` assembler directive is used to define a psect. It takes as arguments a name and an optional *comma*-separated list of flags. See Section 4.15.1 "Compiler-Generated Psects" for a list of all psects that the code generator defines. Chapter 6. Linker has more information on the operation of the linker and on options that can be used to control psect placement in memory.

The assembler associates no significance to the name of a psect. The linker, also, is not aware of which psects are compiler-generated or which are user-defined. Unless defined as `abs` (absolute), psects are relocatable.

Code or data that is not explicitly placed into a psect will become part of the default (unnamed) psect.

When writing assembly code, you can use the existing compiler-generated psects, described in Section 4.15.1 "Compiler-Generated Psects" or create your own. You will not need to adjust the linker options if you are using compiler-generated psects. If you create your own psects, try to associate them with an existing linker class (see Section 4.15.2 "Default Linker Classes" and Section 5.2.9.3.3 "Class") otherwise you can need to specify linker options for them to be allocated correctly.

Note, that the length and placement of psects is important. It is easier to write code if all executable code is located in psects that do not cross any device pages boundaries; so, too, if data psects do not cross bank boundaries. The location of psects (where they are linked) must match the assembly code that accesses the psect contents.

5.2.9 Assembler Directives

Assembler directives, or pseudo-ops, are used in a similar way to instruction mnemonics. With the exception of PAGESEL and BANKSEL, these directives do not generate instructions. The DB, DW and DDW directives place data bytes into the current psect. The directives are listed in Table 5-4, and are detailed below in the following sections.

TABLE 5-4: ASPIC ASSEMBLER DIRECTIVES

Directive	Purpose
GLOBAL	make symbols accessible to other modules or allow reference to other global symbols defined in other modules
END	end assembly
PSECT	declare or resume program section
ORG	set location counter within current psect
EQU	define symbol value
EXTRN	link with global symbols defined in other modules
SET	define or re-define symbol value
DB	define constant byte(s)
DW	define constant word(s)
DDW	define double-width constant word(s) (PIC18 devices only)
DS	reserve storage
DABS	define absolute storage
IF	conditional assembly
ELSIF	alternate conditional assembly
ELSE	alternate conditional assembly
ENDIF	end conditional assembly
FNCALL	inform the linker that one function calls another
FNROOT	inform the linker that a function is the "root" of a call graph
MACRO	macro definition
ENDM	end macro definition
LOCAL	define local tabs
ALIGN	align output to the specified boundary
BANKSEL	generate code to select bank of operand
PAGESEL	generate set/clear instruction to set PCLATH bits for this page
PROCESSOR	define the particular chip for which this file is to be assembled.
REPT	repeat a block of code *n* times
IRP	repeat a block of code with a list
IRPC	repeat a block of code with a character list
SIGNAT	define function signature

© 2012-2018 Microchip Technology Inc.

5.2.9.1 GLOBAL

The GLOBAL directive declares a list of comma-separated symbols. If the symbols are defined within the current module, they are made public. If the symbols are not defined in the current module, they are made references to public symbols defined in external modules. Thus to use the same symbol in two modules the GLOBAL directive must be used at least twice: once in the module that defines the symbol to make that symbol public, and again in the module that uses the symbol to link in with the external definition.

For example:

```
GLOBAL  lab1,lab2,lab3
```

5.2.9.2 END

The END directive is optional, but if present should be at the very end of the program. It will terminate the assembly and not even blank lines should follow this directive.

If an expression is supplied as an argument, that expression will be used to define the entry point of the program. This is stored in a start record in the object file produced by the assembler. Whether this is of any use will depend on the linker.

The default runtime startup code that is defined by the compiler will contain an END directive with a start address. As only one start address can be specified for each project, you generally do not need to define this address – you can use the END directive with no entry point in any file.

For example:

```
END  start_label  ;defines the entry point
```

or

```
END               ;do not define entry point
```

5.2.9.3 PSECT

The PSECT directive declares or resumes a program section. For an introductory guide to psects, see Section 4.15.1 "Compiler-Generated Psects".

The directive takes as argument a name and, optionally, a *comma*-separated list of flags. The allowed flags specify attributes of the psect. They are listed in Table 5-5.

The psect name is in a separate name space to ordinary assembly symbols, so a psect can use the same identifier as an ordinary assembly identifier. However, a psect name cannot be one of the assembler directives, keywords, or psect flags.

Once a psect has been declared, it can be resumed later by another PSECT directive; however, the flags need not be repeated and will be propagated from the earlier declaration. An error is generated if two PSECT directives for the same psect are encountered with contradictory flags, the exceptions being that the `reloc`, `size` and `limit` flags can be respecified without error.

TABLE 5-5: PSECT FLAGS

Flag	Meaning
`abs`	psect is absolute
`bit`	psect holds bit objects
`class=`*`name`*	specify class name for psect
`delta=`*`size`*	size of an addressing unit
`global`	psect is global (default)
`inline`	psect contents (function) can be inlined when called
`keep`	psect will not be deleted after inlining
`limit=`*`address`*	upper address limit of psect (PIC18 only)
`local`	psect is unique and will not link with others having the same name
`lowdata`	psect will be entirely located below the 0x1000 address
`merge=`*`allow`*	allow or prevent merging of this psect
`noexec`	for debugging purposes, this psect contains no executable code
`optim=`*`optimizations`*	specify optimizations allowable with this psect
`ovrld`	psect will overlap same psect in other modules
`pure`	psect is to be read-only
`reloc=`*`boundary`*	start psect on specified boundary
`size=`*`max`*	maximum size of psect
`space=`*`area`*	represents area in which psect will reside
`split=`*`allow`*	allow or prevent splitting of this psect
`with=`*`psect`*	place psect in the same page as specified psect

Some examples of the use of the PSECT directive follow:

```
PSECT fred
PSECT bill,size=100h,global
PSECT joh,abs,ovrld,class=CODE,delta=2
```

© 2012-2018 Microchip Technology Inc.

5.2.9.3.1 Abs

The `abs` flag defines the current psect as being absolute; i.e., it is to start at location 0. This does not mean that this module's contribution to the psect will start at 0, since other modules can contribute to the same psect (See also Section 5.2.9.3.13 "Ovrld").

An `abs`-flagged psect is not relocatable and an error will result if a linker option is issued that attempts to place such a psect at any location.

5.2.9.3.2 Bit

The `bit` flag specifies that a psect holds objects that are 1 bit long. Such psects will have a `scale` value of 8 to indicate that there are 8 addressable units to each byte of storage and all addresses associated with this psect will be bit address, not byte addresses. The scale value is indicated in the map file (see Section 6.4 "Map Files").

5.2.9.3.3 Class

The `class` flag specifies a corresponding linker class name for this psect. A class is a range of addresses in which psects can be placed.

Class names are used to allow local psects to be located at link time, since they cannot always be referred to by their own name in a `-P` linker option (as would be the case if there are more than one local psect with the same name).

Class names are also useful where psects need only be positioned anywhere within a range of addresses rather than at a specific address. The association of a class with a psect that you have defined typically means that you do not need to supply a custom linker option to place it in memory.

See Section 6.2.1 "-Aclass =low-high,..." for information on how linker classes are defined.

5.2.9.3.4 Delta

The `delta` flag defines the size of the addressable unit. In other words, the number of data bytes that are associated with each address.

With PIC mid-range and baseline devices, the program memory space is word addressable; so, psects in this space must use a delta of 2. That is to say, each address in program memory requires 2 bytes of data in the HEX file to define their contents. So, addresses in the HEX file will not match addresses in the program memory.

The data memory space on these devices is byte addressable; so, psects in this space must use a delta of 1. This is the default delta value.

All memory spaces on PIC18 devices are byte addressable; so a delta of 1 (the default) should be used for all psects on these devices.

The redefinition of a psect with conflicting delta values can lead to phase errors being issued by the assembler.

5.2.9.3.5 Global

A psect defined as `global` will be combined with other `global` psects with the same name at link time. Psects are grouped from all modules being linked.

Psects are considered `global` by default, unless the `local` flag is used.

5.2.9.3.6 Inline

This flag is deprecated. Consider, instead, using the `optim` psect flag.

The `inline` flag is used by the code generator to tell the assembler that the contents of a psect can be inlined. If this operation is performed, the contents of the `inline` psect will be copied and used to replace calls to the function defined in the psect.

5.2.9.3.7 Keep

This flag is deprecated. Consider, instead, using the `optim` psect flag.

Psects that are candidates for inlining (see Section 5.2.9.3.6 "Inline") can be deleted after the inlining takes place. This flag ensures that the psect is not deleted after any inlining by the assembler optimizer.

5.2.9.3.8 Limit

The `limit` flag specifies a limit on the highest address to which a psect can extend. If this limit is exceeded when it is positioned in memory, an error will be generated. This is currently only available when building for PIC18 devices.

5.2.9.3.9 Local

A psect defined as `local` will not be combined with other `local` psects from other modules at link time, even if there are others with the same name. Where there are two `local` psects in the one module, they reference the same psect. A `local` psect cannot have the same name as any `global` psect, even one in another module.

Psects which are local and which are not associated with a linker class (see Section 5.2.9.3.3 "Class") cannot be linked to an address using the `-P` linker option, since there could be more than one psect with this name. Typically these psects define a class flag and they are placed anywhere in that class range.

5.2.9.3.10 Merge

This flag is deprecated. Consider, instead, using the `optim` psect flag.

This flag can be assigned 0, 1, or not specified. When assigned 0, the psect will never be merged by the assembly optimizer during optimizations. If assigned the value 1, the psect can be merged if other psect attributes allow it and the optimizer can see an advantage in doing so. If this flag is not specified, then merging will not take place.

Typically, merging is only performed on code-based psects (text psects).

5.2.9.3.11 Noexec

The `noexec` flag is used to indicate that the psect contains no executable code. This information is only relevant for debugging purposes.

© 2012-2018 Microchip Technology Inc.

5.2.9.3.12 Optim

The `optim` psect flag is used to indicate the optimizations that can be performed on the psect's content, provided the assembler optimizer is enabled and that optimization is available in the compiler's operating mode (see Section 3.7.6 "Options for Controlling Optimization"). The optimizations are indicated by a colon-separated list of names, shown in Table 5-6. An empty list implies that no optimizations can be performed on the psect.

TABLE 5-6: OPTIM FLAG NAMES

Name	Optimization
`inline`	allow the psect content to be inlined
`jump`	perform jump-based optimizations
`merge`	allow the psect's content to be merged with that of other similar psects (PIC10/12/16 devices only)
`pa`	perform proceedural abstraction
`peep`	perform peephole optimizations
`remove`	allow the psect to be removed entirely if it is completely inlined
`split`	allow the psect to be split into smaller psects if it surpasses size restrictions (PIC10/12/16 devices only)
`empty`	perform no optimization on this psect

So, for example, the psect definition:

```
PSECT myText,class=CODE,reloc=2,optim=inline:jump:split
```

allows the assembler optimizer to perform inlining, splitting and jump-type optimizations of the `myText` psect content if those optimizations are enabled. The definition:

```
PSECT myText,class=CODE,reloc=2,optim=
```

disables all optimizations associated with this psect regardless of the optimizer setting.

The `optim` psect flag replaces the use of the separate psect flags: `merge`, `split`, `inline`, and `keep`.

5.2.9.3.13 Ovrld

A psect defined as `ovrld` will have the contribution from each module overlaid, rather than concatenated at link time. This flag in combination with the `abs` flag (see Section 5.2.9.3.1 "Abs") defines a truly absolute psect; i.e., a psect within which any symbols defined are absolute.

5.2.9.3.14 Pure

The `pure` flag instructs the linker that this psect will not be modified at runtime. So, for example, be placed in ROM. This flag is of limited usefulness since it depends on the linker and target system enforcing it.

5.2.9.3.15 Reloc

The `reloc` flag allows the specification of a requirement for alignment of the psect on a particular boundary. The boundary specification must be a power of two, for example 2, 8 or 0x40. For example, the flag `reloc=100h` would specify that this psect must start on an address that is a multiple of 0x100 (e.g., 0x100, 0x400, or 0x500).

PIC18 instructions must be word aligned, so a `reloc` value of 2 must be used for any PIC18 psect that contains executable code. All other sections, and all sections for all other devices, can typically use the default `reloc` value of 1.

5.2.9.3.16 Size

The `size` flag allows a maximum size to be specified for the psect, e.g., `size=100h`. This will be checked by the linker after psects have been combined from all modules.

5.2.9.3.17 Space

The `space` flag is used to differentiate areas of memory that have overlapping addresses, but are distinct. Psects that are positioned in program memory and data memory have a different `space` value to indicate that the program space address 0, for example, is a different location to the data memory address 0.

The memory spaces associated with the space flag numbers are shown in Table 5-7.

TABLE 5-7: SPACE FLAG NUMBERS

Space Flag Number	Memory Space
0	Program memory
1	Data memory
2	Reserved
3	EEPROM

Devices that have a banked data space do not use different space values to identify each bank. A full address that includes the bank number is used for objects in this space. So, each location can be uniquely identified. For example, a device with a bank size of 0x80 bytes will use address 0 to 0x7F to represent objects in bank 0, and then addresses 0x80 to 0xFF to represent objects in bank 1, etc.

5.2.9.3.18 Split

This flag is deprecated. Consider, instead, using the `optim` psect flag.

This flag can be assigned 0, 1, or not specified. When assigned 0, the psect will never be split by the assembly optimizer during optimizations. If assigned the value 1, the psect can be split if other psect attributes allow it and the psect is too large to fit in available memory. If this flag is not specified, then the splitability of this psect is based on whether the psect can be merged, see Section 5.2.9.3.10 "Merge".

5.2.9.3.19 With

The `with` flag allows a psect to be placed in the same page with another psect. For example the flag `with=text` will specify that this psect should be placed in the same page as the `text` psect.

The term *withtotal* refers to the sum of the size of each psect that is placed "with" other psects.

5.2.9.4 ORG

The `ORG` directive changes the value of the location counter within the current psect. This means that the addresses set with `ORG` are relative to the base address of the psect, which is not determined until link time.

Note: The much-abused `ORG` directive does *not* move the location counter to the absolute address you specify. Only if the psect in which this directive is placed is absolute and overlaid will the location counter be moved to the specified address. To place objects at a particular address, place them in a psect of their own and link this at the required address using the linkers `-P` option (see Section 6.2.18 "-Pspec"). The `ORG` directive is not commonly required in programs.

The argument to ORG must be either an absolute value, or a value referencing the current psect. In either case, the current location counter is set to the value determined by the argument. It is not possible to move the location counter backward. For example:

```
ORG 100h
```

will move the location counter to the beginning of the current psect plus 100h. The actual location will not be known until link time.

In order to use the ORG directive to set the location counter to an absolute value, the directive must be used from within an absolute, overlaid psect. For example:

```
PSECT absdata,abs,ovrld
    ORG 50h
  ;this is guaranteed to reside at address 50h
```

5.2.9.5 EQU

This pseudo-op defines a symbol and equates its value to an expression. For example

```
thomas EQU 123h
```

The identifier thomas will be given the value 123h. EQU is legal only when the symbol has not previously been defined. See Section 5.2.9.7 “SET” for redefinition of values.

This directive performs a similar function to the preprocessor’s #define directive (see Section 4.14.1 “Preprocessor Directives”).

5.2.9.6 EXTRN

This pseudo-op is similar to GLOBAL (see Section 5.2.9.1 “GLOBAL”), but can only be used to link in with global symbols defined in other modules. An error will be triggered if you use EXTRN with a symbol that is defined in the same module.

5.2.9.7 SET

This pseudo-op is equivalent to EQU (Section 5.2.9.5 “EQU”), except that allows a symbol to be re-defined without error. For example:

```
thomas SET 0h
```

This directive performs a similar function to the preprocessor’s #define directive (see Section 4.14.1 “Preprocessor Directives”).

5.2.9.8 DB

The DB directive is used to initialize storage as bytes. The argument is a *comma*-separated list of expressions, each of which will be assembled into one byte and assembled into consecutive memory locations.

Examples:

```
alabel: DB  ’X’,1,2,3,4,
```

If the size of an address unit in the program memory is 2 bytes, as it will be for baseline and mid-range devices (see Section 5.2.9.3.4 “Delta”), the DB pseudo-op will initialize a word with the upper byte set to zero. So, the above example will define bytes padded to the following words.

```
0058 0001 0002 0003 0004
```

However, on PIC18 devices (PSECT directive’s delta flag should be 1), no padding will occur and the following data will appear in the HEX file.

```
58 01 02 03 04
```

5.2.9.9 DW

The DW directive operates in a similar fashion to DB, except that it assembles expressions into 16-bit words. Example:

```
DW -1, 3664h, 'A'
```

5.2.9.10 DDW

The DDW directive operates in a similar fashion to DW, except that it assembles expressions into double-width (32-bit) words. Example:

```
DDW 'd', 12345678h, 0
```

5.2.9.11 DS

This directive reserves, but does not initialize, memory locations. The single argument is the number of bytes to be reserved.

This directive is typically used to reserve memory location for RAM-based objects in the data memory. If used in a psect linked into the program memory, it will move the location counter, but not place anything in the HEX file output. Note that because the size of an address unit in the program memory is 2 bytes (see Section 5.2.9.3.4 "Delta"), the DS pseudo-op will actually reserve an entire word.

A variable is typically defined by using a label and then the DS directive to reserve locations at the label location.

Examples:

```
alabel: DS 23    ;Reserve 23 bytes of memory
xlabel: DS 2+3   ;Reserve 5 bytes of memory
```

5.2.9.12 DABS

This directive allows one or more bytes of memory to be reserved at the specified address. The general form of the directive is:

DABS *memorySpace*, *address*, *bytes*[,*symbol*]

where *memorySpace* is a number representing the memory space in which the reservation will take place, *address* is the address at which the reservation will take place, and *bytes* is the number of bytes that is to be reserved. The *symbol* is optional and refers to the name of the object at the address.

Use of symbol in the directive will aid debugging. The symbol is automatically made globally accessible and is equated to the address specified in the directive. So, for example, the following directive uses a symbol:

```
DABS 1,0x100,4,foo
```

that is identical to the following directives:

```
GLOBAL foo
foo EQU 0x100
DABS 1,0x100,4
```

This directive differs to the DS directive in that it can be used to reserve memory at any location, not just within the current psect. Indeed, these directives can be placed anywhere in the assembly code and do not contribute to the currently selected psect in any way.

The memory space number is the same as the number specified with the space flag option to psects (see Section 5.2.9.3.17 "Space").

The code generator issues a DABS directive for every user-defined absolute C variable, or for any variables that have been allocated an address by the code generator.

The linker reads this DABS-related information from object files and ensures that the reserved addresses are not used for other memory placement.

5.2.9.13 IF, ELSIF, ELSE AND ENDIF

These directives implement conditional assembly.

© 2012-2018 Microchip Technology Inc.

The argument to IF and ELSIF should be an absolute expression. If it is non-zero, then the code following it up to the next matching ELSE, ELSIF or ENDIF will be assembled. If the expression is zero, then the code up to the next matching ELSE or ENDIF will not be output.At an ELSE, the sense of the conditional compilation will be inverted, while an ENDIF will terminate the conditional assembly block. Conditional assembly blocks can be nested.

These directives do not implement a runtime conditional statement in the same way that the C statement if() does; they are only evaluated at compile time. In addition, assembly code in both true and false cases is always scanned and interpreted, but the machine code corresponding to instructions is *output* only if the condition matches. This implies that assembler directives (e.g., EQU) will be processed regardless of the state of the condition expression, and so, should not be used inside an IF construct.

For example:

```
IF ABC
    goto aardvark
ELSIF DEF
    goto denver
ELSE
    goto grapes
ENDIF
ENDIF
```

In this example, if ABC is non-zero, the first goto instruction will be assembled but not the second or third. If ABC is zero and DEF is non-zero, the second goto instruction will be assembled but the first and third will not. If both ABC and DEF are zero, the third goto instruction will be assembled.

5.2.9.14 MACRO AND ENDM

These directives provide for the definition of assembly macros, optionally with arguments. See Section 5.2.9.5 “EQU” for simple association of a value with an identifier, or Section 4.14.1 “Preprocessor Directives” for the preprocessor’s #define macro directive, which can also work with arguments.

The MACRO directive should be preceded by the macro name and optionally followed by a *comma*-separated list of formal arguments. When the macro is used, the macro name should be used in the same manner as a machine opcode, followed by a list of arguments to be substituted for the formal parameters.

For example:

```
;macro: movlf - Move a literal value into a nominated file register
;args:  arg1 - the literal value to load
;       arg2 - the NAME of the source variable

movlf   MACRO   arg1,arg2
    movlw arg1
    movwf arg2 mod 080h
ENDM
```

When used, this macro will expand to the 2 instructions in the body of the macro, with the formal parameters substituted by the arguments. Thus:

```
    movlf 2,tempvar
```

expands to:

```
    movlw 2
    movwf tempvar mod 080h
```

The & character can be used to permit the concatenation of macro arguments with other text, but is removed in the actual expansion. For example:

```
loadPort MACRO port, value
    movlw value
    movwf PORT&port
ENDM
```

will load PORTA if port is A when called, etc. The special meaning of the & token in macros implies that you can not use the bitwise AND operator, (also represented by &), in assembly macros; use the and form of this operator instead.

A comment can be suppressed within the expansion of a macro (thus saving space in the macro storage) by opening the comment with a double semicolon, ;;.

When invoking a macro, the argument list must be *comma*-separated. If it is desired to include a *comma* (or other delimiter such as a space) in an argument then angle brackets < and > can be used to quote

If an argument is preceded by a percent sign, %, that argument will be evaluated as an expression and passed as a decimal number, rather than as a string. This is useful if evaluation of the argument inside the macro body would yield a different result.

The nul operator can be used within a macro to test a macro argument, for example:

```
IF nul     arg3  ; argument was not supplied.
    ...
ELSE             ; argument was supplied
    ...
ENDIF
```

See Section 5.2.9.15 “LOCAL” for use of unique local labels within macros.

By default, the assembly list file will show macro in an unexpanded format; i.e., as the macro was invoked. Expansion of the macro in the listing file can be shown by using the EXPAND assembler control (see Section 5.2.10.4 “EXPAND”).

5.2.9.15 LOCAL

The LOCAL directive allows unique labels to be defined for each expansion of a given macro. Any symbols listed after the LOCAL directive will have a unique assembler generated symbol substituted for them when the macro is expanded. For example:

```
down MACRO count
    LOCAL more
    more: decfsz count
    goto more
ENDM
```

when expanded, will include a unique assembler generated label in place of more. For example:

```
down foobar
```

expands to:

```
??0001 decfsz foobar
    goto ??0001
```

If invoked a second time, the label more would expand to ??0002, and multiply defined symbol errors will be averted.

© 2012-2018 Microchip Technology Inc.

5.2.9.16 ALIGN

The `ALIGN` directive aligns whatever is following, data storage or code etc., to the specified offset boundary within the current psect. The boundary is specified as a number of bytes following the directive.

For example, to align output to a 2-byte (even) address within a psect, the following could be used.

```
ALIGN 2
```

Note that what follows will only begin on an even absolute address if the psect begins on an even address; i.e., alignment is done within the current psect. See Section 5.2.9.3.15 “Reloc” for psect alignment.

The `ALIGN` directive can also be used to ensure that a psect’s length is a multiple of a certain number. For example, if the above `ALIGN` directive was placed at the end of a psect, the psect would have a length that was always an even number of bytes long.

5.2.9.17 REPT

The `REPT` directive temporarily defines an unnamed macro, then expands it a number of times as determined by its argument.

For example:

```
REPT 3
    addwf fred,w
ENDM
```

will expand to:

```
    addwf fred,w
    addwf fred,w
    addwf fred,w
```

(see Section 5.2.9.18 “IRP and IRPC”).

5.2.9.18 IRP AND IRPC

The `IRP` and `IRPC` directives operate in a similar way to `REPT`; however, instead of repeating the block a fixed number of times, it is repeated once for each member of an argument list.

In the case of `IRP`, the list is a conventional macro argument list. In the case or `IRPC`, it is each character in one argument. For each repetition, the argument is substituted for one formal parameter.

For example:

```
IRP number,4865h,6C6Ch,6F00h
    DW number
ENDM
```

would expand to:

```
    DW 4865h
    DW 6C6Ch
    DW 6F00h
```

Note that you can use local labels and angle brackets in the same manner as with conventional macros.

The `IRPC` directive is similar, except it substitutes one character at a time from a string of non-space characters.

For example:

```
IRPC char,ABC
    DB ’char’
ENDM
```

will expand to:

```
    DB ’A’
    DB ’B’
    DB ’C’
```

5.2.9.19 BANKSEL

This directive can be used to generate code to select the bank of the operand. The operand should be the symbol or address of an object that resides in the data memory (see Section 5.2.1.2 “Bank and Page Selection”).

5.2.9.20 PAGESEL

This directive can be used to generate code to select the page of the address operand. (see Section 5.2.1.2 “Bank and Page Selection”).

5.2.9.21 PROCESSOR

The output of the assembler can vary, depending on the target device. The device name is typically set using the `-mcpu` option to the command-line driver `xc8-cc` (see Section 3.7.1.5 “cpu”). However, it can also be set with this directive for example:

```
PROCESSOR 16F877
```

This directive will override any device selected by any command-line option.

5.2.9.22 SIGNAT

This directive is used to associate a 16-bit signature value with a label. At link time, the linker checks that all signatures defined for a particular label are the same. The linker will produce an error if they are not. The `SIGNAT` directive is used by MPLAB XC8 to enforce link time checking of C function prototypes and calling conventions.

Use the `SIGNAT` directive if you want to write assembly language routines that are called from C. For example:

```
SIGNAT _fred,8192
```

associates the signature value 8192 with the symbol `_fred`. If a different signature value for `_fred` is present in any object file, the linker will report an error.

The easiest way to determine the correct signature value for a routine is to write a C routine with the same prototype as the assembly routine and check the signature value determined by the code generator. This will be shown in the assembly list file (see Section 3.7.10 “Mapped Assembler Options” and Section 5.3 “Assembly-Level Optimizations”).

© 2012-2018 Microchip Technology Inc.

5.2.10 Assembler Controls

Assembler controls can be included in the assembler source to control assembler operation. These keywords have no significance anywhere else in the program. The control is invoked by the directive `OPT`, followed by the control name. Some keywords are followed by one or more arguments. For example:

```
OPT EXPAND
```

A list of keywords is given in Table 5-8, and each is described in the text that follows the table.

TABLE 5-8: ASPIC ASSEMBLER CONTROLS[1]

Control	Meaning	Format

`ASMOPT_ON, ASMOPT_OFF`	start and stop assembly optimizations	`OPT ASMOPT_OFF`
		`;protected code`
		`OPT ASMOPT_ON`

ASMOPT_PUSH,
ASMOPT_POP
	save and restore the state of the assembly optimizations	`OPT ASMOPT_PUSH ;save state`
		`OPT ASMOPT_OFF`
		`;protected code`
		`OPT ASMOPT_POP  ;restore state`

`COND*, NOCOND`	include/do not include conditional code in the listing	`OPT COND`
`EXPAND, NOEXPAND`	expand/do not expand macros in the listing output	`OPT EXPAND`
`INCLUDE`	textually include another source file	`OPT INCLUDE <` *`pathname`* `>`
`LIST*, NOLIST`	define options for listing output/disable listing output	`OPT LIST [<` *`listopt`* `>, ..., <` *`listopt`* `>]`
`PAGE`	start a new page in the listing output	`OPT PAGE`
`SPACE`	add blank lines to listing	`OPT SPACE 3`
`SUBTITLE`	specify the subtitle of the program	`OPT SUBTITLE` “< *`subtitle`* >”
`TITLE`	specify the title of the program	`OPT TITLE` “< *`title`* >”

Note 1: The default options are listed with an asterisk (*)

5.2.10.1 ASMOPT_OFF AND ASMOPT_ON

These controls allow the assembler optimizer to be selectively disabled for sections of assembly code. No code is modified after an `ASMOPT_OFF` control until a subsequent `ASMOPT_ON` control is encountered.

5.2.10.2 ASMOPT_PUSH AND ASMOPT_POP

These controls allow the state of the assembler optimizer to be saved onto a stack of states and then restored at a later time. They are useful when you need to ensure the optimizers are disabled for a small section of code, but you do not know if the optimizers have previously been disabled. See Table 5-8 for an example of how these might be used.

5.2.10.3 COND

Any conditional code is included in the listing output. (see the `NOCOND` control in Section 5.2.10.7 “NOCOND”).

5.2.10.4 EXPAND

When `EXPAND` is in effect, the code generated by macro expansions appears in the listing output. (see the `NOEXPAND` control in Section 5.2.10.8 “NOEXPAND”).

5.2.10.5 INCLUDE

This control causes the file specified by *`pathname`* to be textually included at that point in the assembly file. The `INCLUDE` control must be the last control keyword on the line, for example:

```
OPT INCLUDE "options.h"
```

The driver does not pass any search paths to the assembler, so if the include file is not located in the working directory, the pathname must specify the exact location.

See also how to preprocess assembly source files in Section 3.2.3 “Input File Types” thus allowing use of preprocessor directives, such as `#include`.

5.2.10.6 LIST

If, previously, the listing was turned off using the `NOLIST` control, the `LIST` control automatically turns listing on.

Alternatively, the `LIST` control can include options to control the assembly and the listing. The options are listed in Table 5-9.

TABLE 5-9: LIST CONTROL OPTIONS

List Option	Default	Description
`c=` *`nnn`*	80	Set the page (i.e., column) width.
`n=` *`nnn`*	59	Set the page length.
`t= ON|OFF`	OFF	Truncate listing output lines. The default wraps lines.
`p=<` *`device`* `>`	n/a	Set the device type.
`r=<` *`radix`* `>`	HEX	Set the default radix to HEX, dec or oct.
`x= ON|OFF`	OFF	Turn macro expansion on or off.

(see the `NOLIST` control in Section 5.2.10.9 “NOLIST”).

5.2.10.7 NOCOND

Using this control will prevent conditional code from being included in the assembly list file output (see the `COND` control in Section 5.2.10.3 “COND”).

5.2.10.8 NOEXPAND

The `NOEXPAND` control disables macro expansion in the assembly list file. The macro call will be listed instead. See the `EXPAND` control in Section 5.2.10.4 “EXPAND”. Assembly macros are discussed in Section 5.2.9.14 “MACRO and ENDM”.

5.2.10.9 NOLIST

This control turns the listing output off from a precise point forward (see the `LIST` control in Section 5.2.10.6 “LIST”).

© 2012-2018 Microchip Technology Inc.

5.2.10.10 PAGE

The `PAGE` control causes a new page to be started in the listing output. A Control-L (form feed) character will also cause a new page when it is encountered in the source.

5.2.10.11 SPACE

The `SPACE` control places a number of blank lines in the listing output, as specified by its parameter.

5.2.10.12 SUBTITLE

The `SUBTITLE` control defines a subtitle to appear at the top of every listing page, but under the title. The string should be enclosed in single or double quotes (see the `TITLE` control in Section 5.2.10.13 “TITLE”).

5.2.10.13 TITLE

This control keyword defines a title to appear at the top of every listing page. The string should be enclosed in single or double quotes (see the `SUBTITLE` control in Section 5.2.10.12 “SUBTITLE”).

5.3 ASSEMBLY-LEVEL OPTIMIZATIONS

The assembler performs optimizations on assembly code, in addition to those optimizations performed by the code generator directly on the C code.

The assembler only optimizes hand-written assembly source modules if the `-fasmfile` driver optimization setting is enabled, see Section 3.7.6.5 "asmfile". Assembly added in-line (see Section 4.12.2 "Inline Assembly") with C code is never optimized.

The optimizations that can be performed by the assembler include the following. Note, however, that these optimizations are skipped if the compiler is operating with level 0 or 1 optimizations, unless indicated below (see Section 3.7.6 "Options for Controlling Optimization").

Assembly-level optimizations include:

- **In-lining of small routines** is done so that a call to the routine is not required. Only very small routines (typically a few instructions) that are called only once will be changed so that code size is not adversely impacted. This speeds code execution without a significant increase in code size.
- **Explicit inlining of functions** that use the `inline` specifier (see Section 4.8.1.2 "Inline Specifier").
- **Procedural abstraction** is performed on assembly code sequences that appear more than once. This is essentially a reverse in-lining process. The code sequences are abstracted into callable routines that use a label, `PLx`, where `x` is a number. A call to this routine will replace every instance of the original code sequence. This optimization reduces code size considerably, with a small impact on code speed. It can, however, adversely impact debugging. Procedural abstraction is only employed by compilers operating in PRO mode.
- **Jump-to-jump type optimizations** are made primarily to tidy the output related to conditional code sequences that follow a generic template. Jump-to-jump optimizations can remove jump instructions whose destinations are also jump instructions. This optimization is enabled in all modes, including Free mode.
- **Unreachable code is removed**. Code can become orphaned by other optimizations and cannot be reached during normal execution, e.g., instructions after a return instruction. The presence of any label is considered a possible entry point, and code following a label is always considered reachable.
- **Peephole optimizations** are performed on every instruction. These optimizations consider the state of execution at, and immediately around, each instruction – hence the name. They either alter or delete one or more instructions at each step. For example, if W is known to contain the value 0, and an instruction moves W to an address (`MOVWF`), this might be replaceable with a `CLRF` instruction.
- **Psect merging** can be performed to allow other optimizations to take place. Code within the same psect is guaranteed to be located in the same program memory page. So, calls and jumps within the psect do not need to have the page selection bits set before executing. Code using the `LJMP` and `fcall` instructions will benefit from this optimization (see Section 5.2.1 "Assembly Instruction Deviations").

Assembly optimizations can often interfere with debugging in some tools, such as MPLAB X IDE. It can be necessary to select level disable them when debugging code, if that is possible (see Section 3.7.6 "Options for Controlling Optimization"). The assembler optimizations can drastically reduce code size. However, they typically have little effect on RAM usage.

© 2012-2018 Microchip Technology Inc.

5.4 ASSEMBLY LIST FILES

The assembler will produce an assembly list file if instructed. The `xc8-cc` driver option `-Wa,-a` is typically used to request generation of such a file (see Section 3.7.10 "Mapped Assembler Options").

The assembly list file shows the assembly output produced by the compiler for both C and assembly source code. If the assembler optimizers are enabled, the assembly output can be different than assembly source code. It is still useful for assembly programming.

The list file is in a human-readable form and cannot be go any farther in the compilation sequence. It differs from an assembly output file in that it contains address and op-code data. In addition, the assembler optimizer simplifies some expressions and removes some assembler directives from the listing file for clarity, although these directives are included in the true assembly output files. If you are using the assembly list file to look at the code produced by the compiler, you might wish to turn off the assembler optimizer so that all the compiler-generated directives are shown in the list file. Re-enable the optimizer when continuing development. Section 3.7.6 "Options for Controlling Optimization" gives more information on controlling the optimizers.

Provided that the link stage has successfully concluded, the listing file is updated by the linker so that it contains absolute addresses and symbol values. Thus, you can use the assembler list file to determine the position and exact op codes of instructions.

Tick marks "`'`" in the assembly listing, next to addresses or opcodes, indicate that the linker did not update the list file, most likely due to a compiler error, or a compiler option that stopped compilation before the link stage. For example, in the following listing:

```
85  000A' 027F                      subwf   127,w
86  000B' 1D03                      skipz
87  000C' 2800'                     goto    u15
```

These marks indicate that addresses are just address offsets into their enclosing psect, and that opcodes have not been fixed up. Any address field in the opcode that has not been fixed up is shown with a value of 0.

There is a single assembly list file produced by the assembler for each assembly file passed to it. So, there is a single file produced for all the C source code in a project, including p-code based library code. The file also contains some of the C initialization that forms part of the runtime startup code. There is also a single file produced for each assembly source file. Typically, there is at least one assembly file in each project. It contains some of the runtime startup file and is typically named `startup.s`.

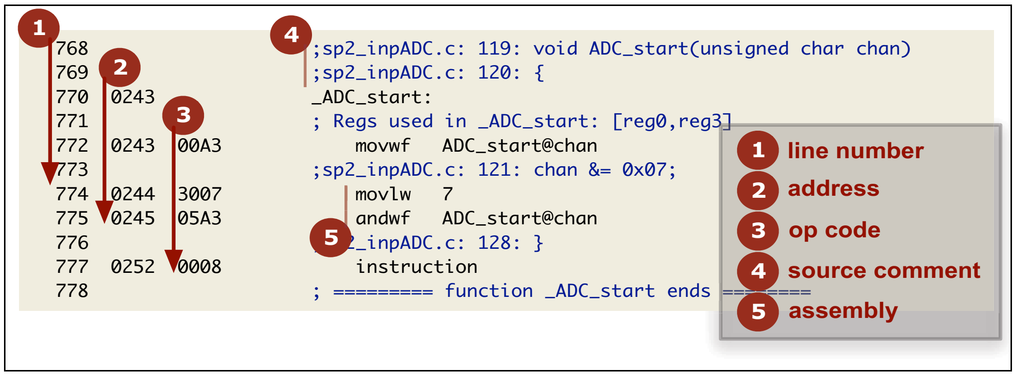
5.4.1 General Format

The format of the main listing is in the form shown in Figure 5-1.

The line numbers purely relate to the assembly list file and are not associated with the lines numbers in the C or assembly source files. Any assembly that begins with a semicolon indicates it is a comment added by the code generator. Such comments contain either the original source code, which corresponds to the generated assembly, or is a comment inserted by the code generator to explain some action taken.

Before the output for each function, there is detailed information regarding that function summarized by the code generator. This information relates to register usage, local variable information, functions called, and the calling function.

FIGURE 5-1: GENERAL FORM OF ASSEMBLY LISTING FILE



```
768                   ;sp2_inpADC.c: 119: void ADC_start(unsigned char chan)
769                   ;sp2_inpADC.c: 120: {
770  0243             _ADC_start:
771                   ; Regs used in _ADC_start: [reg0,reg3]
772  0243  00A3           movwf   ADC_start@chan
773                   ;sp2_inpADC.c: 121: chan &= 0x07;
774  0244  3007           movlw   7
775  0245  05A3           andwf   ADC_start@chan
776                      2_inpADC.c: 128: }
777  0252  0008           instruction
778                   ; ========= function _ADC_start ends ========
```

5.4.2 Psect Information

The assembly list file can be used to determine the name of the psect in which a data object or section of code has been placed.

For global symbols, you can check the symbol table in the map file which lists the psect name with each symbol. For symbols local to a module, find the definition of the symbol in the list file. For labels, it is the symbol’s name followed by a colon, ‘`:`’. Look for the first `PSECT` assembler directive above this code. The name associated with this directive is the psect in which the code is placed (see Section 5.2.9.3 “PSECT”).

5.4.3 Function Information

For each C function, printed before the function’s assembly label (search for the function’s name that is immediately followed by a colon `:`), is general information relating to the resources used by that function. A typical printout is shown in Figure 5-2: Function Information. Most of the information is self-explanatory, but special comments follow.

The locations shown use the format `*offset*[*space*]`. For example, a location of `42[BANK0]` means that the variable was located in the bank 0 memory space and that it appears at an offset of 42 bytes into the compiled stack component in this space (see Section 4.5.2.2.1 “Object Size Limits”).

Whenever pointer variables are shown, they are often accompanied by the targets that the pointer can reference, these targets appear after the arrow `->` (see Section 5.4.5 “Pointer Reference Graph”). The auto and parameter section of this information is especially useful because the size of pointers is dynamic (see Section 4.4.6 “Pointer Types”). This information shows the actual number of bytes assigned to each pointer variable.

© 2012-2018 Microchip Technology Inc.

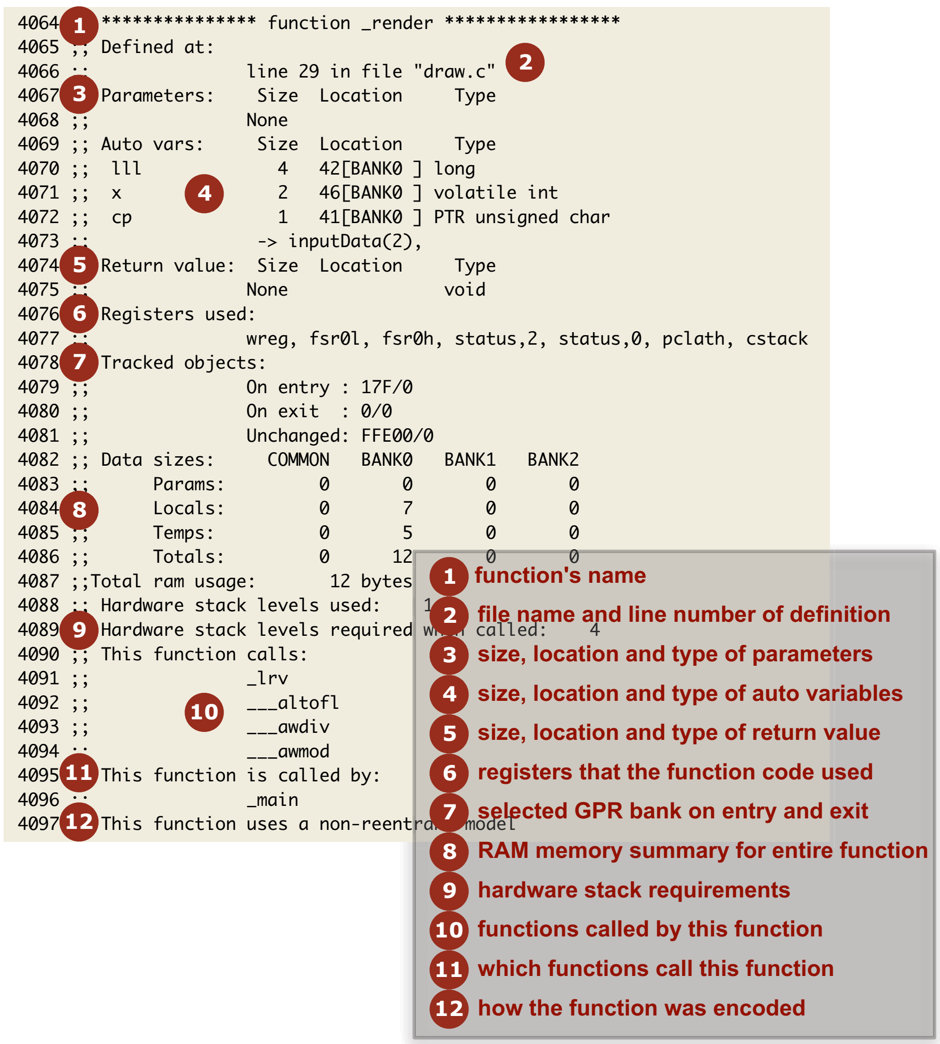
The tracked objects are generally not used. It indicates the known state of the currently selected RAM bank on entry to the function and at its exit points. It also indicates the bank selection bits that did, or did not, change in the function.

The hardware stack information shows how many stack levels were taken up by this function alone, and the total levels used by this function and any functions it calls. Note that this is only valid for functions that are have not been inlined.

Functions that use a non-reentrant model are those that allocate auto and parameter variables to a compiled stack and which are, as a result, not reentrant. If a function is marked as being reentrant, it allocates stack-based variables to the software stack and can be reentrantly called.

Functions marked as using a non-reentrant model are those which allocate auto and parameter variables to a compiled stack and which are, hence, not reentrant. If a function is marked as being reentrant, then it allocates stack-based variables to the software stack and can be reentrantly called.

FIGURE 5-2: FUNCTION INFORMATION



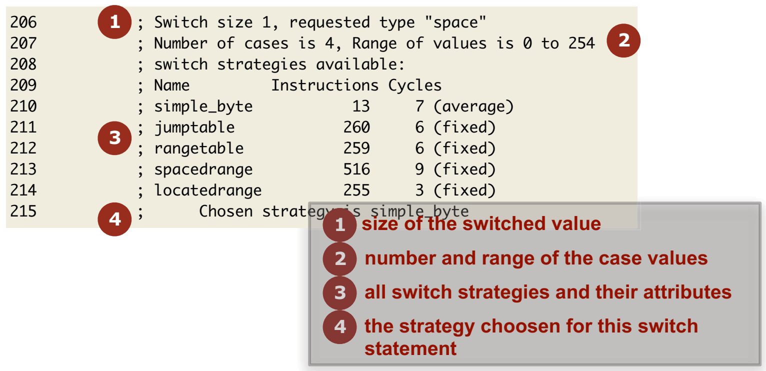
```
4064                ************** function _render ****************
4065 ;; Defined at:
4066 ;;              line 29 in file "draw.c"
4067    Parameters:    Size  Location     Type
4068 ;;              None
4069 ;; Auto vars:      Size  Location     Type
4070 ;;  lll              4   42[BANK0 ] long
4071 ;;  x                2   46[BANK0 ] volatile int
4072 ;;  cp               1   41[BANK0 ] PTR unsigned char
4073 ;;                -> inputData(2),
4074    Return value:  Size  Location     Type
4075 ;;              None                void
4076    Registers used:
4077 ;;              wreg, fsr0l, fsr0h, status,2, status,0, pclath, cstack
4078    Tracked objects:
4079 ;;              On entry : 17F/0
4080 ;;              On exit  : 0/0
4081 ;;              Unchanged: FFE00/0
4082 ;; Data sizes:     COMMON   BANK0   BANK1   BANK2
4083 ;;      Params:         0       0       0       0
4084          Locals:         0       7       0       0
4085 ;;      Temps:          0       5       0       0
4086 ;;      Totals:         0      12       0       0
4087 ;;Total ram usage:       12 bytes
4088 ;; Hardware stack levels used:    1
4089    Hardware stack levels required w   called:    4
4090 ;; This function calls:
4091 ;;              _lrv
4092 ;;              ___altofl
4093 ;;              ___awdiv
4094 ;;              ___awmod
4095    This function is called by:
4096 ;;              _main
4097    This function uses a non-reentra   model
```

1. function's name
2. file name and line number of definition
3. size, location and type of parameters
4. size, location and type of auto variables
5. size, location and type of return value
6. registers that the function code used
7. selected GPR bank on entry and exit
8. RAM memory summary for entire function
9. hardware stack requirements
10. functions called by this function
11. which functions call this function
12. how the function was encoded

5.4.4 Switch Statement Information

Along with the generated code for each `switch` statement is information about how that statement was encoded. There are several strategies the compiler can use for switch statements. The compiler determines the appropriate strategy (see Section 4.6.3 "Switch Statements") or you can indicate a preference for a particular type of strategy using a pragma (see Section 4.14.3.10 "The #pragma switch Directive"). The information printed will look similar to that shown in Figure 5-3.

FIGURE 5-3: SWITCH STATEMENT INFORMATION



```
; Switch size 1, requested type "space"
; Number of cases is 4, Range of values is 0 to 254
; switch strategies available:
; Name         Instructions Cycles
; simple_byte           13     7 (average)
; jumptable            260     6 (fixed)
; rangetable           259     6 (fixed)
; spacedrange          516     9 (fixed)
; locatedrange         255     3 (fixed)
;      Chosen strategy is simple_byte
```

1
2
3
4
1 size of the switched value
2 number and range of the case values
3 all switch strategies and their attributes
4 the strategy choosen for this switch statement

5.4.5 Pointer Reference Graph

Other important information contained in the assembly list file is the pointer reference graph (look for *pointer list with targets:* in the list file). This is a list of each pointer contained in the program and each target the pointer can reference through the program. The size and type of each target is indicated, as well as the size and type of the pointer variable itself.

For example, the following shows a pointer called `task_tmr` in the C code. It is local to the function `timer_intr()`. It is also a pointer to an `unsigned int`, and it is one byte wide. There is only one target to this pointer and it is the member `timer_count` in the structure called `task`. This target variable resides in the BANK0 class and is two bytes wide.

```
timer_intr@task_tmr   PTR unsigned int  size(1); Largest target is 2
                          -> task.timer_count(BANK0[2]),
```

The pointer reference graph shows both pointers to data objects and pointers to functions.

© 2012-2018 Microchip Technology Inc.

5.4.6 Call Graph

The other important information in the assembly list file is the call graph. This is produced for all 8-bit devices, which can use a compiled stack to facilitate stack-based variables (function parameters, `auto` and temporary variables). See Section 4.5.2.2.1 "Object Size Limits", for more detailed information on compiled stack operation.

Call graph tables, showing call information on a function-by-function basis, are presented in the map file, followed by more traditional call graphs for the entire program. The call graphs are built by the code generator, and are used to allow overlapping of functions' auto-parameter blocks (APBs) in the compiled stack. The call graphs are not used when functions use the software stack (see Section 4.5.2.2.1 "Object Size Limits"). The call graphs are not used when functions use the software stack (see Section 4.5.2.2.1 "Object Size Limits"). You can obtain the following information from studying the call graph.

- The functions in the program that are "root" nodes marking the top of a call tree, and that are called spontaneously
- The functions that the linker deemed were called, or can have been called, during program execution (and those which were called indirectly via a pointer)
- The program's hierarchy of function calls
- The size of the auto and parameter areas within each function's APB
- The offset of each function's APB within the compiled stack
- The estimated call tree depth.

These features are discussed in sections that follow.

5.4.6.1 CALL GRAPH TABLES

A typical call graph table can look like the extract shown in Figure 5-4. Look for *Call Graph Tables:* in the list file.

FIGURE 5-4: CALL GRAPH FORM

```
Call Graph Tables:

 ---------------------------------------------------------------------------------
 (Depth) Function              Calls       Base Space   Used Autos Params    Refs
 ---------------------------------------------------------------------------------
 (0) _main                                                12     12      0   34134
                                              43 BANK0     5      5      0
                                               0 BANK1     7      7      0
                               _aOut
                             _initSPI
 ---------------------------------------------------------------------------------
 (1) _aOut                                                 2      0      2      68
                                               2 BANK0     2      0      2
                                 _SPI
                 _GetDACValue (ARG)
 ---------------------------------------------------------------------------------
 (1) _initSPI                                              0      0      0       0
 ---------------------------------------------------------------------------------
 (2) _SPI                                                  2      2      0      23
                                               0 BANK0     2      2      0
...

 Estimated maximum stack depth 6
 ---------------------------------------------------------------------------------
```

The graph table starts with the function `main()`. Note that the function name will always be shown in the assembly form, thus the function `main()` appears as the symbol `_main`. `main()` is always a root of a call tree. Interrupt functions will form separate trees.

All the functions that `main()` calls, or can call, are shown below the function name in the *Calls* column. So in this example, `main()` calls `aOut()` and `initSPI()`. These have been grouped in the orange box in the figure. If a star (`*`) appears next to the function's name, this implies the function has been called indirectly via a pointer. A function's inclusion into the call graph does not imply the function was actually called, but there is a possibility that the function was called. For example, code such as:

```
int test(int a) {
  if(a)
    foo();
  else
    bar();
}
```

will list `foo()` and `bar()` under `test()`, as either can be called. If a is always true, then the function `bar()` will never be called, even though it appears in the call graph.

In addition to the called functions, information relating to the memory allocated in the compiled stack for `main()` is shown. This memory will be used for the stack-based variables that are defined in `main()`, as well as a temporary location for the function's return value, if appropriate.

In the orange box for `main()` you can see that it defines 12 `auto` and temporary variable (under the *Autos* column). It defines no parameters – `main()` never has parameters – under the *Params* column. There is a total of 34134 references in the assembly code to local objects in `main()`, shown under the *Refs* column. The *Used* column indicates the total number of bytes of local storage, i.e., the sum of the *Autos* and *Params* columns.

Rather than the compiled stack being one block of memory in one memory space, it can be broken up into multiple blocks placed in different memory spaces to utilize all of the available memory on the target device. This breakdown is shown under the memory summary line for each function. In this example, it shows that 5 bytes of `auto` objects for `main()` are placed in the bank 0 component of the compiled stack (*Space* column), at an offset of 43 (*Base* column) into this stack. It also shows that 7 bytes of `auto` objects were placed in the bank 1 data component of the compiled stack at an offset of 0. The name listed under the *Space* column, is the same name as the linker class which will hold this section of the stack.

Below the information for `main()` (outside the orange box) you will see the same information repeated for the functions that `main()` called, i.e., `aOut()`and `initSPI()`. For clarity, only the first few functions of this program are shown in the figure.

Before the name of each function, and in brackets, is the call stack depth for that particular function. A function can be called from many places in a program, and it can have a different stack depth in the call graph at each call. The maximum call depth is always shown for a function, regardless of its position in the call table. The `main()` function will always have a depth of 0. The starting call depth for interrupt functions assumes a worst case and will start at the start depth of the previous tree plus one.

After each tree in the call graph, there is an indication of the maximum stack depth that might be realized by that tree. This stack depth is not printed if any functions in the graph use the software stack. (In that case, a single stack depth estimate is printed for the entire program at the end of the graphs.) In the example shown, the estimated maximum stack depth is 6. Check the associated data sheet for the depth of your device's

© 2012-2018 Microchip Technology Inc.

hardware stack (see Section 4.3.4 “Stacks”). The stack depth indicated can be used as a guide to the stack usage of the program. No definitive value can be given for the program’s total stack usage for several reasons:

- Certain parts of the call tree may never be reached, reducing that tree’s stack usage.
- The exact contribution of interrupt (or other) trees to the `main()` tree cannot be determined as the point in `main`’s call tree at which the interrupt (or other function invocation) will occur cannot be known. (The compiler assumes the worst case situation of interrupts occurring at the maximum `main()` depth.)
- The assembler optimizer may have replaced function calls with jumps to functions, reducing that tree’s stack usage.
- The assembler’s procedural abstraction optimizations can have added in calls to abstracted routines, increasing the stack depth. (Checks are made to ensure this does not exceed the maximum stack depth.)
- Functions which are inlined are not called, reducing the stack usage.

The compiler can be configured to manage the hardware stack for PIC10/12/16 devices only (see Section 3.7.1.22 “stackcall”). When this mode is selected, the compiler will convert calls to jumps if it thinks the maximum stack depth of the device is being exceeded. The stack depth estimate listed in the call table will reflect the stack savings made by this feature. Thus, the stack depth and call depth cannot be the same. Note that `main()` is jumped to by the runtime startup, not called; so, `main()` itself does not consume a level of stack (see also Section 4.10.2 “Runtime Startup Code”).

The code generator produces a warning if the maximum stack depth appears to have been exceeded and the stack is not being managed by the compiler. For the above reasons, this warning, too, is intended to be a only a guide to potential stack problems.

5.4.6.2 CALL GRAPH CRITICAL PATHS

Immediately prior to the call graph tables in the list file are the critical paths for memory usage identified in the call graphs. A critical path is printed for each memory space and for each call graph. Look for a line similar to *Critical Paths under _main in BANK0*, which, for this example, indicates the critical path for the `main` function (the root of one call graph) in bank 0 memory. There will be one call graph for the function `main` and another for each interrupt function. Each of these will appear for every memory space the device defines.

A critical path here represents the biggest range of APBs stacked together in a contiguous block. Essentially, it identifies those functions whose APBs are contributing to the program’s memory usage in that particular memory space. If you can reduce the memory usage of these functions in the corresponding memory space, then you will affect the program’s total memory usage in that memory space.

This information can be presented as follows.

```
3793 ;; Critical Paths under _main in BANK0
3794 ;;
3795 ;;   _main->_foobar
3796 ;;   _foobar->___flsub
3797 ;;   ___flsub->___fladd
```

In this example, it shows that of all the call graph paths starting from the function `main`, the path in which `main` calls `foobar`, which calls `flsub`, which calls `fladd`, is using the largest block of memory in bank 0 RAM. The exact memory usage of each function is shown in the call graph tables.

The memory used by functions that are not in the critical path will overlap entirely with that in the critical path. Reducing the memory usage of these will have no impact on the memory usage of the entire program.

5.4.6.3 CALL GRAPH GRAPHS

Following the call tables are the call graphs, which show the full call tree for `main()` and any interrupt functions. This is a subset of the information presented in the call tables, and it is shown in a different form. The call graphs will look similar to the one shown in Figure 5-5.

FIGURE 5-5: CALL GRAPH GRAPHS

```
 Call Graph Graphs:

_main (ROOT)
  _initSPI
  _aOut
    _SPI
    _GetDACValue
      ___ftadd
        ___ftpack
        ___ftmul (ARG)
...
```

Indentation is used to indicate the call depth. In the diagram, you can see that `main()` calls `aOut()`, which in turn calls `GetDACValue()`, which in turn calls the library function `__ftadd()`, etc. If a star (`*`) appears next to the function’s name, this implies that the function has been called indirectly via a pointer.

5.4.6.4 ARG NODES

In both the call trees and the call graph itself, you can see functions listed with the annotation `(ARG)` after its name. This implies that the call to that function at that point in the call graph is made to obtain an argument to another function. For example, in the following code snippet, the function `input()` is called to obtain an argument value to the function `process()`.

```
result = process(input(0x7));
```

For such code, if it were to appear inside the `main()` function, the call graph would contain the following.

```
_main (ROOT)
  _input
  _process
    _input (ARG)
```

This indicates that `main()` calls `input()` and `main()` also calls `process()`, but `input()` is also called as an argument expression to `process()`.

These argument nodes in the graph do *not* contribute to the overall stack depth usage of the program, but they are important for the creation of the compiled stack. The call depth stack usage of the tree indicated above would only be 1, not 2, even though the argument node function is at an indicated depth of 2. This is because there is no actual reentrancy in terms of an actual call and a return address being stored on the hardware stack.

The compiler must ensure that the parameter area for a function and any of its ‘argument functions’ must be at unique addresses in the compiled stack to avoid data corruption. Note that a function’s return value is also stored in its parameter area; so, that needs to be considered by the compiler even if there are no parameters. A function’s parameters become ‘active’ before the function is actually called (when the arguments are passed) and its return value location remains ‘active’ after the function has returned (while that return value is being processed).

© 2012-2018 Microchip Technology Inc.

In terms of data allocation, the compiler assumes a function has been ‘called’ the moment that any of its parameters have been loaded and is still considered ‘called’ up until its return value is no longer required. Thus, the definition for ‘reentrancy’ is much broader when considering data allocation than it is when considering stack call depth.

5.4.7 Symbol Table

At the bottom of each assembly list file is a symbol table. This differs from the symbol table presented in the map file (see Section 6.4.2.6 “Symbol Table”) in two ways:

- It lists only those symbols associated with the assembly module from which the list file is produced (as opposed to the entire program); and
- It lists local as well as global symbols associated with that module.

Each symbol is listed along with the address it has been assigned.

NOTES:

© 2012-2018 Microchip Technology Inc.

Chapter 6. Linker

6.1 INTRODUCTION

This chapter describes the theory behind, and the usage of, the linker.

The application name of the linker is `hlink`. In most instances it will not be necessary to invoke the linker directly, as the compiler driver, `xc8-cc`, will automatically execute the linker with all the necessary arguments. Using the linker directly is not simple, and should be attempted only by those with a sound knowledge of the compiler, and linking in general. The compiler often makes assumptions about the way in which the program will be linked. If the psects are not linked correctly, code failure can result.

If it is absolutely necessary to use the linker directly, the best way to start is to copy the linker arguments constructed by the compiler driver, and modify them as is appropriate. This ensures that the necessary startup module and arguments are present.

The following topics are examined in this chapter of the MPLAB XC8 C Compiler User's Guide:

- Operation
- Relocation and Psects
- Map Files

6.2 OPERATION

A command to the linker takes the following form:

```
hlink [options] files
```

The *`options`* are zero or more linker options, each of which modifies the behavior of the linker in some way. The *`files`* is one or more object files and zero or more library files (`.a` extension).

The options recognized by the linker are listed in Table 6-1 and discussed in the following paragraphs.

TABLE 6-1: LINKER COMMAND-LINE OPTIONS

Option	Effect
`-8`	use 8086 style segment: offset address form
`-A`*class=low-high*`,...`	specify address ranges for a class
`-C`*psect=class*	specify a class name for a global psect
`-C`*baseaddr*	produce binary output file based at *baseaddr*
`-D`*class=delta*	specify a class delta value
`-D`*symfile*	produce old-style symbol file
`-E`*errfile*	write error messages to *errfile*
`-F`	produce `.obj` file with only symbol records
`-G` *spec*	specify calculation for segment selectors
`-H` *symfile*	generate symbol file
`-H+` *symfile*	generate enhanced symbol file
`-I`	ignore undefined symbols
`-J` *num*	set maximum number of errors before aborting
`-K`	prevent overlaying function parameter and auto areas
`-L`	preserve relocation items in `.obj` file
`-LM`	preserve segment relocation items in `.obj` file
`-N`	sort symbol table in map file by address order
`-Nc`	sort symbol table in map file by class address order
`-Ns`	sort symbol table in map file by space address order
`-M`*mapfile*	generate a link map in the named file
`-O`*outfile*	specify name of output file
`-P`*spec*	specify psect addresses and ordering
`-Q`*processor*	specify the device type (for cosmetic reasons only)
`-S`	inhibit listing of symbols in symbol file
`-S`*class=limit[,bound]*	specify address limit, and start boundary for a class of psects
`-U`*symbol*	pre-enter symbol in table as undefined
`-V`*avmap*	use file *avmap* to generate an *Avocet* format symbol file
`-W`*warnlev*	set warning level (-9 to 9)
`-W`*width*	set map file width (>=10)
`-X`	remove any local symbols from the symbol file
`-Z`	remove trivial local symbols from the symbol file
`--DISL=`*`list`*	specify disabled messages
`--EDF=`*`path`*	specify message file location
`--EMAX=`*`number`*	specify maximum number of errors
`--NORLF`	do not relocate list file
`--VER`	print version number and stop

© 2012-2018 Microchip Technology Inc.

If the standard input is a file, then this file is assumed to contain the command-line argument. Lines can be broken by leaving a *backslash* `\` at the end of the preceding line. In this fashion, `hlink` commands of almost unlimited length can be issued. For example, a link command file called `x.lnk` and containing the following text:

```
-Z -OX.OBJ -MX.MAP \
-Ptext=0,data=0/,bss,nvram=bss/. \
X.OBJ Y.OBJ Z.OBJ
```

can be passed to the linker by one of the following:

```
hlink @x.lnk
hlink < x.lnk
```

Several linker options require memory addresses or sizes to be specified. The syntax for all of these is similar. By default, the number is interpreted as a decimal value. To force interpretation as a HEX number, a trailing `H`, or `h`, should be added. For example, `765FH` will be treated as a HEX number.

6.2.1 -A*class =low-high*,...

`-A` option allows one or more of the address ranges to be assigned a linker class, so that psects can be placed anywhere in this class. Ranges do not need to be contiguous. For example:

```
-ACODE=1020h-7FFEh,8000h-BFFEh
```

specifies that the class called `CODE` represents the two distinct address ranges shown.

Psect can be placed anywhere in these ranges by using the `-P` option and the class name as the address (see Section 6.2.18 “-Pspec”), for example:

```
-PmyText=CODE
```

Alternatively, any psect that is made part of the `CODE` class, when it is defined (see Section 5.2.9.3.3 “Class”), will automatically be linked into this range, unless they are explicitly located by another option.

Where there are a number of identical, contiguous address ranges, they can be specified with a repeat count following an `x` character. For example:

```
-ACODE=0-0FFFFhx16
```

specifies that there are 16 contiguous ranges, each 64k bytes in size, starting from address zero. Even though the ranges are contiguous, no psect will straddle a 64k boundary, thus this can result in different psect placement to the case where the option

```
-ACODE=0-0FFFFFh
```

had been specified, which does not include boundaries on 64k multiples.

The `-A` option does not specify the memory space associated with the address. Once a psect is allocated to a class, the space value of the psect is then assigned to the class (see Section 5.2.9.3.17 “Space”).

6.2.2 -C*psect=class*

This option allows a psect to be associated with a specific class. Normally, this is not required on the command line because psect classes are specified in object files (see Section 5.2.9.3.3 “Class”).

6.2.3 -D*class=delta*

This option allows the delta value for psects that are members of the specified class to be defined. The delta value should be a number. It represents the number of bytes per addressable unit of objects within the psects. Most psects do not need this option as they are defined with a delta value (see Section 5.2.9.3.4 “Delta”).

6.2.4 -D*symfile*

Use this option to produce an old-style symbol file. An old-style symbol file is an ASCII file, where each line has the link address of the symbol followed by the symbol name.

6.2.5 -E*errfile*

Error messages from the linker are written to the standard error stream. Under DOS, there is no convenient way to redirect this to a file (the compiler drivers will redirect standard errors, if standard output is redirected). This option makes the linker write all error messages to the specified file instead of the screen, which is the default standard error destination.

6.2.6 -F

Normally the linker will produce an object file that contains both program code and data bytes, and symbol information. Sometimes you want to produce a symbol-only object file that can be used again in a subsequent linker run to supply symbol values. The `-F` option suppresses data and code bytes from the output file, leaving only the symbol records.

This option can be used when part of one project (i.e., a separate build) is to be shared with another, as might be the case with a bootloader and application. The files for one project are compiled using this linker option to produce a symbol-only object file. That file is then linked with the files for the other project.

6.2.7 -G*spec*

When linking programs using segmented, or bank-switched psects, there are two ways the linker can assign segment addresses, or selectors, to each segment. A segment is defined as a contiguous group of psects where each psect in sequence has both its link and load addresses concatenated with the previous psect in the group. The segment address or selector for the segment is the value derived when a segment type relocation is processed by the linker.

By default the segment selector is generated by dividing the base load address of the segment by the relocation quantum of the segment, which is based on the `reloc=` flag value given to psects at the assembler level (see Section 5.2.9.3.15 "Reloc"). The `-G` option allows an alternate method for calculating the segment selector. The argument to `-G` is a string similar to:

```
A /10h-4h
```

where *A* represents the load address of the segment and `/` represents division. This means "Take the load address of the psect, divide by 10 HEX, then subtract 4." This form can be modified by substituting *N* for *A*, `*` for `/` (to represent multiplication) and adding, rather than subtracting, a constant. The token *N* is replaced by the ordinal number of the segment, which is allocated by the linker. For example:

```
N*8+4
```

means "take the segment number, multiply by 8, then add 4." The result is the segment selector. This particular example would allocate segment selectors in the sequence 4, 12, 20, ... for the number of segments defined.

The selector of each psect is shown in the map file (see Section 6.4.2.2 "Psect Information Listed by Module").

6.2.8 -H*symfile*

This option instructs the linker to generate a symbol file. The optional argument *`symfile`* specifies the name of the file to receive the data. The default file name is `l.sym`.

6.2.9 -H+*symfile*

This option will instruct the linker to generate an enhanced symbol file, which provides, in addition to the standard symbol file, class names associated with each symbol and a segments section which lists each class name and the range of memory it occupies. This format is recommended if the code is to be run in conjunction with a debugger. The optional argument *symfile* specifies a file to receive the symbol file. The default file name is `l.sym`.

6.2.10 -I

Usually, failure to resolve a reference to an undefined symbol is a fatal error. Using this option causes undefined symbols to be treated as warnings, instead.

6.2.11 -J*errcount*

The linker will stop processing object files after a certain number of errors (other than warnings). The default number is 10, but the `-J` option allows this to be altered.

6.2.12 -K

This option should not be used. It is for older compilers that use a compiled stack. In those cases, the linker tries to overlay function auto and parameter blocks to reduce the total amount of RAM required. For debugging purposes, that feature can be disabled with this option. However, doing so will increase the data memory requirements.

This option has no effect when compiled stack allocation is performed by the code generator. This is the case for OCG (PRO-Standard-Free mode) compilers, and this option should not be used.

6.2.13 -L

When the linker produces an output file it does not usually preserve any relocation information, since the file is now absolute. In some circumstances a further “relocation” of the program is done at load time. The `-L` option generates, in the output file, one null relocation record for each relocation record in the input.

6.2.14 -LM

Similar to the above option, this preserves relocation records in the output file, but only segment relocations.

6.2.15 -M*mapfile*

This option causes the linker to generate a link map in the named file, or on the standard output, if the file name is omitted. The format of the map file is illustrated in Section 6.4 “Map Files”.

6.2.16 -N, -Ns and-Nc

By default the symbol table in the map file is sorted by name. The `-N` option causes it to be sorted numerically, based on the value of the symbol. The `-Ns` and `-Nc` options work similarly except that the symbols are grouped by either their space value, or class.

6.2.17 -O*outfile*

This option allows specification of an output file name for the object file.

6.2.18 -P*spec*

Psects are linked together and assigned addresses based on information supplied to the linker via `-P` options. The argument to the `-P` option consists of *comma*-separated sequences with the form:

```
-Ppsect=linkaddr+min/loadaddr+min,psect=linkaddr/loadaddr,...
```

All values can be omitted, in which case a default will apply, depending on previous values. The link address of a psect is the address at which it can be accessed at runtime. The load address is the address at which the psect starts within the output file (HEX or binary file etc.), but it is rarely used by 8-bit PIC devices. The addresses specified can be numerical addresses, the names of other psects, classes, or special tokens.

Examples of the basic and most common forms of this option are:

```
-Ptext10=02000h
```

which places (links) the starting address of psect `text10` at address 0x2000;

```
-PmyData=AUXRAM
```

which places the psect `myData` anywhere in the range of addresses specified by the linker class `AUXRAM` (which would need to be defined using the `-A` option, see Section 6.2.1 “-Aclass =low-high,...”), and

```
-PstartCode=0200h,endCode
```

which places `endCode` immediately after the end of `startCode`, which will start at address 0x200.

The additional variants of this option are rarely needed; but, are described below.

If a link or load address cannot be allowed to fall below a minimum value, the `+min`, suffix indicates the minimum address.

If the link address is a negative number, the psect is linked in reverse order with the top of the psect appearing at the specified address minus one. Psects following a negative address will be placed before the first psect in memory.

If the load address is omitted entirely, it defaults to the link address. If the *slash* `/` character is supplied with no address following, the load address will concatenate with the load address of the previous psect. For example, after processing the option:

```
-Ptext=0,data=0/,bss
```

the `text` psect will have a link and load address of 0; `data` will have a link address of 0 and a load address following that of `text`. The `bss` psect will concatenate with `data` in terms of both link and load addresses.

A load address specified as a *dot* character, “`.`” tells the linker to set the load address to be the same as the link address.

The final link and load address of psects are shown in the map file (see Section 6.4.2.2 “Psect Information Listed by Module”).

6.2.19 -Q*processor*

This option allows a device type to be specified. This is purely for information placed in the map file. The argument to this option is a string describing the device. There are no behavioral changes attributable to the device type.

6.2.20 -S

This option prevents symbol information relating from being included in the symbol file produced by the linker. Segment information is still included.

© 2012-2018 Microchip Technology Inc.

6.2.21 -S*class =limit[,bound]*

A class of psects can have an upper address limit associated with it. The following example places a limit on the maximum address of the `CODE` class of psects to one less than 400h.

```
-SCODE=400h
```

Note that to set an upper limit to a psect, this must be set in assembler code using the psect `limit` flag, (see Section 5.2.9.3.8 “Limit”).

If the bound (boundary) argument is used, the class of psects will start on a multiple of the bound address. This example below places the `FARCODE` class of psects at a multiple of 1000h, but with an upper address limit of 6000h.

```
-SFARCODE=6000h,1000h
```

6.2.22 -U*symbol*

This option will enter the specified symbol into the linker’s symbol table as an undefined symbol. This is useful for linking entirely from libraries, or for linking a module from a library where the ordering has been arranged so that by default a later module will be linked.

6.2.23 -V*avmap*

To produce an Avocet format symbol file, the linker needs to be given a map file to allow it to map psect names to Avocet memory identifiers. The avmap file will normally be supplied with the compiler, or created automatically by the compiler driver as required.

6.2.24 -W*num*

The `-W` option can be used to set the warning level, in the range -9 to 9, or the width of the map file, for values of *num* >= 10.

`-W9` will suppress all warning messages. `-W0` is the default. Setting the warning level to -9 (`-W-9`) will give the most comprehensive warning messages.

6.2.25 -X

Local symbols can be suppressed from a symbol file with this option. Global symbols will always appear in the symbol file.

6.2.26 -Z

Some `local` symbols are compiler generated and not of interest in debugging. This option will suppress from the symbol file all local symbols that have the form of a single alphabetic character, followed by a digit string. The set of letters that can start a trivial symbol is currently “`klfLSu`“. The `-Z` option will strip any local symbols starting with one of these letters, and followed by a digit string.

6.2.27 --DISL=*message numbers* Disable Messages

This option is mainly used by the command-line driver, `xc8-cc`, to disable particular message numbers. It takes a *comma*-separate list of message numbers that will be disabled during compilation.

See Section 3.6 “Compiler Messages” for full information about the compiler’s messaging system.

6.2.28 --EDF=*message file*: Set Message File Path

This option is mainly used by the command-line driver, `xc8-cc`, to specify the path of the message description file. The default file is located in the `dat` directory in the compiler’s installation directory.

See Section 3.6 “Compiler Messages” for full information about the compiler’s messaging system.

6.2.29 --EMAX=*number*: Specify Maximum Number of Errors

This option is mainly used by the command-line driver, `xc8-cc`, to specify the maximum number of errors that can be encountered before the assembler terminates. The default number is 10 errors.

This option is applied if compiling using `xc8-cc`, the command-line driver and the `-fmax-errors` driver option (see Section 3.7.4.1 “max-errors”).

See Section 3.6 “Compiler Messages” for full information about the compiler’s messaging system.

6.2.30 --NORLF: Do Not Relocate List File

Use of this option prevents the linker applying fixups to the assembly list file produced by the assembler. This option is normally using by the command line driver, `xc8-cc`, when performing pre-link stages, but is omitted when performing the final link step so that the list file shows the final absolute addresses.

If you are attempting to resolve fixup errors, this option should be disabled so as to fix up the assembly list file and allow absolute addresses to be calculated for this file. If the compiler driver detects the presence of a preprocessor macro `__DEBUG`, which is equated to 1, then this option will be disabled when building. This macro is set when choosing a *Debug* build in MPLAB X IDE. So, always have this option selected if you encounter such errors.

6.2.31 --VER: Print Version Number

This option prints information stating the version and build of the linker. The linker will terminate after processing this option, even if other options and files are present on the command line.

© 2012-2018 Microchip Technology Inc.

6.3 RELOCATION AND PSECTS

This section looks at the input files that the linker has to work with.

The linker can read both relocatable object files and object-file libraries (`.lib` extension). The library files are a collection of object files packaged into a single unit. So, essentially, we only need consider the format of object files.

Each object file consists of a number of records. Each record has a type that indicates what sort of information it holds. Some record types hold general information about the target device and its configuration, other records types can hold data; and others, program debugging information, for example.

A lot of the information in object files relates to psects. Psects are an assembly domain construct and are essentially a block of something, either instructions or data. Everything that contributes to the program is located in a psect. See Section 5.2.8 “Program Sections” for an introductory guide. There is a particular record type that is used to hold the data in psects. The bulk of each object file consists of psect records containing the executable code and variables etc.

We are now in a position to look at the fundamental tasks the linker performs, which are:

- combining all the relocatable object files into one
- relocation of psects contained in the object files into memory
- fixup of symbolic references in the psects

There are at least two object files that are passed to the linker. One is produced from all the C code in the project, including C library code. There is only one of these files since the code generator compiles and combines all the C code of the program and produces just the one assembly output. The other file passed to the linker will be the object code produced from the runtime startup code (see Section 3.4.2 “Startup and Initialization”).

If there are assembly source files in the project, then there will also be one object file produced for each source file, and these will be passed to the linker. Existing object files, or object file libraries can also be specified in a project; and if present, these will also be passed to the linker.

The output of the linker is also an object file, but there is only a single file produced. The file is absolute, since relocation will have been performed by the linker. The output file consists of the information from all input object files, merged together.

Relocation consists of placing the psect data into the memory of the target device.

The target device memory specification is passed to the linker by the way of linker options. These options are generated by the command-line driver, `xc8-cc`. There are no linker scripts or means of specifying options in any source file. The default linker options rarely need adjusting. But, they can be changed, if required, with caution, using the driver option `-Wl`, (see 3.7.11.6 Wl: Linker Option).

When the psects are placed at actual memory locations, symbolic references made in the psects data can be replaced with absolute values. This is a process called fixup.

For each psect record in the object file, there is a corresponding relocation record that indicates which bytes (or bits) in the psect record need to be adjusted once relocation is complete. The relocation records also specify how the values are to be determined. A linker fixup overflow error can occur if the value determined by the linker is too large to fit in the “hole” reserved for the value in the psect. See (477) fixup overflow in expression (location 0x* (0x*+*), size *, value 0x*) (Linker) for information on finding the cause of these errors.

6.4 MAP FILES

The map file contains information relating to the relocation of psects and the addresses assigned to symbols within those psects.

6.4.1 Generation

If compilation is being performed via MPLAB X IDE, a map file is generated by default. If you are using the driver from the command line, use the `-Wl,-Map` option to request that the map file be produced (see Section 3.7.12 "Mapped Linker Options"). Map files have the extension `.map`.

Map files are produced by the linker. If the compilation process is stopped before the linker is executed, then no map file is produced. The linker produces a map file, even if it encounters errors. The file, then, helps you track down the cause of the errors. However, if the linker ultimately reports `too many errors`, the linker did not run to completion, the map file was not created. You can use the `-fmax-errors` option (see Section 3.7.4.1 "max-errors") on the command line to increase the number of errors encountered before the linker exits.

6.4.2 Contents

The sections in the map file, in order of appearance, are as follows.

- the compiler name and version number
- a copy of the command line used to invoke the linker
- the version number of the object code in the first file linked
- the machine type
- a psect summary sorted by the psect's parent object file
- a psect summary sorted by the psect's CLASS
- a segment summary
- unused address ranges summary
- the symbol table
- information summary for each function
- information summary for each module

Portions of an example map file, along with explanatory text, are shown in the following sections.

6.4.2.1 GENERAL INFORMATION

At the top of the map file is general information relating to the execution of the linker.

When analyzing a program, always confirm the compiler version number shown in the map file if you have more than one compiler version installed to ensure the desired compiler is being executed.

The device selected with the `-mcpu` option (Section 3.7.1.5 "cpu"), or the one selected in your IDE, should appear after the Machine type entry.

The *object code version* relates to the file format used by relocatable object files produced by the assembler. Unless either the assembler or linker have been updated independently, this should not be of concern.

A typical map file can begin something like the following. This example has been cut down for clarity.

```
--edf=/home/jeff/Microchip/XC8/1.00/dat/en_msgs.txt -cs -h+main.sym -z \
  -Q16F946 -ol.obj -Mmain.map -ver=XC8 -ACONST=00h-0FFhx32 \
  -ACODE=00h-07FFhx4 -ASTRCODE=00h-01FFFh -AENTRY=00h-0FFhx32 \
  -ASTRING=00h-0FFhx32 -ACOMMON=070h-07Fh -ABANK0=020h-06Fh \
  -ABANK1=0A0h-0EFh -ABANK2=0120h-016Fh -ABANK3=01A0h-01EFh \
  -ARAM=020h-06Fh,0A0h-0EFh,0120h-016Fh,01A0h-01EFh \
  -AABS1=020h-07Fh,0A0h-0EFh,0120h-016Fh,01A0h-01EFh -ASFR0=00h-01Fh \
  -ASFR1=080h-09Fh -ASFR2=0100h-011Fh -ASFR3=0180h-019Fh \
  -preset_vec=00h,intentry,init,end_init -ppowerup=CODE -pfunctab=CODE \
  -ACONFIG=02007h-02007h -pconfig=CONFIG -DCONFIG=2 -AIDLOC=02000h-02003h \
  -pidloc=IDLOC -DIDLOC=2 -AEEDATA=00h-0FFh/02100h -peeprom_data=EEDATA \
  -DEEDATA=2 -DCODE=2 -DSTRCODE=2 -DSTRING=2 -DCONST=2 -DENTRY=2 -k \
  startup.obj main.obj

Object code version is 3.10

Machine type is 16F946
```

The *Linker command line* shows all the command-line options and files that were passed to the linker for the last build. Remember, these are linker options, not command-line driver options.

The linker options are necessarily complex. Fortunately, they rarely need adjusting from their default settings. They are formed by the command-line driver, `xc8-cc`, based on the selected target device and the specified driver options. You can often confirm that driver options were valid by looking at the linker options in the map file. For example, if you ask the driver to reserve an area of memory, you should see a change in the linker options used.

If the default linker options must be changed, this can be done indirectly through the driver using the driver `-Wl` option (see Section 3.7.12 “Mapped Linker Options”). If you use this option, always confirm the change appears correctly in the map file.

6.4.2.2 PSECT INFORMATION LISTED BY MODULE

The next section in the map file lists those modules that have made a contribution to the output, and information regarding the psects that these modules have defined. See Section 4.15.1 “Compiler-Generated Psects” for an introductory explanation of psects.

This section is heralded by the line that contains the headings:

```
Name   Link  Load  Length  Selector  Space  Scale
```

Under this on the far left is a list of object files. These object files include both files generated from source modules and those that were extracted from object library files (`.a` extension). In the latter case, the name of the library file is printed before the object file list. Note that since the code generator combines all C source files (and p-code libraries), there is only one object file representing the entire C part of the program. The object file corresponding to the runtime startup code is normally present in this list.

The information in this section of the map file can be used to confirm that a module is making a contribution to the output file and to determine the exact psects that each module defines.

Shown are all the psects (under the *Name* column) that were linked into the program from each object file, and information about that psect.

The linker deals with two kinds of addresses: link and load. Generally speaking, the link address of a psect is the address by which it is accessed at runtime.

The load address, which is often the same as the link address, is the address at which the psect starts within the output file (HEX or binary file etc.). If a psect is used to hold bits, the load address is irrelevant and is, instead, used to hold the link address (in bit units) converted into a byte address.

The *Length* of the psect is shown in the units that are used by that psect.

The *Selector* is less commonly used and is of no concern when compiling for PIC devices.

The *Space* field is important as it indicates the memory space in which the psect was placed. For Harvard architecture machines, with separate memory spaces (such as the PIC10/12/16 devices), this field must be used in conjunction with the address to specify an exact storage location. A space of 0 indicates the program memory, and a space of 1 indicates the data memory (see Section 5.2.9.3.17 "Space").

The *Scale* of a psect indicates the number of address units per byte. This remains blank if the scale is 1, and shows 8 for psects that hold bit objects. The load address of psects that hold bits is used to display the link address converted into units of bytes, rather than the load address (see Section 5.2.9.3.2 "Bit").

For example, the following appears in a map file.

```
         Name  Link  Load  Length Selector  Space  Scale
ext.obj  text    3A    3A      22       30      0
         bss     4B    4B      10       4B      1
         rbit    50     A       2        0      1      8
```

This indicates that one of the files that the linker processed was called `ext.obj`. (This can have been derived from C code or a source file called `ext.s`.)

This object file contained a `text` psect, as well as psects called `bss` and `rbit`.

The psect `text` was linked at address 3A and `bss` at address 4B. At first glance, this seems to be a problem, given that text is 22 words long. However, they are in different memory areas, as indicated by the space flag (0 for `text` and 1 for `bss`), and so they do not occupy the same memory.

The psect `rbit` contains bit objects, and this can be confirmed by looking at the scale value, which is 8. Again, at first glance it seems that there could be an issue with `rbit` linked over the top of `bss`. Their space flags are the same, but since `rbit` contains bit objects, its link address is in units of bits. The load address field of `rbit` psect displays the link address converted to byte units, i.e., 50h/8 => Ah.

Underneath the object file list there can be a label *COMMON*. This shows the contribution to the program from program-wide psects, in particular that used by the compiled stack.

6.4.2.3 PSECT INFORMATION LISTED BY CLASS

The next section in the map file shows the same psect information but grouped by the psects' class.

This section is heralded by the line that contains the headings:

```
TOTAL   Name  Link  Load  Length
```

Under this are the class names followed by those psects which belong to this class (see Section 5.2.9.3.3 "Class"). These psects are the same as those listed by module in the above section; there is no new information contained in this section, just a different presentation.

© 2012-2018 Microchip Technology Inc.

6.4.2.4 SEGMENT LISTING

The class listing in the map file is followed by a listing of segments. Typically this section of the map file can be ignored by the user.

A segment is a conceptual grouping of contiguous psects in the same memory space, and is used by the linker as an aid in psect placement. There is no segment assembler directive and segments cannot be controlled in any way.

This section is heralded by the line that contains the headings:

```
SEGMENTS   Name  Load  Length  Top  Selector  Space  Class
```

The name of a segment is derived from the psect in the contiguous group with the lowest link address. This can lead to confusion with the psect with the same name. Do not read psect information from this section of the map file.

Again, this section of the map file can be ignored.

6.4.2.5 UNUSED ADDRESS RANGES

The last of the memory summaries show the memory that has not been allocated, and is unused. The linker is aware of any memory allocated by the code generator (for absolute variables), and so this free space is accurate.

This section follows the heading:

```
UNUSED ADDRESS RANGES
```

and is followed by a list of classes and the memory that is still available in each class. If there is more than one memory range available in a class, each range is printed on a separate line. Any paging boundaries located within a class are not displayed. But, the column *Largest block* shows the largest contiguous free space (which takes into account any paging in the memory range). If you are looking to see why psects cannot be placed into memory (e.g., cant-find-space type errors) then this is important information to study.

Note that the memory associated with a class can overlap that in others, thus the total free space is not simply the addition of all the unused ranges.

6.4.2.6 SYMBOL TABLE

The next section in the map file alphabetically lists the global symbols that the program defines. This section has the heading:

```
Symbol Table
```

As always with the linker, any C-derived symbol is shown with its assembler-equivalent symbol name (see Section 4.12.3 "Interaction between Assembly and C Code").

The symbols listed in this table are:

- Global assembly labels
- Global `EQU` /`SET` assembler directive labels
- Linker-defined symbols

Assembly symbols are made global via the `GLOBAL` assembler directive, see Section 5.2.9.1 "GLOBAL" for more information.

Linker-defined symbols act like `EQU` directives. However, they are defined by the linker during the link process, and no definition for them appears in any source or intermediate file (see Section 4.15.6 "Linker-Defined Symbols").

Each symbol is shown with the psect in which it is defined and the value (usually an address) it has been assigned. There is not any information encoded into a symbol to indicate whether it represents code or data – nor in which memory space it resides.

If the psect of a symbol is shown as `(abs)`, this implies that the symbol is not directly associated with a psect. Such is the case for absolute C variables, or any symbols that are defined using an `EQU` directive in assembly.

Note that a symbol table is also shown in each assembler list file. (See Section 3.7.10 "Mapped Assembler Options" for information on generating these files.) These differ to that shown in the map file as they also list local symbols, and they only show symbols defined in the corresponding module.

6.4.2.7 FUNCTION INFORMATION

Following the symbol table is information relating to each function in the program. This information is identical to the function information displayed in the assembly list file. However, the information from all functions is collated in the one location. See Section 5.4.3 "Function Information" for detailed descriptions of this information.

6.4.2.8 MODULE INFORMATION

The final section in the map file shows code usage summaries for each module. Each module in the program will show information similar to the following.

```
Module       Function           Class        Link     Load     Size
main.c
             init               CODE         07D8     0000     1
             main               CODE         07E5     0000     13
             getInput           CODE         07D9     0000     4

main.c estimated size: 18
```

The module name is listed (`main.c` in the above example). The special module name `shared` is used for data objects allocated to program memory and to code that is not specific to any particular module.

Next, the user-defined and library functions defined by each module are listed along with the class in which that psect is located (see Section 4.15.2 "Default Linker Classes"), the psect's link and load address, and its size (shown as bytes for PIC18 devices and words for other 8-bit devices).

After the function list is an estimated size of the program memory used by that module.

© 2012-2018 Microchip Technology Inc.

Chapter 7. Utilities

7.1 INTRODUCTION

This chapter discusses some of the utility applications that are bundled with the compiler.

The applications discussed in this chapter are those more commonly used, but you do not typically need to execute them directly. Most of their features are invoked indirectly by the command line driver that is based on the command-line arguments or MPLAB X IDE project property selections.

The following applications are described in this chapter of the MPLAB XC8 C Compiler User's Guide:

- Librarian
- HEXMATE
- Hash Functions

7.2 LIBRARIAN

The librarian program, `xc8-ar`, has the function of combining several intermediate files into a single file, known as a library or archive file. Libraries are easier to manage and might consume less disk space that the individual files.

The librarian can build all library types needed by the compiler and can detect the format of existing libraries.

7.2.1 Using the Librarian

The librarian program is called `xc8-ar`, and has the following basic command format:

```
xc8-ar [options] file.a [file1.p1 file2.p1...]
```

where *`file.a`* represents the library being created or edited. The following files, if required, are the modules of the library that is required by the command specified.

The *`options`* is zero or more options, shown in Table 7-1, that control the program.

TABLE 7-1: LIBRARIAN COMMAND-LINE OPTIONS

Option	Effect
`-d`	Delete module
`-m`	Re-order modules
`-p`	List modules
`-r`	Replace modules
`-x`	Extract modules
`--target`	Specify target device

When replacing or extracting modules, the names of the modules to be replaced or extracted must be specified. If no names are supplied, all the modules in the library will be replaced or extracted respectively.

Creating a library file or adding a file to an existing library is performed by requesting the librarian to replace the module in the library. Since the module is not present, it will be appended to the library. The librarian creates libraries with the modules in the order in which they were given on the command line. When updating a library, the order of the modules is preserved. Any modules added to a library will be appended to the end.

The ordering of the modules in a library is significant to the linker. If a library contains a module that references a symbol defined in another module in the same library, the module defining the symbol should come after the module referencing the symbol.

When using the -d option, the specified modules will be deleted from the library. In this instance, it is an error not to supply any module names.

The `-p` option will list the modules within the library file.

The `-m` option takes a list of module names and re-orders the matching modules in the library file so that they have the same order as the one listed on the command line. Modules that are not listed are left in their existing order, and will appear after the re-ordered modules.

7.2.1.1 EXAMPLES

Here are some examples of usage of the librarian. The following command:

```
xc8-ar -r myPicLib.a ctime.p1 init.p1
```

creates a library called `myPicLib.a` that contains the modules `ctime.p1` and `init.p1`

The following command deletes the object module `a.p1` from the library `lcd.a`:

```
xc8-ar -d lcd.a a.p1
```

© 2012-2018 Microchip Technology Inc.

7.3 HEXMATE

The hexmate utility is a program designed to manipulate Intel HEX files. hexmate is a post-link stage utility that is automatically invoked by the compiler driver, and that provides the facility to:

- Calculate and store variable-length hash values
- Fill unused memory locations with known data sequences
- Merge multiple Intel HEX files into one output file
- Convert INHX32 files to other INHX formats (e.g., INHX8M)
- Detect specific or partial opcode sequences within a HEX file
- Find/replace specific or partial opcode sequences
- Provide a map of addresses used in a HEX file
- Change or fix the length of data records in a HEX file
- Validate checksums within Intel HEX files.

Typical applications for hexmate might include:

- Merging a bootloader or debug module into a main application at build time
- Calculating a checksum or CRC value over a range of program memory and storing its value in program memory or EEPROM
- Filling unused memory locations with an instruction to send the PC to a known location if it gets lost
- Storage of a serial number at a fixed address
- Storage of a string (e.g., time stamp) at a fixed address
- Store initial values at a particular memory address (e.g., initialize EEPROM)
- Detecting usage of a buggy/restricted instruction
- Adjusting HEX file to meet requirements of particular bootloaders

7.3.1 hexmate Command Line Options

hexmate is automatically called by the command line driver, `xc8-cc`. This is primarily to merge HEX files in with the output generated by the source files. However, there are some `xc8-cc` options which map directly to hexmate options. Other functionality can be requested without running hexmate on the command line explicitly. For other functionality, the following sections detail the options that are available when running this application.

If hexmate is to be run directly, its usage is:

```
hexmate [specs,]file1.hex [... [specs,]fileN.hex] [options]
```

where *`file1.hex`* through to *`fileN.hex`* form a list of input Intel HEX files to merge using hexmate.

If only one HEX file is specified, no merging takes place, but other functionality is specified by additional options. Table 7-2 lists the command line options that hexmate accepts.

TABLE 7-2: HEXMATE COMMAND-LINE OPTIONS

Option	Effect
`--EDF`	Specify the message description file
`--EMAX`	Set the maximum number of permitted errors before terminating
`--MSGDISABLE`	Disable messages with the numbers specified
`--SLA`	Set the start linear address for type 5 records
`--VER`	Display version and build information then quit
`-ADDRESSING`	Set address fields in all hexmate options to use word addressing or other
`-BREAK`	Break continuous data so that a new record begins at a set address.
`-CK`	Calculate and store a value.
`-FILL`	Program unused locations with a known value.
`-FIND`	Search and notify if a particular code sequence is detected.
`-FIND...,DELETE`	Remove the code sequence if it is detected (use with caution).
`-FIND...,REPLACE`	Replace the code sequence with a new code sequence.
`-FORMAT`	Specify maximum data record length or select INHX variant.
`-HELP`	Show all options or display help message for specific option.
`-LOGFILE`	Save hexmate analysis of output and various results to a file.
`-MASK`	Logically AND a memory range with a bitmask
`-Ofile`	Specify the name of the output file.
`-SERIAL`	Store a serial number or code sequence at a fixed address.
`-SIZE`	Report the number of bytes of data contained in the resultant HEX image.
`-STRING`	Store an ASCII string at a fixed address.
`-STRPACK`	Store an ASCII string at a fixed address using string packing.
`-W`	Adjust warning sensitivity.
`+`	Prefix to any option to overwrite other data in its address range, if necessary.

If you are using the driver, `xc8`, to compile your project (or the IDE), a log file is produced by default. It will have the project's name and the extension `.hxl`.

The input parameters to hexmate are now discussed in detail. The format or assumed radix of values associated with options are described with each option. Note that any address fields specified in these options are to be entered as byte addresses, unless specified otherwise in the `-ADDRESSING` option.

© 2012-2018 Microchip Technology Inc.

7.3.1.1 SPECIFICATIONS,FILENAME.HEX

hexmate can process Intel HEX files that use either INHX32 or INHX8M format. Additional specifications can be applied to each HEX file to place restrictions or conditions on how this file should be processed.

If any specifications are used, they must precede the filename. The list of specifications will then be separated from the filename by a *comma*.

A *range restriction* can be applied with the specification `r`*`Start`*`-`*`End`*, where *`Start`* and *`End`* are both assumed to be hexadecimal values. A range restriction will cause only the address data falling within this range to be used. For example:

```
r100-1FF,myfile.hex
```

will use `myfile.hex` as input, but only process data which is addressed within the range 100h-1FFh (inclusive) from that file.

An address shift can be applied with the specification *`sOffset`*. If an address shift is used, data read from this HEX file will be shifted (by the offset specified) to a new address when generating the output. The offset can be either positive or negative. For example:

```
r100-1FFs2000,myfile.HEX
```

will shift the block of data from 100h-1FFh to the new address range 2100h-21FFh.

Be careful when shifting sections of executable code. Program code should only be shifted if it is position independent.

7.3.1.2 + PREFIX

When the + operator precedes an argument or input file, the data obtained from that source will be forced into the output file and will overwrite another other data existing at that address range. For example:

```
+input.HEX +-STRING@1000=”My string”
```

Ordinarily, hexmate will issue an error if two sources try to store differing data at the same location. Using the + operator informs hexmate that if more than one data source tries to store data to the same address, the one specified with a + prefix will take priority.

7.3.1.3 --EDF

This option must be used to have warning and hexmate error messages correctly displayed. The argument should be the full path to the message file to use when executing hexmate. The message files are located in the MPLAB XC8 compiler’s `pic/dat` directory (e.g., the English language file is called `en_msgs.txt`).

7.3.1.4 --EMAX

This option sets the maximum number of errors hexmate will display before execution is terminated, e.g., `--EMAX=25`. By default, up to 20 error messages will be displayed.

7.3.1.5 --MSGDISABLE

This option allows error, warning or advisory messages to be disabled during execution of hexmate.

The option is passed a comma-separated list of message numbers that are to be disabled. Any error message numbers in this list are ignored unless they are followed by an `:off` argument. If the message list is specified as 0, then all warnings are disabled. (See Section 3.6 “Compiler Messages” for more information on the messaging system.)

7.3.1.6 --SLA

This option allows you to specify the linear start address for type 5 records in the Hex output file, e.g., `--SLA=0x10000`.

7.3.1.7 --VER

This option will ask hexmate to print version and build information and then quit.

7.3.1.8 -ADDRESSING

By default, all address arguments in hexmate options expect that values will be entered as byte addresses. In some device architectures, the native addressing format can be something other than byte addressing. In these cases, it would be much simpler to be able to enter address-components in the device's native format. To facilitate this, the `-ADDRESSING` option is used.

This option takes one parameter that configures the number of bytes contained per address location. If, for example, a device's program memory naturally used a 16-bit (2 byte) word-addressing format, the option `-ADDRESSING=2` will configure hexmate to interpret all command line address fields as word addresses. The affect of this setting is global and all hexmate options will now interpret addresses according to this setting. This option will allow specification of addressing modes from one byte per address to four bytes per address.

7.3.1.9 -BREAK

This option takes a *comma*-separated list of addresses. If any of these addresses are encountered in the HEX file, the current data record will conclude and a new data record will recommence from the nominated address. This can be useful to use new data records to force a distinction between functionally different areas of program space. Some HEX file readers depend on this.

7.3.1.10 -CK

The -CK option is for calculating a hash value. The usage of this option is:

`-CK=`*`start-end@dest`* `[+`*`offset`*`][w`*`Width`*`][t`*`Code`*`][g`*`Algorithm`*`][p`*`Polynomial`*`]`

where:

- *`start`* and *`end`* specify the address range over which the hash will be calculated. If these addresses are not a multiple of the algorithm width, the value zero will be padded into the relevant input word locations that are missing.
- *`dest`* is the address where the hash result will be stored. This value cannot be within the range of calculation.
- *`offset`* is an optional initial value to be used in the calculations.
- *`Width`* is optional and specifies the byte-width of the result. Results can be calculated for byte-widths of 1 to 4 bytes. If a positive width is requested, the result will be stored in big-endian byte order. A negative width will cause the result to be stored in little-endian byte order. If the width is left unspecified, the result will be 2 bytes wide and stored in little-endian byte order. This width argument is not used if you have selected any Fletcher algorithm.
- *`Code`* is a hexadecimal code that will trail each byte in the result. This can allow each byte of the hash result to be embedded within an instruction.
- *`Algorithm`* is an integer to select which hexmate hash algorithm to use to calculate the result. A list of selectable algorithms is provided in Table 7-3. If unspecified, the default algorithm used is 8-bit checksum addition (1).
- *`Polynomial`* is a hexadecimal value which is the polynomial to be used if you have selected a CRC algorithm.

© 2012-2018 Microchip Technology Inc.

All numerical arguments are assumed to be hexadecimal values, except for the algorithm selector and result width, which are assumed to be decimal values.

A typical example of the use of the checksum option is:

```
-CK=0-1FFF@2FFE+2100w2g2
```

This will calculate a checksum over the range 0 to 0x1FFF and program the checksum result at address 0x2FFE. The checksum value will be offset by 0x2100. The result will be two bytes wide.

TABLE 7-3: HEXMATE HASH ALGORITHM SELECTION

Selector	Algorithm Description
`-5`	Reflected cyclic redundancy check (CRC)
`-4`	Subtraction of 32 bit values from initial value
`-3`	Subtraction of 24 bit values from initial value
`-2`	Subtraction of 16 bit values from initial value
`-1`	Subtraction of 8 bit values from initial value
`1`	Addition of 8 bit values from initial value
`2`	Addition of 16 bit values from initial value
`3`	Addition of 24 bit values from initial value
`4`	Addition of 32 bit values from initial value
`5`	Cyclic redundancy check (CRC)
`7`	Fletcher’s checksum (8 bit calculation, 2-byte result width)
`8`	Fletcher’s checksum (16 bit calculation, 4-byte result width)

See Section 7.3.2 “Hash Functions” for more details about the algorithms that are used to calculate checksums.

7.3.1.11 -FILL

The `-FILL` option is used for filling unused memory locations with a known value. The usage of this option is:

```
-FILL=[const_width:]fill_expr@address[:end_address]
```

where:

- *`const_width`* has the form `w`*`n`* and signifies the width (*n* bytes) of each constant in *`fill_expr`*. If *`const_width`* is not specified, the default value is two bytes. That is, `-FILL=w1:1` with fill every unused byte with the value 0x01.
- *`fill_expr`* can use the syntax (where *`const`* and *`increment`* are *n*-byte constants):
  - *`const`* fill memory with a repeating constant; i.e., `-FILL=0xBEEF` becomes 0xBEEF, 0xBEEF, 0xBEEF, 0xBEEF
  - *`const`*`+=`*`increment`* fill memory with an incrementing constant; i.e., `-FILL=0xBEEF+=1` becomes 0xBEEF, 0xBEF0, 0xBEF1, 0xBEF2
  - *`const`*`-=`*`increment`* fill memory with a decrementing constant; i.e., `-FILL=0xBEEF-=0x10` becomes 0xBEEF, 0xBEDF, 0xBECF, 0xBEBF
  - *`const`*`,`*`const`*`,...,`*`const`* fill memory with a list of repeating constants; i.e., `-FILL=0xDEAD,0xBEEF` becomes 0xDEAD,0xBEEF,0xDEAD,0xBEEF
- The options following `fill_expr` result in the following behavior:
  - `@`*`address`* fill a specific address with *`fill_expr`*; i.e., `-FILL=0xBEEF@0x1000` puts 0xBEEF at address 1000h. If the fill value is wider than the addressing value specified with `-ADDRESSING`, then only part of the fill value is placed in the output. For example, if the addressing is set to 1, the option above will place 0xEF at address 0x1000 and a warning will be issued.
  - `@`*`address`*`:`*`end_address`* fill a range of memory with *`fill_expr`*; i.e., `-FILL=0xBEEF@0:0xFF` puts 0xBEEF in unused addresses between 0 and 255. If the address range (multiplied by the `-ADDRESSING` value) is not a multiple of the fill value width, the final location will only use part of the fill value, and a warning will be issued.

The fill values are word-aligned so they start on an address that is a multiple of the fill width. Should the fill value be an instruction opcode, this alignment ensures that the instruction can be executed correctly.

All constants can be expressed in (unsigned) binary, octal, decimal or hexadecimal, as per normal C syntax, for example, 1234 is a decimal value, 0xFF00 is hexadecimal and FF00 is illegal.

© 2012-2018 Microchip Technology Inc.

7.3.1.12 -FIND

This option is used to detect and log occurrences of an opcode or partial code sequence. The usage of this option is:

```
-FIND=Findcode [mMask]@Start-End [/Align][w][t"Title"]
```

where:

- `Findcode` is the hexadecimal code sequence to search for and is entered in little endian byte order.
- `Mask` is optional. It specifies a bit mask applied over the `Findcode` value to allow a less restrictive search. It is entered in little endian byte order.
- `Start` and `End` limit the address range to search.
- `Align` is optional. It specifies that a code sequence can only match if it begins on an address that is a multiple of this value.
- `w`, if present, will cause hexmate to issue a warning whenever the code sequence is detected.
- `Title` is optional. It allows a title to be given to this code sequence. Defining a title will make log-reports and messages more descriptive and more readable. A title will not affect the actual search results.

All numerical arguments are assumed to be hexadecimal values.

Here are some examples.

The option `-FIND=3412@0-7FFF/2w` will detect the code sequence `1234h` when aligned on a `2` (two) byte address boundary, between `0h` and `7FFFh`. `w` indicates that a warning will be issued each time this sequence is found.

In this next example, `-FIND=3412M0F00@0-7FFF/2wt"ADDXY"`, the option is the same as in last example but the code sequence being matched is masked with `000Fh`, so hexmate will search for any of the opcodes `123xh`, where `x` is any digit. If a byte-mask is used, is must be of equal byte-width to the opcode it is applied to. Any messaging or reports generated by hexmate will refer to this opcode by the name, *ADDXY,* as this was the title defined for this search.

If hexmate is generating a log file, it will contain the results of all searches. `-FIND` accepts whole bytes of HEX data from 1 to 8 bytes in length. Optionally, `-FIND` can be used in conjunction with `REPLACE` or `DELETE` (as described below).

7.3.1.13 -FIND...,DELETE

If the `DELETE` form of the `-FIND` option is used, any matching sequences will be removed. This function should be used with extreme caution and is not normally recommended for removal of executable code.

7.3.1.14 -FIND...,REPLACE

If the `REPLACE` form of the `-FIND` option is used, any matching sequences will be replaced, or partially replaced, with new codes. The usage for this sub-option is:

```
-FIND...,REPLACE=Code [mMask]
```

where:

- `Code` is a little endian hexadecimal code to replace the sequences that match the `-FIND` criteria.
- `Mask` is an optional bit mask to specify which bits within `Code` will replace the code sequence that has been matched. This can be useful if, for example, it is only necessary to modify 4 bits within a 16-bit instruction. The remaining 12 bits can masked and left unchanged.

7.3.1.15 -FORMAT

The -FORMAT option can be used to specify a particular variant of INHX format or adjust maximum record length. The usage of this option is:

```
-FORMAT=Type [,Length]
```

where:

- `Type` specifies a particular INHX format to generate.
- `Length` is optional and sets the maximum number of bytes per data record. A valid length is between 1 and 16 decimal, with 16 being the default.

Consider the case of a bootloader trying to download an INHX32 file, which fails because it cannot process the extended address records that are part of the INHX32 standard. You know that this bootloader can only program data addressed within the range 0 to 64k, and that any data in the HEX file outside of this range can be safely disregarded. In this case, by generating the HEX file in INHX8M format the operation might succeed. The hexmate option to do this would be `-FORMAT=INHX8M`.

Now, consider if the same bootloader also required every data record to contain exactly 8 bytes of data. This is possible by combining the `-FORMAT` with `-FILL` options. Appropriate use of `-FILL` can ensure that there are no gaps in the data for the address range being programmed. This will satisfy the minimum data length requirement. To set the maximum length of data records to 8 bytes, just modify the previous option to become `-FORMAT=INHX8M,8`.

The possible types that are supported by this option are listed in Table 7-4. Note that INHX032 is not an actual INHX format. Selection of this type generates an INHX32 file, but will also initialize the upper address information to zero. This is a requirement of some device programmers.

TABLE 7-4: INHX TYPES USED IN -FORMAT OPTION

Type	Description
`INHX8M`	cannot program addresses beyond 64K
`INHX32`	can program addresses beyond 64K with extended linear address records
`INHX032`	INHX32 with initialization of upper address to zero

7.3.1.16 -HELP

Using `-HELP` will list all hexmate options. Entering another hexmate option as a parameter of `-HELP` will show a detailed help message for the given option. For example:

```
-HELP=string
```

will show additional help for the `-STRING` hexmate option.

7.3.1.17 -LOGFILE

The `-LOGFILE` option saves HEX file statistics to the named file. For example:

```
-LOGFILE=output.hxl
```

will analyze the HEX file that hexmate is generating, and save a report to a file named `output.hxl`.

© 2012-2018 Microchip Technology Inc.

7.3.1.18 -MASK

Use this option to logically AND a memory range with a particular bitmask. This is used to ensure that the unimplemented bits in program words (if any) are left blank. The usage of this option is as follows:

```
-MASK=hexcode@start-end
```

where *`hexcode`* is a value that will be ANDed with data within the *`start`* to *end* address range. All values are assumed to be hexadecimal. Multibyte mask values can be entered in little endian byte order.

7.3.1.19 -O*FILE*

The generated Intel HEX output will be created in this file. For example:

```
-Oprogram.hex
```

will save the resultant output to `program.hex`. The output file can take the same name as one of its input files; but, by doing so, it will replace the input file entirely.

7.3.1.20 -SERIAL

This option will store a particular HEX value sequence at a fixed address. The usage of this option is:

```
-SERIAL=Code [+/-Increment]@Address [+/-Interval][rRepetitions]
```

where:

- *`Code`* is a hexadecimal sequence to store. The first byte specified is stored at the lowest address.
- *`Increment`* is optional and allows the value of *`Code`* to change by this value with each repetition (if requested).
- *`Address`* is the location to store this code, or the first repetition thereof.
- *`Interval`* is optional and specifies the address shift per repetition of this code.
- *`Repetitions`* is optional and specifies the number of times to repeat this code.

All numerical arguments are assumed to be hexadecimal values, except for the *`Repetitions`* argument, which is decimal value by default.

For example:

```
-SERIAL=000001@EFFE
```

will store HEX code `00001h` to address `EFFEh`.

Another example:

```
-SERIAL=0000+2@1000+10r5
```

will store 5 codes, beginning with value `0000` at address `1000h`. Subsequent codes will appear at address intervals of `+10h` and the code value will change in increments of `+2h`.

7.3.1.21 -SIZE

Using the `-SIZE` option will report the number of bytes of data within the resultant HEX image to standard output. The size will also be recorded in the log file if one has been requested.

7.3.1.22 -STRING

The `-STRING` option will embed an ASCII string at a fixed address. The usage of this option is:

```
-STRING@Address [tCode]="Text"
```

where:

- *`Address`* is assumed to be a hexadecimal value representing the address at which the string will be stored.
- *`Code`* is optional and allows a byte sequence to trail each byte in the string. This can allow the bytes of the string to be encoded within an instruction.
- *`Text`* is the string to convert to ASCII and embed.

For example:

```
-STRING@1000="My favorite string"
```

will store the ASCII data for the string, `My favorite string` (including the null character terminator), at address `1000`h.

And again:

```
-STRING@1000t34="My favorite string"
```

will store the same string, trailing every byte in the string with the HEX code `34`h.

7.3.1.23 -STRPACK

This option performs the same function as `-STRING`, but with two important differences. First, only the lower seven bits from each character are stored. Pairs of 7-bit characters are then concatenated and stored as a 14-bit word rather than in separate bytes. This is known as string packing. This is usually only useful for devices where program space is addressed as 14-bit words (PIC10/12/16 devices). The second difference is that `-STRING`'s `t` specifier is not applicable with the `-STRPACK` option.

7.3.2 Hash Functions

A hash value is a small fixed-size value that is calculated from, and used to represent, all the values in an arbitrary-sized block of data. If that data block is copied, a hash recalculated from the new block can be compared to the original hash. Agreement between the two hashes provides a high level of certainty that the copy is valid. There are many hash algorithms. More complex algorithms provide a more robust verification, but could use too many resources when used in an embedded environment.

hexmate can be used to calculate the hash of a program image that is contained in a HEX file built by the MPLAB XC8 compiler. This hash can be embedded into that HEX file and burned into the target device along with the program image. At runtime, the target device might be able to run a similar hash algorithm over the program image, now stored in its memory. If the stored and calculated hashes are the same, the embedded program can assume that it has a valid program image to execute.

hexmate implements several checksum and cyclic redundancy check algorithms to calculate the hash. If you are using the XC8 C Compiler driver or MPLAB X IDE to perform project builds, the driver's `-mchecksum` option (see 3.7.1.2 checksum) will instruct the driver to invoke hexmate and pass it the appropriate hexmate options. If you are driving hexmate explicitly, the option to select the algorithm is described in Section 7.3.1.10 "-CK". In the discussion of the algorithms below, it is assumed you are using the compiler driver to request a checksum or CRC.

Some consideration is required when program images contain unused memory locations. The driver's `-mchecksum` option automatically requests that hexmate fill unused memory locations to match unprogrammed device memory. You might need to mimic this action if invoking hexmate explicitly.

© 2012-2018 Microchip Technology Inc.

Although hexmate will work with any PIC device, not all devices can read the entire width of their program memory. Thus some devices cannot calculate a hash at runtime from memory containing instructions, and the code examples in the following sections are not usable with all devices.

The following sections provide examples of the algorithms that can be used to calculate the hash at runtime.

7.3.3 Addition Algorithms

hexmate has several simple checksum algorithms that sum data values over a range in the program image. These algorithms correspond to the selector values 1, 2, 3, and 4 in the `algorithm` suboption and read the data in the program image as 1, 2, 3 or 4 byte quantities, respectively. This summation is added to an initial value (offset) that is supplied to the algorithm via the same option. The width to which the final checksum is truncated is also specified by this option and can be 1, 2, 3, or 4 bytes. hexmate will automatically store the checksum in the HEX file at the address specified in the checksum option.

The function shown below can be customized to work with any combination of data size (`readType`) and checksum width (`resultType`).

```
typedef unsigned char readType; // size of data values read and summed
typedef unsigned int  resultType; // size of checksum result

// add to offset n additions of values starting at address data,
// truncating and returning the result
// data: the address of the first value to sum
// n:    the number of sums to perform
// offset: the intial value to which the sum is added
resultType ck_add(const readType *data, unsigned n, resultType offset)
{
        resultType chksum;

        chksum = offset;
        while(n--) {
                chksum += *data;
                data++;
        }
        return chksum;
}
```

The `readType` and `resultType` type definitions should be adjusted to suit the data read/sum width and checksum result width, respectively. When using MPLAB XC8 and for a size of 1, use a `char` type; for a size of 4, use a `long` type, etc., or consider using the exact-width types provided by `<stdint.h>`. If you never use an offset, that parameter can be removed and `chksum` assigned 0 before the loop.

Here is how this function might be used when, for example, a 2-byte-wide checksum is to be calculated from the addition of 1-byte-wide values over the address range 0x100 to 0x7fd, starting with an offset of 0x20. The checksum is to be stored at 0x7fe and 0x7ff in little endian format. The following option is specified when building the project. (In MPLAB X IDE, only enter the information to the right of the first = in the Checksum field in the Additional options Option category in the XC8 Linker category.)

```
-mchecksum=100-7fd@7fe,offset=20,algorithm=1,width=-2
```

Into your project, add the following code snippet, which calls `ck_add`, above, and compare the runtime checksum with that stored by hexmate at compile time.

```
extern const readType ck_range[0x6fe/sizeof(readType)] @ 0x100;
extern const resultType hexmate @ 0x7fe;
resultType result;
```

```
result = ck_add(ck_range, sizeof(ck_range)/sizeof(readType), 0x20);
if(result != hexmate)
    ck_failure();  // take appropriate action
```

This code uses the placeholder array, `ck_range`, to represent the memory over which the checksum is calculated, and the variable `hexmate` is mapped over the locations where hexmate will have stored its checksum result. Being `extern` and absolute, neither of these objects consume additional device memory. Adjust the addresses and sizes of these objects to match the option you pass to hexmate.

hexmate can calculate a checksum over any address range; however, the test function, `ck_add`, assumes that the start and end address of the range being summed are a multiple of the `readType` width. (Clearly this is a non-issue if the size of `readType` is 1.) It is recommended that your checksum specification adheres to this assumption, otherwise you will need to modify the test code to perform partial reads of the starting and/or ending data values. This will significantly increase the code complexity.

© 2012-2018 Microchip Technology Inc.

7.3.4 Subtraction Algorithms

hexmate has several checksum algorithms that subtract data values over a range in the program image. These algorithms correspond to the selector values -1, -2, -3, and -4 in the `algorithm` suboption and read the data in the program image as 1-, 2-, 3- or 4-byte quantities, respectively. In other respects, these algorithms are identical to the addition algorithms described in Section 7.3.3 "Addition Algorithms".

The function shown below can be customized to work with any combination of data size (`readType`) and checksum width (`resultType`).

```
typedef unsigned char readType; // size of data values read and summed
typedef unsigned int  resultType; // size of checksum result

// add to offset n subtractions of values starting at address data,
// truncating and returning the result
// data: the address of the first value to subtract
// n:    the number of subtractions to perform
// offset: the intial value to which the subtraction is added
resultType ck_sub(const readType *data, unsigned n, resultType offset)
{
        resultType chksum;

        chksum = offset;
        while(n--) {
                chksum -= *data;
                data++;
        }
        return chksum;
}
```

Here is how this function might be used when, for example, a 4-byte-wide checksum is to be calculated from the addition of 2-byte-wide values over the address range 0x0 to 0x7fd, starting with an offset of 0x0. The checksum is to be stored at 0x7fe and 0x7ff in little endian format. The following option is specified when building the project. (In MPLAB X IDE, only enter the information to the right of the first = in the Checksum field in the Additional options Option category in the XC8 Linker category.)

```
-mchecksum=0-7fd@7fe,offset=0,algorithm=-2,width=-4
```

Into your project add the following code snippet, which calls `ck_sub`, above, and compare the runtime checksum with that stored by hexmate at compile time.

```
extern const readType ck_range[0x7fe/sizeof(readType)] @ 0x0;
extern const resultType hexmate @ 0x7fe;
resultType result;

result = ck_sub(ck_range, sizeof(ck_range)/sizeof(readType), 0x0);
if(result != hexmate)
    ck_failure();  // take appropriate action
```

7.3.5 Fletcher Algorithms

hexmate has several algorithms that implement Fletcher’s checksum. These algorithms are more complex, providing a robustness approaching that of a cyclic redundancy check, but with less computational effort. There are two forms of this algorithm, which correspond to the selector values 7 and 8 in the `algorithm` suboption, and which implement a 1-byte calculation and 2-byte result, and a 2-byte calculation and 4-byte result, respectively. hexmate will automatically store the checksum in the HEX file at the address specified in the checksum option.

The function shown below performs a 1-byte-wide addition and produces a 2-byte result.

```
unsigned int
fletcher8(const unsigned char * data, unsigned int n )
{
        unsigned int sum = 0xff, sumB = 0xff;
        unsigned char tlen;

        while (n) {
                tlen = n > 20 ? 20 : n;
                n -= tlen;
                do {
                        sumB += sum += *data++;
                } while (--tlen);
                sum = (sum & 0xff) + (sum >> 8);
                sumB = (sumB & 0xff) + (sumB >> 8);
        }
        sum = (sum & 0xff) + (sum >> 8);
        sumB = (sumB & 0xff) + (sumB >> 8);

        return sumB << 8 | sum;
}
```

This code can be called in a manner similar to that shown for the addition algorithms (see Section 7.3.3 “Addition Algorithms”).

The code for the 2-byte-addition Fletcher algorithm, producing a 4-byte result is shown below.

```
unsigned long
fletcher16(const unsigned int * data, unsigned n)
{
   unsigned long sum = 0xffff, sumB = 0xffff;
   unsigned tlen;

   while (n) {
      tlen = n > 359 ? 359 : n;
      n -= tlen;
      do {
         sumB += sum += *data++;
      } while (--tlen);
      sum = (sum & 0xffff) + (sum >> 16);
      sumB = (sumB & 0xffff) + (sumB >> 16);
   }
   sum = (sum & 0xffff) + (sum >> 16);
   sumB = (sumB & 0xffff) + (sumB >> 16);

   return sumB << 16 | sum;
}
```

© 2012-2018 Microchip Technology Inc.

7.3.6 CRC Algorithms

hexmate has several algorithms that implement the robust cyclic redundancy checks (CRC). There is a choice of two algorithms that correspond to the selector values 5 and -5 in the `algorithm` suboption to `-mchecksum`, and that implement a CRC calculation and reflected CRC calculation, respectively. The reflected algorithm works on the least significant bit of the data first. The polynomial to be used and the initial value can be specified in the option. hexmate will automatically store the CRC result in the HEX file at the address specified in the checksum option.

The function shown below can be customized to work with any result width (`resultType`). It calculates a CRC hash value using the polynomial specified by the `POLYNOMIAL` macro.

```
typedef unsigned int resultType;
#define POLYNOMIAL     0x1021
#define WIDTH   (8 * sizeof(resultType))
#define MSb     ((resultType)1 << (WIDTH - 1))

resultType
crc(const unsigned char * data, unsigned n, resultType remainder) {
    unsigned pos;
    unsigned char bitp;

    for (pos = 0; pos != n; pos++) {
        remainder ^= ((resultType)data[pos] << (WIDTH - 8));
        for (bitp = 8; bitp > 0; bitp--) {
            if (remainder & MSb) {
                remainder = (remainder << 1) ^ POLYNOMIAL;
            } else {
                remainder <<= 1;
            }
        }
    }

    return remainder;
}
```

The `resultType` type definition should be adjusted to suit the result width. When using MPLAB XC8 and for a size of 1, use a `char` type; for a size of 4, use a `long` type, etc., or consider using the exact-width types provided by <`stdint.h`>.

Here is how this function might be used when, for example, a 2-byte-wide CRC hash value is to be calculated values over the address range 0x0 to 0xFF, starting with an initial value of 0xFFFF. The result is to be stored at 0x100 and 0x101 in little endian format. The following option is specified when building the project. (In MPLAB X IDE, only enter the information to the right of the first = in the Checksum field in the Additional options Option category in the XC8 Linker category.)

```
-mchecksum=0-FF@100,offset=0xFFFF,algorithm=5,width=-2,polynomial=0x1021
```

Into your project, add the following code snippet, which calls `crc()`, above, and compares the runtime hash result with that stored by hexmate at compile time.

```
extern const unsigned char ck_range[0x100] @ 0x0;
extern const resultType hexmate @ 0x100;
resultType   result;

result = crc(ck_range, sizeof(ck_range), 0xFFFF));
if(result != hexmate){
        // something’s not right, take appropriate action
        ck_failure();
}
// data verifies okay, continue with the program
```

The reflected CRC result can be calculated by reflecting the input data and final result, or by reflecting the polynomial. The functions shown below can be customized to work with any result width (`resultType`). The `crc_reflected_IO()` function calculates a reflected CRC hash value by reflecting the data stream bit positions. The `crc_reflected_poly()` function does not adjust the data stream but reflects instead the polynomial, which in both functions is specified by the `POLYNOMIAL` macro. Both functions use the `reflect()` function to perform bit reflection.

```
typedef unsigned int resultType;
typedef unsigned char readType;
typedef unsigned int reflectWidth;

// This is the polynomial used by the CRC-16 algorithm we are using.
#define POLYNOMIAL     0x1021

#define WIDTH   (8 * sizeof(resultType))
#define MSb     ((resultType)1 << (WIDTH - 1))
#define LSb     (1)

#define REFLECT_DATA(X)       ((readType) reflect((X), 8))
#define REFLECT_REMAINDER(X)  (reflect((X), WIDTH))

reflectWidth
reflect(reflectWidth data, unsigned char nBits)
{
    reflectWidth reflection = 0;
    reflectWidth reflectMask = (reflectWidth)1 << nBits - 1;
    unsigned char bitp;

    for (bitp = 0; bitp != nBits; bitp++) {
        if (data & 0x01) {
            reflection |= reflectMask;
        }
        data >>= 1;
        reflectMask >>= 1;
    }

    return reflection;
}
```

© 2012-2018 Microchip Technology Inc.

```
resultType
crc_reflected_IO(const unsigned char * data, unsigned n, resultType
remainder) {
    unsigned pos;
    unsigned char reflected;
    unsigned char bitp;

    for (pos = 0; pos != n; pos++) {
        reflected = REFLECT_DATA(data[pos]);
        remainder ^= ((resultType)reflected << (WIDTH - 8));

        for (bitp = 8; bitp > 0; bitp--) {
            if (remainder & MSb) {
                remainder = (remainder << 1) ^ POLYNOMIAL;
            } else {
                remainder <<= 1;
            }
        }
    }
    remainder = REFLECT_REMAINDER(remainder);

    return remainder;
}

resultType
crc_reflected_poly(const unsigned char * data, unsigned n, resultType
remainder) {
    unsigned pos;
    unsigned char bitp;
    resultType rpoly;

    rpoly = reflect(POLYNOMIAL, WIDTH);
    for (pos = 0; pos != n; pos++) {
        remainder ^= data[pos];

        for (bitp = 8; bitp > 0; bitp--) {
            if (remainder & LSb) {
                remainder = (remainder >> 1) ^ rpoly;
            } else {
                remainder >>= 1;
            }
        }
    }

    return remainder;
}
```

Here is how this function might be used when, for example, a 2-byte-wide reflected CRC result is to be calculated over the address range 0x0 to 0xFF, starting with an initial value of 0xFFFF. The result is to be stored at 0x100 and 0x101 in little endian format. The following option is specified when building the project. (Note the algorithm selected is *negative* 5 in this case.)

```
-mchecksum=0-FF@100,offset=0xFFFF,algorithm=-5,width=-2,polynomial=0x1021
```

In your project, call `crc()`, as shown previously.

NOTES:

© 2012-2018 Microchip Technology Inc.

Appendix A. Library Functions

A.1 INTRODUCTION

The functions, variables, types, and preprocessor macros defined by the standard compiler library are summarized in this chapter, listed under the header file which declares them.

TABLE A-1: DECLARATIONS PROVIDED BY <ASSERT.H>

Name	Definition
`NDEBUG`	
`__conditional_software_breakpoint`	`__conditional_software_breakpoint(expression)`
`assert`	`void assert(scalar expression)`

TABLE A-2: DECLARATIONS PROVIDED BY <CTYPE.H>

Name	Definition
`isalnum`	`int isalnum(int c);`
`isalpha`	`int isalpha(int c);`
`isblank`	`int isblank(int c);`
`iscntrl`	`int iscntrl(int c);`
`isdigit`	`int isdigit(int c);`
`isgraph`	`int isgraph(int c);`
`islower`	`int islower(int c);`
`isprint`	`int isprint(int c);`
`ispunct`	`int ispunct(int c);`
`isspace`	`int isspace(int c);`
`isupper`	`int isupper(int c);`
`isxdigit`	`int isxdigit(int c);`
`tolower`	`int tolower(int c);`
`toupper`	`int toupper(int c);`

TABLE A-3: DECLARATIONS PROVIDED BY <ERRNO.H>

Name	Definition
`EDOM`	
`EILSEQ`	
`ERANGE`	
`errno`	

Those macros defined by `<float.h>,` below, that contain *XXX* are defined for `float` and `double` types, and *XXX* can be either of `FLT` or `DBL`, respectively.

TABLE A-4: DECLARATIONS PROVIDED BY <FLOAT.H>

Name	Definition
`FLT_RADIX`	2
`FLT_ROUNDS`	1
`FLT_EVAL_METHOD`	0
`DECIMAL_DIG`	9
XXX`_MAX`	3.40282346639e+38
XXX`_MIN`	1.17549435082e-38
XXX`_MIN_EXP`	-125
XXX`_MIN_10_EXP`	-37
XXX`_MAX_EXP`	128
XXX`_MAX_10_EXP`	38
XXX`_DIG`	6
XXX`_MANT_DIG`	24
XXX`_EPSILON`	1.19209289551e-07

Those macros defined by `<inttypes.h>`, shown below, that contain *PPP* are defined as the placeholder string for printing `intmax_t` and `intptr_t` types, and *PPP* can be either of `MAX` or `PTR`, respectively. Those macros below that contain *YYYY* are defined as the placeholder string for printing `intn_t`, `intleastn_t` and `intfastn_t` types (where *n* is the size, in bytes, of the type) and *YYYY* can be either of <empty>, `LEAST` or `FAST`, respectively. For example `PRIdLEAST16` could be used as the placeholder string for a value with `int_least16_t` type.

TABLE A-5: DECLARATIONS PROVIDED BY C99 <INTTYPES.H>

Name	Definition
`PRId`*PPP*	
`PRId`*YYYYn*	
`PRIi`*PPP*	
`PRIi`*YYYYn*	
`PRIo`*PPP*	
`PRIo`*YYYYn*	
`PRIu`*PPP*	
`PRIu`*YYYYn*	
`PRIx`*PPP*	
`PRIx`*YYYYn*	
`PRIX`*PPP*	
`PRIX`*YYYYn*	
`SCNd`*PPP*	
`SCNd`*YYYYn*	
`SCNi`*PPP*	
`SCNi`*YYYYn*	
`SCNo`*PPP*	
`SCNo`*YYYYn*	
`SCNu`*PPP*	

© 2012-2018 Microchip Technology Inc.

TABLE A-5: DECLARATIONS PROVIDED BY C99 <INTTYPES.H>

Name	Definition
`SCNu`*`YYYYn`*	
`SCNx`*`PPP`*	
`SCNx`*`YYYYn`*	
`imaxdiv_t`	
`imaxabs`	`intmax_t imaxabs(intmax_t j);`
`imaxdiv`	`imaxdiv_t imaxdiv(intmax_t numer, intmax_t denom);`

`strtoimax`	`intmax_t strtoimax(const char * restrict nptr,`
	`        char ** restrict endptr, int base);`

`strtoumax`	`uintmax_t strtoumax(const char * restrict nptr,`
	`        char ** restrict endptr, int base);`

TABLE A-6: DECLARATIONS PROVIDED BY C99 <ISO646.H>

Name	Definition
`and`	`&&`
`and_eq`	`&=`
`bitand`	`&`
`bitor`	`|`
`compl`	`~`
`not`	`!`
`not_eq`	`!=`
`or`	`||`
`or_eq`	`|=`
`xor`	`^`
`xor_eq`	`^=`

The `long long` types are 64-bit C99 Standard types when building for PIC18 devices, but when compiling to the C90 Standard or for any other device, this implementation limits their size to only 32 bits.

TABLE A-7: DECLARATIONS PROVIDED BY <LIMITS.H>

Name	C99 PIC18 Definition	All other Definitions
CHAR_BIT	8	8
CHAR_MAX	255	255
CHAR_MIN	0	0
SCHAR_MAX	127	127
SCHAR_MIN	-128	-128
UCHAR_MAX	255	255
SHRT_MAX	32767	32767
SHRT_MIN	-32768	-32768
USHRT_MAX	65535	65535
INT_MAX	32767	32767
INT_MIN	-32768	-32768
UINT_MAX	65535	65535
SHRTLONG_MAX	8388607	8388607
SHRTLONG_MIN	-8388608	-8388608
USHRTLONG_MAX	16777215	16777215
LONG_MAX	2147483647	2147483647
LONG_MIN	-2147483648	-2147483648
ULONG_MAX	4294967295	4294967295
LLONG_MAX	9223372036854775807	2147483647
LLONG_MIN	-9223372036854775808	-2147483648
ULLONG_MAX	18446744073709551615	4294967295

TABLE A-8: DECLARATIONS DEFINED BY <MATH.H>

Name	Definition
HUGE_VAL	
HUGE_VALF	
HUGE_VALL	
INFINITY	
NAN	
FP_INFINITE	
FP_NAN	
FP_NORMAL	
FP_SUBNORMAL	
FP_ZERO	
FP_FAST_FMA	
FP_FAST_FMAF	
FP_FAST_FMAL	

© 2012-2018 Microchip Technology Inc.

TABLE A-8: DECLARATIONS DEFINED BY <MATH.H>

Name	Definition
`FP_ILOGB0`	
`FP_ILOGBNAN`	
`MATH_ERRNO`	
`MATH_ERREXCEPT`	
`math_errhandling`	
`float_t`	
`double_t`	
`fpclassify`	`int fpclassify(`*`real-floating`*` x);`
`isfinite`	`int isfinite(`*`real-floating`*` x);`
`isinf`	`int isinf(`*`real-floating`*` x);`
`isnan`	`int isnan(`*`real-floating`*` x);`
`isnormal`	`int isnormal(`*`real-floating`*` x);`
`signbit`	`int signbit(`*`real-floating`*` x);`
`acos`	`double acos(double x);`
`acosf`	`float acosf(float x);`
`acosl`	`long double acosl(long double x);`
`asin`	`double asin(double x);`
`asinf`	`float asinf(float x);`
`asinl`	`long double asinl(long double x);`
`atan`	`double atan(double x);`
`atanf`	`float atanf(float x);`
`atanl`	`long double atanl(long double x);`
`atan2`	`double atan2(double y, double x);`
`atan2f`	`float atan2f(float y, float x);`
`atan2l`	`long double atan2l(long double y, long double x);`
`cos`	`double cos(double x);`
`cosf`	`float cosf(float x);`
`cosl`	`long double cosl(long double x);`
`sin`	`double sin(double x);`
`sinf`	`float sinf(float x);`
`sinl`	`long double sinl(long double x);`
`tan`	`double tan(double x);`
`tanf`	`float tanf(float x);`
`tanl`	`long double tanl(long double x);`
`acosh`	`double acosh(double x);`
`acoshf`	`float acoshf(float x);`
`acoshl`	`long double acoshl(long double x);`
`asinh`	`double asinh(double x);`
`asinhf`	`float asinhf(float x);`
`asinhl`	`long double asinhl(long double x);`
`atanh`	`double atanh(double x);`
`atanhf`	`float atanhf(float x);`

TABLE A-8: DECLARATIONS DEFINED BY <MATH.H>

Name	Definition
atanhl	long double atanhl(long double x);
cosh	double cosh(double x);
coshf	float coshf(float x);
coshl	long double coshl(long double x);
sinh	double sinh(double x);
sinhf	float sinhf(float x);
sinhl	long double sinhl(long double x);
tanh	double tanh(double x);
tanhf	float tanhf(float x);
tanhl	long double tanhl(long double x);
exp	double exp(double x);
expf	float expf(float x);
expl	long double expl(long double x);
exp2	double exp2(double x);
exp2f	float exp2f(float x);
exp2l	long double exp2l(long double x);
expm1	double expm1(double x);
expm1f	float expm1f(float x);
expm1l	long double expm1l(long double x);
frexp	double frexp(double value, int *exp);
frexpf	float frexpf(float value, int *exp);
frexpl	long double frexpl(long double value, int *exp);
ilogb	int ilogb(double x);
ilogbf	int ilogbf(float x);
ilogbl	int ilogbl(long double x);
ldexp	double ldexp(double x, int exp);
ldexpf	float ldexpf(float x, int exp);
ldexpl	long double ldexpl(long double x, int exp);
log	double log(double x);
logf	float logf(float x);
logl	long double logl(long double x);
log10	double log10(double x);
log10f	float log10f(float x);
log10l	long double log10l(long double x);
log1p	double log1p(double x);
log1pf	float log1pf(float x);
log1pl	long double log1pl(long double x);
log2	double log2(double x);
log2f	float log2f(float x);
log2l	long double log2l(long double x);
logb	double logb(double x);
logbf	float logbf(float x);

© 2012-2018 Microchip Technology Inc.

TABLE A-8: DECLARATIONS DEFINED BY <MATH.H>

Name	Definition
`logbl`	`long double logbl(long double x);`
`modf`	`double modf(double value, double *iptr);`
`modff`	`float modff(float value, float *iptr);`
`modfl`	`long double modfl(long double value, long double *iptr);`
`scalbn`	`double scalbn(double x, int n);`
`scalbnf`	`float scalbnf(float x, int n);`
`scalbnl`	`long double scalbnl(long double x, int n);`
`scalbln`	`double scalbln(double x, long int n);`
`scalblnf`	`float scalblnf(float x, long int n);`
`scalblnl`	`long double scalblnl(long double x, long int n);`
`cbrt`	`double cbrt(double x);`
`cbrtf`	`float cbrtf(float x);`
`cbrtl`	`long double cbrtl(long double x);`
`fabs`	`double fabs(double x);`
`fabsf`	`float fabsf(float x);`
`fabsl`	`long double fabsl(long double x);`
`hypot`	`double hypot(double x, double y);`
`hypotf`	`float hypotf(float x, float y);`
`hypotl`	`long double hypotl(long double x, long double y);`
`pow`	`double pow(double x, double y);`
`powf`	`float powf(float x, float y);`
`powl`	`long double powl(long double x, long double y);`
`sqrt`	`double sqrt(double x);`
`sqrtf`	`float sqrtf(float x);`
`sqrtl`	`long double sqrtl(long double x);`
`erf`	`double erf(double x);`
`erff`	`float erff(float x);`
`erfl`	`long double erfl(long double x);`
`erfc`	`double erfc(double x);`
`erfcf`	`float erfcf(float x);`
`erfcl`	`long double erfcl(long double x);`
`lgamma`	`double lgamma(double x);`
`lgammaf`	`float lgammaf(float x);`
`lgammal`	`long double lgammal(long double x);`
`tgamma`	`double tgamma(double x);`
`tgammaf`	`float tgammaf(float x);`
`tgammal`	`long double tgammal(long double x);`
`ceil`	`double ceil(double x);`
`ceilf`	`float ceilf(float x);`
`ceill`	`long double ceill(long double x);`
`floor`	`double floor(double x);`
`floorf`	`float floorf(float x);`

TABLE A-8: DECLARATIONS DEFINED BY <MATH.H>

Name	Definition
`floorl`	`long double floorl(long double x);`
`nearbyint`	`double nearbyint(double x);`
`nearbyintf`	`float nearbyintf(float x);`
`nearbyintl`	`long double nearbyintl(long double x);`
`rint`	`double rint(double x);`
`rintf`	`float rintf(float x);`
`rintl`	`long double rintl(long double x);`
`lrint`	`long int lrint(double x);`
`lrintf`	`long int lrintf(float x);`
`lrintl`	`long int lrintl(long double x);`
`llrint`	`long long int llrint(double x);`
`llrintf`	`long long int llrintf(float x);`
`llrintl`	`long long int llrintl(long double x);`
`round`	`double round(double x);`
`roundf`	`float roundf(float x);`
`roundl`	`long double roundl(long double x);`
`lround`	`long int lround(double x);`
`lroundf`	`long int lroundf(float x);`
`lroundl`	`long int lroundl(long double x);`
`llround`	`long long int llround(double x);`
`llroundf`	`long long int llroundf(float x);`
`llroundl`	`long long int llroundl(long double x);`
`trunc`	`double trunc(double x);`
`truncf`	`float truncf(float x);`
`truncl`	`long double truncl(long double x);`
`fmod`	`double fmod(double x, double y);`
`fmodf`	`float fmodf(float x, float y);`
`fmodl`	`long double fmodl(long double x, long double y);`
`remainder`	`double remainder(double x, double y);`
`remainderf`	`float remainderf(float x, float y);`
`remainderl`	`long double remainderl(long double x, long double y);`
`remquo`	`double remquo(double x, double y, int *quo);`
`remquof`	`float remquof(float x, float y, int *quo);`
`remquol`	`long double remquol(long double x, long double y,int *quo);`
`copysign`	`double copysign(double x, double y);`
`copysignf`	`float copysignf(float x, float y);`
`copysignl`	`long double copysignl(long double x, long double y);`
`nan`	`double nan(const char *tagp);`
`nanf`	`float nanf(const char *tagp);`
`nanl`	`long double nanl(const char *tagp);`
`nextafter`	`double nextafter(double x, double y);`
`nextafterf`	`float nextafterf(float x, float y);`

© 2012-2018 Microchip Technology Inc.

TABLE A-8: DECLARATIONS DEFINED BY <MATH.H>

Name	Definition
`nextafterl`	`long double nextafterl(long double x, long double y);`
`nexttoward`	`double nexttoward(double x, long double y);`
`nexttowardf`	`float nexttowardf(float x, long double y);`
`nexttowardl`	`long double nexttowardl(long double x, long double y);`
`fdim`	`double fdim(double x, double y);`
`fdimf`	`float fdimf(float x, float y);`
`fdiml`	`long double fdiml(long double x, long double y);`
`fmax`	`double fmax(double x, double y);`
`fmaxf`	`float fmaxf(float x, float y);`
`fmaxl`	`long double fmaxl(long double x, long double y);`
`fmin`	`double fmin(double x, double y);`
`fminf`	`float fminf(float x, float y);`
`fminl`	`long double fminl(long double x, long double y);`
`fma`	`double fma(double x, double y, double z);`
`fmaf`	`float fmaf(float x, float y, float z);`
`fmal`	`long double fmal(long double x, long double y, long double z);`
`isgreater`	`int isgreater(real-floating x, real-floating y);`
`isgreaterequal`	`int isgreaterequal(real-floating x, real-floating y);`
`isless`	`int isless(real-floating x, real-floating y);`
`islessequal`	`int islessequal(real-floating x, real-floating y);`
`islessgreater`	`int islessgreater(real-floating x, real-floating y);`
`isunordered`	`int isunordered(real-floating x, real-floating y);`

TABLE A-9: DECLARATIONS PROVIDED BY <SETJMP.H>

Name	Definition
`jmp_buf`	
`setjmp`	`int setjmp(jmp_buf env);`
`longjmp`	`void longjmp(jmp_buf env, int val);`

TABLE A-10: DECLARATIONS PROVIDED BY <STDARG.H>

Name	Definition
`va_list`	
`va_arg`	*type* `va_arg(va_list ap,` *type*`);`
`va_copy`	`void va_copy(va_list dest, va_list src);`
`va_end`	`void va_end(va_list ap);`
`va_start`	`void va_start(va_list ap,` *parmN*`);`

TABLE A-11: DECLARATIONS PROVIDED BY C99 <STDBOOL.H>

Name	Definition
`bool`	`_Bool`
`true`	`1`
`false`	`0`
`__bool_true_false_are_defined`	`1`

TABLE A-12: DECLARATIONS PROVIDED BY <STDDEF.H>

Name	Definition
`NULL`	
`ptrdiff_t`	
`size_t`	
`offsetof`	`offsetof(`*`type`*`, `*`member-designator`*`)`

TABLE A-13: DECLARATIONS PROVIDED BY C99 <STDINT.H>

Name	Definition
INT*N*_MIN	
INT*N*_MAX	
UINT*N*_MAX	
INT_LEAST*N*_MIN	
INT_LEAST*N*_MAX	
UINT_LEAST*N*_MAX	
INT_FAST*N*_MIN	
INT_FAST*N*_MAX	
UINT_FAST*N*_MAX	
`INTPTR_MIN`	
`INTPTR_MAX`	
`UINTPTR_MAX`	
`INTMAX_MIN`	
`INTMAX_MAX`	
`UINTMAX_MAX`	
`PTRDIFF_MIN`	
`PTRDIFF_MAX`	
`SIG_ATOMIC_MIN`	
`SIG_ATOMIC_MAX`	
`SIZE_MAX`	
INT*N*_C	`INTN_C(value)`
UINT*N*_C	`UINTN_C(value)`
`INTMAX_C`	`INTMAX_C(value)`
`UINTMAX_C`	`UINTMAX_C(value)`
int*N*_t	

© 2012-2018 Microchip Technology Inc.

TABLE A-13: DECLARATIONS PROVIDED BY C99 <STDINT.H>

Name	Definition
`uint`*`N`*`_t`	
`int_least`*`N`*`_t`	
`uint_least`*`N`*`_t`	
`int_fast`*`N`*`_t`	
`uint_fast`*`N`*`_t`	
`intptr_t`	
`uintptr_t`	
`intmax_t`	
`uintmax_t`	

TABLE A-14: DECLARATIONS PROVIDED BY <STDIO.H>

Name	Definition
`NULL`	
`size_t`	
`printf`	`int printf(const char * restrict format, ...);`
`scanf`	`int scanf(const char * restrict format, ...);`

`snprintf`	`int snprintf(char * restrict s, size_t n,`
	`const char * restrict format, ...);`

`sprintf`	`int sprintf(char * restrict s,`
	`const char * restrict format, ...);`

`sscanf`	`int sscanf(const char * restrict s,`
	`const char * restrict format, ...);`

`vprintf`	`int vprintf(const char * restrict format, va_list arg);`
`vscanf`	`int vscanf(const char * restrict format, va_list arg);`

`vsnprintf`	`int vsnprintf(char * restrict s, size_t n,`
	`const char * restrict format, va_list arg);`

`vsprintf`	`int vsprintf(char * restrict s,`
	`const char * restrict format, va_list arg);`

`vsscanf`	`int vsscanf(const char * restrict s,`
	`const char * restrict format, va_list arg);`

`getchar`	`int getchar(void);`
`gets`	`char *gets(char *s);`
`putchar`	`int putchar(int c);`
`puts`	`int puts(const char *s);`
`perror`	`void perror(const char *s);`

TABLE A-15: DECLARATIONS PROVIDED BY <STDLIB.H>

Name	Definition
`NULL`	
`EXIT_FAILURE`	
`EXIT_SUCCESS`	
`RAND_MAX`	

TABLE A-15: DECLARATIONS PROVIDED BY <STDLIB.H>

Name	Definition
`size_t`	
`div_t`	
`ldiv_t`	
`lldiv_t`	
`atexit`	`int atexit(void (*func)(void));`
`atof`	`double atof(const char *nptr);`
`atoi`	`int atoi(const char *nptr);`
`atol`	`long int atol(const char *nptr);`
`atoll`	`long long int atoll(const char *nptr);`

`strtod`	`double strtod(const char * restrict nptr,`
	`char ** restrict endptr);`

`strtof`	`float strtof(const char * restrict nptr,`
	`char ** restrict endptr);`

`strtold`	`long double strtold(const char * restrict nptr,`
	`char ** restrict endptr);`

`strtol`	`long int strtol(const char * restrict nptr,`
	`char ** restrict endptr, int base);`

`strtoll`	`long long int strtoll(const char * restrict nptr,`
	`char ** restrict endptr, int base);`

`strtoul`	`unsigned long int strtoul(const char * restrict nptr,`
	`char ** restrict endptr, int base);`

`strtoull`	`unsigned long long int strtoull(const char * restrict nptr,`
	`char ** restrict endptr, int base);`

`rand`	`int rand(void);`
`srand`	`void srand(unsigned int seed);`
`abort`	`void abort(void);`
`exit`	`void exit(int status);`

`bsearch`	`void *bsearch(const void *key, const void *base,`
	`size_t nmemb, size_t size,`
	`int (*compar)(const void *, const void *));`

`qsort`	`void qsort(void *base, size_t nmemb, size_t size,`
	`int (*compar)(const void *, const void *));`

`abs`	`int abs(int j);`
`labs`	`long int labs(long int j);`
`llabs`	`long long int llabs(long long int j);`
`div`	`div_t div(int numer, int denom);`
`ldiv`	`ldiv_t ldiv(long int numer, long int denom);`
`lldiv`	`lldiv_t lldiv(long long int numer, long long int denom);`
`_Exit`	`void _Exit(int status);`

TABLE A-16: DECLARATIONS PROVIDED BY <STRING.H>

Name	Definition
`NULL`	
`size_t`	

© 2012-2018 Microchip Technology Inc.

TABLE A-16: DECLARATIONS PROVIDED BY <STRING.H>

Name	Definition

`memcpy`	`void *memcpy(void * restrict s1,`
	`     const void * restrict s2, size_t n);`

`memmove`	`void *memmove(void *s1, const void *s2, size_t n);`
`strcpy`	`char *strcpy(char * restrict s1, const char * restrict s2);`

`strncpy`	`char *strncpy(char * restrict s1,`
	`     const char * restrict s2, size_t n);`

`strcat`	`char *strcat(char * restrict s1, const char * restrict s2);`

`strncat`	`char *strncat(char * restrict s1,`
	`     const char * restrict s2, size_t n);`

`memcmp`	`int memcmp(const void *s1, const void *s2, size_t n);`
`strcmp`	`int strcmp(const char *s1, const char *s2);`
`strcoll`	`int strcoll(const char *s1, const char *s2);`
`strncmp`	`int strncmp(const char *s1, const char *s2, size_t n);`

`strxfrm`	`size_t strxfrm(char * restrict s1,`
	`     const char * restrict s2, size_t n);`

`memchr`	`void *memchr(const void *s, int c, size_t n);`
`strchr`	`char *strchr(const char *s, int c);`
`strcspn`	`size_t strcspn(const char *s1, const char *s2);`
`strpbrk`	`char *strpbrk(const char *s1, const char *s2);`
`strrchr`	`char *strrchr(const char *s, int c);`
`strspn`	`size_t strspn(const char *s1, const char *s2);`
`strstr`	`char *strstr(const char *s1, const char *s2);`
`strtok`	`char *strtok(char * restrict s1, const char * restrict s2);`
`memset`	`void *memset(void *s, int c, size_t n);`
`strerror`	`char *strerror(int errnum);`
`strlen`	`size_t strlen(const char *s);`

TABLE A-17: DECLARATIONS PROVIDED BY <TIME.H>

Name	Definition
NULL	
size_t	
time_t	
tm	struct tm
difftime	double difftime(time_t time1, time_t time0);
mktime	time_t mktime(struct tm *timeptr);
time	time_t time(time_t *timer);
asctime	char *asctime(const struct tm *timeptr);
ctime	char *ctime(const time_t *timer);
gmtime	struct tm *gmtime(const time_t *timer);
localtime	struct tm *localtime(const time_t *timer);
strftime	size_t strftime(char * restrict s, size_t maxsize, const char * restrict format, const struct tm * restrict timeptr);

The macros and functions provided by <xc.h> are device-specified and are described in the sections that follow Table A-18.

TABLE A-18: DECLARATIONS PROVIDED BY <XC.H>

Name	Definition
di	
ei	
CRLWDT	
EEPROM_READ	EEPROM_READ(*address*)
EEPROM_WRITE	EEPROM_WRITE(*address*, *value*)
NOP	
READTIMER*X*	
RESET	
SLEEP	
WRITETIMER*X*	WRITETIMER(*value*)
eeprom_read	unsigned char eeprom_read(unsigned char address);
eeprom_write	void eeprom_write(unsigned char address, unsigned char value);
__debug_break	
___mkstr	___mkstr(*value*)
__EEPROM_DATA	__EEPROM_DATA(*a*, *b*, *c*, *d*, *e*, *f*, *g*, *h*)
get_cal_data	double get_cal_data(const unsigned char *);
_delay	_delay(*n*)
_delaywdt	_delaywdt(*n*)
_delay3	_delay3(*n*)
__builtin_software_breakpoint	void __builtin_software_breakpoint(void);
__delay_ms	__delay_ms(*time*)

© 2012-2018 Microchip Technology Inc.

TABLE A-18: DECLARATIONS PROVIDED BY <XC.H>

Name	Definition
`__delay_us`	`__delay_us(`*`time`*`)`
`__delaywdt_ms`	`__delaywdt_ms(`*`time`*`)`
`__delaywdt_us`	`__delaywdt_us(`*`time`*`)`
`__fpnormalize`	`double __fpnormalize(double);`
`__osccal_val`	`unsigned char __osccal_val(void);`

EEPROM_READ

Synopsis

```
#include <xc.h>

unsigned char eeprom_read(unsigned char address);
```

Description

This function is available for all Mid-range devices that implement EEPROM. For PIC18 devices, calls to this routine will instead attempt to call the equivalent functions in the legacy PIC18 peripheral library, which you must download and install separately. It is recommended that for PIC18 devices you use MPLAB MCC to generate EEPROM access code, if possible.

This function tests and waits for any concurrent writes to EEPROM to conclude before performing the required operation.

Example

```
#include <xc.h>

int
main (void)
{
    unsigned char serNo;

    serNo = eeprom_read(0x20);
}
```

EEPROM_WRITE

Synopsis

```
#include <xc.h>

void eeprom_write(unsigned char address, unsigned char value);
```

Description

This function is available for all Mid-range devices that implement EEPROM. For PIC18 devices, calls to this routine will instead attempt to call the equivalent functions in the legacy PIC18 peripheral library, which you must download and install separately. It is recommended that for PIC18 devices you use MPLAB MCC to generate EEPROM access code, if possible.

This function tests and waits for any concurrent writes to EEPROM to conclude before performing the required operation. The function will initiate the write to EEPROM and this process will still be taking place when the function returns. The new data written to EEPROM will become valid at a later time. See your device data sheet for exact information about EEPROM on your target device.

Example

```
#include <xc.h>

int
main (void)
{
    eeprom_write(0x20, 0x55);
}
```

© 2012-2018 Microchip Technology Inc.

EEPROM_READ (MACRO)

Synopsis

```
#include <xc.h>

EEPROM_READ(address);
```

Description

This macro is available for all Mid-range devices that implement EEPROM.

Unlike the function version, this macro does not wait for any concurrent writes to EEPROM to conclude before performing the required operation.

Example

```
#include <xc.h>

int
main (void)
{
    unsigned char serNo;

// wait for end-of-write before EEPROM_READ
    while(WR)
        continue;    // read from EEPROM at address
    serNo = EEPROM_READ(0x55);

}
```

EEPROM_WRITE (MACRO)

Synopsis

```
#include <xc.h>

EEPROM_WRITE(address, value);
```

Description

This macro is available for all Mid-range devices that implement EEPROM.

This macro tests and waits for any concurrent writes to EEPROM to conclude before performing the required operation. The function will initiate the write to EEPROM and this process will still be taking place when the function returns. The new data written to EEPROM will become valid at a later time. See your device data sheet for exact information about EEPROM on your target device.

Example

```
#include <xc.h>

int
main (void)
{
    EEPROM_WRITE(0x20, 0x55);
}
```

__BUILTIN_SOFTWARE_BREAKPOINT

Synopsis

```
#include <xc.h>

void __builtin_software_breakpoint(void);
```

Description

This builtin unconditionally inserts code into the program output which triggers a software breakpoint when the code is executed using a debugger.

The software breakpoint code is only generated for mid-range and PIC18 devices. Baseline devices do not support software breakpoints in this way, and the builtin will be ignored if used with these devices.

Example

```
#include <xc.h>

int
main (void)
{
    __builtin_software_breakpoint();  // stop here to begin
...
```

__CONDITIONAL_SOFTWARE_BREAKPOINT

Synopsis

```
#include <assert.h>

__conditional_software_breakpoint(expression)
```

Description

This macro implements a light-weight embedded version of the standard C `assert()` macro, and is used in the same way.

When executed, the *`expression`* argument is evaluated. If the argument is false the macro attempts to halt program execution; the macro performs no action if the argument is true.

The macro is removed from the program output if the manifest constant `NDEBUG` is defined. In addition, it is included only for debug builds (i.e., when the `__DEBUG` macro is defined). Thus, it does not consume device resources for production builds.

If the target device does not support the ability to halt via a software breakpoint, use of this macro will trigger a compiler error.

Example

```
#include <assert.h>

void getValue(int * ip) {
    __conditional_software_breakpoint(ip != NULL);
    ...
}
```

© 2012-2018 Microchip Technology Inc.

__DEBUG_BREAK

Synopsis

```
#include <xc.h>

void __debug_break(void);
```

Description

This macro conditionally inserts code into the program output which triggers a software breakpoint when the code is executed using a debugger. The code is only generated for debug builds (see Section 2.3.7 “What is Different About an MPLAB X IDE Debug Build?”) and is omitted for production builds (i.e., when the `__DEBUG` macro is defined).

The software breakpoint code is only generated for mid-range and PIC18 devices. Baseline devices do not support software breakpoints in this way, and the macro will be ignored if used with these devices.

Example

```
#include <xc.h>

int
main (void)
{
    __debug_break();  // stop here to begin
...
```

See also

`__builtin_software_breakpoint()`

__DELAY_MS, __DELAY_US, __DELAYWDT_US, __DELAYWDT_MS

Synopsis

```
__delay_ms(x)  // request a delay in milliseconds
__delay_us(x)  // request a delay in microseconds
__delaywdt_ms(x)  // request a delay in milliseconds
__delaywdt_us(x)  // request a delay in microseconds
```

Description

It is often more convenient to request a delay in time-based terms, rather than in cycle counts. The macros `__delay_ms(`*x*`)` and `__delay_us(`*x*`)` are provided to meet this need. These macros convert the time-based request into instruction cycles that can be used with `_delay(`*n*`)`. In order to achieve this, these macros require the prior definition of preprocessor macro `_XTAL_FREQ`, which indicates the system frequency. This macro should equate to the oscillator frequency (in hertz) used by the system. Note that this macro only controls the behavior of these delays and does not affect the device execution speed.

On PIC18 devices only, you can use the alternate WDT-form of these functions, which uses the `CLRWDT` instruction as part of the delay code. See the `_delaywdt` function.

The macro argument must be a constant expression. An error will result if these macros are used without defining the oscillator frequency symbol, the delay period requested is too large, or the delay period is not a constant.

See also

`_delay(), _delaywdt()`

__EEPROM_DATA

Synopsis

```
#include <xc.h>

__EEPROM_DATA(a,b,c,d,e,f,g,h)
```

Description

This macro is used to store initial values in the device’s EEPROM registers at the time of programming.

The macro must be given blocks of 8 bytes to write each time it is called, and can be called repeatedly to store multiple blocks.

`__EEPROM_DATA()` will begin writing to EEPROM address zero, and auto-increments the address written to by 8 each time it is used.

Example

```
#include <xc.h>

__EEPROM_DATA(0x00,0x01,0x02,0x03,0x04,0x05,0x06,0x07)
__EEPROM_DATA(0x08,0x09,0x0A,0x0B,0x0C,0x0D,0x0E,0x0F)

void
main (void)
{
}
```

__FPNORMALIZE

Synopsis

```
#include <xc.h>

double __fpnormalize(double fnum)
```

Description

This function can be used to ensure that an arbitrary 32-bit floating-point value (which is not the result of a calculation performed by the compiler) conforms to the "relaxed" floating-point rules (as described in Section 4.4.4 “Floating-Point Data Types”).

This function returns the value passed to it, but ensures that any subnormal argument is flushed to zero, and converts any negative zero argument to a positive zero result.

Example

```
#include <xc.h>

void
main (void)
{
    double input_fp;

    // read in a floating-point value from an external source
    input_fp = getFP();
    // ensure it is formatted using the relaxed rules
    input_fp = __fpnormalize(input_fp);
    ...
}
```

© 2012-2018 Microchip Technology Inc.

__OSCCAL_VAL

Synopsis

```
#include <xc.h>

unsigned char __osccal_val(void);
```

Description

This is a pseudo-function that is defined by the code generator to be a label only. The label's value is equated to the address of the `retlw` instruction, which encapsulates the oscillator configuration value. This function is only available for those devices that are shipped with such a value stored in program memory.

Calls to the function will return the device's oscillator configuration value, which can then be used in any expression, if required.

Note that this function is automatically called by the runtime start-up code (unless you have explicitly disabled this option, see Section 3.7.1.14 "osccal") and you do not need to call it to calibrate the internal oscillator.

Example

```
#include <xc.h>

void
main (void)
{
  unsigned char c;
  c = __osccal_val();
}
```

_DELAY() , _DELAYWDT

Synopsis

```
#include <xc.h>

void _delay(unsigned long cycles);
void _delaywdt(unsigned long cycles);
```

Description

This is an in-line function that is expanded by the code generator. When called, this routine expands to an in-line assembly delay sequence. The sequence will consist of code that delays for the number of instruction cycles that is specified as the argument. The argument must be a constant expression.

The `_delay` in-line function can use loops and the `NOP` instruction to implement the delay. The `_delaywdt` in-line function performs the same task, but will use the `CLRWDT` instruction, as well as loops, to achieve the specified delay.

An error will result if the requested delay is not a constant expression or is greater than 50,463,240 instructions. For even larger delays, call this function multiple times.

Example

```
#include <xc.h>

void
main (void)
{
  control |= 0x80;
  _delay(10);    // delay for 10 cycles
  control &= 0x7F;
}
```

_DELAY3()

Synopsis

```
#include <xc.h>

void _delay3(unsigned char cycles);
```

Description

This is an in-line function that is expanded by the code generator. It is only available on PIC18 and enhanced mid-range devices. When called, this routine expands to an in-line assembly delay sequence consisting of code that delays for 3 times the argument value, assuming that the argument can be loaded to WREG in one instruction, and that there are no errata-workaround NOPs present in the loop. If this is not the case, the delay will be longer. The argument can be a byte-sized constant or variable.

Example

```
#include <xc.h>

void
main (void)
{
  control |= 0x80;
  _delay3(10);    // delay for 30 cycles
  control &= 0x7F;
}
```

© 2012-2018 Microchip Technology Inc.

ASSERT

Synopsis

```
#include <assert.h>

void assert (int e)
```

Description

This macro is used for debugging purposes; the basic method of usage is to place assertions liberally throughout your code at points where correct operation of the code depends upon certain conditions being true initially. An `assert()` routine can be used to ensure at runtime that an assumption holds true. For example, the following statement asserts that `mode` is larger than zero:

```
assert(mode > 0);
```

If the expression passed to `assert()` evaluates to false at runtime, the macro attempts to print diagnostic information and abort the program. A fuller discussion of the uses of `assert()` is impossible in limited space, but it is closely linked to methods of proving program correctness.

The `assert()` macro depends on the implementation of the function `_fassert()`. The default `_fassert()` function, built into the library files, first calls the `printf()` function, which prints a message identifying the source file and line number of the assertion. Next, `_fassert()` attempts to terminate program execution by calling `abort()`. The exact behaviour of `abort()` is dependent on the selected device and whether the executable is a debug or production build. For debug builds, `abort()` will consist of a software breakpoint instruction followed by a Reset instruction, if possible. For production builds, `abort()` will consist only of a Reset instruction, if possible. In both cases, if a Reset instruction is not available, a goto instruction that jumps to itself in an endless loop is output.

The `_fassert()` routine can be adjusted to ensure it meets your application needs. Include the source file defining this function into your project, if you modify it.

Example

```
#include <assert.h>

void
ptrfunc (struct xyz * tp)
{
    assert(tp != 0);
}
```

CLRWDT

Synopsis

```
#include <xc.h>

CLRWDT();
```

Description

This macro is used to clear the device’s internal watchdog timer.

Example

```
#include <xc.h>

void
main (void)
{
    WDTCON=1;
      /* enable the WDT */
    CLRWDT();
}
```

DI, EI

Synopsis

```
#include <xc.h>

void ei (void)
void di (void)
```

Description

The `di()` and `ei()` routines disable and re-enable interrupts respectively. These are implemented as macros. The example shows the use of `ei()` and `di()` around access to a long variable that is modified during an interrupt. If this was not done, it would be possible to return an incorrect value, if the interrupt occurred between accesses to successive words of the count value.

The `ei()` macro should never be called in an interrupt function.

Example

```
#include <xc.h>

long count, val;

void
__interrupt(high_priority) tick (void)
{
    count++;
}

void
getticks (void)
{
    di();
    val = count;
    ei();
}
```

© 2012-2018 Microchip Technology Inc.

EVAL_POLY

Synopsis

```
#include <math.h>

double eval_poly (double x, const double * d, int n)
```

Description

The `eval_poly()` function evaluates a polynomial, whose coefficients are contained in the array `d`, at `x`, for example:

```
y = x*x*d2 + x*d1 + d0.
```

The order of the polynomial is passed in `n`.

Example

```
#include <stdio.h>
#include <math.h>

void
main (void)
{
    double x, y;
    double d[3] = {1.1, 3.5, 2.7};

    x = 2.2;
    y = eval_poly(x, d, 2);
    printf("The polynomial evaluated at %f is %f\n", x, y);
}
```

Return Value

A double value, being the polynomial evaluated at `x`.

`abs(), labs()`

GET_CAL_DATA

Synopsis

```
#include <xc.h>

double get_cal_data (const unsigned char * code_ptr)
```

Description

This function returns the 32-bit floating-point calibration data from the PIC MCU 14000 calibration space. It cannot be used with other devices. Only use this function to access `KREF`, `KBG`, `VHTHERM` and `KTC` (that is, the 32-bit floating-point parameters). `FOSC` and `TWDT` can be accessed directly as they are bytes.

Example

```
#include <xc.h>

void
main (void)
{
    double x;
    unsigned char y;

        /* Get the slope reference ratio. */
    x = get_cal_data(KREF);

        /* Get the WDT time-out. */
    y = TWDT;
}
```

Return Value

The value of the calibration parameter

NOP

Synopsis

```
#include <xc.h>

NOP();
```

Description

Execute `NOP` instruction here. This is often useful to fine tune delays or create a handle for breakpoints. The `NOP` instruction is sometimes required during some sensitive sequences in hardware.

Example

```
#include <xc.h>

void
crude_delay(void) {
    RA1 = 0;
    NOP();
    RA1 = 1;
   }
}
```

© 2012-2018 Microchip Technology Inc.

PUTCH

Synopsis

```
#include <conio.h>

void putch (char c)
```

Description

The `putch()` function is provided as an empty stub which can be completed as each project requires. It must be defined if you intend to use the `printf()` function. Typically this function will accept one byte of data and send this to a peripheral which is associated with stdout.

Example

```
#include <conio.h>

char * x = "This is a string";

void
main (void)
{
    char * cp;

    cp = x;
    while(*x)
        putch(*x++);
    putch('\n');
}
```

READTIMERx

Synopsis

```
#include <xc.h>
unsigned short READTIMERx (void);
```

Description

The `READTIMERx()` macro returns the value held by the TMRx register, where `x` is one of the digits 0, 1 or 3.

Example

```
#include <xc>

void
main (void)
{
    while(READTIMER0() != 0xFF)

        continue;

   SLEEP();
}
```

See Also

`WRITETIMERx()`

Return Value

The value held by the `TMRx` register.

Note

This macro can only be used with PIC18 devices.

RESET

Synopsis

```
#include <xc.h>

RESET();
```

Description

Execute a `RESET` instruction here. This will trigger a software device Reset.

Example

```
#include <xc.h>

void
main(void)
{
    init();
    while( ! (fail_code = getStatus())) {
        process();
    }
    if(fail_code > 2) // something’s serious wrong
        RESET();  // reset the whole device
    // otherwise try restart code from main()
  }
```

© 2012-2018 Microchip Technology Inc.

SLEEP

Synopsis

```
#include <xc.h>

SLEEP();
```

Description

This macro is used to put the device into a low-power standby mode.

Example

```
#include <xc.h>
extern void init(void);

void
main (void)
{
    init(); /* enable peripherals/interrupts */

    while(1)
        SLEEP();  /* save power while nothing happening */
}
```

WRITETIMERx

Synopsis

```
#include <xc.h>
void WRITETIMERx (int n);
```

Description

The `WRITETIMERx()` macro writes the 16-bit argument, n, to both bytes of the TMRx register, where `x` is one of the digits 0, 1 or 3.

Example

```
#include <xc.h>
void
main (void)
{
    WRITETIMER1(0x4A);

    while(1)

       continue;
}
```

Note

This macro can only be used with PIC18 devices.

NOTES:

© 2012-2018 Microchip Technology Inc.

Appendix B. Error and Warning Messages

B.1 INTRODUCTION

This chapter lists the MPLAB XC8 C Compiler error, warning, and advisory messages with an explanation of each message. This is the complete and historical message set covering all former HI-TECH C compilers and all compiler versions. Not all messages shown here will be relevant for the compiler version you are using.

Most messages have been assigned a unique number that appears in brackets before each message description. It is also printed by the compiler when the message is issued. The messages shown here are sorted by their number. Unnumbered messages appear toward the end and are sorted alphabetically.

The name of the application(s) that could have produced the messages are listed in brackets opposite the error message. In some cases examples of code or options that could trigger the error are given. The use of * in the error message is used to represent a string that the compiler will substitute that is specific to that particular error.

Note that one problem in your C or assembler source code can trigger more than one error message. You should attempt to resolve errors or warnings in the order in which they are produced.

MESSAGES 1-249

(1) too many errors (*) *(all applications)*

The executing compiler application has encountered too many errors and will exit immediately. Other uncompiled source files will be processed, but the compiler applications that would normally be executed in due course will not be run. The number of errors that can be accepted is controlled using the `-fmax-errors` option, See Section 3.7.4.1 "max-errors".

(2) error/warning (*) generated but no description available *(all applications)*

The executing compiler application has emitted a message (advisory/warning/error), but there is no description available in the message description file (MDF) to print. This could be because the MDF is out-of-date, or the message issue has not been translated into the selected language.

(3) malformed error information on line * in file * *(all applications)*

The compiler has attempted to load the messages for the selected language, but the message description file (MDF) was corrupted and could not be read correctly.

(100) unterminated #if[n][def] block from line * *(Preprocessor)*

A `#if` or similar block was not terminated with a matching `#endif`, for example:

```
#if INPUT        /* error flagged here */
void main(void)
{
  run();
}                /* no #endif was found in this module */
```

(101) #* cannot follow #else *(Preprocessor)*

A #else or #elif has been used in the same conditional block as a #else. These can only follow a #if, for example:

```
#ifdef FOO
  result = foo;
#else
  result = bar;
#elif defined(NEXT)   /* the #else above terminated the #if */
  result = next(0);
#endif
```

(102) #* must be in an #if *(Preprocessor)*

The #elif, #else or #endif directive must be preceded by a matching #if line. If there is an apparently corresponding #if line, check for things like extra #endifs, or improperly terminated comments, for example:

```
#ifdef FOO
  result = foo;
#endif
  result = bar;
#elif defined(NEXT)   /* the #endif above terminated the #if */
  result = next(0);
#endif
```

(103) #error: * *(Preprocessor)*

This is a programmer generated error; there is a directive causing a deliberate error. This is normally used to check compile time defines, etc. Remove the directive to remove the error, but first determine why the directive is there.

(104) preprocessor #assert failure *(Preprocessor)*

The argument to a preprocessor #assert directive has evaluated to zero. This is a programmer induced error.

```
#assert SIZE == 4  /* size should never be 4 */
```

(105) no #asm before #endasm *(Preprocessor)*

A #endasm operator has been encountered, but there was no previous matching #asm, for example:

```
void cleardog(void)
{
  clrwdt
#endasm  /* in-line assembler ends here,
            only where did it begin? */
}
```

(106) nested #asm directives *(Preprocessor)*

It is not legal to nest #asm directives. Check for a missing or misspelled #endasm directive, for example:

```
#asm
   MOVE   r0, #0aah
#asm      ; previous #asm must be closed before opening another
   SLEEP
#endasm
```

© 2012-2018 Microchip Technology Inc.

(107) illegal # directive "*" *(Preprocessor, Parser)*

The compiler does not understand the # directive. It is probably a misspelling of a directive token, for example:

```
#indef DEBUG  /* oops -- that should be #undef DEBUG */
```

(108) #if[n][def] without an argument *(Preprocessor)*

The preprocessor directives `#if`, `#ifdef`, and `#ifndef` must have an argument. The argument to `#if` should be an expression, while the argument to `#ifdef` or `#ifndef` should be a single name, for example:

```
#if            /* oops -- no argument to check */
  output = 10;
#else
  output = 20;
#endif
```

(109) #include syntax error *(Preprocessor)*

The syntax of the filename argument to `#include` is invalid. The argument to `#include` must be a valid file name, either enclosed in double quotes `""` or angle brackets `< >`. Spaces should not be included, and the closing quote or bracket must be present. There should be nothing else on the line other than comments, for example:

```
#include stdio.h  /* oops -- should be: #include <stdio.h> */
```

(110) too many file arguments; usage: cpp [input [output]] *(Preprocessor)*

`CPP` should be invoked with at most two file arguments. Contact Microchip Technical Support if the preprocessor is being executed by a compiler driver.

(111) redefining preprocessor macro "*" *(Preprocessor)*

The macro specified is being redefined to something different than the original definition. If you want to deliberately redefine a macro, use `#undef` first to remove the original definition, for example:

```
#define ONE 1
/* elsewhere: */
/* Is this correct? It will overwrite the first definition. */
#define ONE one
```

(112) #define syntax error *(Preprocessor)*

A macro definition has a syntax error. This could be due to a macro or formal parameter name that does not start with a letter or a missing *closing parenthesis*, `)`, for example:

```
#define FOO(a, 2b)  bar(a, 2b)  /* 2b is not to be! */
```

(113) unterminated string in preprocessor macro body *(Preprocessor, Assembler)*

A macro definition contains a string that lacks a closing quote.

(114) illegal #undef argument *(Preprocessor)*

The argument to `#undef` must be a valid name. It must start with a letter, for example:

```
#undef 6YYY  /* this isn't a valid symbol name */
```

(115) recursive preprocessor macro definition of "*" defined by "* " *(Preprocessor)*

The named macro has been defined in such a manner that expanding it causes a recursive expansion of itself.

(116) end of file within preprocessor macro argument from line * *(Preprocessor)*

A macro argument has not been terminated. This probably means the closing parenthesis has been omitted from a macro invocation. The line number given is the line where the macro argument started, for example:

```
#define FUNC(a, b) func(a+b)
FUNC(5, 6;    /* oops -- where is the closing bracket? */
```

(117) misplaced constant in #if *(Preprocessor)*

A constant in a `#if` expression should only occur in syntactically correct places. This error is probably caused by omission of an operator, for example:

```
#if FOO BAR  /* oops -- did you mean: #if FOO == BAR ? */
```

(118) stack overflow processing #if expression *(Preprocessor)*

The preprocessor filled up its expression evaluation stack in a `#if` expression. Simplify the expression – it probably contains too many parenthesized subexpressions.

(119) invalid expression in #if line *(Preprocessor)*

This is an internal compiler error. Contact Microchip Technical Support with details.

(120) operator "*" in incorrect context *(Preprocessor)*

An operator has been encountered in a `#if` expression that is incorrectly placed (two binary operators are not separated by a value), for example:

```
#if FOO * % BAR == 4  /* what is "* %" ? */
  #define BIG
#endif
```

(121) expression stack overflow at operator "*" *(Preprocessor)*

Expressions in `#if` lines are evaluated using a stack with a size of 128. It is possible for very complex expressions to overflow this. Simplify the expression.

(122) unbalanced parenthesis at operator "*" *(Preprocessor)*

The evaluation of a `#if` expression found mismatched parentheses. Check the expression for correct parenthesizing, for example:

```
#if ((A) + (B)  /* oops -- a missing ), I think */
  #define ADDED
#endif
```

(123) misplaced "?" or ":"; previous operator is "*" *(Preprocessor)*

A colon operator has been encountered in a `#if` expression that does not match up with a corresponding ? operator, for example:

```
#if XXX : YYY  /* did you mean:  #if COND ? XXX : YYY */
```

© 2012-2018 Microchip Technology Inc.

(124) illegal character "*" in #if *(Preprocessor)*

There is a character in a `#if` expression that should not be there. Valid characters are the letters, digits, and those comprising the acceptable operators, for example:

```
#if YYY  /* what are these characters doing here? */
  int m;
#endif
```

(125) illegal character (* decimal) in #if *(Preprocessor)*

There is a non-printable character in a `#if` expression that should not be there. Valid characters are the letters, digits, and those comprising the acceptable operators, for example:

```
#if ^S YYY  /* what is this control characters doing here? */
  int m;
#endif
```

(126) strings can't be used in #if *(Preprocessor)*

The preprocessor does not allow the use of strings in `#if` expressions, for example:

```
/* no string operations allowed by the preprocessor */
#if MESSAGE > "hello"
#define DEBUG
#endif
```

(127) bad syntax for defined() in #[el]if *(Preprocessor)*

The `defined()` pseudo-function in a preprocessor expression requires its argument to be a single name. The name must start with a letter and should be enclosed in parentheses, for example:

```
/* oops -- defined expects a name, not an expression */
#if defined(a&b)
  input = read();
#endif
```

(128) illegal operator in #if *(Preprocessor)*

A `#if` expression has an illegal operator. Check for correct syntax, for example:

```
#if FOO = 6  /* oops -- should that be: #if FOO == 5 ? */
```

(129) unexpected "\" in #if *(Preprocessor)*

The *backslash* is incorrect in the `#if` statement, for example:

```
#if FOO == \34
  #define BIG
#endif
```

(130) unknown type "*" in #[el]if sizeof() *(Preprocessor)*

An unknown type was used in a preprocessor `sizeof()`. The preprocessor can only evaluate `sizeof()` with basic types, or pointers to basic types, for example:

```
#if sizeof(unt) == 2  /* should be: #if sizeof(int) == 2 */
  i = 0xFFFF;
#endif
```

(131) illegal type combination in #[el]if sizeof() *(Preprocessor)*

The preprocessor found an illegal type combination in the argument to `sizeof()` in a `#if` expression, for example:

```
/* To sign, or not to sign, that is the error. */
#if sizeof(signed unsigned int) == 2
  i = 0xFFFF;
#endif
```

(132) no type specified in #[el]if sizeof() *(Preprocessor)*

Sizeof() was used in a preprocessor `#if` expression, but no type was specified. The argument to `sizeof()` in a preprocessor expression must be a valid simple type, or pointer to a simple type, for example:

```
#if sizeof()  /* oops -- size of what? */
  i = 0;
#endif
```

(133) unknown type code (0x*) in #[el]if sizeof() *(Preprocessor)*

The preprocessor has made an internal error in evaluating a `sizeof()` expression. Check for a malformed type specifier. This is an internal error. Contact Microchip Technical Support with details.

(134) syntax error in #[el]if sizeof() *(Preprocessor)*

The preprocessor found a syntax error in the argument to `sizeof` in a `#if` expression. Probable causes are mismatched parentheses and similar things, for example:

```
#if sizeof(int == 2)  // oops - should be: #if sizeof(int) == 2
  i = 0xFFFF;
#endif
```

(135) unknown operator (*) in #if *(Preprocessor)*

The preprocessor has tried to evaluate an expression with an operator it does not understand. This is an internal error. Contact Microchip Technical Support with details.

(137) strange character "*" after ## *(Preprocessor)*

A character has been seen after the token catenation operator ## that is neither a letter nor a digit. Because the result of this operator must be a legal token, the operands must be tokens containing only letters and digits, for example:

```
/* the ' character will not lead to a valid token */
#define cc(a, b) a ## 'b
```

(138) strange character (*) after ## *(Preprocessor)*

An unprintable character has been seen after the token catenation operator ## that is neither a letter nor a digit. Because the result of this operator must be a legal token, the operands must be tokens containing only letters and digits, for example:

```
/* the ' character will not lead to a valid token */
#define cc(a, b) a ## 'b
```

© 2012-2018 Microchip Technology Inc.

(139) end of file in comment *(Preprocessor)*

End of file was encountered inside a comment. Check for a missing closing comment flag, for example:

```
   /* Here the comment begins. I'm not sure where I end, though
}
```

(140) can't open * file "*": * *(Driver, Preprocessor, Code Generator, Assembler)*

The command file specified could not be opened for reading. Confirm the spelling and path of the file specified on the command line, for example:

```
xc8 @communds
```

should that be:

```
xc8 @commands
```

(141) can't open * file "*": * *(Any)*

An output file could not be created. Confirm the spelling and path of the file specified on the command line.

(144) too many nested #if blocks *(Preprocessor)*

`#if`, `#ifdef`, etc., blocks can only be nested to a maximum of 32.

(146) #include filename too long *(Preprocessor)*

A filename constructed while looking for an include file has exceeded the length of an internal buffer. Because this buffer is 4096 bytes long, this is unlikely to happen.

(147) too many #include directories specified *(Preprocessor)*

A maximum of 7 directories can be specified for the preprocessor to search for include files. The number of directories specified with the driver is too many.

(148) too many arguments for preprocessor macro *(Preprocessor)*

A macro can only have up to 31 parameters, per the C Standard.

(149) preprocessor macro work area overflow *(Preprocessor)*

The total length of a macro expansion has exceeded the size of an internal table. This table is normally 32768 bytes long. Thus any macro expansion must not expand to a total of more than 32K bytes.

(150) illegal "__" preprocessor macro "*" *(Preprocessor)*

This is an internal compiler error. Contact Microchip Technical Support with details.

(151) too many arguments in preprocessor macro expansion *(Preprocessor)*

There were too many arguments supplied in a macro invocation. The maximum number allowed is 31.

(152) bad dp/nargs in openpar(): c = * *(Preprocessor)*

This is an internal compiler error. Contact Microchip Technical Support with details.

(153) out of space in preprocessor macro * argument expansion ***(Preprocessor)***

A macro argument has exceeded the length of an internal buffer. This buffer is normally 4096 bytes long.

(155) work buffer overflow concatenating "*" ***(Preprocessor)***

This is an internal compiler error. Contact Microchip Technical Support with details.

(156) work buffer "*" overflow ***(Preprocessor)***

This is an internal compiler error. Contact Microchip Technical Support with details.

(157) can't allocate * bytes of memory ***(Code Generator, Assembler)***

This is an internal compiler error. Contact Microchip Technical Support with details.

(158) invalid disable in preprocessor macro "*" ***(Preprocessor)***

This is an internal compiler error. Contact Microchip Technical Support with details.

(159) too many calls to unget() ***(Preprocessor)***

This is an internal compiler error. Contact Microchip Technical Support with details.

(161) control line "*" within preprocessor macro expansion ***(Preprocessor)***

A preprocessor control line (one starting with a #) has been encountered while expanding a macro. This should not happen.

(162) #warning: * ***(Preprocessor, Driver)***

This warning is either the result of user-defined `#warning` preprocessor directive, or the driver encountered a problem reading the map file. If the latter, contact Microchip Technical Support with details

(163) unexpected text in control line ignored ***(Preprocessor)***

This warning occurs when extra characters appear on the end of a control line. The extra text will be ignored, but a warning is issued. It is preferable (and in accordance with Standard C) to enclose the text as a comment, for example:

```
#if defined(END)
  #define NEXT
#endif END     /* END would be better in a comment here */
```

(164) #include filename "*" was converted to lower case ***(Preprocessor)***

The `#include` file name had to be converted to lowercase before it could be opened, for example:

```
#include <STDIO.H>  /* oops -- should be: #include <stdio.h> */
```

(165) #include filename "*" does not match actual name (check upper/lower case) ***(Preprocessor)***

In Windows versions this means the file to be included actually exists and is spelled the same way as the `#include` filename; however, the case of each does not exactly match. For example, specifying `#include "code.c"` will include `Code.c`, if it is found. In Linux versions this warning could occur if the file wasn't found.

© 2012-2018 Microchip Technology Inc.

(166) too few values specified with option "*" *(Preprocessor)*

The list of values to the preprocessor (CPP) `-S` option is incomplete. This should not happen if the preprocessor is being invoked by the compiler driver. The values passed to this option represent the sizes of `char`, `short`, `int`, `long`, `float` and `double` types.

(167) too many values specified with -S option; "*" unused *Preprocessor)*

There were too many values supplied to the -S preprocessor option. See message 166.

(168) unknown option "*" *(Any)*

The option given to the component which caused the error is not recognized.

(169) strange character (*) after ## *(Preprocessor)*

There is an unexpected character after #.

(170) symbol "*" in undef was never defined *(Preprocessor)*

The symbol supplied as argument to `#undef` was not already defined. This warning can be disabled with some compilers. This warning can be avoided with code like:

```
#ifdef SYM
  #undef SYM  /* only undefine if defined */
#endif
```

(171) wrong number of preprocessor macro arguments for "*" (* instead of *) *(Preprocessor)*

A macro has been invoked with the wrong number of arguments, for example:

```
#define ADD(a, b) (a+b)
ADD(1, 2, 3)        /* oops -- only two arguments required */
```

(172) formal parameter expected after # *(Preprocessor)*

The stringization operator # (not to be confused with the leading # used for preprocessor control lines) must be followed by a formal macro parameter, for example:

```
#define str(x) #y  /* oops -- did you mean x instead of y? */
```

If you need to stringize a token, you will need to define a special macro to do it, for example:

```
#define __mkstr__(x) #x
```

then use `__mkstr__(token)` wherever you need to convert a token into a string.

(173) undefined symbol "*" in #if; 0 used *(Preprocessor)*

A symbol on a `#if` expression was not a defined preprocessor macro. For the purposes of this expression, its value has been taken as zero. This warning can be disabled with some compilers. Example:

```
#if FOO+BAR    /* e.g. FOO was never #defined */
  #define GOOD
#endif
```

(174) multi-byte constant "*" isn’t portable *(Preprocessor)*

Multi-byte constants are not portable; and, in fact, will be rejected by later passes of the compiler, for example:

```
#if CHAR == ’ab’
  #define MULTI
#endif
```

(175) division by zero in #if; zero result assumed *(Preprocessor)*

Inside a `#if` expression, there is a division by zero which has been treated as yielding zero, for example:

```
#if foo/0  /* divide by 0: was this what you were intending? */
  int a;
#endif
```

(176) missing newline *(Preprocessor)*

A new line is missing at the end of the line. Each line, including the last line, must have a new line at the end. This problem is normally introduced by editors.

(177) symbol "*" in -U option was never defined *(Preprocessor)*

A macro name specified in a `-U` option to the preprocessor was not initially defined, and thus cannot be undefined.

(179) nested comments *(Preprocessor)*

This warning is issued when nested comments are found. A nested comment can indicate that a previous closing comment marker is missing or malformed, for example:

```
output = 0;  /* a comment that was left unterminated
flag = TRUE; /* next comment:
                hey, where did this line go? */
```

(180) unterminated comment in included file *(Preprocessor)*

Comments begun inside an included file must end inside the included file.

(181) non-scalar types can’t be converted to other types *(Parser)*

You cannot convert a structure, union, or array to another type, for example:

```
struct TEST test;
struct TEST * sp;
sp = test;       /* oops -- did you mean: sp = &test; ? */
```

(182) illegal conversion between types *(Parser)*

This expression implies a conversion between incompatible types, i.e., a conversion of a structure type into an integer, for example:

```
struct LAYOUT layout;
int i;
layout = i;          /* int cannot be converted to struct */
```

Note that even if a structure only contains an `int` , for example, it cannot be assigned to an `int` variable and vice versa.

© 2012-2018 Microchip Technology Inc.

(183) function or function pointer required *(Parser)*

Only a function or function pointer can be the subject of a function call, for example:

```
int a, b, c, d;
a = b(c+d);   /* b is not a function --
                 did you mean a = b*(c+d) ? */
```

(184) calling an interrupt function is illegal *(Parser)*

A function-qualified `interrupt` cannot be called from other functions. It can only be called by a hardware (or software) interrupt. This is because an `interrupt` function has special function entry and exit code that is appropriate only for calling from an interrupt. An `interrupt` function can call other non-`interrupt` functions.

(185) function does not take arguments *(Parser, Code Generator)*

This function has no parameters, but it is called here with one or more arguments, for example:

```
int get_value(void);
void main(void)
{
  int input;
  input = get_value(6);  /* oops --
                            parameter should not be here */
}
```

(186) too many function arguments *(Parser)*

This function does not accept as many arguments as there are here.

```
void add(int a, int b);
add(5, 7, input);      /* call has too many arguments */
```

(187) too few function arguments *(Parser)*

This function requires more arguments than are provided in this call, for example:

```
void add(int a, int b);
add(5);                  /* this call needs more arguments */
```

(188) constant expression required *(Parser)*

In this context an expression is required that can be evaluated to a constant at compile time, for example:

```
int a;
switch(input) {
  case a:  /* oops!
              cannot use variable as part of a case label */
    input++;
}
```

(189) illegal type for array dimension *(Parser)*

An array dimension must be either an integral type or an enumerated value.

```
int array[12.5];  /* oops -- twelve and a half elements, eh? */
```

(190) illegal type for index expression *(Parser)*

An index expression must be either integral or an enumerated value, for example:

```
int i, array[10];
i = array[3.5];   /* oops --
                     exactly which element do you mean? */
```

(191) cast type must be scalar or void *(Parser)*

A typecast (an abstract type declarator enclosed in parentheses) must denote a type which is either scalar (i.e., not an array or a structure) or the type `void`, for example:

```
lip = (long [])input;  /* oops -- possibly: lip = (long *)input */
```

(192) undefined identifier "*" *(Parser)*

This symbol has been used in the program, but has not been defined or declared. Check for spelling errors if you think it has been defined.

(193) not a variable identifier "*" *(Parser)*

This identifier is not a variable; it can be some other kind of object, i.e., a label.

(194) ")" expected *(Parser)*

A *closing parenthesis*, `)`, was expected here. This can indicate you have left out this character in an expression, or you have some other syntax error. The error is flagged on the line at which the code first starts to make no sense. This can be a statement following the incomplete expression, for example:

```
if(a == b  /* the closing parenthesis is missing here */
  b = 0;   /* the error is flagged here */
```

(195) expression syntax *(Parser)*

This expression is badly formed and cannot be parsed by the compiler, for example:

```
a /=% b;  /* oops -- possibly that should be: a /= b; */
```

(196) struct/union required *(Parser)*

A structure or union identifier is required before a *dot* `"."` , for example:

```
int a;
a.b = 9;  /* oops -- a is not a structure */
```

(197) struct/union member expected *(Parser)*

A structure or union member name must follow a *dot* "`.`" or an arrow ("`->`").

(198) undefined struct/union "*" *(Parser)*

The specified structure or union tag is undefined, for example:

```
struct WHAT what;  /* a definition for WHAT was never seen */
```

(199) logical type required *(Parser)*

The expression used as an operand to `if`, `while` statements or to boolean operators like `!` and && must be a scalar integral type, for example:

```
struct FORMAT format;
if(format)            /* this operand must be a scaler type */
  format.a = 0;
```

© 2012-2018 Microchip Technology Inc.

(200) taking the address of a register variable is illegal *(Parser)*

A variable declared register cannot have storage allocated for it in memory, and thus it is illegal to attempt to take the address of it by applying the & operator, for example:

```
int * proc(register int in)
{
  int * ip = &in;
  /* oops -- in cannot have an address to take */
  return ip;
}
```

(201) taking the address of this object is illegal *(Parser)*

The expression which was the operand of the & operator is not one that denotes memory storage (“an lvalue”) and therefore its address cannot be defined, for example:

```
ip = &8;  /* oops -- you cannot take the address of a literal */
```

(202) only lvalues can be assigned to or modified *(Parser)*

Only an lvalue (i.e., an identifier or expression directly denoting addressable storage) can be assigned to or otherwise modified, for example:

```
int array[10];
int * ip;
char c;
array = ip;   /* array is not a variable,
                 it cannot be written to */
```

A typecast does not yield an lvalue, for example:

```
/* the contents of c cast to int
   is only a intermediate value */
(int)c = 1;
```

However, you can write this using pointers:

```
*(int *)&c = 1
```

(203) illegal operation on bit variable *(Parser)*

Not all operations on `bit` variables are supported. This operation is one of those, for example:

```
bit   b;
int * ip;
ip = &b;  /* oops --
             cannot take the address of a bit object */
```

(204) void function can’t return a value *(Parser)*

A void function cannot return a value. Any `return` statement should not be followed by an expression, for example:

```
void run(void)
{
  step();
  return 1;
  /* either run should not be void, or remove the 1 */
}
```

(205) integral type required *(Parser)*

This operator requires operands that are of integral type only.

(206) illegal use of void expression ***(Parser)***

A `void` expression has no value and therefore you cannot use it anywhere an expression with a value is required, i.e., as an operand to an arithmetic operator.

(207) simple type required for "*" ***(Parser)***

A simple type (i.e., not an array or structure) is required as an operand to this operator.

(208) operands of "*" not same type ***(Parser)***

The operands of this operator are of different pointers, for example:

```
int * ip;
char * cp, * cp2;
cp = flag ? ip : cp2;
/* result of ? : will be int * or char * */
```

Possibly, you meant something like:

```
cp = flag ? (char *)ip : cp2;
```

(209) type conflict ***(Parser)***

The operands of this operator are of incompatible types.

(210) bad size list ***(Parser)***

This is an internal compiler error. Contact Microchip Technical Support with details.

(211) taking sizeof bit is illegal ***(Parser)***

It is illegal to use the `sizeof` operator with the C `bit` type. When used against a type, the `sizeof` operator gives the number of bytes required to store an object that type. Therefore its usage with the `bit` type make no sense and it is an illegal operation.

(212) missing number after pragma "pack" ***(Parser)***

The pragma `pack` requires a decimal number as argument. This specifies the alignment of each member within the structure. Use this with caution as some processors enforce alignment and will not operate correctly if word fetches are made on odd boundaries, for example:

```
#pragma pack  /* what is the alignment value */
```

Possibly, you meant something like:

```
#pragma pack 2
```

(214) missing number after pragma "interrupt_level" ***(Parser)***

The pragma `interrupt_level` requires an argument to indicate the interrupt level. It will be the value 1 for mid-range devices, or 1 or 2 or PIC18 devices.

(215) missing argument to pragma "switch" ***(Parser)***

The pragma switch requires an argument of `auto`, `direct` or `simple`, for example:

```
#pragma switch  /* oops -- this requires a switch mode */
```

Possibly, you meant something like:

```
#pragma switch simple
```

© 2012-2018 Microchip Technology Inc.

(216) missing argument to pragma "psect" *(Parser)*

The pragma `psect` requires an argument of the form *oldname* = *newname* where *old-name* is an existing psect name known to the compiler and *newname* is the desired new name, for example:

```
#pragma psect  /* oops -- this requires an psect to redirect */
```

Possibly, you meant something like:

```
#pragma psect text=specialtext
```

(218) missing name after pragma "inline" *(Parser)*

The `inline` pragma expects the name of a function to follow. The function name must be recognized by the code generator for it to be expanded; other functions are not altered, for example:

```
#pragma inline  /* what is the function name? */
```

Possibly, you meant something like:

```
#pragma inline memcpy
```

(219) missing name after pragma "printf_check" *(Parser)*

The `printf_check` pragma expects the name of a function to follow. This specifies printf-style format string checking for the function, for example:

```
#pragma printf_check  /* what function is to be checked? */
```

Possibly, you meant something like:

```
#pragma printf_check sprintf
```

Pragmas for all the standard printf-like function are already contained in `<stdio.h>`.

(220) exponent expected *(Parser)*

A floating-point constant must have at least one digit after the `e` or `E`, for example:

```
float f;
f = 1.234e;  /* oops -- what is the exponent? */
```

(221) hexadecimal digit expected *(Parser)*

After `0x` should follow at least one of the HEX digits `0-9` and `A-F` or `a-f`, for example:

```
a = 0xg6;  /* oops -- was that meant to be a = 0xf6 ? */
```

(222) binary digit expected *(Parser)*

A binary digit was expected following the `0b` format specifier, for example:

```
i = 0bf000;  /* oops -- f000 is not a base two value */
```

(223) digit out of range *(Parser, Assembler)*

A digit in this number is out of range of the radix for the number, i.e., using the digit 8 in an octal number, or HEX digits A-F in a decimal number. An octal number is denoted by the digit string commencing with a zero, while a HEX number starts with “0X” or “0x”. For example:

```
int a = 058;
/* leading 0 implies octal which has digits 0 - 7 */
```

(224) illegal "#" directive ***(Parser)***

An illegal # preprocessor has been detected. Likely, a directive has been misspelled in your code somewhere.

(225) missing character in character constant **(Parser)**

The character inside the single quotes is missing, for example:

```
char c = "; /* the character value of what? */
```

(226) char const too long ***(Parser)***

A character constant enclosed in single quotes cannot contain more than one character, for example:

```
c = ’12’; /* oops -- only one character can be specified */
```

(227) "." expected after ".." ***(Parser)***

The only context in which two successive dots can appear is as part of the *ellipsis* symbol, which must have 3 dots. (An *ellipsis* is used in function prototypes to indicate a variable number of parameters.)

Either `..` was meant to be an *ellipsis* symbol which would require you to add an extra *dot*, or it was meant to be a *structure member operator* which would require you to remove one *dot*.

(228) illegal character (*) ***(Parser)***

This character is illegal in the C code. Valid characters are the letters, digits and those comprising the acceptable operators, for example:

```
c = a; /* oops -- did you mean c = ’a’; ? */
```

(229) unknown qualifier "*" given to -A ***(Parser)***

This is an internal compiler error. Contact Microchip Technical Support with details.

(230) missing argument to -A ***(Parser)***

This is an internal compiler error. Contact Microchip Technical Support with details.

(231) unknown qualifier "*" given to -I ***(Parser)***

This is an internal compiler error. Contact Microchip Technical Support with details.

(232) missing argument to -I ***(Parser)***

This is an internal compiler error. Contact Microchip Technical Support with details.

(233) bad -Q option "*" ***(Parser)***

This is an internal compiler error. Contact Microchip Technical Support with details.

(234) close error ***(Parser)***

This is an internal compiler error. Contact Microchip Technical Support with details.

© 2012-2018 Microchip Technology Inc.

(236) simple integer expression required ***(Parser)***

A simple integral expression is required after the operator `@`, used to associate an absolute address with a variable, for example:

```
int address;
char LOCK @ address;
```

(237) function "*" redefined ***(Parser)***

More than one definition for a function has been encountered in this module. Function overloading is illegal, for example:

```
int twice(int a)
{
  return a*2;
}
/* only one prototype & definition of rv can exist */
long twice(long a)
{
  return a*2;
}
```

(238) illegal initialization ***(Parser)***

You cannot initialize a `typedef` declaration, because it does not reserve any storage that can be initialized, for example:

```
/* oops -- uint is a type, not a variable */
typedef unsigned int uint = 99;
```

(239) identifier "*" redefined (from line *) ***(Parser)***

This identifier has already been defined in the same scope. It cannot be defined again, for example:

```
  int a;  /* a filescope variable called "a" */
  int a;  /* attempting to define another of the same name */
```

Note that variables with the same name, but defined with different scopes, are legal; but; not recommended.

(240) too many initializers ***(Parser)***

There are too many initializers for this object. Check the number of initializers against the object definition (array or structure), for example:

```
/* three elements, but four initializers */
int ivals[3] = { 2, 4, 6, 8};
```

(241) initialization syntax ***(Parser)***

The initialization of this object is syntactically incorrect. Check for the correct placement and number of braces and commas, for example:

```
int iarray[10] = {{’a’, ’b’, ’c’};
/* oops -- one two many {s */
```

(242) illegal type for switch expression *(Parser)*

A `switch` operation must have an expression that is either an integral type or an enumerated value, e.g:

```
double d;
switch(d) {  /* oops -- this must be integral */
  case '1.0':
    d = 0;
}
```

(243) inappropriate break/continue *(Parser)*

A `break` or `continue` statement has been found that is not enclosed in an appropriate control structure. A `continue` can only be used inside a `while`, `for`, or `do while` loop, while `break` can only be used inside those loops or a `switch` statement, for example:

```
switch(input) {
  case 0:
    if(output == 0)
      input = 0xff;
    } /* oops! this should not be here; it closed the switch */
    break;     /* this should be inside the switch */
```

(244) "default" case redefined *(Parser)*

Only one `default` label is allowed to be in a switch statement. You have more than one, for example:

```
switch(a) {
default:     /* if this is the default case... */
  b = 9;
  break;
default:     /* then what is this? */
  b = 10;
  break;
```

(245) "default" case not in switch *(Parser)*

A label has been encountered called `default`, but it is not enclosed by a `switch` statement. A `default` label is only legal inside the body of a `switch` statement.

If there is a `switch` statement before this `default` label, there could be one too many closing braces in the `switch` code. That would prematurely terminate the `switch` statement. See message 246.

© 2012-2018 Microchip Technology Inc.

(246) case label not in switch *(Parser)*

A `case` label has been encountered, but there is no enclosing `switch` statement. A `case` label can only appear inside the body of a `switch` statement.

If there is a `switch` statement before this `case` label, there might be one too many closing braces in the `switch` code. That would prematurely terminate the `switch` statement, for example:

```
switch(input) {
  case ’0’:
    count++;
    break;
  case ’1’:
    if(count>MAX)
      count= 0;
    }          /* oops -- this shouldn’t be here */
    break;
  case ’2’:    /* error flagged here */
```

(247) duplicate label "*" *(Parser)*

The same name is used for a label more than once in this function. Note that the scope of labels is the entire function, not just the block that encloses a label, for example:

```
start:
  if(a > 256)
    goto end;
start:           /* error flagged here */
  if(a == 0)
    goto start;  /* which start label do I jump to? */
```

(248) inappropriate "else" *(Parser)*

An `else` keyword has been encountered that cannot be associated with an `if` statement. This can mean there is a missing brace or other syntactic error, for example:

```
/* here is a comment which I have forgotten to close...
if(a > b) {
  c = 0;
/* ... that will be closed here, thus removing the "if" */
else        /* my "if" has been lost */
  c = 0xff;
```

(249) probable missing "}" in previous block *(Parser)*

The compiler has encountered what looks like a function or other declaration, but the preceding function was ended with a closing brace. This probably means that a closing brace has been omitted from somewhere in the previous function, although it might not be the last one, for example:

```
void set(char a)
{
  PORTA = a;
                    /* the closing brace was left out here */
void clear(void)  /* error flagged here */
{
  PORTA = 0;
}
```

MESSAGES 250-499

(251) array dimension redeclared *(Parser)*

An array dimension has been declared as a different non-zero value from its previous declaration. It is acceptable to redeclare the size of an array that was previously declared with a zero dimension; but, not otherwise, for example:

```
extern int array[5];
int array[10];       /* oops -- has it 5 or 10 elements? */
```

(252) argument * conflicts with prototype *(Parser)*

The argument specified (argument 0 is the left most argument) of this function definition does not agree with a previous prototype for this function, for example:

```
/* this is supposedly calc's prototype */
extern int calc(int, int);
int calc(int a, long int b)  /* hmmm -- which is right? */
{                            /* error flagged here */
  return sin(b/a);
}
```

(253) argument list conflicts with prototype *(Parser)*

The argument list in a function definition is not the same as a previous prototype for that function. Check that the number and types of the arguments are all the same.

```
extern int calc(int);   /* this is supposedly calc's prototype */
int calc(int a, int b)  /* hmmm -- which is right? */
{                       /* error flagged here */
  return a + b;
}
```

(254) undefined *: "*" *(Parser)*

This is an internal compiler error. Contact Microchip Technical Support with details.

(255) not a member of the struct/union "*" *(Parser)*

This identifier is not a member of the structure or union type with which it used here, for example:

```
struct {
  int a, b, c;
} data;
if(data.d)    /* oops --
                 there is no member d in this structure */
  return;
```

(256) too much indirection *(Parser)*

A pointer declaration can only have 16 levels of indirection.

(257) only "register" storage class allowed *(Parser)*

The only storage class allowed for a function parameter is `register`, for example:

```
void process(static int input)
```

© 2012-2018 Microchip Technology Inc.

(258) duplicate qualifier *(Parser)*

There are two occurrences of the same qualifier in this type specification. This can occur either directly or through the use of a typedef. Remove the redundant qualifier. For example:

```
typedef volatile int vint;
/* oops -- this results in two volatile qualifiers */
volatile vint very_vol;
```

(259) object can’t be qualified both far and near *(Parser)*

It is illegal to qualify a type as both `far` and `near`, for example:

```
far near int spooky;  /* oops -- choose far or near, not both */
```

(260) undefined enum tag "*" *(Parser)*

This enum tag has not been defined, for example:

```
enum WHAT what;  /* a definition for WHAT was never seen */
```

(261) struct/union member "*" redefined *(Parser)*

This name of this member of the struct or union has already been used in this `struct` or `union`, for example:

```
struct {
  int a;
  int b;
  int a;  /* oops -- a different name is required here */
} input;
```

(262) struct/union "*" redefined *(Parser)*

A structure or union has been defined more than once, for example:

```
struct {
  int a;
} ms;
struct {
  int a;
} ms;    /* was this meant to be the same name as above? */
```

(263) members can’t be functions *(Parser)*

A member of a structure or a union cannot be a function. It could be a pointer to a function, for example:

```
struct {
  int a;
  int get(int);  /* should be a pointer: int (*get)(int); */
} object;
```

(264) bad bitfield type *(Parser)*

A bit-field can only have a type of `int` (or `unsigned`), for example:

```
struct FREG {
  char b0:1;   /* these must be part of an int, not char */
  char   :6;
  char b7:1;
} freg;
```

(265) integer constant expected *(Parser)*

A *colon* appearing after a member name in a structure declaration indicates that the member is a bit-field. An integral constant must appear after the *colon* to define the number of bits in the bit-field, for example:

```
struct {
  unsigned first:  /* oops -- should be: unsigned first; */
  unsigned second;
} my_struct;
```

If this was meant to be a structure with bit-fields, then the following illustrates an example:

```
struct {
  unsigned first : 4;  /* 4 bits wide */
  unsigned second: 4;  /* another 4 bits */
} my_struct;
```

(266) storage class illegal *(Parser)*

A structure or union member cannot be given a storage class. Its storage class is determined by the storage class of the structure, for example:

```
struct {
  /* no additional qualifiers can be present with members */
  static int first;
} ;
```

(267) bad storage class *(Code Generator)*

The code generator has encountered a variable definition whose storage class is invalid, for example:

```
auto int foo; /* auto not permitted with global variables */
int power(static int a)  /* parameters cannot be static */
{
  return foo * a;
}
```

(268) inconsistent storage class *(Parser)*

A declaration has conflicting storage classes. Only one storage class should appear in a declaration, for example:

```
extern static int where;  /* so is it static or extern? */
```

(269) inconsistent type *(Parser)*

Only one basic type can appear in a declaration, for example:

```
int float input;  /* is it int or float? */
```

(270) variable can't have storage class "register" *(Parser)*

Only function parameters or `auto` variables can be declared using the `register` qualifier, for example:

```
register int gi;      /* this cannot be qualified register */
int process(register int input)  /* this is okay */
{
  return input + gi;
}
```

© 2012-2018 Microchip Technology Inc.

(271) type can’t be long *(Parser)*

Only `int` and `float` can be qualified with `long`.

```
long char lc;  /* what? */
```

(272) type can’t be short *(Parser)*

Only `int` can be modified with `short`, for example:

```
short float sf;  /* what? */
```

(273) type can’t be both signed and unsigned *(Parser)*

The type modifiers `signed` and `unsigned` cannot be used together in the same declaration, as they have opposite meaning, for example:

```
signed unsigned int confused;  /* which is it? */
```

(274) type can’t be unsigned *(Parser)*

A floating-point type cannot be made `unsigned`, for example:

```
unsigned float uf;  /* what? */
```

(275) "..." illegal in non-prototype argument list *(Parser)*

The *ellipsis* symbol can only appear as the last item in a prototyped argument list. It cannot appear on its own, nor can it appear after argument names that do not have types; i.e., K&R-style non-prototype function definitions. For example:

```
/* K&R-style non-prototyped function definition */
int kandr(a, b, ...)
  int a, b;
{
```

(276) type specifier required for prototyped argument *(Parser)*

A type specifier is required for a prototyped argument. It is not acceptable to just have an identifier.

(277) can’t mix prototyped and non-prototyped arguments *(Parser)*

A function declaration can only have all prototyped arguments (i.e., with types inside the parentheses) or all K&R style arguments (i.e., only names inside the parentheses and the argument types in a declaration list before the start of the function body), for example:

```
int plus(int a, b)  /* oops -- a is prototyped, b is not */
int b;
{
  return a + b;
}
```

(278) argument "*" redeclared *(Parser)*

The specified argument is declared more than once in the same argument list, for example:

```
/* cannot have two parameters called "a" */
int calc(int a, int a)
```

(279) initialization of function arguments is illegal ***(Parser)***

A function argument cannot have an initializer in a declaration. The initialization of the argument happens when the function is called and a value is provided for the argument by the calling function, for example:

```
/* oops -- a is initialized when proc is called */
extern int proc(int a = 9);
```

(280) arrays of functions are illegal ***(Parser)***

You cannot define an array of functions. You can, however, define an array of pointers to functions, for example:

```
int * farray[](); /* oops -- should be: int (* farray[])(); */
```

(281) functions can't return functions ***(Parser)***

A function cannot return a function. It can return a function pointer. A function returning a pointer to a function could be declared like this: int (* (name()))(). Note the many parentheses that are necessary to make the parts of the declaration bind correctly.

(282) functions can't return arrays ***(Parser)***

A function can return only a scalar (simple) type or a structure. It cannot return an array.

(283) dimension required ***(Parser)***

Only the most significant (i.e., the first) dimension in a multi-dimension array cannot be assigned a value. All succeeding dimensions must be present as a constant expression, for example:

```
/* This should be, for example: int arr[][7] */
int get_element(int arr[2][])
{
  return array[1][6];
}
```

(284) invalid dimension ***(Parser)***

The array dimension specified is not valid. It must be larger than 0.

```
int array[0]; // oops -- you cannot have an array of size 0
```

(285) no identifier in declaration ***(Parser)***

The identifier is missing in this declaration. This error can also occur when the compiler has been confused by such things as missing closing braces, for example:

```
void interrupt(void) /* what is the name of this function? */
{
}
```

(286) declarator too complex ***(Parser)***

This declarator is too complex for the compiler to handle. Examine the declaration and find a way to simplify it. If the compiler finds it too complex, so will anybody maintaining the code.

© 2012-2018 Microchip Technology Inc.

(287) arrays of bits or pointers to bit are illegal *(Parser)*

It is not legal to have an array of bits, or a pointer to bit variable, for example:

```
bit barray[10];  /* wrong -- no bit arrays */
bit * bp;        /* wrong -- no pointers to bit variables */
```

(288) the type 'void' is applicable only to functions *(Parser)*

A variable cannot be `void`. Only a function can be `void`, for example:

```
int a;
void b;  /* this makes no sense */
```

(289) the specifier 'interrupt' is applicable only to functions *(Parser)*

The qualifier `interrupt` cannot be applied to anything except a function, for example:

```
/* variables cannot be qualified interrupt */
interrupt int input;
```

(290) illegal function qualifier(s) *(Parser)*

A qualifier has been applied to a function which makes no sense in this context. Some qualifier only make sense when used with an `lvalue`, i.e., `const` or `volatile`. This can indicate that you have forgotten a star `*` that is indicating that the function should return a pointer to a qualified object, for example:

```
const char ccrv(void) /* const * char ccrv(void) perhaps? */
{                     /* error flagged here */
  return ccip;
}
```

(291) K&R identifier "*" not an argument *(Parser)*

This identifier, that has appeared in a K&R style argument declarator, is not listed inside the parentheses after the function name, for example:

```
int process(input)
int unput;        /* oops -- that should be int input; */
{
}
```

(292) a function is not a valid parameter type *(Parser)*

A function parameter cannot be a function. It can be a pointer to a function, so perhaps a "`*`" has been omitted from the declaration.

(293) bad size in index_type() *(Parser)*

This is an internal compiler error. Contact Microchip Technical Support with details.

(294) can’t allocate * bytes of memory *(Code Generator, Hexmate)*

This is an internal compiler error. Contact Microchip Technical Support with details.

(295) expression too complex *(Parser)*

This expression has caused overflow of the compiler’s internal stack and should be rearranged or split into two expressions.

(296) out of memory *(Objtohex)*

This could be an internal compiler error. Contact Microchip Technical Support with details.

(297) bad argument (*) to tysize() *(Parser)*

This is an internal compiler error. Contact Microchip Technical Support with details.

(298) end of file in #asm *(Preprocessor)*

An end of file has been encountered inside a `#asm` block. This probably means the `#endasm` is missing or misspelled, for example:

```
#asm
  MOV  r0, #55
  MOV  [r1], r0
}                /* oops -- where is the #endasm */
```

(300) unexpected end of file *(Parser)*

An end-of-file in a C module was encountered unexpectedly, for example:

```
void main(void)
{
  init();
  run();    /* is that it? What about the close brace */
```

(301) end of file on string file *(Parser)*

This is an internal compiler error. Contact Microchip Technical Support with details.

(302) can't reopen "*": * *(Parser)*

This is an internal compiler error. Contact Microchip Technical Support with details.

(303) can't allocate * bytes of memory (line *) *(Parser)*

The parser was unable to allocate memory for the longest string encountered, as it attempts to sort and merge strings. Try reducing the number or length of strings in this module.

(306) can't allocate * bytes of memory for * *(Code Generator)*

This is an internal compiler error. Contact Microchip Technical Support with details.

(307) too many qualifier names *(Parser)*

This is an internal compiler error. Contact Microchip Technical Support with details.

(308) too many case labels in switch *(Code Generator)*

There are too many `case` labels in this `switch` statement. The maximum allowable number of `case` labels in any one `switch` statement is 511.

(309) too many symbols *(Assembler, Parser)*

There are too many symbols for the assembler's symbol table. Reduce the number of symbols in your program.

© 2012-2018 Microchip Technology Inc.

(310) "]" expected ***(Parser)***

A closing square bracket was expected in an array declaration or an expression using an array index, for example:

```
process(carray[idx);  /* oops --
                         should be: process(carray[idx]); */
```

(311) closing quote expected ***(Parser)***

A closing quote was expected for the indicated string.

(312) "*" expected ***(Parser)***

The indicated token was expected by the parser.

(313) function body expected ***(Parser)***

Where a function declaration is encountered with K&R style arguments (i.e., argument names; but, no types inside the parentheses) a function body is expected to follow, for example:

```
/* the function block must follow, not a semicolon */
int get_value(a, b);
```

(314) ";" expected ***(Parser)***

A *semicolon* is missing from a statement. A close brace or keyword was found following a statement with no terminating *semicolon* , for example:

```
while(a) {
  b = a--  /* oops -- where is the semicolon? */
}          /* error is flagged here */
```

Note: Omitting a semicolon from statements not preceding a close brace or keyword typically results in some other error being issued for the following code which the parser assumes to be part of the original statement.

(315) "{" expected ***(Parser)***

An *opening brace* was expected here. This error can be the result of a function definition missing the *opening brace*, for example:

```
/* oops! no opening brace after the prototype */
void process(char c)
  return max(c, 10) * 2; /* error flagged here */
}
```

(316) "}" expected ***(Parser)***

A *closing brace* was expected here. This error can be the result of a initialized array missing the *closing brace*, for example:

```
char carray[4] = { 1, 2, 3, 4;  /* oops -- no closing brace */
```

(317) "(" expected ***(Parser)***

An *opening parenthesis* , `(`, was expected here. This must be the first token after a `while` , `for` , `if` , do or `asm` keyword, for example:

```
if a == b  /* should be: if(a == b) */
  b = 0;
```

(318) string expected *(Parser)*

The operand to an `asm` statement must be a string enclosed in parentheses, for example:

```
asm(nop);  /* that should be asm("nop");
```

(319) while expected *(Parser)*

The keyword `while` is expected at the end of a `do` statement, for example:

```
do {
  func(i++);
}              /* do the block while what condition is true? */
if(i > 5)      /* error flagged here */
  end();
```

(320) ":" expected *(Parser)*

A *colon* is missing after a `case` label, or after the keyword `default`. This often occurs when a *semicolon* is accidentally typed instead of a *colon*, for example:

```
switch(input) {
  case 0;         /* oops -- that should have been: case 0: */
    state = NEW;
```

(321) label identifier expected *(Parser)*

An identifier denoting a label must appear after `goto`, for example:

```
if(a)
  goto 20;
/* this is not BASIC -- a valid C label must follow a goto */
```

(322) enum tag or "{" expected *(Parser)*

After the keyword `enum`, must come either an identifier that is, or will be, defined as an `enum` tag, or an opening brace, for example:

```
enum 1, 2;  /* should be, for example: enum {one=1, two }; */
```

(323) struct/union tag or "{" expected *(Parser)*

An identifier denoting a structure or union or an opening brace must follow a `struct` or `union` keyword, for example:

```
struct int a;  /* this is not how you define a structure */
```

You might mean something like:

```
struct {
  int a;
} my_struct;
```

(324) too many arguments for printf-style format string *(Parser)*

There are too many arguments for this format string. This is harmless, but can represent an incorrect format string, for example:

```
/* oops -- missed a placeholder? */
printf("%d - %d", low, high, median);
```

© 2012-2018 Microchip Technology Inc.

(325) error in printf-style format string *(Parser)*

There is an error in the format string here. The string has been interpreted as a `printf()` style format string, and it is not syntactically correct. If not corrected, this will cause unexpected behavior at runtime, for example:

```
printf("%l", lll);  /* oops -- possibly: printf("%ld", lll); */
```

(326) long int argument required in printf-style format string *(Parser)*

A long argument is required for this format specifier. Check the number and order of format specifiers and corresponding arguments, for example:

```
printf("%lx", 2);  // possibly you meant: printf("%lx", 2L);
```

(327) long long int argument required in printf-style format string *(Parser)*

A `long long` argument is required for this format specifier. Check the number and order of format specifiers and corresponding arguments, for example:

```
printf("%llx", 2);  // possibly you meant: printf("%llx", 2LL);
```

Note that MPLAB XC8 does not provide direct support for a `long long` integer type.

(328) int argument required in printf-style format string *(Parser)*

An integral argument is required for this printf-style format specifier. Check the number and order of format specifiers and corresponding arguments, for example:

```
printf("%d", 1.23); /* wrong number or wrong placeholder */
```

(329) double argument required in printf-style format string *(Parser)*

The printf format specifier corresponding to this argument is `%f` or similar, and requires a floating-point expression. Check for missing or extra format specifiers or arguments to printf.

```
printf("%f", 44);  /* should be: printf("%f", 44.0); */
```

(330) pointer to * argument required in printf-style format string *(Parser)*

A pointer argument is required for this format specifier. Check the number and order of format specifiers and corresponding arguments.

(331) too few arguments for printf-style format string *(Parser)*

There are too few arguments for this format string. This would result in a garbage value being printed or converted at runtime, for example:

```
printf("%d - %d", low);
  /* oops! where is the other value to print? */
```

(332) "interrupt_level" should be 0 to 7 *(Parser)*

The pragma `interrupt_level` must have an argument from 0 to 7; however, mid-range devices only use level 1. PIC18 devices can use levels 1 or 2. For example:

```
#pragma interrupt_level  9 /* oops -- the level is too high */
void interrupt isr(void)
{
  /* isr code goes here */
}
```

(333) unrecognized qualifier name after "strings" *(Parser)*

The `pragma strings` was passed a qualifier that was not identified, for example:

```
/* oops -- should that be #pragma strings const ? */
#pragma strings cinst
```

(334) unrecognized qualifier name after "printf_check" *(Parser)*

The `#pragma printf_check` was passed a qualifier that could not be identified, for example:

```
/* oops -- should that be const not cinst? */
#pragma printf_check(printf) cinst
```

(335) unknown pragma "*" *(Parser)*

An unknown `pragma` directive was encountered, for example:

```
#pragma rugsused myFunc w  /* I think you meant regsused */
```

(336) string concatenation across lines *(Parser)*

Strings on two lines will be concatenated. Check that this is the desired result, for example:

```
char * cp = "hi"
  "there";    /* this is okay,
                   but is it what you had intended? */
```

(337) line does not have a newline on the end *(Parser)*

The last line in the file is missing the *newline* (operating system dependent character) from the end. Some editors will create such files, which can cause problems for include files. The ANSI C standard requires all source files to consist of complete lines only.

(338) can’t create * file "*" *(Any)*

The application tried to create or open the named file, but it could not be created. Check that all file path names are correct.

(339) initializer in extern declaration *(Parser)*

A declaration containing the keyword `extern` has an initializer. This overrides the `extern` storage class, because to initialize an object it is necessary to define (i.e., allocate storage for) it, for example:

```
extern int other = 99;  /* if it’s extern and not allocated
                           storage, how can it be initialized? */
```

(340) string not terminated by null character *(Parser)*

A char array is being initialized with a string literal larger than the array. Hence there is insufficient space in the array to safely append a null terminating character, for example:

```
char foo[5] = "12345"; /* the string stored in foo won’t have
                            a null terminating, i.e.
                            foo = [’1’, ’2’, ’3’, ’4’, ’5’] */
```

© 2012-2018 Microchip Technology Inc.

(343) implicit return at end of non-void function *(Parser)*

A function that has been declared to return a value has an execution path that will allow it to reach the end of the function body, thus returning without a value. Either insert a `return` statement with a value, or if the function is not to return a value, declare it `void`, for example:

```
int mydiv(double a, int b)
{
  if(b != 0)
    return a/b;   /* what about when b is 0? */
}                 /* warning flagged here */
```

(344) non-void function returns no value *(Parser)*

A function that is declared as returning a value has a `return` statement that does not specify a return value, for example:

```
int get_value(void)
{
  if(flag)
    return val++;
  return;
  /* what is the return value in this instance? */
}
```

(345) unreachable code *(Parser)*

This section of code will never be executed, because there is no execution path by which it could be reached, for example:

```
while(1)          /* how does this loop finish? */
  process();
flag = FINISHED;  /* how do we get here? */
```

(346) declaration of "*" hides outer declaration *(Parser)*

An object has been declared that has the same name as an outer declaration (i.e., one outside and preceding the current function or block). This is legal, but can lead to accidental use of one variable when the outer one was intended, for example:

```
int input;         /* input has filescope */
void process(int a)
{
  int input;       /* local blockscope input */
  a = input;       /* this will use the local variable.
                      Is this right? */
```

(347) external declaration inside function *(Parser)*

A function contains an `extern` declaration. This is legal but is invariably not desirable as it restricts the scope of the function declaration to the function body. This means that if the compiler encounters another declaration, use, or definition of the extern object later in the same file, it will no longer have the earlier declaration and thus will be unable to check that the declarations are consistent. This can lead to strange behavior of your program or signature errors at link time. It will also hide any previous declarations of the same thing, again subverting the compiler's type checking. As a general rule, always declare `extern` variables and functions outside any other functions. For example:

```
int process(int a)
{
  /* this would be better outside the function */
  extern int away;
  return away + a;
}
```

(348) auto variable "*" should not be qualified *(Parser)*

An `auto` variable should not have qualifiers such as `near` or `far` associated with it. Its storage class is implicitly defined by the stack organization. An `auto` variable can be qualified with `static`, but it is then no longer `auto`.

(349) non-prototyped function declaration for "*" *(Parser)*

A function has been declared using old-style (K&R) arguments. It is preferable to use prototype declarations for all functions, for example:

```
int process(input)
int input;          /* warning flagged here */
{
}
```

This would be better written:

```
int process(int input)
{
}
```

(350) unused * "*" (from line *) *(Parser)*

The indicated object was never used in the function or module being compiled. Either this object is redundant, or the code that was meant to use it was excluded from compilation or misspelled the name of the object. Note that the symbols `rcsid` and `sccsid` are never reported as being unused.

(352) float parameter coerced to double *(Parser)*

Where a non-prototyped function has a parameter declared as `float`, the compiler converts this to a `double float`. This is because the default C type conversion conventions provide that when a floating-point number is passed to a non-prototyped function, it is converted to `double`. It is important that the function declaration be consistent with this convention, for example:

```
double inc_flt(f)  /* f will be converted to double */
float f;           /* warning flagged here */
{
  return f * 2;
}
```

© 2012-2018 Microchip Technology Inc.

(353) sizeof external array "*" is zero *(Parser)*

The size of an external array evaluates to zero. This is probably due to the array not having an explicit dimension in the extern declaration.

(354) possible pointer truncation *(Parser)*

A pointer qualified far has been assigned to a default pointer, or a pointer qualified near, or a default pointer has been assigned to a pointer qualified near. This can result in truncation of the pointer and loss of information, depending on the memory model in use.

(355) implicit signed to unsigned conversion *(Parser)*

A `signed` number is being assigned or otherwise converted to a larger `unsigned` type. Under the ANSI C "value preserving" rules, this will result in the `signed` value being first sign-extended to a `signed` number the size of the target type, then converted to `unsigned` (which involves no change in bit pattern). An unexpected sign extension can occur. To ensure this does not happen, first convert the signed value to an unsigned equivalent, for example:

```
signed char sc;
unsigned int ui;
ui = sc;    /* if sc contains 0xff,
               ui will contain 0xffff for example */
```

will perform a sign extension of the `char` variable to the longer type. If you do not want this to take place, use a cast, for example:

```
ui = (unsigned char)sc;
```

(356) implicit conversion of float to integer *(Parser)*

A floating-point value has been assigned or otherwise converted to an integral type. This could result in truncation of the floating-point value. A typecast will make this warning go away.

```
double dd;
int i;
i = dd;    /* is this really what you meant? */
```

If you do intend to use an expression like this, then indicate that this is so by a cast:

```
i = (int)dd;
```

(357) illegal conversion of integer to pointer *(Parser)*

An integer has been assigned to, or otherwise converted to, a pointer type. This will usually mean that you have used the wrong variable. But, if this is genuinely what you want to do, use a typecast to inform the compiler that you want the conversion and the warning will be suppressed. This can also mean that you have forgotten the & address operator, for example:

```
int * ip;
int i;
ip = i;    /* oops -- did you mean ip = &i ? */
```

If you do intend to use an expression like this, then indicate that this is so by a cast:

```
ip = (int *)i;
```

(358) illegal conversion of pointer to integer *(Parser)*

A pointer has been assigned to, or otherwise converted to, a integral type. This will usually mean that you have used the wrong variable. But, if this is genuinely what you want to do, use a typecast to inform the compiler that you want the conversion and the warning will be suppressed. This can also mean that you have forgotten the * dereference operator, for example:

```
int * ip;
int i;
i = ip;    /* oops -- did you mean i = *ip ? */
```

If you do intend to use an expression like this, indicate your intention by a cast:

```
i = (int)ip;
```

(359) illegal conversion between pointer types *(Parser)*

A pointer of one type (i.e., pointing to a particular kind of object) has been converted into a pointer of a different type. This usually means that you have used the wrong variable, but if this is genuinely what you want to do, use a typecast to inform the compiler that you want the conversion and the warning will be suppressed, for example:

```
long input;
char * cp;
cp = &input;  /* is this correct? */
```

This is a common way of accessing bytes within a multi-byte variable. To indicate that this is the intended operation of the program, use a cast:

```
cp = (char *)&input;  /* that's better */
```

This warning can also occur when converting between pointers to objects that have the same type, but which have different qualifiers, for example:

```
char * cp;
/* yes, but what sort of characters? */
cp = "I am a string of characters";
```

If the default type for string literals is `const char *`, then this warning is quite valid. This should be written:

```
const char * cp;
cp = "I am a string of characters";  /* that's better */
```

Omitting a qualifier from a pointer type is often disastrous and almost certainly not what you intend.

(360) array index out of bounds *(Parser)*

An array is being indexed with a constant value that is less than zero, or greater than or equal to the number of elements in the array. This warning will not be issued when accessing an array element via a pointer variable, for example:

```
int i, * ip, input[10];
i = input[-2];          /* oops -- this element doesn't exist */
ip = &input[5];
i = ip[-2];             /* this is okay */
```

© 2012-2018 Microchip Technology Inc.

(361) function declared implicit int *(Parser)*

When the compiler encounters a function call of a function whose name is presently undefined, the compiler will automatically declare the function to be of type `int`, with unspecified (K&R style) parameters. If a definition of the function is subsequently encountered, it is possible that its type and arguments will be different from the earlier implicit declaration, causing a compiler error. The solution is to ensure that all functions are defined (or at least declared) before use, preferably with prototyped parameters. If it is necessary to make a forward declaration of a function, it should be preceded with the keywords `extern` or `static`, as appropriate. For example:

```
/* I can prevent an error arising from calls below */
extern void set(long a, int b);

void main(void)
{
  /* at this point, a prototype for set() has already been seen */
  set(10L, 6);
}
```

(362) redundant "&" applied to array *(Parser)*

The address operator & has been applied to an array. Because using the name of an array gives its address anyway, this is unnecessary and has been ignored, for example:

```
int array[5];
int * ip;
/* array is a constant, not a variable; the & is redundant. */
ip = &array;
```

(363) redundant "&" or "*" applied to function address *(Parser)*

The address operator “&” has been applied to a function. Because using the name of a function gives its address anyway, this is unnecessary and has been ignored, for example:

```
extern void foo(void);
void main(void)
{
    void(*bar)(void);
    /* both assignments are equivalent */
    bar = &foo;
    bar = foo;  /* the & is redundant */
}
```

(364) attempt to modify object qualified * *(Parser)*

Objects declared `const` or `code` cannot be assigned to or modified in any other way by your program. The effect of attempting to modify such an object is compiler specific.

```
const int out = 1234;  /* "out" is read only */
out = 0;               /* oops --
                          writing to a read-only object */
```

(365) pointer to non-static object returned *(Parser)*

This function returns a pointer to a non-`static` (e.g., `auto`) variable. This is likely to be an error, because the storage associated with automatic variables becomes invalid when the function returns, for example:

```
char * get_addr(void)
{
  char c;
  /* returning this is dangerous;
     the pointer could be dereferenced */
  return &c;
}
```

(366) operands of "*" not same pointer type *(Parser)*

The operands of this operator are of different pointer types. This probably means you have used the wrong pointer, but if the code is actually what you intended, use a typecast to suppress the error message.

(367) identifier is already extern; can't be static *(Parser)*

This function was already declared `extern`, possibly through an implicit declaration. It has now been redeclared `static`, but this redeclaration is invalid.

```
void main(void)
{
  /* at this point the compiler assumes set is extern... */
  set(10L, 6);
}
/* now it finds out otherwise */
static void set(long a, int b)
{
  PORTA = a + b;
}
```

(368) array dimension on "*[]" ignored *(Preprocessor)*

An array dimension on a function parameter has been ignored because the argument is actually converted to a pointer when passed. Thus arrays of any size can be passed. Either remove the dimension from the parameter, or define the parameter using pointer syntax, for example:

```
/* param should be: "int array[]" or "int *" */
int get_first(int array[10])
{                             /* warning flagged here */
  return array[0];
}
```

(369) signed bitfields not supported *(Parser)*

Only `unsigned` bit-fields are supported. If a bit-field is declared to be type `int`, the compiler still treats it as `unsigned`, for example:

```
struct {
  signed int sign: 1;    /* oops -- this must be unsigned */
  signed int value: 7;
} ;
```

© 2012-2018 Microchip Technology Inc.

(370) illegal basic type; int assumed *(Parser)*

The basic type of a cast to a qualified basic type could not be recognized and the basic type was assumed to be `int`, for example:

```
/* here ling is assumed to be int */
unsigned char bar = (unsigned ling) ’a’;
```

(371) missing basic type; int assumed *(Parser)*

This declaration does not include a basic type, so `int` has been assumed. This declaration is not illegal, but it is preferable to include a basic type to make it clear what is intended, for example:

```
char c;
i;      /* don’t let the compiler make assumptions, use : int i */
func(); /* ditto, use: extern int func(int); */
```

(372) "," expected *(Parser)*

A *comma* was expected here. This could mean you have left out the *comma* between two identifiers in a declaration list. It can also mean that the immediately preceding type name is misspelled, and has been interpreted as an identifier, for example:

```
unsigned char a;
/* thinks: chat & b are unsigned, but where is the comma? */
unsigned chat b;
```

(373) implicit signed to unsigned conversion *(Parser)*

An `unsigned` type was expected where a `signed` type was given and was implicitly cast to `unsigned`, for example:

```
unsigned int foo = -1;
/* the above initialization is implicitly treated as:
   unsigned int foo = (unsigned) -1; */
```

(374) missing basic type; int assumed *(Parser)*

The basic type of a cast to a qualified basic type was missing and assumed to be `int`., for example:

```
int i = (signed) 2; /* (signed) assumed to be (signed int) */
```

(375) unknown FNREC type "*" *(Linker)*

This is an internal compiler error. Contact Microchip Technical Support with details.

(376) bad non-zero node in call graph *(Linker)*

The linker has encountered a top level node in the call graph that is referenced from lower down in the call graph. This probably means the program has indirect recursion, which is not allowed when using a compiled stack.

(378) can’t create * file "*" *(Hexmate)*

This type of file could not be created. Is the file, or a file by this name, already in use?

(379) bad record type "*" *(Linker)*

This is an internal compiler error. Ensure that the object file is a valid object file. Contact Microchip Technical Support with details.

(380) unknown record type (*) ***(Linker)***

This is an internal compiler error. Contact Microchip Technical Support with details.

(381) record "*" too long (*) ***(Linker)***

This is an internal compiler error. Contact Microchip Technical Support with details.

(382) incomplete record: type = *, length = * ***(Dump, Xstrip)***

This message is produced by the DUMP or XSTRIP utilities and indicates that the object file is not a valid object file, or that it has been truncated. Contact Microchip Technical Support with details.

(383) text record has length (*) too small ***(Linker)***

This is an internal compiler error. Contact Microchip Technical Support with details.

(384) assertion failed: file *, line *, expression * ***(Linker, Parser)***

This is an internal compiler error. Contact Microchip Technical Support with details.

(387) illegal or too many -G options ***(Linker)***

There has been more than one linker `-g` option, or the `-g` option did not have any arguments following. The arguments specify how the segment addresses are calculated.

(388) duplicate -M option ***(Linker)***

The map file name has been specified to the linker for a second time. This should not occur if you are using a compiler driver. If invoking the linker manually, ensure that only one instance of this option is present on the command line. See 3.7.12 Mapped Linker Options for information on the correct syntax for this option.

(389) illegal or too many -O options ***(Linker)***

This linker `-o` flag is illegal, or another `-o` option has been encountered. A `-o` option to the linker must be immediately followed by a filename with no intervening space.

(390) missing argument to -P ***(Linker)***

There have been too many `-p` options passed to the linker, or a `-p` option was not followed by any arguments. The arguments of separate `-p` options can be combined and separated by *commas*.

(391) missing argument to -Q ***(Linker)***

The `-Q` linker option requires the machine type for an argument.

(392) missing argument to -U ***(Linker)***

The `-U` (undefine) option needs an argument.

(393) missing argument to -W ***(Linker)***

The `-W` option (listing width) needs a numeric argument.

© 2012-2018 Microchip Technology Inc.

(394) duplicate -D or -H option ***(Linker)***

The symbol file name has been specified to the linker for a second time. This should not occur if you are using a compiler driver. If invoking the linker manually, ensure that only one instance of either of these options is present on the command line.

(395) missing argument to -J ***(Linker)***

The maximum number of errors before aborting must be specified following the `-j` linker option.

(397) usage: hlink [-options] files.obj files.lib ***(Linker)***

Improper usage of the command-line linker. If you are invoking the linker directly, refer to Section Section 6.2 "Operation" for more details. Otherwise, this could be an internal compiler error and you should contact Microchip Technical Support with details.

(398) output file can't be also an input file ***(Linker)***

The linker has detected an attempt to write its output file over one of its input files. This cannot be done, because it needs to simultaneously read and write input and output files.

(400) bad object code format ***(Linker)***

This is an internal compiler error. The object code format of an object file is invalid. Ensure it is a valid object file. Contact Microchip Technical Support with details.

(402) bad argument to -F ***(Objtohex)***

The `-F` option for `objtohex` has been supplied an invalid argument. If you are not invoking this tool directly, this is an internal compiler error, and you should contact Microchip Technical Support with details.

(403) bad -E option: "*" ***(Objtohex)***

This is an internal compiler error. Contact Microchip Technical Support with details.

(404) bad maximum length value to -<digits> ***(Objtohex)***

The first value to the OBJTOHEX `-n,m` HEX length/rounding option is invalid.

(405) bad record size rounding value to -<digits> ***(Objtohex)***

The second value to the OBJTOHEX `-n,m` HEX length/rounding option is invalid.

(406) bad argument to -A ***(Objtohex)***

This is an internal compiler error. Contact Microchip Technical Support with details.

(407) bad argument to -U ***(Objtohex)***

This is an internal compiler error. Contact Microchip Technical Support with details.

(408) bad argument to -B ***(Objtohex)***

This option requires an integer argument in either base 8, 10, or 16. If you are not invoking this tool directly, this is an internal compiler error, and you should contact Microchip Technical Support with details.

(409) bad argument to -P ***(Objtohex)***

This option requires an integer argument in either base 8, 10, or 16. If you are not invoking this tool directly, this is an internal compiler error, and you should contact Microchip Technical Support with details.

(410) bad combination of options ***(Objtohex)***

The combination of options supplied to `OBJTOHEX` is invalid.

(412) text does not start at 0 ***(Objtohex)***

Code in some things must start at zero. Here it doesn't.

(413) write error on "*" ***(Assembler, Linker, Cromwell)***

A write error occurred on the named file. This probably means you have run out of disk space.

(414) read error on "*" ***(Linker)***

The linker encountered an error trying to read this file.

(415) text offset too low in COFF file ***(Objtohex)***

This is an internal compiler error. Contact Microchip Technical Support with details.

(416) bad character (*) in extended TEKHEX line ***(Objtohex)***

This is an internal compiler error. Contact Microchip Technical Support with details.

(417) seek error in "*" ***(Linker)***

This is an internal compiler error. Contact Microchip Technical Support with details.

(418) image too big ***(Objtohex)***

This is an internal compiler error. Contact Microchip Technical Support with details.

(419) object file is not absolute ***(Objtohex)***

The object file passed to `OBJTOHEX` has relocation items in it. This can indicate it is the wrong object file, or that the linker or OBJTOHEX have been given invalid options. The object output files from the assembler are relocatable, not absolute. The object file output of the linker is absolute.

(420) too many relocation items ***(Objtohex)***

This is an internal compiler error. Contact Microchip Technical Support with details.

(421) too many segments ***(Objtohex)***

This is an internal compiler error. Contact Microchip Technical Support with details.

(422) no end record ***(Linker)***

This object file has no end record. This probably means it is not an object file. Contact Microchip Technical Support if the object file was generated by the compiler.

© 2012-2018 Microchip Technology Inc.

(423) illegal record type ***(Linker)***

There is an error in an object file. This is either an invalid object file, or an internal error in the linker. Contact Microchip Technical Support with details if the object file was created by the compiler.

(424) record too long ***(Objtohex)***

This is an internal compiler error. Contact Microchip Technical Support with details.

(425) incomplete record ***(Objtohex, Libr)***

The object file passed to OBJTOHEX or the librarian is corrupted. Contact Microchip Technical Support with details.

(427) syntax error in list ***(Objtohex)***

There is a syntax error in a list read by OBJTOHEX. The list is read from standard input in response to an option.

(428) too many segment fixups ***(Objtohex)***

This is an internal compiler error. Contact Microchip Technical Support with details.

(429) bad segment fixups ***(Objtohex)***

This is an internal compiler error. Contact Microchip Technical Support with details.

(430) bad specification ***(Objtohex)***

A list supplied to `OBJTOHEX` is syntactically incorrect.

(431) bad argument to -E ***(Objtoexe)***

This option requires an integer argument in either base 8, 10, or 16. If you are invoking `objtoexe` directly then check this argument. Otherwise, this can be an internal compiler error and you should contact Microchip Technical Support with details.

(432) usage: objtohex [-ssymfile] [object-file [exe-file]] ***(Objtohex)***

Improper usage of the command-line tool `objtohex`. If you are not invoking this tool directly, this is an internal compiler error and you should contact Microchip Technical Support with details.

(434) too many symbols (*) ***(Linker)***

There are too many symbols in the symbol table, which has a limit of * symbols. Change some global symbols to local symbols to reduce the number of symbols.

(435) bad segment selector "*" ***(Linker)***

The segment specification option (`-G`) to the linker is invalid, for example:

```
-GA/f0+10
```

Did you forget the radix?

```
-GA/f0h+10
```

(436) psect "*" re-orged ***(Linker)***

This psect has had its start address specified more than once.

(437) missing "=" in class spec *(Linker)*

A class spec needs an = sign, e.g., -Ctext=ROM. See Section 6.2.2 "-Cpsect=class" for more information.

(438) bad size in -S option *(Linker)*

The address given in a `-S` specification is invalid, it should be a valid number, in decimal, octal, or hexadecimal radix. The radix is specified by a trailing `O`, for octal, or `H` for HEX. A leading `0x` can also be used for hexadecimal. Case in not important for any number or radix. Decimal is the default, for example:

```
-SCODE=f000
```

Did you forget the radix?

```
-SCODE=f000h
```

(439) bad -D spec: "*" *(Linker)*

The format of a `-D` specification, giving a *delta* value to a class, is invalid, for example:

```
-DCODE
```

What is the *delta* value for this class? Possibly, you meant something like:

```
-DCODE=2
```

(440) bad delta value in -D spec *(Linker)*

The *delta* value supplied to a `-D` specification is invalid. This value should an integer of base 8, 10, or 16.

(441) bad -A spec: "*" *(Linker)*

The format of a `-A` specification, giving address ranges to the linker, is invalid, for example:

```
-ACODE
```

What is the range for this class? Possibly, you meant:

```
-ACODE=0h-1fffh
```

(442) missing address in -A spec *(Linker)*

The format of a `-A` specification, giving address ranges to the linker, is invalid, for example:

```
-ACODE=
```

What is the range for this class? Possibly, you meant:

```
-ACODE=0h-1fffh
```

(443) bad low address "*" in -A spec *(Linker)*

The low address given in a -A specification is invalid: it should be a valid number, in decimal, octal, or hexadecimal radix. The radix is specified by a trailing `O` (for octal) or `H` for HEX. A leading `0x` can also be used for hexadecimal. Case in not important for any number or radix. Decimal is default, for example:

```
-ACODE=1fff-3fffh
```

Did you forget the radix?

```
-ACODE=1fffh-3fffh
```

© 2012-2018 Microchip Technology Inc.

(444) expected "-" in -A spec *(Linker)*

There should be a minus sign, `-`, between the high and low addresses in a `-A` linker option, for example:

```
-AROM=1000h
```

Possibly, you meant:

```
-AROM=1000h-1fffh
```

(445) bad high address "*" in -A spec *(Linker)*

The high address given in a `-A` specification is invalid: it should be a valid number, in decimal, octal, or hexadecimal radix. The radix is specified by a trailing `O`, for octal, or `H` for HEX. A leading `0x` can also be used for hexadecimal. Case in not important for any number or radix. Decimal is the default, for example:

```
-ACODE=0h-ffff
```

Did you forget the radix?

```
-ACODE=0h-ffffh
```

See Section 6.2.1 “-Aclass =low-high,...” for more information.

(446) bad overrun address "*" in -A spec *(Linker)*

The overrun address given in a -A specification is invalid: it should be a valid number, in decimal, octal, or hexadecimal radix. The radix is specified by a trailing `O` (for octal) or `H` for HEX. A leading `0x` can also be used for hexadecimal. Case in not important for any number or radix. Decimal is default, for example:

```
-AENTRY=0-0FFh-1FF
```

Did you forget the radix?

```
-AENTRY=0-0FFh-1FFh
```

(447) bad load address "*" in -A spec *(Linker)*

The load address given in a `-A` specification is invalid: it should be a valid number, in decimal, octal, or hexadecimal radix. The radix is specified by a trailing `O` (for octal) or `H` for HEX. A leading `0x` can also be used for hexadecimal. Case in not important for any number or radix. Decimal is default, for example:

```
-ACODE=0h-3fffh/a000
```

Did you forget the radix?

```
-ACODE=0h-3fffh/a000h
```

(448) bad repeat count "*" in -A spec *(Linker)*

The repeat count given in a `-A` specification is invalid, for example:

```
-AENTRY=0-0FFhxf
```

Did you forget the radix?

```
-AENTRY=0-0FFhxfh
```

(449) syntax error in -A spec: * *(Linker)*

The `-A` spec is invalid. A valid -A spec should be something like:

-AROM=1000h-1FFFh

(450) psect "*" was never defined, or is local *(Linker)*

This psect has been listed in a `-P` option, but is not defined in any module within the program. Alternatively, the psect is defined using the `local` psect flag, but with no class flag; and, so, cannot be linked to an address. Check the assembly list file to ensure that the psect exists and that it is does not specify the `local` psect flag.

(451) bad psect origin format in -P option *(Linker)*

The origin format in a `-p` option is not a validly formed decimal, octal, or HEX number, nor is it the name of an existing psect. A HEX number must have a trailing H, for example:

```
-pbss=f000
```

Did you forget the radix?

```
-pbss=f000h
```

(452) bad "+" (minimum address) format in -P option *(Linker)*

The minimum address specification in the linker's `-p` option is badly formatted, for example:

```
-pbss=data+f000
```

Did you forget the radix?

```
-pbss=data+f000h
```

(453) missing number after "%" in -P option *(Linker)*

The `%` operator in a `-p` option (for rounding boundaries) must have a number after it.

(454) link and load address can't both be set to "." in -P option *(Linker)*

The link and load address of a psect have both been specified with a *dot* character. Only one of these addresses can be specified in this manner, for example:

```
-Pmypsect=1000h/.
-Pmypsect=./1000h
```

Both of these options are valid and equivalent. However, the following usage is ambiguous:

```
-Pmypsect=./.
```

What is the link or load address of this psect?

(455) psect "*" not relocated on 0x* byte boundary *(Linker)*

This psect is not relocated on the required boundary. Check the relocatability of the psect and correct the `-p` option. if necessary.

(456) psect "*" not loaded on 0x* boundary *(Linker)*

This psect has a relocatability requirement that is not met by the load address given in a `-p` option. For example, if a psect must be on a 4K byte boundary, you could not start it at 100H.

(459) remove failed; error: *, * *(Xstrip)*

The creation of the output file failed when removing an intermediate file.

© 2012-2018 Microchip Technology Inc.

(460) rename failed; error: *, * ***(Xstrip)***

The creation of the output file failed when renaming an intermediate file.

(461) can’t create * file "*" ***(Assembler, Code Generator)***

This is an internal compiler error. Contact Microchip Technical Support with details.

(464) missing key in avmap file ***(Linker)***

This is an internal compiler error. Contact Microchip Technical Support with details.

(465) undefined symbol "*" in FNBREAK record ***(Linker)***

The linker has found an undefined symbol in the `FNBREAK` record for a non-reentrant function. Contact Microchip Technical Support if this is not handwritten assembler code.

(466) undefined symbol "*" in FNINDIR record ***(Linker)***

The linker has found an undefined symbol in the `FNINDIR` record for a non-reentrant function. Contact Microchip Technical Support if this is not handwritten assembler code.

(467) undefined symbol "*" in FNADDR record ***(Linker)***

The linker has found an undefined symbol in the FNADDR record for a non-reentrant function. Contact Microchip Technical Support if this is not handwritten assembler code.

(468) undefined symbol "*" in FNCALL record ***(Linker)***

The linker has found an undefined symbol in the `FNCALL` record for a non-reentrant function. Contact Microchip Technical Support if this is not handwritten assembler code.

(469) undefined symbol "*" in FNROOT record ***(Linker)***

The linker has found an undefined symbol in the `FNROOT` record for a non-reentrant function. Contact Microchip Technical Support if this is not handwritten assembler code.

(470) undefined symbol "*" in FNSIZE record ***(Linker)***

The linker has found an undefined symbol in the `FNSIZE` record for a non-reentrant function. Contact Microchip Technical Support if this is not handwritten assembler code.

(471) recursive function calls: *(Linker)*

These functions (or function) call each other recursively. One or more of these functions has statically allocated local variables (compiled stack). Either use the `reentrant` keyword (if supported with this compiler) or recode to avoid recursion, for example:

```
int test(int a)
{
   if(a == 5) {
      /* recursion cannot be supported by some compilers */
      return test(a++);
   }
   return 0;
}
```

(472) non-reentrant function "*" appears in multiple call graphs: rooted at "*" and "*" *(Linker)*

This function can be called from both main-line code and interrupt code. Use the `reentrant` keyword, if this compiler supports it, or recode to avoid using local variables or parameters, or duplicate the function, for example:

```
void interrupt my_isr(void)
{
  scan(6);     /* scan is called from an interrupt function */
}
void process(int a)
{
  scan(a);     /* scan is also called from main-line code */
}
```

(473) function "*" is not called from specified interrupt_level *(Linker)*

The indicated function is never called from an interrupt function of the same interrupt level, for example:

```
#pragma interrupt_level 1
void foo(void)
{
    ...
}
#pragma interrupt_level 1
void interrupt bar(void)
{
    // this function never calls foo()
}
```

(474) no psect specified for function variable/argument allocation *(Linker)*

The `FNCONF` assembler directive which specifies to the linker information regarding the auto/parameter block was never seen. This is supplied in the standard runtime files if necessary. This error can imply that the correct run-time startup module was not linked. Ensure you have used the `FNCONF` directive if the runtime startup module is hand-written.

(475) conflicting FNCONF records *(Linker)*

The linker has seen two conflicting `FNCONF` directives. This directive should be specified only once and is included in the standard runtime startup code which is normally linked into every program.

© 2012-2018 Microchip Technology Inc.

(476) fixup overflow referencing * * (location 0x* (0x*+*), size *, value 0x*) ***(Linker)***

The linker was asked to relocate (fixup) an item that would not fit back into the space after relocation. See the following error message (1356) for more information.

(477) fixup overflow in expression (location 0x* (0x*+*), size *, value 0x*) ***(Linker)***

The linker was asked to relocate (fixup) an item that would not fit back into the space after relocation. See the following error message (1356) for more information.

(478) * range check failed (location 0x* (0x*+*), value 0x* > limit 0x*) ***(Linker)***

This is an internal compiler error. Contact Microchip Technical Support with details.

(479) circular indirect definition of symbol "*" ***(Linker)***

The specified symbol has been equated to an external symbol which, in turn, has been equated to the first symbol.

(480) function signatures do not match: * (*): 0x*/0x* ***(Linker)***

The specified function has different signatures in different modules. This means it has been declared differently; i.e., it can have been prototyped in one module and not another. Check what declarations for the function are visible in the two modules specified and make sure they are compatible, for example:

```
extern int get_value(int in);
/* and in another module: */
/* this is different to the declaration */
int get_value(int in, char type)
{
```

(481) common symbol "*" psect conflict ***(Linker)***

A common symbol has been defined to be in more than one psect.

(482) symbol "*" is defined more than once in "*" ***(Assembler)***

This symbol has been defined in more than one place. The assembler will issue this error if a symbol is defined more than once in the same module, for example:

```
_next:
  MOVE r0, #55
  MOVE [r1], r0
_next:          ; oops -- choose a different name
```

The linker will issue this warning if the symbol (C or assembler) was defined multiple times in different modules. The names of the modules are given in the error message. Note that C identifiers often have an *underscore* prepended to their name after compilation.

(483) symbol "*" can't be global ***(Linker)***

This is an internal compiler error. Contact Microchip Technical Support with details.

(484) psect "*" can't be in classes "*" and "*" *(Linker)*

A psect cannot be in more than one class. This is either due to assembler modules with conflicting `class=` options to the PSECT directive, or use of the `-C` option to the linker, for example:

```
psect final,class=CODE
finish:
/* elsewhere: */
psect final,class=ENTRY
```

(485) unknown "with" psect referenced by psect "*" *(Linker)*

The specified psect has been placed with a psect using the psect `with` flag. The psect it has been placed with does not exist, for example:

```
psect starttext,class=CODE,with=rext
    ; was that meant to be with text?
```

(486) psect "*" selector value redefined *(Linker)*

The selector value for this psect has been defined more than once.

(487) psect "*" type redefined: */* *(Linker)*

This psect has had its type defined differently by different modules. This probably means you are trying to link incompatible object modules, i.e., linking 386 flat model code with 8086 real mode code.

(488) psect "*" memory space redefined: */* *(Linker)*

A global psect has been defined in two different memory spaces. Either rename one of the psects or, if they are the same psect, place them in the same memory space using the `space` psect flag, for example:

```
psect spdata,class=RAM,space=0
  ds 6
; elsewhere:
psect spdata,class=RAM,space=1
```

(489) psect "*" memory delta redefined: */* *(Linker)*

A global psect has been defined with two different delta values, for example:

```
psect final,class=CODE,delta=2
finish:
; elsewhere:
psect final,class=CODE,delta=1
```

(490) class "*" memory space redefined: */* *(Linker)*

A class has been defined in two different memory spaces. Either rename one of the classes or, if they are the same class, place them in the same memory space.

(491) can't find 0x* words for psect "*" in segment "*" *(Linker)*

One of the main tasks the linker performs is positioning the blocks (or psects) of code and data that is generated from the program into the memory available for the target device. This error indicates that the linker was unable to find an area of free memory large enough to accommodate one of the psects. The error message indicates the name of the psect that the linker was attempting to position and the segment name which is typically the name of a class which is defined with a linker `-A` option.

© 2012-2018 Microchip Technology Inc.

Section 4.15.1 “Compiler-Generated Psects” lists each compiler-generated psect and what it contains. Typically psect names which are, or include, `text` relate to program code. Names such as `bss` or `data` refer to variable blocks. This error can be due to two reasons.

First, the size of the program or the program’s data has exceeded the total amount of space on the selected device. In other words, some part of your device’s memory has completely filled. If this is the case, then the size of the specified psect must be reduced.

The second cause of this message is when the total amount of memory needed by the psect being positioned is sufficient, but that this memory is fragmented in such a way that the largest contiguous block is too small to accommodate the psect. The linker is unable to split psects in this situation. That is, the linker cannot place part of a psect at one location and part somewhere else. Thus, the linker must be able to find a contiguous block of memory large enough for every psect. If this is the cause of the error, then the psect must be split into smaller psects if possible.

To find out what memory is still available, generate and look in the map file, see 3.7.12 Mapped Linker Options for information on how to generate a map file. Search for the string `UNUSED ADDRESS RANGES`. Under this heading, look for the name of the segment specified in the error message. If the name is not present, then all the memory available for this psect has been allocated. If it is present, there will be one address range specified under this segment for each free block of memory. Determine the size of each block and compare this with the number of words specified in the error message.

Psects containing code can be reduced by using all the compiler’s optimizations, or restructuring the program. If a code psect must be split into two or more small psects, this requires splitting a function into two or more smaller functions (which can call each other). These functions can need to be placed in new modules.

Psects containing data can be reduced when invoking the compiler optimizations, but the effect is less dramatic. The program can need to be rewritten so that it needs less variables. If the default linker options must be changed, this can be done indirectly through the driver using the driver -L- option (see 3.7.12 Mapped Linker Options). 3.7.12 Mapped Linker Options has information on interpreting the map file’s call graph if the compiler you are using uses a compiled stack. (If the string `Call graph:` is not present in the map file, then the compiled code uses a hardware stack.) If a data psect needs to be split into smaller psects, the definitions for variables will need to be moved to new modules or more evenly spread in the existing modules. Memory allocation for `auto` variables is entirely handled by the compiler. Other than reducing the number of these variables used, the programmer has little control over their operation. This applies whether the compiled code uses a hardware or compiled stack.

For example, after receiving the message:

```
Can’t find 0x34 words (0x34 withtotal) for psect text
 in segment CODE (error)
```

look in the map file for the ranges of unused memory.

```
UNUSED ADDRESS RANGES
        CODE             00000244-0000025F
                         00001000-0000102f
        RAM              00300014-00301FFB
```

In the `CODE` segment, there is 0x1c (0x25f-0x244+1) bytes of space available in one block and 0x30 available in another block. Neither of these are large enough to accommodate the psect `text` which is 0x34 bytes long. Notice that the total amount of memory available is larger than 0x34 bytes.

(492) attempt to position absolute psect "*" is illegal *(Linker)*

This psect is absolute and should not have an address specified in a `-P` option. Either remove the `abs` psect flag, or remove the `-P` linker option.

(493) origin of psect "*" is defined more than once *(Linker)*

The origin of this psect is defined more than once. There is most likely more than one `-p` linker option specifying this psect.

(494) bad -P format "*/*" *(Linker)*

The `-P` option given to the linker is malformed. This option specifies placement of a psect, for example:

```
-Ptext=10g0h
```

Possibly, you meant:

```
-Ptext=10f0h
```

(495) use of both "with=" and "INCLASS/INCLASS" allocation is illegal *(Linker)*

It is not legal to specify both the link and location of a psect as within a class, when that psect was also defined using a `with` psect flag.

(497) psect "*" exceeds max size: *h > *h *(Linker)*

The psect has more bytes in it than the maximum allowed as specified using the `size` psect flag.

(498) psect "*" exceeds address limit: *h > *h *(Linker)*

The maximum address of the psect exceeds the limit placed on it using the `limit` psect flag. Either the psect needs to be linked at a different location or there is too much code/data in the psect.

(499) undefined symbol: *(Assembler, Linker)*

The symbol following is undefined at link time. This could be due to spelling error, or failure to link an appropriate module.

© 2012-2018 Microchip Technology Inc.

MESSAGES 500-749

(500) undefined symbols: *(Linker)*

A list of symbols follows that were undefined at link time. These errors could be due to spelling error, or failure to link an appropriate module.

(501) program entry point is defined more than once *(Linker)*

There is more than one entry point defined in the object files given the linker. End entry point is specified after the `END` directive. The runtime startup code defines the entry point, for example:

```
powerup:
  goto start
  END  powerup  ; end of file and define entry point
; other files that use END should not define another entry point
```

(502) incomplete * record body: length = * *(Linker)*

An object file contained a record with an illegal size. This probably means the file is truncated or not an object file. Contact Microchip Technical Support with details.

(503) ident records do not match *(Linker)*

The object files passed to the linker do not have matching ident records. This means they are for different device types.

(504) object code version is greater than *.* *(Linker)*

The object code version of an object module is higher than the highest version the linker is known to work with. Check that you are using the correct linker. Contact Microchip Technical Support if you have not patched the linker.

(505) no end record found inobject file *(Linker)*

An object file did not contain an end record. This probably means the file is corrupted or not an object file. Contact Microchip Technical Support if the object file was generated by the compiler.

(506) object file record too long: *+* *(Linker)*

This is an internal compiler error. Contact Microchip Technical Support with details.

(507) unexpected end of file in object file *(Linker)*

This is an internal compiler error. Contact Microchip Technical Support with details.

(508) relocation offset (*) out of range 0..*-*-1 *(Linker)*

This is an internal compiler error. Contact Microchip Technical Support with details.

(509) illegal relocation size: * *(Linker)*

There is an error in the object code format read by the linker. This either means you are using a linker that is out of date, or that there is an internal error in the assembler or linker. Contact Microchip Technical Support with details if the object file was created by the compiler.

(510) complex relocation not supported for -R or -L options ***(Linker)***

The linker was given a `-R` or `-L` option with file that contain complex relocation.

(511) bad complex range check ***(Linker)***

This is an internal compiler error. Contact Microchip Technical Support with details.

(512) unknown complex operator 0x* ***(Linker)***

This is an internal compiler error. Contact Microchip Technical Support with details.

(513) bad complex relocation ***(Linker)***

The linker has been asked to perform complex relocation that is not syntactically correct. Probably means an object file is corrupted.

(514) illegal relocation type: * ***(Linker)***

An object file contained a relocation record with an illegal relocation type. This probably means the file is corrupted or not an object file. Contact Microchip Technical Support with details if the object file was created by the compiler.

(515) unknown symbol type * ***(Linker)***

This is an internal compiler error. Contact Microchip Technical Support with details.

(516) text record has bad length: *-*-(*+1) < 0 ***(Linker)***

This is an internal compiler error. Contact Microchip Technical Support with details.

(520) function "*" is never called ***(Linker)***

This function is never called. This cannot represent a problem, but space could be saved by removing it. If you believe this function should be called, check your source code. Some assembler library routines are never called, although they are actually execute. In this case, the routines are linked in a special sequence so that program execution falls through from one routine to the next.

(521) call depth exceeded by function "*" ***(Linker)***

The call graph shows that functions are nested to a depth greater than specified.

(522) library "*" is badly ordered ***(Linker)***

This library is badly ordered. It will still link correctly, but it will link faster if better ordered.

(523) argument to -W option (*) illegal and ignored ***(Linker)***

The argument to the linker option `-w` is out of range. This option controls two features. For warning levels, the range is -9 to 9. For the map file width, the range is greater than or equal to 10.

(524) unable to open list file "*": * ***(Linker)***

The named list file could not be opened. The linker would be trying to fixup the list file so that it will contain absolute addresses. Ensure that an assembler list file was generated during the compilation stage. Alternatively, remove the assembler list file generation option from the link step.

© 2012-2018 Microchip Technology Inc.

(525) too many address (memory) spaces; space (*) ignored *(Linker)*

The limit to the number of address spaces (specified with the `PSECT` assembler directive) is currently 16.

(526) psect "*" not specified in -P option (first appears in "*") *(Linker)*

This psect was not specified in a `-P` or `-A` option to the linker. It has been linked at the end of the program, which is probably not where you wanted it.

(528) no start record; entry point defaults to zero *(Linker)*

None of the object files passed to the linker contained a start record. The start address of the program has been set to zero. This can be harmless, but it is recommended that you define a start address in your startup module by using the `END` directive.

(529) usage: objtohex [-Ssymfile] [object-file [HEX-file]] *(Objtohex)*

Improper usage of the command-line tool `objtohex`. If you are not invoking this tool directly, this is an internal compiler error, and you should contact Microchip Technical Support with details.

(593) can't find 0x* words (0x* withtotal) for psect "*" in segment "*" *(Linker)*

See message (491).

(594) undefined symbol: *(Linker)*

The symbol following is undefined at link time. This could be due to spelling error, or failure to link an appropriate module.

(595) undefined symbols: *(Linker)*

A list of symbols follows that were undefined at link time. These errors could be due to spelling error, or failure to link an appropriate module.

(596) segment "*" (*-*) overlaps segment "*" (*-*) *(Linker)*

The named segments have overlapping code or data. Check the addresses being assigned by the `-P` linker option.

(599) No psect classes given for COFF write *(Cromwell)*

`CROMWELL` requires that the program memory psect classes be specified to produce a COFF file. Ensure that you are using the `-N` option.

(600) No chip arch given for COFF write *(Cromwell)*

`CROMWELL` requires that the chip architecture be specified to produce a COFF file. Ensure that you are using the -P option.

(601) Unknown chip arch "*" for COFF write *(Cromwell)*

The chip architecture specified for producing a COFF file isn't recognized by `CROMWELL`. Ensure that you are using the -P option, and that the architecture is correctly specified.

(602) null file format name *(Cromwell)*

The `-I` or `-O` option to `CROMWELL` must specify a file format.

(603) ambiguous file format name "*" *(Cromwell)*

The input or output format specified to `CROMWELL` is ambiguous. These formats are specified with the `-i` *key* and `-o` *key* options respectively.

(604) unknown file format name "*" *(Cromwell)*

The output format specified to `CROMWELL` is unknown, for example:

```
cromwell -m -P16F877 main.HEX main.sym -ocot
```

and output file type of `cot`, did you mean `cof`?

(605) did not recognize format of input file *(Cromwell)*

The input file to `CROMWELL` is required to have a Cromwell map file (CMF), COD, Intel HEX, Motorola HEX, COFF, OMF51, ELF, UBROF or HI-TECH format.

(606) inconsistent symbol tables *(Cromwell)*

This is an internal compiler error. Contact Microchip Technical Support with details.

(607) inconsistent line number tables *(Cromwell)*

This is an internal compiler error. Contact Microchip Technical Support with details.

(608) bad path specification *(Cromwell)*

This is an internal compiler error. Contact Microchip Technical Support with details.

(609) missing device spec after -P *(Cromwell)*

The `-p` option to `CROMWELL` must specify a device name.

(610) missing psect classes after -N *(Cromwell)*

`CROMWELL` requires that the `-N` option be given a list of the names of psect classes.

(611) too many input files *(Cromwell)*

To many input files have been specified to be converted by `CROMWELL`.

(612) too many output files *(Cromwell)*

To many output file formats have been specified to `CROMWELL`.

(613) no output file format specified *(Cromwell)*

The output format must be specified to `CROMWELL`.

(614) no input files specified *(Cromwell)*

`CROMWELL` must have an input file to convert.

(616) option -Cbaseaddr is illegal with options -R or -L *(Linker)*

The linker option `-Cbaseaddr` cannot be used in conjunction with either the `-R` or `-L` linker options.

© 2012-2018 Microchip Technology Inc.

(618) error reading COD file data ***(Cromwell)***

An error occurred reading the input COD file. Confirm the spelling and path of the file specified on the command line.

(619) I/O error reading symbol table ***(Cromwell)***

The COD file has an invalid format in the specified record.

(620) filename index out of range in line number record ***(Cromwell)***

The COD file has an invalid value in the specified record.

(621) error writing ELF/DWARF section "*" on "*" ***(Cromwell)***

An error occurred writing the indicated section to the given file. Confirm the spelling and path of the file specified on the command line.

(622) too many type entries ***(Cromwell)***

This is an internal compiler error. Contact Microchip Technical Support with details.

(623) bad class in type hashing ***(Cromwell)***

This is an internal compiler error. Contact Microchip Technical Support with details.

(624) bad class in type compare ***(Cromwell)***

This is an internal compiler error. Contact Microchip Technical Support with details.

(625) too many files in COFF file ***(Cromwell)***

This is an internal compiler error. Contact Microchip Technical Support with details.

(626) string lookup failed in COFF: get_string() ***(Cromwell)***

This is an internal compiler error. Contact Microchip Technical Support with details.

(627) missing "*" in SDB file "*" line * column * ***(Cromwell)***

This is an internal compiler error. Contact Microchip Technical Support with details.

(629) bad storage class "*" in SDB file "*" line * column * ***(Cromwell)***

This is an internal compiler error. Contact Microchip Technical Support with details.

(630) invalid syntax for prefix list in SDB file "*" ***(Cromwell)***

This is an internal compiler error. Contact Microchip Technical Support with details.

(631) syntax error at token "*" in SDB file "*" line * column * ***(Cromwell)***

This is an internal compiler error. Contact Microchip Technical Support with details.

(632) can't handle address size (*) ***(Cromwell)***

This is an internal compiler error. Contact Microchip Technical Support with details.

(633) unknown symbol class (*) ***(Cromwell)***

`CROMWELL` has encountered a symbol class in the symbol table of a COFF, Microchip COFF, or ICOFF file which it cannot identify.

(634) error dumping "*" ***(Cromwell)***

Either the input file to `CROMWELL` is of an unsupported type or that file cannot be dumped to the screen.

(635) invalid HEX file "*" on line * ***(Cromwell)***

The specified HEX file contains an invalid line. Contact Microchip Technical Support if the HEX file was generated by the compiler.

(636) error in Intel HEX file "*" on line * ***(Cromwell, Hexmate)***

An error was found at the specified line in the specified Intel HEX file. The HEX file may be corrupt.

(637) unknown prefix "*" in SDB file "*" ***(Cromwell)***

This is an internal compiler warning. Contact Microchip Technical Support with details.

(638) version mismatch: 0x* expected ***(Cromwell)***

The input Microchip COFF file wasn't produced using `CROMWELL`.

(639) zero bit width in Microchip optional header ***(Cromwell)***

The optional header in the input Microchip COFF file indicates that the program or data memory spaces are zero bits wide.

(668) prefix list did not match any SDB types ***(Cromwell)***

This is an internal compiler error. Contact Microchip Technical Support with details.

(669) prefix list matched more than one SDB type ***(Cromwell)***

This is an internal compiler error. Contact Microchip Technical Support with details.

(670) bad argument to -T ***(Clist)***

The argument to the `-T` option to specify tab size was not present or correctly formed. The option expects a decimal integer argument.

(671) argument to -T should be in range 1 to 64 ***(Clist)***

The argument to the `-T` option to specify tab size was not in the expected range. The option expects a decimal integer argument ranging from 1 to 64 inclusive.

(673) missing filename after * option ***(Objtohex)***

The indicated option requires a valid file name. Ensure that the filename argument supplied to this option exists and is spelled correctly.

(674) too many references to "*" ***(Cref)***

This is an internal compiler error. Contact Microchip Technical Support with details.

© 2012-2018 Microchip Technology Inc.

(677) set_fact_bit on pic17! ***(Code Generator)***

This is an internal compiler error. Contact Microchip Technical Support with details.

(678) case 55 on pic17! ***(Code Generator)***

This is an internal compiler error. Contact Microchip Technical Support with details.

(679) unknown extraspecial: * ***(Code Generator)***

This is an internal compiler error. Contact Microchip Technical Support with details.

(680) bad format for -P option ***(Code Generator)***

This is an internal compiler error. Contact Microchip Technical Support with details.

(681) bad common spec in -P option ***(Code Generator)***

This is an internal compiler error. Contact Microchip Technical Support with details.

(682) this architecture is not supported by the PICC™ Lite compiler ***(Code Generator)***

A target device other than baseline, mid-range or highend was specified. This compiler only supports devices from these architecture families.

(683) bank 1 variables are not supported by the PICC Lite compiler ***(Code Generator)***

A variable with an absolute address located in bank 1 was detected. This compiler does not support code generation of variables in this bank.

(684) bank 2 and 3 variables are not supported by the PICC Lite compiler ***(Code Generator)***

A variable with an absolute address located in bank 2 or 3 was detected. This compiler does not support code generation of variables in these banks.

(685) bad putwsize() ***(Code Generator)***

This is an internal compiler error. Contact Microchip Technical Support with details.

(686) bad switch size (*) ***(Code Generator)***

This is an internal compiler error. Contact Microchip Technical Support with details.

(687) bad pushreg "*" ***(Code Generator)***

This is an internal compiler error. Contact Microchip Technical Support with details.

(688) bad popreg "*" ***(Code Generator)***

This is an internal compiler error. Contact Microchip Technical Support with details.

(689) unknown predicate "*" ***(Code Generator)***

This is an internal compiler error. Contact Microchip Technical Support with details.

(690) interrupt function requires address *(Code Generator)*

The high end PIC devices support multiple interrupts. An @ *address* is required with the interrupt definition to indicate with which vector this routine is associated, for example:

```
void interrupt isr(void) @ 0x10
{
  /* isr code goes here */
}
```

This construct is not required for mid-range PIC devices.

(691) interrupt functions not implemented for 12 bit PIC MCU *(Code Generator)*

The 12-bit range of PIC MCU processors do not support interrupts.

(692) more than one interrupt level is associated with the interrupt function "*" *(Code Generator)*

Only one interrupt level can be associated with an `interrupt` function. Check to ensure that only one `interrupt_level` pragma has been used with the function specified. This pragma can be used more than once on main-line functions that are called from `interrupt` functions. For example:

```
#pragma interrupt_level 0
#pragma interrupt_level 1  /* oops -- which is it to be: 0 or 1? */
void interrupt isr(void)
{
```

(693) 0 (default) or 1 are the only acceptable interrupt levels for this function *(Code Generator)*

The only possible interrupt levels are 0 or 1. Check to ensure that all `interrupt_level` pragmas use these levels.

```
#pragma interrupt_level 2  /* oops -- only 0 or 1 */
void interrupt isr(void)
{
  /* isr code goes here */
}
```

(694) no interrupt strategy available *(Code Generator)*

The device does not support saving and subsequent restoring of registers during an interrupt service routine.

(695) duplicate case label (*) *(Code Generator)*

There are two case labels with the same value in this `switch` statement, for example:

```
switch(in) {
case ’0’:  /* if this is case ’0’... */
  b++;
  break;
case ’0’:  /* then what is this case? */
  b--;
  break;
}
```

(696) out-of-range case label (*) *(Code Generator)*

This case label is not a value that the controlling expression can yield, and thus this label will never be selected.

© 2012-2018 Microchip Technology Inc.

(697) non-constant case label ***(Code Generator)***

A `case` label in this `switch` statement has a value which is not a constant.

(698) bit variables must be global or static ***(Code Generator)***

A `bit` variable cannot be of type `auto`. If you require a `bit` variable with scope local to a block of code or function, qualify it `static`, for example:

```
bit proc(int a)
{
  bit bb;        /* oops --  this should be: static bit bb; */
  bb = (a > 66);
  return bb;
}
```

(699) no case labels in switch ***(Code Generator)***

There are no `case` labels in this `switch` statement, for example:

```
switch(input) {
}               /* there is nothing to match the value of input */
```

(700) truncation of enumerated value ***(Code Generator)***

An enumerated value larger than the maximum value supported by this compiler was detected and has been truncated, for example:

```
enum { ZERO, ONE, BIG=0x99999999 } test_case;
```

(701) unreasonable matching depth ***(Code Generator)***

This is an internal compiler error. Contact Microchip Technical Support with details.

(702) regused(): bad arg to G ***(Code Generator)***

This is an internal compiler error. Contact Microchip Technical Support with details.

(703) bad GN ***(Code Generator)***

This is an internal compiler error. Contact Microchip Technical Support with details.

(704) bad RET_MASK ***(Code Generator)***

This is an internal compiler error. Contact Microchip Technical Support with details.

(705) bad which (*) after I ***(Code Generator)***

This is an internal compiler error. Contact Microchip Technical Support with details.

(706) bad which in expand() ***(Code Generator)***

This is an internal compiler error. Contact Microchip Technical Support with details.

(707) bad SX ***(Code Generator)***

This is an internal compiler error. Contact Microchip Technical Support with details.

(708) bad mod "+" for how = "*" ***(Code Generator)***

This is an internal compiler error. Contact Microchip Technical Support with details.

(709) metaregister "*" can’t be used directly *(Code Generator)*

This is an internal compiler error. Contact Microchip Technical Support with details.

(710) bad U usage *(Code Generator)*

This is an internal compiler error. Contact Microchip Technical Support with details.

(711) bad how in expand() *(Code Generator)*

This is an internal compiler error. Contact Microchip Technical Support with details.

(712) can’t generate code for this expression *(Code Generator)*

This error indicates that a C expression is too difficult for the code generator to actually compile. For successful code generation, the code generator must know how to compile an expression and there must be enough resources (i.e., registers or temporary memory locations) available. Simplifying the expression, i.e., using a temporary variable to hold an intermediate result, can often bypass this situation.

This error can also be issued if the code being compiled is unusual. For example, code which writes to a const-qualified object is illegal and will result in warning messages, but the code generator can unsuccessfully try to produce code to perform the write.

This error can also result from an attempt to redefine a function that uses the `intrinsic` pragma.

(713) bad initialization list *(Code Generator)*

This is an internal compiler error. Contact Microchip Technical Support with details.

(714) bad intermediate code *(Code Generator)*

This is an internal compiler error. Contact Microchip Technical Support with details.

(715) bad pragma "*" *(Code Generator)*

The code generator has been passed a `pragma` directive that it does not understand. This implies that the pragma you have used is not implemented for the target device.

(716) bad argument to -M option "*" *(Code Generator)*

The code generator has been passed a `-M` option that it does not understand. This should not happen if it is being invoked by a standard compiler driver.

(718) incompatible intermediate code version; should be *.* *(Code Generator)*

The intermediate code file produced by P1 is not the correct version for use with this code generator. This is either that incompatible versions of one or more compilers have been installed in the same directory, or a temporary file error has occurred leading to corruption of a temporary file. Check the setting of the TEMP environment variable. If it refers to a long path name, change it to something shorter. Contact Microchip Technical Support with details if required.

(720) multiple free: * *(Code Generator)*

This is an internal compiler error. Contact Microchip Technical Support with details.

© 2012-2018 Microchip Technology Inc.

(721) element count must be constant expression ***(Code Generator)***

The expression that determines the number of elements in an array must be a constant expression. Variables qualified as `const` do not form such an expression.

```
const unsigned char mCount = 5;
int mDeadtimeArr[mCount];  // oops -- the size cannot be a variable
```

(722) bad variable syntax in intermediate code ***(Code Generator)***

This is an internal compiler error. Contact Microchip Technical Support with details.

(723) function definitions nested too deep ***(Code Generator)***

This error is unlikely to happen with C code, because C cannot have nested functions! Contact Microchip Technical Support with details.

(724) bad op (*) in revlog() ***(Code Generator)***

This is an internal compiler error. Contact Microchip Technical Support with details.

(726) bad op "*" in uconval() ***(Code Generator)***

This is an internal compiler error. Contact Microchip Technical Support with details.

(727) bad op "*" in bconfloat() ***(Code Generator)***

This is an internal code generator error. Contact Microchip Technical Support with details.

(728) bad op "*" in confloat() ***(Code Generator)***

This is an internal compiler error. Contact Microchip Technical Support with details.

(729) bad op "*" in conval() ***(Code Generator)***

This is an internal compiler error. Contact Microchip Technical Support with details.

(730) bad op "*" ***(Code Generator)***

This is an internal compiler error. Contact Microchip Technical Support with details.

(731) expression error with reserved word ***(Code Generator)***

This is an internal compiler error. Contact Microchip Technical Support with details.

(732) initialization of bit types is illegal ***(Code Generator)***

Variables of type `bit` cannot be initialized, for example:

```
bit b1 = 1; /* oops!  b1 must be assigned after its definition */
```

(733) bad string "*" in pragma "psect" ***(Code Generator)***

The code generator has been passed a `pragma psect` directive that has a badly formed string, for example:

```
#pragma psect text  /* redirect text psect into what? */
```

Possibly, you meant something like:

```
#pragma psect text=special_text
```

(734) too many "psect" pragmas ***(Code Generator)***

Too many `#pragma psect` directives have been used.

(735) bad string "*" in pragma "stack_size" ***(Code Generator)***

The argument to the stack_size pragma is malformed. This pragma must be followed by a number representing the maximum allowed stack size.

(737) unknown argument "*" to pragma "switch" ***(Code Generator)***

The `#pragma switch` directive has been used with an invalid switch code generation method. Possible arguments are: `auto` , `simple` and `direct`.

(739) error closing output file ***(Code Generator)***

The compiler detected an error when closing a file. Contact Microchip Technical Support with details.

(740) zero dimension array is illegal ***(Code Generator)***

The code generator has been passed a declaration that results in an array having a zero dimension.

(741) bitfield too large (* bits) ***(Code Generator)***

The maximum number of bits in a bit-field is 8, the same size as the storage unit width.

```
struct {
  unsigned flag  : 1;
  unsigned value : 12;  /* oops -- that's larger than 8 bits wide */
  unsigned cont  : 6;
} object;
```

(742) function "*" argument evaluation overlapped ***(Linker)***

A function call involves arguments which overlap between two functions. This could occur with a call like:

```
void fn1(void)
{
  fn3( 7, fn2(3), fn2(9));    /* Offending call */
}
char fn2(char fred)
{
  return fred + fn3(5,1,0);
}
char fn3(char one, char two, char three)
{
  return one+two+three;
}
```

where `fn1` is calling `fn3` , and two arguments are evaluated by calling `fn2` , which in turn calls `fn3`. The program structure should be modified to prevent this type of call sequence.

(743) divide by zero ***(Code Generator)***

An expression involving a division by zero has been detected in your code.

© 2012-2018 Microchip Technology Inc.

(744) static object "*" has zero size ***(Code Generator)***

A static object has been declared, but has a size of zero.

(745) nodecount = * ***(Code Generator)***

This is an internal compiler error. Contact Microchip Technical Support with details.

(746) object "*" qualified const but not initialized ***(Code Generator)***

An object has been qualified as `const`, but there is no initial value supplied at the definition. As this object cannot be written by the C program, this can imply the initial value was accidentally omitted.

(747) unrecognized option "*" to -Z ***(Code Generator)***

This is an internal compiler error. Contact Microchip Technical Support with details.

(748) variable "*" possibly used before being assigned a value ***(Code Generator)***

This variable has possibly been used before it was assigned a value. Because it is an `auto` variable, this will result in it having an unpredictable value, for example:

```
void main(void)
{
  int a;
  if(a)         /* oops -- ’a’ has never been assigned a value */
    process();
}
```

(749) unknown register name "*" used with pragma ***(Linker)***

This is an internal compiler error. Contact Microchip Technical Support with details.

MESSAGES 750-999

(750) constant operand to || or && *(Code Generator)*

One operand to the logical operators `||` or && is a constant. Check the expression for missing or badly placed parentheses. This message can also occur if the global optimizer is enabled and one of the operands is an `auto` or `static` local variable whose value has been tracked by the code generator, for example:

```
{
int a;
a = 6;
if(a || b)  /* a is 6, therefore this is always true */
    b++;
```

(751) arithmetic overflow in constant expression *(Code Generator)*

A constant expression has been evaluated by the code generator that has resulted in a value that is too big for the type of the expression. The most common code to trigger this warning is assignments to `signed` data types. For example:

```
signed char c;
c = 0xFF;
```

As a `signed` 8-bit quantity, c can only be assigned values -128 to 127. The constant is equal to 255 and is outside this range. If you mean to set all bits in this variable, then use either of:

```
c = ~0x0;
c = -1;
```

which sets all the bits in the variable, regardless of variable size, and without warning.

This warning can also be triggered by intermediate values overflowing. For example:

```
unsigned int i;  /* assume ints are 16 bits wide */
i = 240 * 137;   /* this should be okay, right? */
```

A quick check with your calculator reveals that 240 * 137 is 32880 which can easily be stored in an `unsigned int`, but a warning is produced. Why? Because 240 and 137 and both `signed int` values. Therefore the result of the multiplication must also be a `signed int` value, but a `signed int` cannot hold the value 32880. (Both operands are constant values so the code generator can evaluate this expression at compile time, but it must do so following all the ANSI C rules.) The following code forces the multiplication to be performed with an `unsigned` result:

```
i = 240u * 137;  /* force at least one operand
                    to be unsigned */
```

(752) conversion to shorter data type *(Code Generator)*

Truncation can occur in this expression as the `lvalue` is of shorter type than the `rvalue`, for example:

```
char a;
int b, c;
a = b + c;  /* int to char conversion
               can result in truncation */
```

© 2012-2018 Microchip Technology Inc.

(753) undefined shift (* bits) *(Code Generator)*

An attempt has been made to shift a value by a number of bits equal to or greater than the number of bits in the data type. This will produce an undefined result on many processors. This is non-portable code and is flagged as having undefined results by the C Standard, for example:

```
int input;
input <<= 33;  /* oops -- that shifts the entire value out */
```

(754) bitfield comparison out of range *(Code Generator)*

This is the result of comparing a bit-field with a value when the value is out of range of the bit-field. That is, comparing a 2-bit bit-field to the value 5 will never be true as a 2-bit bit-field has a range from 0 to 3. For example:

```
struct {
  unsigned mask : 2;  /* mask can hold values 0 to 3 */
} value;
int compare(void)
{
  return (value.mask == 6);  /* test can
}
```

(755) divide by zero *(Code Generator)*

A constant expression that was being evaluated involved a division by zero, for example:

```
a /= 0;  /* divide by 0: was this what you were intending */
```

(757) constant conditional branch ***(Code Generator)***

A conditional branch (generated by an `if`, `for`, `while` statement etc.) always follows the same path. This will be some sort of comparison involving a variable and a constant expression. For the code generator to issue this message, the variable must have local scope (either `auto` or `static` local) and the global optimizer must be enabled, possibly at higher level than 1, and the warning level threshold can need to be lower than the default level of 0.

The global optimizer keeps track of the contents of local variables for as long as is possible during a function. For C code that compares these variables to constants, the result of the comparison can be deduced at compile time and the output code hard coded to avoid the comparison, for example:

```
{
  int a, b;
  a = 5;
  /* this can never be false;
     always perform the true statement */
  if(a == 5)
    b = 6;
```

will produce code that sets a to 5, then immediately sets b to 6.

No code will be produced for the comparison `if(a == 5)`. If a was a global variable, it can be that other functions (particularly interrupt functions) can modify it and so tracking the variable cannot be performed.

This warning can indicate more than an optimization made by the compiler. It can indicate an expression with missing or badly placed parentheses, causing the evaluation to yield a value different to what you expected.

This warning can also be issued because you have written something like `while(1)`. To produce an infinite loop, use `for(;;)`.

A similar situation arises with for loops, for example:

```
{
  int a, b;
  /* this loop must iterate at least once */
  for(a=0; a!=10; a++)
    b = func(a);
```

In this case the code generator can again pick up that a is assigned the value 0, then immediately checked to see if it is equal to 10. Because a is modified during the `for` loop, the comparison code cannot be removed, but the code generator will adjust the code so that the comparison is not performed on the first pass of the loop; only on the subsequent passes. This cannot reduce code size, but it will speed program execution.

© 2012-2018 Microchip Technology Inc.

(758) constant conditional branch: possible use of "=" instead of "==" *(Code Generator)*

There is an expression inside an `if` or other conditional construct, where a constant is being assigned to a variable. This can mean you have inadvertently used an assignment = instead of a compare ==, for example:

```
  int a, b;
  /* this can never be false;
     always perform the true statement */
  if(a = 4)
    b = 6;
```

will assign the value 4 to a, then , as the value of the assignment is always true, the comparison can be omitted and the assignment to b always made. Did you mean:

```
/* this can never be false;
   always perform the true statement */
if(a == 4)
    b = 6;
```

which checks to see if a is equal to 4.

(759) expression generates no code *(Code Generator)*

This expression generates no output code. Check for things like leaving off the parentheses in a function call, for example:

```
int fred;
fred;     /* this is valid, but has no effect at all */
```

Some devices require that special function register need to be read to clear hardware flags. To accommodate this, in some instances the code generator *does* produce code for a statement which only consists of a variable ID. This can happen for variables which are qualified as `volatile`. Typically the output code will read the variable, but not do anything with the value read.

(760) portion of expression has no effect *(Code Generator)*

Part of this expression has no side effects and no effect on the value of the expression, for example:

```
int a, b, c;
a = b,c;  /* "b" has no effect,
             was that meant to be a comma? */
```

(761) sizeof yields 0 *(Code Generator)*

The code generator has taken the size of an object and found it to be zero. This almost certainly indicates an error in your declaration of a pointer; i.e., you can have declared a pointer to a zero length array. In general, pointers to arrays are of little use. If you require a pointer to an array of objects of unknown length, you only need a pointer to a single object that can then be indexed or incremented.

(762) constant truncated when assigned to bitfield *(Code Generator)*

A constant value is too large for a bitfield structure member to which it is being assigned, for example:

```
struct INPUT {
  unsigned a : 3;
  unsigned b : 5;
} input_grp;
input_grp.a = 0x12;  /* oops -- 0x12 cannot fit into a 3-bit wide
object */
```

(763) constant left operand to "? :" operator *(Code Generator)*

The left operand to a conditional operator ? is constant, thus the result of the tertiary operator `?:` will always be the same, for example:

```
a = 8 ? b : c;  /* this is the same as saying a = b; */
```

(764) mismatched comparison *(Code Generator)*

A comparison is being made between a variable or expression and a constant value which is not in the range of possible values for that expression, for example:

```
unsigned char c;
if(c > 300)      /* oops -- how can this be true? */
  close();
```

(765) degenerate unsigned comparison *(Code Generator)*

There is a comparison of an `unsigned` value with zero, which will always be true or false, for example:

```
unsigned char c;
if(c >= 0)
```

will always be true, because an `unsigned` value can never be less than zero.

(766) degenerate signed comparison *(Code Generator)*

There is a comparison of a `signed` value with the most negative value possible for this type, such that the comparison will always be true or false, for example:

```
char c;
if(c >= -128)
```

will always be true, because an 8 bit signed char has a maximum negative value of -128.

(767) constant truncated to bitfield width *(Code Generator)*

A constant value is too large for a bit-field structure member on which it is operating, for example:

```
struct INPUT {
  unsigned a : 3;
  unsigned b : 5;
} input_grp;
input_grp.a |= 0x13;   /* oops -- 0x13 to large for 3-bit wide object
*/
```

(768) constant relational expression *(Code Generator)*

There is a relational expression that will always be true or false. This, for example, can be the result of comparing an `unsigned` number with a negative value; or comparing a variable with a value greater than the largest number it can represent, for example:

```
unsigned int a;
if(a == -10)    /* if a is unsigned, how can it be -10? */
  b = 9;
```

(769) no space for macro definition *(Assembler)*

The assembler has run out of memory.

© 2012-2018 Microchip Technology Inc.

(772) include files nested too deep ***(Assembler)***

Macro expansions and include file handling have filled up the assembler's internal stack. The maximum number of open macros and include files is 30.

(773) macro expansions nested too deep ***(Assembler)***

Macro expansions in the assembler are nested too deep. The limit is 30 macros and include files nested at one time.

(774) too many macro parameters ***(Assembler)***

There are too many macro parameters on this macro definition.

(776) can't allocate space for object "*" (offs: *) ***(Assembler)***

The assembler has run out of memory.

(777) can't allocate space for opnd structure within object "*" (offs: *) ***(Assembler)***

The assembler has run out of memory.

(780) too many psects defined ***(Assembler)***

There are too many psects defined! Boy, what a program!

(781) can't enter abs psect ***(Assembler)***

This is an internal compiler error. Contact Microchip Technical Support with details.

(782) REMSYM error ***(Assembler)***

This is an internal compiler error. Contact Microchip Technical Support with details.

(783) "with" psects are cyclic ***(Assembler)***

If Psect A is to be placed “with” Psect B, and Psect B is to be placed “with” Psect A, there is no hierarchy. The `with` flag is an attribute of a psect and indicates that this psect must be placed in the same memory page as the specified psect.

Remove a `with` flag from one of the psect declarations. Such an assembler declaration can look like:

```
psect my_text,local,class=CODE,with=basecode
```

which will define a psect called `my_text` and place this in the same page as the psect `basecode`.

(784) overfreed ***(Assembler)***

This is an internal compiler error. Contact Microchip Technical Support with details.

(785) too many temporary labels ***(Assembler)***

There are too many temporary labels in this assembler file. The assembler allows a maximum of 2000 temporary labels.

(787) can't handle "v_rtype" of * in copyexpr ***(Assembler)***

This is an internal compiler error. Contact Microchip Technical Support with details.

(788) invalid character "*" in number *(Assembler)*

A number contained a character that was not part of the range 0-9 or 0-F.

(790) end of file inside conditional *(Assembler)*

END-of-FILE was encountered while scanning for an "endif" to match a previous "if".

(793) unterminated macro argument *(Assembler)*

An argument to a macro is not terminated. Note that angle brackets ("< >") are used to quote macro arguments.

(794) invalid number syntax *(Assembler)*

The syntax of a number is invalid. This, for example, can be use of 8 or 9 in an octal number, or other malformed numbers.

(796) use of LOCAL outside macros is illegal *(Assembler)*

The `LOCAL` directive is only legal inside macros. It defines local labels that will be unique for each invocation of the macro.

(797) syntax error in LOCAL argument *(Assembler)*

A symbol defined using the `LOCAL` assembler directive in an assembler macro is syntactically incorrect. Ensure that all symbols and all other assembler identifiers conform with the assembly language of the target device.

(798) use of macro arguments in a LOCAL directive is illegal *(Assembler)*

The list of labels after the directive `LOCAL` cannot include any of the formal parameters to an enclosing macro, for example:

```
mmm MACRO a1
   MOVE   r0, #a1
   LOCAL  a1  ; oops -- the parameter cannot be used with LOCAL
ENDM
```

(799) REPT argument must be >= 0 *(Assembler)*

The argument to a REPT directive must be greater than zero, for example:

```
REPT -2             ; -2 copies of this code? */
  MOVE    r0, [r1]++
ENDM
```

(800) undefined symbol "*" *(Assembler)*

The named symbol is not defined in this module, and has not been specified `GLOBAL`.

(801) range check too complex *(Assembler)*

This is an internal compiler error. Contact Microchip Technical Support with details.

(802) invalid address after END directive *(Assembler)*

The start address of the program which is specified after the assembler `END` directive must be a label in the current file.

© 2012-2018 Microchip Technology Inc.

(803) undefined temporary label ***(Assembler)***

A temporary label has been referenced that is not defined. Note that a temporary label must have a number >= 0.

(804) write error on object file ***(Assembler)***

The assembler failed to write to an object file. This can be an internal compiler error. Contact Microchip Technical Support with details.

(806) attempted to get an undefined object (*) ***(Assembler)***

This is an internal compiler error. Contact Microchip Technical Support with details.

(807) attempted to set an undefined object (*) ***(Assembler)***

This is an internal compiler error. Contact Microchip Technical Support with details.

(808) bad size in add_reloc() ***(Assembler)***

This is an internal compiler error. Contact Microchip Technical Support with details.

(809) unknown addressing mode (*) ***(Assembler)***

An unknown addressing mode was used in the assembly file.

(811) "cnt" too large (*) in display() ***(Assembler)***

This is an internal compiler error. Contact Microchip Technical Support with details.

(814) device type not defined ***(Assembler)***

The device must be defined either from the command line (e.g., -16c84), via the device assembler directive, or via the LIST assembler directive.

(815) syntax error in chipinfo file at line * ***(Assembler)***

The chipinfo file contains non-standard syntax at the specified line.

(816) duplicate ARCH specification in chipinfo file "*" at line * ***(Assembler, Driver)***

The chipinfo file has a device section with multiple ARCH values. Only one ARCH value is allowed. If you have not manually edited the chip info file, contact Microchip Technical Support with details.

(817) unknown architecture in chipinfo file at line * ***(Assembler, Driver)***

An chip architecture (family) that is unknown was encountered when reading the chip INI file.

(818) duplicate BANKS for "*" in chipinfo file at line * ***(Assembler)***

The chipinfo file has a device section with multiple BANKS values. Only one BANKS value is allowed. If you have not manually edited the chip info file, contact Microchip Technical Support with details.

(819) duplicate ZEROREG for "*" in chipinfo file at line * ***(Assembler)***

The chipinfo file has a device section with multiple ZEROREG values. Only one ZEROREG value is allowed. If you have not manually edited the chip info file, contact Microchip Technical Support with details.

(820) duplicate SPAREBIT for "*" in chipinfo file at line * ***(Assembler)***

The chipinfo file has a device section with multiple SPAREBIT values. Only one SPAREBIT value is allowed. If you have not manually edited the chip info file, contact Microchip Technical Support with details.

(821) duplicate INTSAVE for "*" in chipinfo file at line * ***(Assembler)***

The chipinfo file has a device section with multiple INTSAVE values. Only one INTSAVE value is allowed. If you have not manually edited the chip info file, contact Microchip Technical Support with details.

(822) duplicate ROMSIZE for "*" in chipinfo file at line * ***(Assembler)***

The chipinfo file has a device section with multiple ROMSIZE values. Only one ROMSIZE value is allowed. If you have not manually edited the chip info file, contact Microchip Technical Support with details.

(823) duplicate START for "*" in chipinfo file at line * ***(Assembler)***

The chipinfo file has a device section with multiple START values. Only one START value is allowed. If you have not manually edited the chip info file, contact Microchip Technical Support with details.

(824) duplicate LIB for "*" in chipinfo file at line * ***(Assembler)***

The chipinfo file has a device section with multiple `LIB` values. Only one `LIB` value is allowed. If you have not manually edited the chip info file, contact Microchip Technical Support with details.

(825) too many RAMBANK lines in chipinfo file for "*" ***(Assembler)***

The chipinfo file contains a device section with too many RAMBANK fields. Reduce the number of values.

(826) inverted ram bank in chipinfo file at line * ***(Assembler, Driver)***

The second HEX number specified in the RAM field in the chipinfo file must be greater in value than the first.

(827) too many COMMON lines in chipinfo file for "*" ***(Assembler)***

There are too many lines specifying common (access bank) memory in the chip configuration file.

(828) inverted common bank in chipinfo file at line * ***(Assembler, Driver)***

The second HEX number specified in the COMMON field in the chipinfo file must be greater in value than the first. Contact Microchip Technical Support if you have not modified the chipinfo INI file.

© 2012-2018 Microchip Technology Inc.

(829) unrecognized line in chipinfo file at line * *(Assembler)*

The chipinfo file contains a device section with an unrecognized line. Contact Microchip Technical Support if the INI has not been edited.

(830) missing ARCH specification for "*" in chipinfo file *(Assembler)*

The chipinfo file has a device section without an ARCH values. The architecture of the device must be specified. Contact Microchip Technical Support if the chipinfo file has not been modified.

(832) empty chip info file "*" *(Assembler)*

The chipinfo file contains no data. If you have not manually edited the chip info file, contact Microchip Technical Support with details.

(833) no valid entries in chipinfo file *(Assembler)*

The chipinfo file contains no valid device descriptions.

(834) page width must be >= 60 *(Assembler)*

The listing page width must be at least 60 characters. Any less will not allow a properly formatted listing to be produced, for example:

```
LIST C=10  ; the page width will need to be wider than this
```

(835) form length must be >= 15 *(Assembler)*

The form length specified using the `-F` *length* option must be at least 15 lines. Setting this length to zero is allowed and turns off paging altogether. The default value is zero (pageless).

(836) no file arguments *(Assembler)*

The assembler has been invoked without any file arguments. It cannot assemble anything.

(839) relocation too complex *(Assembler)*

The complex relocation in this expression is too big to be inserted into the object file.

(840) phase error *(Assembler)*

The assembler has calculated a different value for a symbol on two different passes. This is commonly due to the redefinition of a psect with conflicting delta values (see Section 5.2.9.3.4 “Delta”).

(841) bad source/destination for movfp/movpf instruction *(Assembler)*

The absolute address specified with the `MOVFP`/`MOVPF` instruction is too large.

(842) bad bit number *(Assembler)*

A bit number must be an absolute expression in the range 0-7.

(843) a macro name can't also be an EQU/SET symbol *(Assembler)*

An EQU or SET symbol has been found with the same name as a macro. This is not allowed. For example:

```
getval MACRO
  MOV  r0, r1
ENDM
getval EQU 55h  ; oops -- choose a different name to the macro
```

(844) lexical error *(Assembler)*

An unrecognized character or token has been seen in the input.

(845) symbol "*" defined more than once *(Assembler)*

This symbol has been defined in more than one place. The assembler will issue this error if a symbol is defined more than once in the same module, for example:

```
_next:
   MOVE   r0, #55
   MOVE   [r1], r0
_next:           ; oops -- choose a different name
```

The linker will issue this warning if the symbol (C or assembler) was defined multiple times in different modules. The names of the modules are given in the error message. Note that C identifiers often have an *underscore* prepended to their name after compilation.

(846) relocation error *(Assembler)*

It is not possible to add together two relocatable quantities. A constant can be added to a relocatable value, and two relocatable addresses in the same psect can be subtracted. An absolute value must be used in various places where the assembler must know a value at assembly time.

(847) operand error *(Assembler)*

The operand to this opcode is invalid. Check your assembler reference manual for the proper form of operands for this instruction.

(848) label defined in this module has also been declared EXTRN *(Assembler)*

The definition for an assembly label, and an `EXTRN` declaration for the same symbol, appear in the same module. Use `GLOBAL` instead of `EXTRN` if you want this symbol to be accessible from other modules.

(849) illegal instruction for this device *(Assembler)*

The instruction is not supported by this device.

(850) PAGESEL not usable with this device *(Assembler)*

The PAGESEL pseudo-instruction is not usable with the device selected.

(851) illegal destination *(Assembler)*

The destination (either `,f` or `,w`) is not correct for this instruction.

© 2012-2018 Microchip Technology Inc.

(852) radix must be from 2 - 16 ***(Assembler)***

The radix specified using the `RADIX` assembler directive must be in the range from 2 (binary) to 16 (hexadecimal).

(853) invalid size for FNSIZE directive ***(Assembler)***

The assembler FNSIZE assembler directive arguments must be positive constants.

(855) ORG argument must be a positive constant ***(Assembler)***

An argument to the `ORG` assembler directive must be a positive constant or a symbol which has been equated to a positive constant, for example:

```
ORG -10  /* this must a positive offset to the current psect */
```

(856) ALIGN argument must be a positive constant ***(Assembler)***

The `align` assembler directive requires a non-zero positive integer argument.

(857) use of both local and global psect flags is illegal with same psect ***(Linker)***

A local psect cannot have the same name as a global psect, for example:

```
psect text,class=CODE       ; the text psect is implicitly global
   MOVE   r0, r1
; elsewhere:
psect text,local,class=CODE
   MOVE   r2, r4
```

The `global` flag is the default for a psect if its scope is not explicitly stated.

(859) argument to C option must specify a positive constant ***(Assembler)***

The parameter to the `LIST` assembler control's `C=` option (which sets the column width of the listing output) must be a positive decimal constant number, for example:

```
LIST C=a0h  ; constant must be decimal and positive,
              try: LIST C=80
```

(860) page width must be >= 49 ***(Assembler)***

The page width suboption to the `LIST` assembler directive must specify a width of at least 49.

(861) argument to N option must specify a positive constant ***(Assembler)***

The parameter to the `LIST` assembler control's `N` option (which sets the page length for the listing output) must be a positive constant number, for example:

```
LIST N=-3  ; page length must be positive
```

(862) symbol is not external ***(Assembler)***

A symbol has been declared as EXTRN but is also defined in the current module.

(863) symbol can't be both extern and public ***(Assembler)***

If the symbol is declared as extern, it is to be imported. If it is declared as public, it is to be exported from the current module. It is not possible for a symbol to be both.

(864) argument to "size" psect flag must specify a positive constant *(Assembler)*

The parameter to the PSECT assembler directive's `size` option must be a positive constant number, for example:

```
PSECT text,class=CODE,size=-200  ; a negative size?
```

(865) psect flag "size" redefined *(Assembler)*

The `size` flag to the PSECT assembler directive is different from a previous PSECT directive, for example:

```
psect spdata,class=RAM,size=400
; elsewhere:
psect spdata,class=RAM,size=500
```

(866) argument to "reloc" psect flag must specify a positive constant *(Assembler)*

The parameter to the PSECT assembler directive's `reloc` option must be a positive constant number, for example:

```
psect test,class=CODE,reloc=-4  ; the reloc must be positive
```

(867) psect flag "reloc" redefined *(Assembler)*

The `reloc` flag to the PSECT assembler directive is different from a previous PSECT directive, for example:

```
psect spdata,class=RAM,reloc=4
; elsewhere:
psect spdata,class=RAM,reloc=8
```

(868) argument to "delta" psect flag must specify a positive constant *(Assembler)*

The parameter to the PSECT assembler directive's DELTA option must be a positive constant number, for example:

```
PSECT text,class=CODE,delta=-2  ; negative delta value doesn't make
sense
```

(869) psect flag "delta" redefined *(Assembler)*

The 'DELTA' option of a psect has been redefined more than once in the same module.

(870) argument to "pad" psect flag must specify a positive constant *(Assembler)*

The parameter to the PSECT assembler directive's 'PAD' option must be a non-zero positive integer.

(871) argument to "space" psect flag must specify a positive constant *(Assembler)*

The parameter to the PSECT assembler directive's `space` option must be a positive constant number, for example:

```
PSECT text,class=CODE,space=-1  ; space values start at zero
```

(872) psect flag "space" redefined *(Assembler)*

The `space` flag to the PSECT assembler directive is different from a previous PSECT directive, for example:

```
psect spdata,class=RAM,space=0
; elsewhere:
psect spdata,class=RAM,space=1
```

© 2012-2018 Microchip Technology Inc.

(873) a psect can only be in one class *(Assembler)*

You cannot assign a psect to more than one class. The psect was defined differently at this point than when it was defined elsewhere. A psect's class is specified via a flag as in the following:

```
psect text,class=CODE
```

Look for other psect definitions that specify a different class name.

(874) a psect can only have one "with" option *(Assembler)*

A psect can only be placed with one other psect. Look for other psect definitions that specify a different `with` psect name. A psect's `with` option is specified via a flag, as shown in the following:

```
psect bss,with=data
; elsewhere
psect bss,with=lktab  ; oops -- bss is to be linked with two psects
```

(875) bad character constant in expression *(Assembler)*

The character constant was expected to consist of only one character, but was found to be greater than one character or none at all. An assembler specific example:

```
MOV  r0, #'12'    ; '12' specifies two characters
```

(876) syntax error *(Assembler)*

A syntax error has been detected. This could be caused a number of things.

(877) yacc stack overflow *(Assembler)*

This is an internal compiler error. Contact Microchip Technical Support with details.

(878) -S option used: "*" ignored *(Driver)*

The indicated assembly file has been supplied to the driver in conjunction with the `-S` option. The driver really has nothing to do because the file is already an assembly file.

(880) invalid number of parameters. Use "* –HELP" for help *(Driver)*

Improper command-line usage of the of the compiler's driver.

(881) setup succeeded *(Driver)*

The compiler has been successfully setup using the `--setup` driver option.

(883) setup failed *(Driver)*

The compiler was not successfully setup using the `--setup` driver option. Ensure that the directory argument to this option is spelled correctly, is syntactically correct for your host operating system and it exists.

(884) please ensure you have write permissions to the configuration file *(Driver)*

The compiler was not successfully setup using the `--setup` driver option because the driver was unable to access the XML configuration file. Ensure that you have write permission to this file. The driver will search the following configuration files in order:

- the file specified by the environment variable `XC_XML`
- the file `/etc/xc.xml` if the directory '`/etc` ' is writable and there is no `.xc.xml` file in your home directory
- the file `.xc.xml` file in your home directory

If none of the files can be located, then the above error will occur.

(889) this * compiler has expired *(Driver)*

The demo period for this compiler has concluded.

(890) contact Microchip to purchase and re-activate this compiler *(Driver)*

The evaluation period of this demo installation of the compiler has expired. You will need to purchase the compiler to re-activate it. If you sincerely believe the evaluation period has ended prematurely, contact Microchip technical support.

(891) can't open psect usage map file "*": * *(Driver)*

The driver was unable to open the indicated file. The psect usage map file is generated by the driver when the driver option `--summary=file` is used. Ensure that the file is not open in another application.

(892) can't open memory usage map file "*": * *(Driver)*

The driver was unable to open the indicated file. The memory usage map file is generated by the driver when the driver option `--summary=file` is used. Ensure that the file is not open in another application.

(893) can't open HEX usage map file "*": * *(Driver)*

The driver was unable to open the indicated file. The HEX usage map file is generated by the driver when the driver option `--summary=file` is used. Ensure that the file is not open in another application.

(894) unknown source file type "*" *(Driver)*

The extension of the indicated input file could not be determined. Only files with the extensions `as`, `c`, `obj`, `usb`, `p1`, `lib` or `HEX` are identified by the driver.

(895) can't request and specify options in the one command *(Driver)*

The usage of the driver options `--getoption` and `--setoption` is mutually exclusive.

(896) no memory ranges specified for data space *(Driver)*

No on-chip or external memory ranges have been specified for the data space memory for the device specified.

(897) no memory ranges specified for program space *(Driver)*

No on-chip or external memory ranges have been specified for the program space memory for the device specified.

© 2012-2018 Microchip Technology Inc.

(899) can’t open option file "*" for application "*": * ***(Driver)***

An option file specified by a `--getoption` or `--setoption` driver option could not be opened. If you are using the `--setoption` option, ensure that the name of the file is spelled correctly and that it exists. If you are using the `--getoption` option ensure that this file can be created at the given location or that it is not in use by any other application.

(900) exec failed: * ***(Driver)***

The subcomponent listed failed to execute. Does the file exist? Try re-installing the compiler.

(902) no chip name specified; use "* –CHIPINFO" to see available chip names ***(Driver)***

The driver was invoked without selecting what chip to build for. Running the driver with the `–CHIPINFO` option will display a list of all chips that could be selected to build for.

(904) illegal format specified in "*" option ***(Driver)***

The usage of this option was incorrect. Confirm correct usage with –HELP or refer to the part of the manual that discusses this option.

(905) illegal application specified in "*" option ***(Driver)***

The application given to this option is not understood or does not belong to the compiler.

(907) unknown memory space tag "*" in "*" option specification ***(Driver)***

A parameter to this memory option was a string but did not match any valid *tags*. Refer to the section of this manual that describes this option to see what tags (if any) are valid for this device.

(908) exit status = * ***(Driver)***

One of the subcomponents being executed encountered a problem and returned an error code. Other messages should have been reported by the subcomponent to explain the problem that was encountered.

(913) "*" option can cause compiler errors in some standard header files ***(Driver)***

Using this option will invalidate some of the qualifiers used in the standard header files, resulting in errors. This issue and its solution are detailed in the section of this manual that specifically discusses this option.

(915) no room for arguments ***(Preprocessor, Parser, Code Generator, Linker, Objtohex)***

The code generator could not allocate any more memory.

(917) argument too long ***(Preprocessor, Parser)***

This is an internal compiler error. Contact Microchip Technical Support with details.

(918) *: no match ***(Preprocessor, Parser)***

This is an internal compiler error. Contact Microchip Technical Support with details.

(919) * in chipinfo file "*" at line * ***(Driver)***

The specified parameter in the chip configuration file is illegal.

(920) empty chipinfo file ***(Driver, Assembler)***

The chip configuration file was able to be opened but it was empty. Try re-installing the compiler.

(922) chip "*" not present in chipinfo file "*" ***(Driver)***

The chip selected does not appear in the compiler's chip configuration file. Contact Microchip to see whether support for this device is available or it is necessary to upgrade the version of your compiler.

(923) unknown suboption "*" ***(Driver)***

This option can take suboptions, but this suboption is not understood. This can just be a simple spelling error. If not, –HELP to look up what suboptions are permitted here.

(924) missing argument to "*" option ***(Driver)***

This option expects more data but none was given. Check the usage of this option.

(925) extraneous argument to "*" option ***(Driver)***

This option does not accept additional data, yet additional data was given. Check the usage of this option.

(926) duplicate "*" option ***(Driver)***

This option can only appear once, but appeared more than once.

(928) bad "*" option value ***(Driver, Assembler)***

The indicated option was expecting a valid hexadecimal integer argument.

(929) bad "*" option ranges ***(Driver)***

This option was expecting a parameter in a range format (*start_of_range-end_of_range*), but the parameter did not conform to this syntax.

(930) bad "*" option specification ***(Driver)***

The parameters to this option were not specified correctly. Run the driver with –HELP or refer to the driver's chapter in this manual to verify the correct usage of this option.

(931) command file not specified ***(Driver)***

Command file to this application, expected to be found after `'@'` or `'<'` on the command line was not found.

(939) no file arguments ***(Driver)***

The driver has been invoked with no input files listed on its command line. If you are getting this message while building through a third party IDE, perhaps the IDE could not verify the source files to compile or object files to link and withheld them from the command line.

© 2012-2018 Microchip Technology Inc.

(940) *-bit * placed at * *(Objtohex)*

Presenting the result of the requested calculation.

(941) bad "*" assignment; USAGE: ** *(Hexmate)*

An option to HEXMATE was incorrectly used or incomplete. Follow the usage supplied by the message and ensure that the option has been formed correctly and completely.

(942) unexpected character on line * of file "*" *(Hexmate)*

File contains a character that was not valid for this type of file, the file can be corrupt. For example, an Intel HEX file is expected to contain only ASCII representations of hexadecimal digits, colons (:) and line formatting. The presence of any other characters will result in this error.

(944) data conflict at address *h between * and * *(Hexmate)*

Sources to Hexmate request differing data to be stored to the same address. To force one data source to override the other, use the '+' specifier. If the two named sources of conflict are the same source, then the source can contain an error.

(945) range (*h to *h) contained an indeterminate value *(Hexmate)*

The range for this calculation contained a value that could not be resolved. This can happen if the result was to be stored within the address range of the calculation.

(948) result width must be between 1 and 4 bytes *(Hexmate)*

The requested byte size is illegal. Checksum results must be within 1 to 4 bytes wide. Check the parameters to the -CKSUM option.

(949) start of range must be less than end of range *(Hexmate)*

The -CKSUM option has been given a range where the start is greater than the end. The parameters can be incomplete or entered in the wrong order.

(951) start of fill range must be less than end of range *(Hexmate)*

The -FILL option has been given a range where the start is greater than the end. The parameters can be incomplete or entered in the wrong order.

(953) unknown -HELP sub-option: * *(Hexmate)*

Invalid sub-option passed to -HELP. Check the spelling of the sub-option or use -HELP with no sub-option to list all options.

(956) -SERIAL value must be between 1 and * bytes long *(Hexmate)*

The serial number being stored was out of range. Ensure that the serial number can be stored in the number of bytes permissible by this option.

(958) too many input files specified; * file maximum *(Hexmate)*

Too many file arguments have been used. Try merging these files in several stages rather than in one command.

(960) unexpected record type (*) on line * of "*" *(Hexmate)*

Intel HEX file contained an invalid record type. Consult the Intel HEX format specification for valid record types.

(962) forced data conflict at address *h between * and * *(Hexmate)*

Sources to `HEXMATE` force differing data to be stored to the same address. More than one source using the '+' specifier store data at the same address. The actual data stored there cannot be what you expect.

(963) range includes voids or unspecified memory locations *(Hexmate)*

The hash (checksum) range had gaps in data content. The runtime hash calculated is likely to differ from the compile-time hash due to gaps/unused byes within the address range that the hash is calculated over. Filling unused locations with a known value will correct this.

(964) unpaired nibble in -FILL value will be truncated *(Hexmate)*

The hexadecimal code given to the FILL option contained an incomplete byte. The incomplete byte (nibble) will be disregarded.

(965) -STRPACK option not yet implemented; option will be ignored *(Hexmate)*

This option currently is not available and will be ignored.

(966) no END record for HEX file "*" *(Hexmate)*

Intel HEX file did not contain a record of type END. The HEX file can be incomplete.

(967) unused function definition "*" (from line *) *(Parser)*

The indicated `static` function was never called in the module being compiled. Being static, the function cannot be called from other modules so this warning implies the function is never used. Either the function is redundant, or the code that was meant to call it was excluded from compilation or misspelled the name of the function.

(968) unterminated string *(Assembler)*

A string constant appears not to have a closing quote.

(969) end of string in format specifier *(Parser)*

The format specifier for the `printf()` style function is malformed.

(970) character not valid at this point in format specifier *(Parser)*

The `printf()` style format specifier has an illegal character.

(971) type modifiers not valid with this format *(Parser)*

Type modifiers cannot be used with this format.

(972) only modifiers "h" and "l" valid with this format *(Parser)*

Only modifiers h (`short`) and `l` (`long`) are legal with this `printf` format specifier.

(973) only modifier "l" valid with this format *(Parser)*

The only modifier that is legal with this format is `l` (for long).

© 2012-2018 Microchip Technology Inc.

(974) type modifier already specified *(Parser)*

This type modifier has already be specified in this type.

(975) invalid format specifier or type modifier *(Parser)*

The format specifier or modifier in the `printf`-style string is illegal for this particular format.

(976) field width not valid at this point *(Parser)*

A field width cannot appear at this point in a `printf()` type format specifier.

(978) this identifier is already an enum tag *(Parser)*

This identifier following a `struct` or `union` keyword is already the tag for an enumerated type, and thus should only follow the keyword `enum`, for example:

```
enum IN {ONE=1, TWO};
struct IN {             /* oops -- IN is already defined */
  int a, b;
};
```

(979) this identifier is already a struct tag *(Parser)*

This identifier following a `union` or `enum` keyword is already the tag for a structure, and thus should only follow the keyword `struct`, for example:

```
struct IN {
  int a, b;
};
enum IN {ONE=1, TWO};  /* oops -- IN is already defined */
```

(980) this identifier is already a union tag *(Parser)*

This identifier following a `struct` or `enum` keyword is already the tag for a `union`, and thus should only follow the keyword `union`, for example:

```
union IN {
  int a, b;
};
enum IN {ONE=1, TWO};  /* oops -- IN is already defined */
```

(981) pointer required *(Parser)*

A pointer is required here, for example:

```
struct DATA data;
data->a = 9;      /* data is a structure,
                     not a pointer to a structure */
```

(982) unknown op "*" in nxtuse() *(Assembler)*

This is an internal compiler error. Contact Microchip Technical Support with details.

(983) storage class redeclared *(Parser)*

A variable previously declared as being *static* , has now be redeclared as *extern*.

(984) type redeclared *(Parser)*

The type of this function or object has been redeclared. This can occur because of two incompatible declarations, or because an implicit declaration is followed by an incompatible declaration, for example:

```
int a;
char a;  /* oops -- what is the correct type? */
```

(985) qualifiers redeclared *(Parser)*

This function or variable has different qualifiers in different declarations.

(986) enum member redeclared *(Parser)*

A member of an enumeration is defined twice or more with differing values. Does the member appear twice in the same list or does the name of the member appear in more than one enum list?

(987) arguments redeclared *(Parser)*

The data types of the parameters passed to this function do not match its prototype.

(988) number of arguments redeclared *(Parser)*

The number of arguments in this function declaration does not agree with a previous declaration of the same function.

(989) module has code below file base of *h *(Linker)*

This module has code below the address given, but the `-C` option has been used to specify that a binary output file is to be created that is mapped to this address. This would mean code from this module would have to be placed before the beginning of the file! Check for missing psect directives in assembler files.

(990) modulus by zero in #if; zero result assumed *(Preprocessor)*

A modulus operation in a `#if` expression has a zero divisor. The result has been assumed to be zero, for example:

```
#define ZERO 0
#if FOO%ZERO    /* this will have an assumed result of 0 */
  #define INTERESTING
#endif
```

(991) integer expression required *(Parser)*

In an `enum` declaration, values can be assigned to the members, but the expression must evaluate to a constant of type `int`, for example:

```
enum {one = 1, two, about_three = 3.12};
  /* no non-int values allowed */
```

(992) can't find op *(Assembler)*

This is an internal compiler error. Contact Microchip Technical Support with details.

(993) some command-line options are disabled *(Driver)*

The compiler is operating in demo mode. Some command-line options are disabled.

© 2012-2018 Microchip Technology Inc.

(994) some command-line options are disabled and compilation is delayed ***(Driver)***

The compiler is operating in demo mode. Some command-line options are disabled, the compilation speed will be slower.

(995) some command-line options are disabled; code size is limited to 16kB, compilation is delayed ***(Driver)***

The compiler is operating in demo mode. Some command-line options are disabled; the compilation speed will be slower, and the maximum allowed code size is limited to 16 KB.

MESSAGES 1000-1249

(1015) missing "*" specification in chipinfo file "*" at line * ***(Driver)***

This attribute was expected to appear at least once but was not defined for this chip.

(1016) missing argument* to "*" specification in chipinfo file "*" at line * ***(Driver)***

This value of this attribute is blank in the chip configuration file.

(1017) extraneous argument* to "*" specification in chipinfo file "*" at line * ***(Driver)***

There are too many attributes for the listed specification in the chip configuration file.

(1018) illegal number of "*" specification* (* found; * expected) in chipinfo file "*" at line * ***(Driver)***

This attribute was expected to appear a certain number of times; but, it did not appear for this chip.

(1019) duplicate "*" specification in chipinfo file "*" at line * ***(Driver)***

This attribute can only be defined once but has been defined more than once for this chip.

(1020) unknown attribute "*" in chipinfo file "*" at line * ***(Driver)***

The chip configuration file contains an attribute that is not understood by this version of the compiler. Has the chip configuration file or the driver been replaced with an equivalent component from another version of this compiler?

(1021) syntax error reading "*" value in chipinfo file "*" at line * ***(Driver)***

The chip configuration file incorrectly defines the specified value for this device. If you are modifying this file yourself, take care and refer to the comments at the beginning of this file for a description on what type of values are expected here.

(1022) syntax error reading "*" range in chipinfo file "*" at line * ***(Driver)***

The chip configuration file incorrectly defines the specified range for this device. If you are modifying this file yourself, take care and refer to the comments at the beginning of this file for a description on what type of values are expected here.

(1024) syntax error in chipinfo file "*" at line * ***(Driver)***

The chip configuration file contains a syntax error at the line specified.

(1025) unknown architecture in chipinfo file "*" at line * ***(Driver)***

The attribute at the line indicated defines an architecture that is unknown to this compiler.

(1026) missing architecture in chipinfo file "*" at line * ***(Assembler)***

The chipinfo file has a device section without an ARCH values. The architecture of the device must be specified. Contact Microchip Technical Support if the chipinfo file has not been modified.

© 2012-2018 Microchip Technology Inc.

(1027) activation was successful ***(Driver)***

The compiler was successfully activated.

(1028) activation was not successful - error code (*) ***(Driver)***

The compiler did not activated successfully.

(1029) compiler not installed correctly - error code (*) ***(Driver)***

This compiler has failed to find any activation information and cannot proceed to execute. The compiler can have been installed incorrectly or incompletely. The error code quoted can help diagnose the reason for this failure. You can be asked for this failure code if contacting Microchip for assistance with this problem.

(1030) Hexmate - Intel HEX editing utility (Build 1.%i) ***(Hexmate)***

Indicating the version number of the `HEXMATE` being executed.

(1031) USAGE: * [input1.HEX] [input2.HEX]... [inputN.HEX] [options] ***(Hexmate)***

The suggested usage of `HEXMATE`.

(1032) use –HELP=<option> for usage of these command line options ***(Hexmate)***

More detailed information is available for a specific option by passing that option to the HELP option.

(1033) available command-line options: ***(Hexmate)***

This is a simple heading that appears before the list of available options for this application.

(1034) type "*" for available options ***(Hexmate)***

It looks like you need help. This advisory suggests how to get more information about the options available to this application or the usage of these options.

(1035) bad argument count (*) ***(Parser)***

The number of arguments to a function is unreasonable. This is an internal compiler error. Contact Microchip Technical Support with details.

(1036) bad "*" optional header length (0x* expected) ***(Cromwell)***

The length of the optional header in this COFF file was of an incorrect length.

(1037) short read on * ***(Cromwell)***

When reading the type of data indicated in this message, it terminated before reaching its specified length.

(1038) string table length too short ***(Cromwell)***

The specified length of the COFF string table is less than the minimum.

(1039) inconsistent symbol count ***(Cromwell)***

The number of symbols in the symbol table has exceeded the number indicated in the COFF header.

(1040) bad : record 0x*, 0x* *(Cromwell)*

A record of the type specified failed to match its own value.

(1041) short record *(Cromwell)*

While reading a file, one of the file's records ended short of its specified length.

(1042) unknown * record type 0x* *(Cromwell)*

The type indicator of this record did not match any valid types for this file format.

(1043) unknown optional header *(Cromwell)*

When reading this Microchip COFF file, the optional header within the file header was of an incorrect length.

(1044) end of file encountered *(Cromwell, Linker)*

The end of the file was found while more data was expected. Has this input file been truncated?

(1045) short read on block of * bytes *(Cromwell)*

A while reading a block of byte data from a UBROF record, the block ended before the expected length.

(1046) short string read *(Cromwell)*

A while reading a string from a UBROF record, the string ended before the specified length.

(1047) bad type byte for UBROF file *(Cromwell)*

This UBROF file did not begin with the correct record.

(1048) bad time/date stamp *(Cromwell)*

This UBROF file has a bad time/date stamp.

(1049) wrong CRC on 0x* bytes; should be * *(Cromwell)*

An end record has a mismatching CRC value in this UBROF file.

(1050) bad date in 0x52 record *(Cromwell)*

A debug record has a bad date component in this UBROF file.

(1051) bad date in 0x01 record *(Cromwell)*

A start of program record or segment record has a bad date component in this UBROF file.

(1052) unknown record type *(Cromwell)*

A record type could not be determined when reading this UBROF file.

(1053) additional RAM ranges larger than bank size *(Driver)*

A block of additional RAM being requested exceeds the size of a bank. Try breaking the block into multiple ranges that do not cross bank boundaries.

(1054) additional RAM range out of bounds *(Driver)*

The RAM memory range as defined through custom RAM configuration is out of range.

(1055) RAM range out of bounds (*) *(Driver)*

The RAM memory range as defined in the chip configuration file or through custom configuration is out of range.

(1056) unknown chip architecture *(Driver)*

The compiler is attempting to compile for a device of an architecture that is either unsupported or disabled.

(1057) fast double option only available on 17 series processors *(Driver)*

The fast double library cannot be selected for this device. These routines are only available for PIC17 devices.

(1058) assertion *(Code Generator)*

This is an internal compiler error. Contact Microchip Technical Support with details.

(1059) rewrite loop *(Code Generator)*

This is an internal compiler error. Contact Microchip Technical Support with details.

(1081) static initialization of persistent variable "*" *(Parser, Code Generator)*

A persistent variable has been assigned an initial value. This is somewhat contradictory as the initial value will be assigned to the variable during execution of the compiler's startup code; however, the *persistent* qualifier requests that this variable shall be unchanged by the compiler's startup code.

(1082) size of initialized array element is zero *(Code Generator)*

This is an internal compiler error. Contact Microchip Technical Support with details.

(1088) function pointer "*" is used but never assigned a value *(Code Generator)*

A function call involving a function pointer was made, but the pointer was never assigned a target address, for example:

```
void (*fp)(int);
fp(23);     /* oops -- what function does fp point to? */
```

(1089) recursive function call to "*" *(Code Generator)*

A recursive call to the specified function has been found. The call can be direct or indirect (using function pointers) and can be either a function calling itself, or calling another function whose call graph includes the function under consideration.

(1090) variable "*" is not used *(Code Generator)*

This variable is declared but has not been used by the program. Consider removing it from the program.

(1091) main function "*" not defined *(Code Generator)*

The *main* function has not been defined. Every C program must have a function called *main*.

(1094) bad derived type ***(Code Generator)***

This is an internal compiler error. Contact Microchip Technical Support with details.

(1095) bad call to typeSub() ***(Code Generator)***

This is an internal compiler error. Contact Microchip Technical Support with details.

(1096) type should be unqualified ***(Code Generator)***

This is an internal compiler error. Contact Microchip Technical Support with details.

(1097) unknown type string "*" ***(Code Generator)***

This is an internal compiler error. Contact Microchip Technical Support with details.

(1098) conflicting declarations for variable "*" (*:*) ***(Parser, Code Generator)***

Differing type information has been detected in the declarations for a variable, or between a declaration and the definition of a variable, for example:

```
extern long int test;
int test;    /* oops -- which is right? int or long int ? */
```

(1104) unqualified error ***(Code Generator)***

This is an internal compiler error. Contact Microchip Technical Support with details.

(1118) bad string "*" in getexpr(J) ***(Code Generator)***

This is an internal compiler error. Contact Microchip Technical Support with details.

(1119) bad string "*" in getexpr(LRN) ***(Code Generator)***

This is an internal compiler error. Contact Microchip Technical Support with details.

(1121) expression error ***(Code Generator)***

This is an internal compiler error. Contact Microchip Technical Support with details.

(1137) match() error: * ***(Code Generator)***

This is an internal compiler error. Contact Microchip Technical Support with details.

(1157) W register must be W9 ***(Assembler)***

The working register required here has to be W9, but an other working register was selected.

(1159) W register must be W11 ***(Assembler)***

The working register required here has to be W11, but an other working register was selected.

(1178) the "*" option has been removed and has no effect ***(Driver)***

This option no longer exists in this version of the compiler and has been ignored. Use the compiler's –*help* option or refer to the manual to find a replacement option.

© 2012-2018 Microchip Technology Inc.

(1179) interrupt level for function "*" cannot exceed * ***(Code Generator)***

The interrupt level for the function specified is too high. Each interrupt function is assigned a unique interrupt level. This level is considered when analyzing the call graph and reentrantly called functions. If using the `interrupt_level` pragma, check the value specified.

(1180) directory "*" does not exist ***(Driver)***

The directory specified in the setup option does not exist. Create the directory and try again.

(1182) near variables must be global or static ***(Code Generator)***

A variable qualified as *near* must also be qualified with *static* or made global. An auto variable cannot be qualified as *near*.

(1183) invalid version number ***(Activation)***

During activation, no matching version number was found on the Microchip activation server database for the serial number specified.

(1184) activation limit reached ***(Activation)***

The number of activations of the serial number specified has exceeded the maximum number allowed for the license.

(1185) invalid serial number ***(Activation)***

During activation, no matching serial number was found on the Microchip activation server database.

(1186) license has expired ***(Driver)***

The time-limited license for this compiler has expired.

(1187) invalid activation request ***(Driver)***

The compiler has not been correctly activated.

(1188) network error * ***(Activation)***

The compiler activation software was unable to connect to the Microchip activation server via the network.

(1190) FAE license only - not for use in commercial applications ***(Driver)***

Indicates that this compiler has been activated with an FAE license. This license does not permit the product to be used for the development of commercial applications.

(1191) licensed for educational use only ***(Driver)***

Indicates that this compiler has been activated with an education license. The educational license is only available to educational facilities and does not permit the product to be used for the development of commercial applications.

(1192) licensed for evaluation purposes only ***(Driver)***

Indicates that this compiler has been activated with an evaluation license.

(1193) this license will expire on * ***(Driver)***

The compiler has been installed as a time-limited trial. This trial will end on the date specified.

(1195) invalid syntax for "*" option ***(Driver)***

A command line option that accepts additional parameters was given inappropriate data or insufficient data. For example, an option can expect two parameters with both being integers. Passing a string as one of these parameters or supplying only one parameter could result in this error.

(1198) too many "*" specifications; * maximum ***(Hexmate)***

This option has been specified too many times. If possible, try performing these operations over several command lines.

(1199) compiler has not been activated ***(Driver)***

The trial period for this compiler has expired. The compiler is now inoperable until activated with a valid serial number. Contact Microchip to purchase this software and obtain a serial number.

(1200) Found %0*lXh at address *h ***(Hexmate)***

The code sequence specified in a -FIND option has been found at this address.

(1201) all FIND/REPLACE code specifications must be of equal width ***(Hexmate)***

All find, replace and mask attributes in this option must be of the same byte width. Check the parameters supplied to this option. For example, finding 1234h (2 bytes) masked with FFh (1 byte) results in an error; but, masking with 00FFh (2 bytes) works.

(1202) unknown format requested in -FORMAT: * ***(Hexmate)***

An unknown or unsupported INHX format has been requested. Refer to documentation for supported INHX formats.

(1203) unpaired nibble in * value will be truncated ***(Hexmate)***

Data to this option was not entered as whole bytes. Perhaps the data was incomplete or a leading zero was omitted. For example, the value Fh contains only four bits of significant data and is not a whole byte. The value 0Fh contains eight bits of significant data and is a whole byte.

(1204) * value must be between 1 and * bytes long ***(Hexmate)***

An illegal length of data was given to this option. The value provided to this option exceeds the maximum or minimum bounds required by this option.

© 2012-2018 Microchip Technology Inc.

(1205) using the configuration file *; you can override this with the environment variable HTC_XML *(Driver)*

This is the compiler configuration file selected during compiler setup. This can be changed via the HTC_XML environment variable. This file is used to determine where the compiler has been installed.

(1207) some of the command line options you are using are now obsolete *(Driver)*

Some of the command line options passed to the driver have now been discontinued in this version of the compiler; however, during a grace period these old options will still be processed by the driver.

(1208) use –help option or refer to the user manual for option details *(Driver)*

An obsolete option was detected. Use –help or refer to the manual to find a replacement option that will not result in this advisory message.

(1209) An old MPLAB tool suite plug-in was detected. *(Driver)*

The options passed to the driver resemble those that the Microchip MPLAB 8 IDE would pass to a previous version of this compiler. Some of these options are now obsolete – however, they were still interpreted. It is recommended that you install an updated Microchip options plug-in for the IDE.

(1210) Visit the Microchip website (www.microchip.com) for a possible upgrade *(Driver)*

Visit our website to see if an upgrade is available to address the issue(s) listed in the previous compiler message. Navigate to the MPLAB XC8 C Compiler page and look for a version upgrade downloadable file. If your version is current, contact Microchip Technical Support for further information.

(1212) Found * (%0*lXh) at address *h *(Hexmate)*

The code sequence specified in a -FIND option has been found at this address.

(1213) duplicate ARCH for * in chipinfo file at line * *(Assembler, Driver)*

The chipinfo file has a device section with multiple ARCH values. Only one ARCH value is allowed. If you have not manually edited the chip info file, contact Microchip Technical Support with details.

(1218) can’t create cross reference file * *(Assembler)*

The assembler attempted to create a cross reference file; but, it could not be created. Check that the file’s path name is correct.

(1228) unable to locate installation directory *(Driver)*

The compiler cannot determine the directory where it has been installed.

(1230) dereferencing uninitialized pointer "*" *(Code Generator)*

A pointer that has not yet been assigned a value has been dereferenced. This can result in erroneous behavior at runtime.

(1235) unknown keyword * *(Driver)*

The token contained in the USB descriptor file was not recognized.

(1236) invalid argument to *: * *(Driver)*

An option that can take additional parameters was given an invalid parameter value. Check the usage of the option or the syntax or range of the expected parameter.

(1237) endpoint 0 is pre-defined *(Driver)*

An attempt has been made to define endpoint 0 in a USB file.

(1238) FNALIGN failure on * *(Linker)*

Two functions have their auto/parameter blocks aligned using the `FNALIGN` directive, but one function calls the other, which implies that must not be aligned. This will occur if a function pointer is assigned the address of each function, but one function calls the other. For example:

```
int one(int a) { return a; }
int two(int a) { return two(a)+2; }  /* ! */
int (*ip)(int);
ip = one;
ip(23);
ip = two;      /* ip references one and two; two calls one */
ip(67);
```

(1239) pointer * has no valid targets *(Code Generator)*

A function call involving a function pointer was made, but the pointer was never assigned a target address, for example:

```
void (*fp)(int);
fp(23);     /* oops -- what function does fp point to? */
```

(1240) unknown algorithm type (%i) *(Driver)*

The error file specified after the `-Efile` or `-E+file` options could not be opened. Check to ensure that the file or directory is valid and that has read only access.

(1241) bad start address in * *(Driver)*

The start of range address for the `--CHECKSUM` option could not be read. This value must be a hexadecimal number.

(1242) bad end address in * *(Driver)*

The end of range address for the `--CHECKSUM` option could not be read. This value must be a hexadecimal number.

(1243) bad destination address in * *(Driver)*

The destination address for the `--CHECKSUM` option could not be read. This value must be a hexadecimal number.

(1245) value greater than zero required for * *(Hexmate)*

The *align* operand to the `HEXMATE -FIND` option must be positive.

(1246) no RAM defined for variable placement *(Code Generator)*

No memory has been specified to cover the banked RAM memory.

© 2012-2018 Microchip Technology Inc.

(1247) no access RAM defined for variable placement ***(Code Generator)***

No memory has been specified to cover the access bank memory.

(1248) symbol (*) encountered with undefined type size ***(Code Generator)***

The code generator was asked to position a variable, but the size of the variable is not known. This is an internal compiler error. Contact Microchip Technical Support with details.

MESSAGES 1250-1499

(1250) could not find space (* byte*) for variable * *(Code Generator)*

The code generator could not find space in the banked RAM for the variable specified.

(1253) could not find space (* byte*) for auto/param block *(Code Generator)*

The code generator could not find space in RAM for the psect that holds `auto` and parameter variables.

(1254) could not find space (* byte*) for data block *(Code Generator)*

The code generator could not find space in RAM for the data psect that holds initialized variables.

(1255) conflicting paths for output directory *(Driver)*

The compiler has been given contradictory paths for the output directory via any of the `-O` or `--OUTDIR` options, for example:

```
--outdir=../../   -o../main.HEX
```

(1256) undefined symbol "*" treated as HEX constant *(Assembler)*

A token which could either be interpreted as a symbol or a hexadecimal value does not match any previously defined symbol and so will be interpreted as the latter. Use a leading *zero* to avoid the ambiguity, or use an alternate radix specifier such as `0x`. For example:

```
MOV  a, F7h  ; is this the symbol F7h, or the HEX number 0xF7?
```

(1257) local variable "*" is used but never given a value *(Code Generator)*

An `auto` variable has been defined and used in an expression, but it has not been assigned a value in the C code before its first use. Auto variables are not cleared on startup and their initial value is undefined. For example:

```
void main(void) {
  double src, out;
  out = sin(src);   /* oops -- what value was in src? */
```

(1258) possible stack overflow when calling function "*" *(Code Generator)*

The call tree analysis by the code generator indicates that the hardware stack can overflow. This should be treated as a guide only. Interrupts, the assembler optimizer and the program structure can affect the stack usage. The stack usage is based on the C program and does not include any call tree derived from assembly code.

(1259) can't optimize for both speed and space *(Driver)*

The driver has been given contradictory options of compile for speed and compile for space, for example:

```
--opt=speed,space
```

© 2012-2018 Microchip Technology Inc.

(1260) macro "*" redefined *(Assembler)*

More than one definition for a macro with the same name has been encountered, for example:

```
MACRO fin
  ret
ENDM
MACRO fin   ; oops -- was this meant to be a different macro?
  reti
ENDM
```

(1261) string constant required *(Assembler)*

A string argument is required with the DS or DSU directive, for example:

```
DS ONE     ; oops -- did you mean DS "ONE"?
```

(1262) object "*" lies outside available * space *(Code Generator)*

An absolute variable was positioned at a memory location which is not within the memory defined for the target device, for example:

```
int data @ 0x800     /* oops -- is this the correct address? */
```

(1264) unsafe pointer conversion *(Code Generator)*

A pointer to one kind of structure has been converted to another kind of structure and the structures do not have a similar definition, for example:

```
struct ONE {
  unsigned a;
  long b;          /* ! */
} one;
struct TWO {
  unsigned a;
  unsigned b;      /* ! */
} two;
struct ONE * oneptr;
oneptr = & two;    /* oops --
                   was ONE meant to be same struct as TWO? */
```

(1267) fixup overflow referencing * into * bytes at 0x* *(Linker)*

See error message 1356 for more information.

(1268) fixup overflow storing 0x* in * bytes at * *(Linker)*

See error message 1356 for more information.

(1273) Omniscient Code Generation not available in Free mode *(Driver)*

This message advises that advanced features of the compiler are not be enabled in this Free mode compiler.

(1275) the qualifier "*" is only applicable to functions *(Parser)*

A qualifier which only makes sense when used in a function definition has been used with a variable definition.

```
interrupt int dacResult;  /* oops --
            the interrupt qualifier can only be used with functions */
```

(1276) buffer overflow in DWARF location list ***(Cromwell)***

A buffer associated with the ELF/DWARF debug file has overflowed. Contact Microchip Technical Support with details.

(1278) omitting "*" which does not have a location ***(Cromwell)***

A variable has no storage location listed and will be omitted from the debug output. Contact Microchip Technical Support with details.

(1284) malformed mapfile while generating summary: CLASS expected but not found ***(Driver)***

The map file being read to produce a memory summary is malformed. Either the file has been edited or corrupted, or this is a compiler error – contact Microchip Technical Support with details.

(1285) malformed mapfile while generating summary: no name at position * ***(Driver)***

The map file being read to produce a memory summary is malformed. Either the file has been edited or corrupted, or this is a compiler error – contact Microchip Technical Support with details.

(1286) malformed mapfile while generating summary: no link address at position * ***(Driver)***

The map file being read to produce a memory summary is malformed. Either the file has been edited or corrupted, or this is a compiler error – contact Microchip Technical Support with details.

(1287) malformed mapfile while generating summary: no load address at position * ***(Driver)***

The map file being read to produce a memory summary is malformed. Either the file has been edited or corrupted, or this is a compiler error – contact Microchip Technical Support with details.

(1288) malformed mapfile while generating summary: no length at position * ***(Driver)***

The map file being read to produce a memory summary is malformed. Either the file has been edited or corrupted, or this is a compiler error – contact Microchip Technical Support with details.

(1289) line range limit exceeded, possibly affecting ability to debug code ***(Cromwell)***

A C statement has produced assembly code output whose length exceeds a preset limit. This means that debug information produced by `CROMWELL` may not be accurate. This warning does not indicate any potential code failure.

(1290) buffer overflow in DWARF debugging information entry ***(Cromwell)***

A buffer associated with the ELF/DWARF debug file has overflowed. Contact Microchip Technical Support with details.

(1291) bad ELF string table index ***(Cromwell)***

An ELF file passed to `CROMWELL` is malformed and cannot be used.

(1292) malformed define in .SDB file * ***(Cromwell)***

The named SDB file passed to `CROMWELL` is malformed and cannot be used.

© 2012-2018 Microchip Technology Inc.

(1293) couldn't find type for "*" in DWARF debugging information entry *(Cromwell)*

The type of symbol could not be determined from the SDB file passed to `CROMWELL`. Either the file has been edited or corrupted, or this is a compiler error – contact Microchip Technical Support with details.

(1294) there is only one day left until this license expires *(Driver)*

The compiler is running as a demo and will be unable to run in PRO mode after the evaluation license has expired in less than one day's time. After expiration, the compiler can be operated in Free mode indefinitely, but will produce a larger output binary.

(1295) there are * days left until this license will expire *(Driver)*

The compiler is running as a demo and will be unable to run in PRO mode after the evaluation license has expired in the indicated time. After expiration, the compiler can be operated in Free mode indefinitely, but will produce a larger output binary.

(1296) source file "*" conflicts with "*" *(Driver)*

The compiler has encountered more than one source file with the same base name. This can only be the case if the files are contained in different directories. As the compiler and IDEs based the names of intermediate files on the base names of source files, and intermediate files are always stored in the same location, this situation is illegal. Ensure the base name of all source files are unique.

(1297) option * not available in Free mode *(Driver)*

Some options are not available when the compiler operates in Free mode. The options disabled are typically related to how the compiler is executed, e.g., `--GETOPTION` and `--SETOPTION`, and do not control compiler features related to code generation.

(1298) use of * outside macros is illegal *(Assembler)*

Some assembler directives, e.g., `EXITM`, can only be used inside macro definitions.

(1299) non-standard modifier "*" - use "*" instead *(Parser)*

A `printf` placeholder modifier has been used which is non-standard. Use the indicated modifier instead. For example, the standard hh modifier should be used in preference to b to indicate that the value should be printed as a `char` type.

(1300) maximum number of program classes reached; some classes may be excluded from debugging information *(Cromwell)*

`CROMWELL` is passed a list of class names on the command line. If the number of class names passed in is too large, not all will be used and there is the possibility that debugging information will be inaccurate.

(1301) invalid ELF section header; skipping *(Cromwell)*

`CROMWELL` found an invalid section in an ELF section header. This section will be skipped.

(1302) could not find valid ELF output extension for this device *(Cromwell)*

The extension could not be for the target device family.

(1303) invalid variable location detected: * - * **(*Cromwell*)**

A symbol location could not be determined from the SDB file.

(1304) unknown register name: "*" **(*Cromwell*)**

The location for the indicated symbol in the SDB file was a register, but the register name was not recognized.

(1305) inconsistent storage class for variable: "*" **(*Cromwell*)**

The storage class for the indicated symbol in the SDB file was not recognized.

(1306) inconsistent size (* vs *) for variable: "*" **(*Cromwell*)**

The size of the symbol indicated in the SDB file does not match the size of its type.

(1307) psect * truncated to * bytes **(*Driver*)**

The psect representing either the stack or heap could not be made as large as requested and will be truncated to fit the available memory space.

(1308) missing/conflicting interrupts sub-option; defaulting to "*" **(*Driver*)**

The suboptions to the `--INTERRUPT` option are missing or malformed, for example:

```
--INTERRUPTS=single,multi
```

Oops, did you mean single-vector or multi-vector interrupts?

(1309) ignoring invalid runtime * sub-option (*) using default **(*Driver*)**

The indicated suboption to the `--RUNTIME` option is malformed, for example:

```
--RUNTIME=default,speed:0y1234
```

Oops, that should be 0x1234.

(1310) specified speed (*Hz) exceeds max operating frequency (*Hz); defaulting to *Hz **(*Driver*)**

The frequency specified to the `perform` suboption to `--RUNTIME` option is too large for the selected device.

```
--RUNTIME=default,speed:0xffffffff
```

Oops, that value is too large.

(1311) missing configuration setting for config word *; using default **(*Driver*)**

The configuration settings for the indicated word have not be supplied in the source code and a default value will be used.

(1312) conflicting runtime perform sub-option and configuration word settings; assuming *Hz **(*Driver*)**

The configuration settings and the value specified with the `perform` suboption of the `--RUNTIME` options conflict and a default frequency has been selected.

© 2012-2018 Microchip Technology Inc.

(1313) * sub-options ("*") ignored ***(Driver)***

The argument to a suboption is not required and will be ignored.

```
--OUTPUT=intel:8
```

Oops, the `:8` is not required

(1314) illegal action in memory allocation ***(Code Generator)***

This is an internal error. Contact Microchip Technical Support with details.

(1315) undefined or empty class used to link psect * ***(Linker)***

The linker was asked to place a psect within the range of addresses specified by a class, but the class was either never defined, or contains no memory ranges.

(1316) attribute "*" ignored ***(Parser)***

An attribute has been encountered that is valid, but which is not implemented by the parser. It will be ignored by the parser and the attribute will have no effect. Contact Microchip Technical Support with details.

(1317) missing argument to attribute "*" ***(Parser)***

An attribute has been encountered that requires an argument, but this is not present. Contact Microchip Technical Support with details.

(1318) invalid argument to attribute "*" ***(Parser)***

An argument to an attribute has been encountered, but it is malformed. Contact Microchip Technical Support with details.

(1319) invalid type "*" for attribute "*" ***(Parser)***

This indicated a bad option passed to the parser. Contact Microchip Technical Support with details.

(1320) attribute "*" already exists ***(Parser)***

This indicated the same attribute option being passed to the parser more than once. Contact Microchip Technical Support with details.

(1321) bad attribute -T option "%s" ***(Parser)***

The attribute option passed to the parser is malformed. Contact Microchip Technical Support with details.

(1322) unknown qualifier "%s" given to -T ***(Parser)***

The qualifier specified in an attribute option is not known. Contact Microchip Technical Support with details.

(1323) attribute expected ***(Parser)***

The __attribute__ directive was used but did not specify an attribute type.

```
int rv (int a) __attribute__(())  /* oops -- what is the attribute? */
```

(1324) qualifier "*" ignored (*Parser)*

Some qualifiers are valid, but cannot be implemented on some compilers or target devices. This warning indicates that the qualifier will be ignored.

(1325) no such CP* register: ($*), select (*) (*Code Generator)*

A variable has been qualifier as cp0, but no corresponding co-device register exists at the address specified with the variable.

```
cp0 volatile unsigned int mycpvar @ 0x7000;    /* oops --
                                        did you mean 0x700, try... */
cp0 volatile unsigned int mycpvar @ __REGADDR(7, 0);
```

(1326) "*" qualified variable (*) missing address (*Code Generator)*

A variable has been qualifier as cp0, but the co-device register address was not specified.

```
cp0 volatile unsigned int mycpvar;  /* oops -- what address ? */
```

(1327) interrupt function "*" redefined by "*" (*Code Generator)*

An interrupt function has been written that is linked to a vector location that already has an interrupt function linked to it.

```
void interrupt timer1_isr(void) @ TIMER_1_VCTR { ... }
void interrupt timer2_isr(void) @ TIMER_1_VCTR { ... }    /* oops --
                             did you mean that to be TIMER_2_VCTR */
```

(1328) coprocessor * registers can't be accessed from * code (*Code Generator)*

Code in the indicated instruction set has illegally attempted to access the coprocessor registers. Ensure the correct instruction set is used to encode the enclosing function.

(1329) can only modify RAM type interrupt vectors (*Code Generator)*

The `SETVECTOR()` macro has been used to attempt to change the interrupt vector table, but this table is in ROM and cannot be changed at runtime.

(1330) instruction set architecture qualifiers are only applicable to functions or function pointers (*Code Generator)*

An instruction set qualifier has been used with something that does not represent executable code.

```
mips16e int input;   /* oops -- you cannot qualify a variable with an
instruction set type */
```

(1331) "*" qualifier is not applicable to interrupt functions (*Code Generator)*

A illegal function qualifier has been used with an interrupt function.

```
mips16e void interrupt tisr(void) @ CORE_TIMER_VCTR;   /* oops --
                  you cannot use mips16e with interrupt functions */
```

(1332) invalid qualifier (*) and type combination on "*" (*Code Generator)*

Some qualified variables must have a specific type or size. A combination has been detected that is not allowed.

```
volatile cp0 int mycpvar @ __REGADDR(7,0);   /* oops --
                you must use unsigned types with the cp0 qualifier */
```

© 2012-2018 Microchip Technology Inc.

(1333) can't extend instruction (*Assembler)*

An attempt was made to extend a MIPS16E instruction where the instruction is non-extensible. This is an internal error. Contact Microchip Technical Support with details.

(1334) invalid * register operand (*Assembler)*

An illegal register was used with an assembly instruction. Either this is an internal error or caused by hand-written assembly code.

```
        psect my_text,isa=mips16e,reloc=4
        move t0,t1  /* oops -- these registers cannot be used in the
16-bit instruction set */
```

(1335) instruction "*" is deprecated (*Assembler)*

An assembly instruction was used that is deprecated.

```
beql t0,t1,12  /* oops -- this instruction is no longer supported */
```

(1336) a psect must belong to only one ISA (*Assembler)*

Psects that have a flag that defines the allowed instruction set architecture. A psect has been defined whose ISA flag conflicts with that of another definition for the same psect.

```
mytext,global,isa=mips32r2,reloc=4,delta=1
mytext,global,isa=mips16e,reloc=4,delta=1   /* oops --
               is this the right psect name or the wrong ISA value */
```

(1337) instruction/macro "*" is not part of psect ISA (*Assembler)*

An instruction from one instruction set architecture has been found in a psect whose ISA flag specifies a different architecture type.

```
   psect my_text,isa=mips16e,reloc=4
   mtc0  t0,t1   /* oops -- this is a 32-bit instruction */
```

(1338) operand must be a * bit value (*Assembler)*

The constant operand to an instruction is too large to fit in the instruction field width.

```
   psect my_text,isa=mips32r2,reloc=4
   li  t0,0x123456789  /* oops -- this constant is too large */
```

(1339) operand must be a * bit * value (*Assembler)*

The constant operand to an instruction is too large to fit in the instruction field width and must have the indicated type.

```
addiu   a3, a3, 0x123456   /* oops --
      the constant operand to this MIPS16E instruction is too large */
```

(1340) operand must be >= * and <= * (*Assembler)*

The operand must be within the specified range.

```
ext t0,t1,50,3   /* oops -- third operand is too large */
```

(1341) pos+size must be > 0 and <= 32 (*Assembler)*

The size and position operands to bit-field instruction must total a value within the specified range.

```
ext t0,t1,50,3   /* oops -- 50 + 3 is too large */
```

(1342) whitespace after "\" ***(Preprocessor)***

Whitespace characters have been found between a *backslash* and *newline* characters and will be ignored.

(1343) hexfile data at address 0x* (0x*) overwritten with 0x* ***(Objtohex)***

The indicated address is about to be overwritten by additional data. This would indicate more than one section of code contributing to the same address.

(1346) can't find 0x* words for psect "*" in segment "*" (largest unused contiguous range 0x%lX) ***(Linker)***

See also message (491). The new form of message also indicates the largest free block that the linker could find. Unless there is a single space large enough to accommodate the psect, the linker will issue this message. Often when there is banking or paging involved the largest free space is much smaller than the total amount of space remaining,

(1347) can't find 0x* words (0x* withtotal) for psect "*" in segment "*" (largest unused contiguous range 0x%lX) ***(Linker)***

See also message (593). The new form of message also indicates the largest free block that the linker could find. Unless there is a single space large enough to accommodate the psect, the linker will issue this message. Often when there is banking or paging involved the largest free space is much smaller than the total amount of space remaining,

(1348) enum tag "*" redefined (from *:*) ***(Parser)***

More than one enum tag with the same name has been defined, The previous definition is indicated in the message.

```
enum VALS { ONE=1, TWO, THREE };
enum VALS { NINE=9, TEN };  /* oops -- is VALS the right tag name? */
```

(1350) pointer operands to "-" must reference the same array ***(Code Generator)***

If two addresses are subtracted, the addresses must be of the same object to be ANSI compliant.

```
int * ip;
int fred, buf[20];
ip = &buf[0] - &fred;  /* oops --
          second operand must be an address of a "buf" element */
```

(1352) truncation of operand value (0x*) to * bits ***(Assembler)***

The operand to an assembler instruction was too large and was truncated.

```
movlw  0x321  ; oops -- is this the right value?
```

(1354) ignoring configuration setting for unimplemented word * ***(Driver)***

A Configuration Word setting was specified for a Word that does not exist on the target device.

```
__CONFIG(3, 0x1234);  /* config word 3 does not exist on an 18C801 */
```

© 2012-2018 Microchip Technology Inc.

(1355) in-line delay argument too large *(Code Generator)*

The in-line delay sequence `_delay` has been used, but the number of instruction cycles requested is too large. Use this routine multiple times to achieve the desired delay length.

```
#include <xc.h>
void main(void) {
  delay(0x400000); /* oops -- cannot delay by this number of cycles */
}
```

(1356) fixup overflow referencing * * (0x*) into * byte* at 0x*/0x* -> 0x* (*** */0x*) *(Linker)*

’Fixup’ is the process conducted by the linker of replacing symbolic references to operands with an absolute value. This takes place after positioning the psects (program sections or blocks) into the available memory. ‘Fixup overflow’ is when a symbol’s value is too large to fit within the assembler instruction. For example, if an assembler instruction has an 8-bit field to hold an address and the linker determines that the symbol used to represent this address has the value 0x110, then clearly this value cannot be encoded into the instruction.

Fixup errors are often caused by hand-written assembly code. Common mistakes that trigger these errors include failing to mask a full, banked data address in file register instructions, or failing to mask the destination address in jump or call instructions. If this error is triggered by assembly code generated from C source, then it is often that constructs like switch() statements have generated a block of assembly too large for jump instructions to span. Adjusting the default linker options can also causes such errors.

To identify these errors, follow these steps.

- Perform a debug build (in MPLAB X IDE select Debug > Discrete Debugger Operation > Build for Debugging; alternatively, on the command line use the `-D__DEBUG` option)
- Open the relevant assembler list file (ensure the MPLAB X IDE project properties has XC8 Compiler > Preprocessing and Messaging > Generate the ASM listing file enabled; alternatively, on the command line, use the `--ASMLIST` option)
- Find the instruction at the address quoted in the error message

Consider the following error message.

```
main.c: 4: (1356)(linker) fixup overflow referencing psect bssBANK1
(0x100) into 1 byte at 0x7FF0/0x1 -> 0x7FF0 (main.obj 23/0x0)
```

The file being linked was `main.obj`. This tells you the assembly list file in which you should be looking is `main.lst`. The location of the instruction at fault is 0x7FF0. (You can also tell from this message that the instruction is expecting a 1 byte quantity—this size is rounded to the nearest byte—but the value was determined to be 0x100.)

In the assembly list file, search for the address specified in the error message.

```
61  007FF0  6F00      movwf   _foobar,b       ;#
```

and to confirm, look for the symbol referenced in the assembler instruction at this address in the symbol table at the bottom of the same file.

```
Symbol Table                        Tue Oct 28 11:06:37 2014
 _foobar 0100
```

In this example, the hand-written PIC18 `MOVWF` instruction causing the problem takes an 8-bit offset into a bank of memory, but clearly the address 0x100 exceeds this size. The instruction should have been written as:

```
MOVWF  BANKMASK(_foo)
```

which masks out the top bits of the address containing the bank information (see Section 5.2.1.3 "Address Masking").

If the assembler instruction that caused this error was generated by the compiler, in the assembler list file look back up the file from the instruction at fault to determine which C statement has generated this instruction. You will then need to examine the C code for possible errors.

(1357) fixup overflow storing 0x* in * byte* at 0x*/0x* -> 0x* (*** */0x*) *(Linker)*

See message (1356).

(1358) no space for * temps (*) *(Code Generator)*

The code generator was unable to find a space large enough to hold the temporary variables (scratch variables) for this program.

(1359) no space for * parameters *(Code Generator)*

The code generator was unable to find a space large enough to hold the parameter variables for a particular function.

(1360) no space for auto/param * *(Code Generator)*

The code generator was unable to find a space large enough to hold the auto variables for a particular function. Some parameters passed in registers can need to be allocated space in this auto area as well.

(1361) syntax error in configuration argument *(Parser)*

The argument to `#pragma config` was malformed.

```
#pragma config WDT     /* oops -- is WDT on or off? */
```

(1362) configuration setting *=* redefined *(Code Generator)*

The same config pragma setting have been issued more than once with different values.

```
#pragma config WDT=OFF
#pragma config WDT=ON     /* oops -- is WDT on or off? */
```

(1363) unknown configuration setting (* = *) used *(Driver)*

The configuration value and setting is not known for the target device. The use of an unknown configuration register number may also trigger this message.

```
#pragma config WDR=ON     /* oops -- did you mean WDT? */
#pragma config CONFIG1L=0x46 /* oops -- no 1L register on a 18F4520 */
```

(1364) can't open configuration registers data file * *(Driver)*

The file containing value configuration settings could not be found.

© 2012-2018 Microchip Technology Inc.

(1365) missing argument to pragma "varlocate" *(Parser)*

The argument to `#pragma varlocate` was malformed.

```
#pragma varlocate    /* oops -- what do you want to locate & where? */
```

(1366) syntax error in pragma "varlocate" *(Parser)*

The argument to `#pragma varlocate` was malformed.

```
#pragma varlocate fred     /* oops -- which bank for fred? */
```

(1367) end of file in _asm *(Parser)*

An end-of-file marker was encountered inside a `_asm _endasm` block.

(1368) assembler message: * *(Assembler)*

Displayed is an assembler advisory message produced by the `MESSG` directive contained in the assembler source.

(1369) can’t open proc file * *(Driver)*

The proc file for the selected device could not be opened.

(1370) peripheral library support is not available for the * *(Driver)*

The peripheral library is not available for the selected device.

(1371) float type can’t be bigger than double type; double has been changed to * bits *(Driver)*

Use of the `--float` and `--double` options has result in the size of the `double` type being smaller than that of the `float` type. This is not permitted by the C Standard. The `double` type size has been increased to be that indicated.

(1372) interrupt level cannot be greater than * *(Code Generator)*

The specific interrupt_level is too high for the device selected.

```
#pragma interrupt_level 4
// oops - there aren't that many interrupts on this device
```

(1374) the compiler feature "*" is no longer supported; * *(Driver)*

The feature indicated is no longer supported by the compiler.

(1375) multiple interrupt functions (* and *) defined for device with only one interrupt vector *(Code Generator)*

The named functions have both been qualified interrupt, but the target device only supports one interrupt vector and hence one interrupt function.

```
interrupt void isr_lo(void) {
  // ...
}
interrupt void isr_hi(void) {   // oops, cannot define two ISRs
  // ...
}
```

(1376) initial value (*) too large for bitfield width (*) ***(Code Generator)***

A structure with bit-fields has been defined an initialized with values. The value indicated it too large to fit in the corresponding bit-field width.

```
struct {
  unsigned flag :1;
  unsigned mode :3;
} foobar = { 1, 100 };   // oops, 100 is too large for a 3 bit object
```

(1377) no suitable strategy for this switch ***(Code Generator)***

The compiler was unable to determine the switch strategy to use to encode a C switch statement based on the code and your selection using the `#pragma switch` directive. You can need to choose a different strategy.

(1378) syntax error in pragma "*" ***(Parser)***

The arguments to the indicated pragma are not valid.

```
#pragma addrqual ingore  // oops -- did you mean ignore?
```

(1379) no suitable strategy for this switch ***(Code Generator)***

The compiler encodes `switch()` statements according to one of a number of strategies. The specific number and values of the case values, and the switch expression, as well as the `switch` pragma determine the strategy chosen. This error indicates that no strategy was available to encode the `switch()` statement. Contact Microchip support with program details.

(1380) unable to use switch strategy "*" ***(Code Generator)***

The compiler encodes `switch()` statements according to one of a number of strategies. The specific number and values of the case values, and the switch expression, as well as the `switch` pragma, determine the strategy chosen. This error indicates that the strategy that was requested cannot be used to encode the `switch()` statement. Contact Microchip support with program details.

(1381) invalid case label range ***(Parser)***

The values supplied for the case range are not correct. They must form an ascending range and be integer constants.

```
case 0 ... -2:  // oops -- do you mean -2 ... 0  ?
```

(1385) * "*" is deprecated (declared at *:*) ***(Parser)***

Code is using a variable or function that was marked as being deprecated using an attribute.

```
char __attribute__((deprecated)) foobar;
foobar = 9;     // oops -- this variable is near end-of-life
```

(1386) unable to determine the semantics of the configuration setting "*" for register "*" ***(Parser, Code Generator)***

The numerical value supplied to a configuration bit setting has no direct association setting specified in the data sheet. The compiler will attempt to honor your request, but check your device data sheet.

```
#pragma config OSC=11
// oops -- there is no direct association for that value on an 18F2520
// either use OSC=3 or OSC=RC
```

© 2012-2018 Microchip Technology Inc.

(1387) in-line delay argument must be constant *(Code Generator)*

The `__delay` in-line function can only take a constant expression as its argument.

```
int delay_val = 99;
__delay(delay_val);   // oops, argument must be a constant expression
```

(1388) configuration setting/register of "*" with 0x* will be truncated by 0x* *(Parser, Code Generator)*

A Configuration bit has been programmed with a value that is either too large for the setting, or is not one of the prescribed values.

```
#pragma config WDTPS=138  // oops -- do you mean 128?
```

(1389) attempt to reprogram configuration * "*" with * (is *) *(Parser, Code Generator)*

A Configuration bit that was already programmed has been programmed again with a conflicting setting to the original.

```
#pragma config WDT=ON
#pragma config WDT=OFF  // oops -- watchdog on or off?
```

(1390) identifier specifies insignificant characters beyond maximum identifier length *(Parser)*

An identifier that has been used is so long that it exceeds the set identifier length. This can mean that long identifiers cannot be correctly identified and the code will fail. The maximum identifier length can be adjusted using the `-N` option.

```
int theValueOfThePortAfterTheModeBitsHaveBeenSet;
        // oops, make your symbol shorter or increase the maximum
        // identifier length
```

(1391) constant object size of * exceeds the maximum of * for this chip *(Code Generator)*

The const object defined is too large for the target device.

```
const int array[200] = { ... };  // oops -- not on a Baseline part!
```

(1392) function "*" is called indirectly from both mainline and interrupt code *(Code Generator)*

A function has been called by main-line (non-interrupt) and interrupt code. If this warning is issued, it highlights that such code currently violates a compiler limitation for the selected device.

(1393) possible hardware stack overflow detected; estimated stack depth: * *(Code Generator)*

The compiler has detected that the call graph for a program could be using more stack space that allocated on the target device. If this is the case, the code can fail. The compiler can only make assumption regarding the stack usage, when interrupts are involved and these lead to a worst-case estimate of stack usage. Confirm the function call nesting if this warning is issued.

(1394) attempting to create memory range (* - *) larger than page size * *(Driver)*

The compiler driver has detected that the memory settings include a program memory "page" that is larger than the page size for the device. This would mostly likely be the case if the `--ROM` option is used to change the default memory settings. Consult your device data sheet to determine the page size of the device you are using and to ensure that any contiguous memory range you specify using the `--ROM` option has a boundary that corresponds to the device page boundaries.

```
--ROM=100-1fff
```

The above might need to be paged. If the page size is 800h, the above could specified as

```
--ROM=100-7ff,800-fff,1000-17ff,1800-1fff
```

(1395) notable code sequence candidate suitable for compiler validation suite detected (*) *(Code Generator)*

The compiler has in-built checks that can determine if combinations of internal code templates have been encountered. Where unique combinations are uncovered when compiling code, this message is issued. This message is not an error or warning and its presence does not indicate possible code failure, but if you are willing to participate, the code you are compiling can be sent to Support to assist with the compiler testing process.

(1396) "*" positioned in the * memory region (0x* - 0x*) reserved by the compiler *(Code Generator)*

Some memory regions are reserved for use by the compiler. These regions are not normally used to allocate variables defined in your code. However, by making variables absolute, it is possible to place variables in these regions and avoid errors that would normally be issued by the linker. (Absolute variables can be placed at any location, even on top of other objects.) This warning from the code generator indicates that an absolute has been detected that will be located at memory that the compiler will be reserving. You must locate the absolute variable at a different location. This message will commonly be issued when placing variables in the common memory space.

```
char shared @ 0x7;   // oops, this memory is required by the compiler
```

(1397) unable to implement non-stack call to "*"; possible hardware stack overflow *(Code Generator)*

The compiler must encode a C function call without using a call assembly instruction and the hardware stack (i.e., use a lookup table), but is unable to. A call instruction might be required if the function is called indirectly via a pointer, but if the hardware stack is already full, an additional call will cause a stack overflow.

(1401) eeprom qualified variables can't be accessed from both interrupt and mainline code *(Code Generator)*

All eeprom variables are accessed via routines that are not reentrant. Code might fail if an attempt is made to access `eeprom`-qualified variables from interrupt and main-line code. Avoid accessing eeprom variables in interrupt functions.

(1402) a pointer to eeprom can't also point to other data types *(Code Generator)*

A pointer cannot have targets in both the EEPROM space and ordinary data space.

© 2012-2018 Microchip Technology Inc.

(1403) pragma "*" ignored ***(Parser)***

The pragma you have specified has no effect and will be ignored by the compiler. This message can only be issued in C18 compatibility mode.

```
#pragma varlocate "mySection" fred  // oops -- not accepted
```

(1404) unsupported: * ***(Parser)***

The `unsupported __attribute__` has been used to indicate that some code feature is not supported.

The message printed will indicate the feature that is not supported and which should be avoided.

(1405) storage class specifier "*" ignored ***(Parser)***

The storage class you have specified is not required and will be ignored by the compiler. This message can only be issued in C18 compatibility mode.

```
int procInput(auto int inValue)  // oops -- no need for auto
{ ...
```

(1406) auto eeprom variables are not supported ***(Code Generator)***

Variables qualified as `eeprom` cannot be `auto`. You can define `static` local objects qualified as eeprom, if required.

```
void main(void) {
    eeprom int mode;  // oops -- make this static or global
```

(1407) bit eeprom variables are not supported ***(Code Generator)***

Variables qualified as `eeprom` cannot have type `bit`.

```
eeprom bit myEEbit;    // oops -- you cannot define bits in EEPROM
```

(1408) ignoring initialization of far variables ***(Code Generator)***

Variables qualified as `far` cannot be assigned an initial value. Assign the value later in the code.

```
far int chan = 0x1234; // oops -- you cannot assign a value here
```

(1409) warning number used with pragma "warning" is invalid ***(Parser)***

The message number used with the warning pragma is below zero or larger than the highest message number available.

```
#pragma warning disable 1316 13350   // oops -- possibly number 1335?
```

(1410) can’t assign the result of an invalid function pointer ***(Code Generator)***

The compiler will allow some functions to be called via a constant cast to be a function pointer, but not all. The address specified is not valid for this device.

```
foobar += ((int (*)(int))0x0)(77);
        // oops -- you cannot call a function with a NULL pointer
```

(1411) Additional ROM range out of bounds ***(Driver)***

Program memory specified with the `--ROM` option is outside of the on-chip, or external, memory range supported by this device.

```
--ROM=default,+2000-2ffff
```

Oops -- memory too high, should that be `2fff`?

(1412) missing argument to pragma "warning disable" *(Parser)*

Following the `#pragma warning` disable should be a comma-separated list of message numbers to disable.

```
#pragma warning disable  // oops -- what messages are to be disabled?
```

Try something like the following.

```
#pragma warning disable 1362
```

(1413) pointer comparisons involving address of "*", positioned at address 0x0, may be invalid *(Code Generator)*

An absolute object placed at address 0 has had its address taken. By definition, this is a NULL pointer and code which checks for NULL (i.e., checks to see if the address is valid) can fail.

```
int foobar @ 0x00;
int  * ip;

void
main(void)
{
   ip = &foobar;  // oops -- 0 is not a valid address
```

(1414) option * is defunct and has no effect *(Driver)*

The option used is now longer supported. It will be ignored.

```
xc8 --chip=18f452 --cp=24 main.c
```

Oops -- the `--cp` option is no longer required.

(1415) argument to "merge" psect flag must be 0 or 1 *(Assembler)*

This psect flag must be assigned a 0 or 1.

```
PSECT myTxt,class=CODE,merge=true  ; oops -- I think you mean merge=1
```

(1416) psect flag "merge" redefined *(Assembler)*

A psect with a name seen before specifies a different merge flag value to that previously seen.

```
psect mytext,class=CODE,merge=1
; and later
psect mytext,class=CODE,merge=0
Oops, can mytext be merged or not?
```

(1417) argument to "split" psect flag must be 0 or 1 *(Assembler)*

This psect flag must be assigned a 0 or 1.

```
psect mytext,class=CODE,split=5
```

Oops, the `split` flag argument must be 0 or 1.

(1418) Attempt to read "control" qualified object which is Write-Only *(Code Generator)*

An attempt was made to read a write-only register.

```
state = OPTION;  // oops -- you cannot read this register
```

© 2012-2018 Microchip Technology Inc.

(1419) using the configuration file *; you can override this with the environment variable XC_XML ***(Driver)***

This is the compiler configuration file that is selected during compiler setup. This can be changed via the `XC_XML` environment variable. This file is used to determine where the compiler has been installed. See message 1205.

(1420) ignoring suboption "*" ***(Driver)***

The suboption you have specified is not valid in this implementation and will be ignored.

```
--RUNTIME=default,+ramtest
```

oops -- what is `ramtest`?

(1421) the qualifier __xdata is not supported by this architecture ***(Parser)***

The qualifier you have specified is not valid in this implementation and will be ignored.

```
__xdata int coeff[2];  // that has no meaning for this target
```

(1422) the qualifier __ydata is not supported by this architecture ***(Parser)***

The qualifier you have specified is not valid in this implementation and will be ignored.

```
__ydata int coeff[2];  // that has no meaning for this target
```

(1423) case ranges are not supported ***(Driver)***

The use of GCC-style numerical ranges in case values does not conform to the CCI Standard. Use individual case labels and values to conform.

```
switch(input) {
case 0 ... 5:    // oops -- ranges of values are not supported
    low();
```

(1424) short long integer types are not supported ***(Parser)***

The use of the short long type does not conform to the CCI Standard. Use the corresponding `long` type instead.

```
short long typeMod;    // oops -- not a valid type for CCI
```

(1425) __pack qualifier only applies to structures and structure members ***(Parser)***

The qualifier you have specified only makes sense when used with structures or structure members. It will be ignored.

```
__pack int c;  // oops -- there aren't inter-member spaces to pack in
an int
```

(1426) 24-bit floating point types are not supported; * have been changed to 32-bits ***(Driver)***

Floating-point types must be 32-bits wide to conform to the CCI Standard. These types will be compiled as 32-bit wide quantities.

```
--DOUBLE=24
```

oops -- you cannot set this double size

(1427) machine-dependent path specified in name of included file; use -I instead ***(Preprocessor)***

To conform to the CCI Standard, header file specifications must not contain directory separators.

```
#inlcude <inc\lcd.h>    // oops -- do not indicate directories here
```

Remove the path information and use the -I option to indicate this, for example:

```
#include <lcd.h>
```

and issue the `-Ilcd` option.

(1429) attribute "*" is not understood by the compiler; this attribute will be ignored ***(Parser)***

The indicated attribute you have used is not valid with this implementation. It will be ignored.

```
int x __attribute__ ((deprecate)) = 0;
```

oops -- did you mean `deprecated`?

(1430) section redefined from "*" to "*" ***(Parser)***

You have attempted to place an object in more than one section.

```
int __section("foo") __section("bar") myvar;  // oops -- which section
should it be in?
```

(1431) the __section specifier is applicable only to variable and function definitions at file-scope ***(Parser)***

You cannot attempt to locate local objects using the `__section()` specifier.

```
int main(void) {
    int __section("myData") counter;  // oops -- you cannot specify a
section for autos
```

(1432) "*" is not a valid section name ***(Parser)***

The section name specified with __section() is not a valid section name. The section name must conform to normal C identifier rules.

```
    int __section("28data") counter;  // oops -- name cannot start
with digits
```

(1433) function "*" could not be inlined ***(Assembler)***

The specified function could not be made in-line. The function will called in the usual way.

```
int inline getData(int port)   // sorry -- no luck inlining this
{   //...
```

(1434) missing name after pragma "intrinsic" ***(Parser)***

The intrinsic pragma needs a function name. This pragma is not needed in most situations. If you mean to in-line a function, see the `inline` keyword or pragma.

```
#pragma intrinsic    // oops -- what function is intrinsically called?
```

© 2012-2018 Microchip Technology Inc.

(1435) variable "*" is incompatible with other objects in section "*" *(Code Generator)*

You cannot place variables that have differing startup initializations into the same psect. That is, variables that are cleared at startup and variables that are assigned an initial non-zero value must be in different psects. Similarly, `bit` objects cannot be mixed with byte objects, like `char` or `int`.

```
int __section("myData") input;   // okay
int __section("myData") output;  // okay
int __section("myData") lvl = 0x12;  // oops -- not with uninitialized
bit __section("myData") mode;    // oops again -- no bits with bytes
// each different object to their own new section
```

(1436) "*" is not a valid nibble; use hexadecimal digits only *(Parser)*

When using `__IDLOC()`, the argument must only consist of hexadecimal digits with no radix specifiers or other characters. Any character which is not a hexadecimal digit will be programmed as a 0 in the corresponding location.

```
__IDLOC(0x51);  // oops -- you cannot use the 0x radix modifier
```

(1437) CMF error * *(Cromwell, Linker)*

The CMF file being read by Cromwell or the linker is invalid. Unless you have modified or manually generated this file, this is an internal error. Contact Microchip Technical Support with details.

(1438) pragma "*" options ignored *(Parser)*

You have used unsupported options with a pragma. The options will be ignored.

```
#pragma inline=forced  // oops -- no options allowed with this pragma
```

(1439) message: * *(Parser)*

This is a programmer generated message; there is a pragma directive causing this advisory to be printed. This is only printed when using IAR C extensions.

```
#pragma message "this is a message from your programmer"
```

(1440) big-endian storage is not supported by this compiler *(Parser)*

You have specified the `__big_endian` IAR extension for a variable. The big-endian storage format is not supported by this compiler. Remove the specification and ensure that other code does not rely on this endianism.

```
__big_endian int  volume;  // oops -- this won't be big endian
```

(1441) use __at() instead of '@' and ensure the address is applicable *(Parser)*

You have used the `@ address` specifier when using the IAR C extensions. Any address specified is unlikely to be correct on a new architecture. Review the address in conjunction with your device data sheet. To prevent this warning from appearing again, use the reviewed address with the `__at()` specifier instead.

(1442) type used in definition is incomplete ***(Parser)***

When defining objects, the type must be complete. If you attempt to define an object using an incomplete type, this message is issued.

```
typedef struct foo foo_t;
foo_t x;   // oops -- you cannot use foo_t until it is fully defined

struct foo {
  int i;
};
```

(1443) unknown --EXT sub-option "*" ***(Driver)***

The suboption to the `--EXT` option is not valid.

```
xc8 --chip=18f8585 x.c --ext=arm --ext=cci
```

Oops -- valid choices are `iar`, `cci` and `xc8`

(1444) respecified C extension from "*" to "*" ***(Driver)***

The `--EXT` option has been used more than once, with conflicting arguments. The last use of the option will dictate the C extensions accepted by the compiler.

```
xc8 --chip=18f8585 x.c --ext=iar --ext=cci
```

Oops -- which C extension do you mean?

(1445) #advisory: * ***(Preprocessor)***

This is a programmer generated message; there is a directive causing this advisory to be printed.

```
#advisory "please listen to this good advice"
```

(1446) #info: * ***(Preprocessor)***

This is a programmer generated message; there is a directive causing this advisory to be printed. It is identical to `#advisory` messages (1445).

```
#info "the following is for your information only"
```

(1447) extra -L option (-L*) ignored ***(Preprocessor)***

This error relates to a duplicate `-L` option being passed to the preprocessor. Unless you are explicitly running this application, consider this an internal error. Contact Microchip Technical Support with details.

(1448) no dependency file type specified with -L option ***(Preprocessor)***

This error relates to a malformed `-L` option being passed to the preprocessor. Unless you are explicitly running this application, consider this an internal error. Contact Microchip Technical Support with details.

(1449) unknown dependency file type (*) ***(Preprocessor)***

This error relates to a unknown dependency file format being passed to the preprocessor. Unless you are explicitly running this application, consider this an internal error. Contact Microchip Technical Support with details.

© 2012-2018 Microchip Technology Inc.

(1450) invalid --*-spaces argument (*) ***(Cromwell)***

The option passed to Cromwell does not relate to a valid memory space. The space arguments must be a valid number that represents the space.

```
--data-spaces=a
```

Oops — a is not a valid data space number.

(1451) no * spaces have been defined ***(Cromwell)***

Cromwell must be passed information that indicates the type for each numbered memory space. This is down via the `--code-spaces` and `--data-spaces` options. Unless you are explicitly running this application, consider this an internal error. Contact Microchip Technical Support with details.

(1452) one or more spaces are defined as data and code ***(Cromwell)***

The options passed to Cromwell indicate memory space is both in the code and data space. Unless you are explicitly running this application, consider this an internal error. Contact Microchip Technical Support with details.

```
--code-space=1,2  --data-space=1
```

Oops — is space 1 code or data?

(1453) stack size specified for non-existent * interrupt ***(Driver)***

The `--STACK` option has been used to specify the maximum sizes for each stack. A size has been used for each interrupt, but the compiler cannot see the corresponding interrupt function definition, which means the stack space can never be used. Ensure that you create the interrupt function for each interrupt the device supports.

```
--STACK=reentrant:20:20:auto
```

Oops, you have asked for two interrupt stacks, but the compiler cannot see both interrupt function definitions.

(1454) stack size specified (*) is greater than available (*) ***(Driver)***

The `--STACK` option has been used to specify the maximum sizes for each stack, but the total amount of memory requested exceeds the amount of memory available.

```
--STACK=software:1000:1000:20000
```

Oops, that is too much stack space for a small device.

(1455) unrecognized stack size "*" in "*" ***(Driver)***

The `--STACK` option has been used to specify the maximum sizes for each stack, but one or more of the sizes are not a valid value. Use only decimal values in this option, or the token `auto`, for a default size.

```
--STACK=software:30:all:default
```

Oops, only use decimal numbers or `auto`.

(1456) too many stack size specifiers **(*Driver*)**

Too many software stack maximum sizes have been specified in the `--STACK` option. The maximum stack sizes are optional. If used, specify one size for each interrupt and one for main-line code.

```
--STACK=reentrant:20:20:auto
```

Oops, too many sizes for a device with only one interrupt.

(1457) local variable "*" cannot be made absolute **(*Code Generator*)**

You cannot specify the address of any local variable, whether it be an auto, parameter, or static local object.

```
int pushState(int a) {
int cnt __at(0x100); // oops -- you cannot specify an address ...
```

(1458) Omniscient Code Generation not available in Standard mode **(*Driver*)**

This message warns you that not all optimizations are enabled in the Standard operating mode.

(1459) peripheral library support is missing for the * **(*Driver*)**

The peripheral libraries do not have code present for the device you have selected. Disable the option that links in the peripheral library.

(1460) function-level profiling is not available for the selected chip **(*Driver*)**

Function profiling is only available for PIC18 or enhanced mid-range devices. If you are not using such a device, do not attempt to use function profiling.

(1461) insufficient h/w stack to profile function "*" **(*Code Generator*)**

Function profiling requires a level of hardware stack. The entire stack has been used by this program so not all functions can be profiled. The indicated function will not have profiling code embedded into it, and it will not contribute to the profiling information displayed by MPLAB X IDE.

(1462) reentrant data stack model option conflicts with stack management option and will be ignored **(*Code Generator*)**

The managed stack option allows conversion of function calls that would exceed the hardware stack depth to calls that will use a lookup table. This option cannot be enabled if the reentrant function model is also enabled. If you attempt to use both the managed stack and reentrant function model options, this message will be generated. Code will be compiled with the stack management option disabled. Either disable the reentrant function model or the managed stack option.

(1463) reentrant data stack model not supported on this device; using compiled stack for data **(*Code Generator*)**

The target device does not support reentrant functions. The program will be compiled so that stack-based data is placed on a compiled stack.

(1464) number of arguments passed to function "*" does not match function's prototype **(*Code Generator*)**

A function was called with arguments, but the definition of the function had an empty parameter list (as opposed to a parameter list of `void`).

```
int test();    // oops--this should define the parameters
...
test(12, input);
```

© 2012-2018 Microchip Technology Inc.

(1465) the stack frame size for function "*" (* bytes) has exceeded the maximum allowable (* bytes) **(*Code Generator*)**

The compiler has been able to determine that the software stack requirements for the named function's auto, parameter, and temporary variables exceed the maximum allowable. The limits are 31 for enhanced mid-range devices and 127 for PIC18 devices. Reduce the size or number of these variables. Consider static local objects instead of auto objects.

```
reentrant int addOffset(int offset) {
int report[400];    // oops--this will never fit on the software stack
```

(1466) registers * unavailable for code generation of this expression **(*Code Generator*)**

The compiler has been unable to generate code for this statement. This is essentially a "can't generate code" error message (message 712), but the reason for this inability to compile relates to there not being enough registers available. See message 712 for suggested workarounds.

(1467) pointer used for writes includes read-only target "*" **(*Code Generator*)**

A pointer to a non-`const` qualified type is being used to write a value, but the compiler knows that this pointer has targets (the first of which is indicated) that have been qualified `const`. This could lead to code failure or other error messages being generated.

```
void keepTotal(char * cp) {
    *cp += total;
}
char c;
const char name[] = "blender";
keepTotal(&c);
keepTotal(&name[2]);  // oops--will write a read-only object
```

(1468) unknown ELF/DWARF specification (*) in --output option **(*Driver*)**

The ELF suboption uses flags that are unknown.

```
–output=elf:3
```

Oops, there is no `elf` flag of 3.

This ELF suboption and its flags are usually issued by the MPLAB X IDE plugin. Contact Microchip Technical Support with details of the compiler and IDE if this error is issued.

(1469) function specifier "reentrant/software" used with "*" ignored **(*Code Generator*)**

The `reentrant` (or `software`) specifier was used with a function (indicated) that cannot be encoded to use the software stack. The specifier will be ignored and the function will use the compiled stack.

```
reentrant int main(void)   // oops--main cannot be reentrant
...
```

(1470) trigraph sequence "??*" replaced ***(Preprocessor)***

The preprocessor has replaced a trigraph sequence in the source code. Ensure you intended to use a trigraph sequence.

```
char label[] = “What??!”;  // you do know that’s a trigraph
                           // sequence, right?
```

(1471) indirect function call via a NULL pointer ignored *(Code Generator)*

The compiler has detected a function pointer with no valid target other than NULL. That pointer has been used to call a function. The call will not be made.

```
int (*fp)(int, int);
result = fp(8,10);  // oops--this pointer has not been initialized
```

(1472) --CODEOFFSET option ignored: * *(Driver)*

The compiler is ignoring an invocation of the `--CODEOFFSET` option. The printed description will indicate whether the option is being ignored because the compiler has seen this option previously or the compilation mode does not support its use.

(1474) read-only target "*" may be indirectly written via pointer *(Code Generator)*

This is the same as message 1467, but for situations where an error is required. The compiler has encountered a pointer that is used to write, and one or more of the pointer's targets are read-only.

```
const char c = ‘x’;
char * cp = &c; // will produce warning 359 about address assignment
*cp = 0x44;     // oops--you ignored the warning above, now you are
                // actually going to write using the pointer?
```

(1478) initial value for "*" differs to that in *:* *(Code Generator)*

The named object has been defined more than once and its initial values do not agree. Remember that uninitialized objects of static storage duration are implicitly initialized with the value zero (for all object elements or members, where appropriate).

```
char myArray[5] = { 0 };
// elsewhere
char myArray[5] = {0,2,4,6,8};  // oops--previously initialized
                               // with zeros, now with different values
```

(1479) EEPROM data not supported by this device *(Parser)*

The `eeprom` qualifier was used but there is no EEPROM on the target device. Any instances of this qualifier will be ignored.

```
eeprom int serialNo;      // oops--no EEPROM on this device
```

(1480) initial value(s) not supplied in braces; zero assumed *(Code Generator)*

The assignment operator was used to indicate that the object was to be initialized, but no values were found in the braces. The object will be initialized with the value(s) 0.

```
int xy_map[3][3] = { };   // oops--did you mean to supply values?
```

(1481) call from non-reentrant function, "*", to "*" might corrupt parameters *(Code Generator)*

If several functions can be called indirectly by the same function pointer, they are called ‘buddy’ functions, and the parameters to buddy functions are aligned in memory. This allows the parameters to be loaded without knowing exactly which function was called by the pointer (as is often the case). However, this means that the buddy functions cannot directly or indirectly call each other.

```
// fpa can call any of these, so they are all buddies
int (*fpa[])(int) = { one, two, three };
int one(int x) {
    return three(x+1);  // oops--one() cannot call buddy three()
}
```

© 2012-2018 Microchip Technology Inc.

(1482) absolute object * overlaps * ***(Linker)***

The reservation for an absolute object has been found to overlap with the memory reserved by another absolute object.

```
unsigned char nfo[6] @ 0x80;
unsigned char nfo2[6] @ 0x7b;  //oops--this overlaps nfo
```

(1483) __pack qualifier ignored ***(Parser)***

The __pack qualifier has no affect on auto or static local structures and has been ignored.

```
int setInput(void) {
    __pack struct {       //oops--this will not be packed
        unsigned x, y;
    } inputData;
```

(1484) the branch errata option is turned on and a BRW instruction was detected ***(Assembler)***

The use of this instruction may cause code failure with the selected device. Check the published errata for your device to see if this restriction is applicable for your device revision. If so, remove this instruction from hand-written assembly code.

```
btfsc status,2
brw  next      ;oops--this instruction cannot be safely used
call  update
```

(1485) * mode is not available with the current license and other modes are not permitted by the NOFALLBACK option ***(Driver)***

This compiler’s license does not allow the requested compiler operating mode. Since the `--NOFALLBACK` option is enabled, the compiler has produced this error and will not fall back to a lower operating mode. If you believe that you are entitled to use the compiler in the requested mode, this error indicates that your compiler might not be activated correctly.

(1486) size of pointer cannot be determined during preprocessing. Using default size * **(*Preprocessor*)**

The preprocessor cannot determine the size of pointer type. Do not use the `sizeof` operator in expressions that need to be evaluated by the preprocessor.

```
#if sizeof(int *) == 3   // oops - you can't take the size of a
pointer type
#define MAX 40
#endif
```

(1488) the stack frame size for function "*" may have exceeded the maximum allowable (* bytes) **(*Code Generator*)**

This message is emitted in the situation where the indicated function's software-stack data has exceeded the theoretical maximum allowable size. Data outside this stack space will only be accessible by some instructions that could attempt to access it. In some situations the excess data can be retrieved, your code will work as expected, and you can ignore this warning. This is likely if the function calls a reentrant function that returns a large object, like a structure, on the stack. At other times, instructions that are unable to access this data will, in addition to this warning, trigger an error message at the assembly stage of the build process, and you will need to look at reducing the amount of stack data defined by the function.

(1489) unterminated IF directive at end of psect * (*Assembler*)

The assembler has reached the end of the named psect and not seen the terminating ENDIF directive associated with the last IF or ELSIF directive previously encountered.

```
psect mytext,class=CODE,reloc=2
  movlw 20h
IF TEST_ONLY
  movlw 00h
  movwf _mode,c  ; oops--where does the IF end?
psect nexttext,class=CODE,reloc=2
```

(1490) ENDIF not inside an IF directive (*Assembler*)

The assembler has encountered an ENDIF directive that does not have any corresponding IF or ELSIF directive.

```
psect mytext,class=CODE,reloc=2
  movlw 20h
IF TEST_ONLY
  movlw 00h
ENDIF
ENDIF; oops--what does this terminate?
```

(1491) runtime sub-option "*" is not available for this device (*Driver*)

A specified suboption to the --RUNTIME option is not available for the selected device.

```
xc8 --CHIP=MCP19114 --RUNTIME=+osccal main.c
```

Oops, the osccal suboption is not available for this device.

(1492) using updated 32-bit floating-point libraries; improved accuracy might increase code size (*Code Generator*)

This advisory message ensures you are aware of the changes in 32-bit floating-point library code operation that might lead to an increase in code size.

(1493) updated 32-bit floating-point routines might trigger "can't find space" messages appearing after updating to this release; consider using the smaller 24-bit floating-point types (*Linker*)

This advisory message ensures you are aware of the changes in 32-bit floating-point library code operation which might lead to the Can't Find Space error message that has been issued.

(1494) invalid argument to normalize32 (*Assembler*)

The NORMALIZE32 operator has been used on an operand that is not a literal constant.

```
NORMALIZE(_foobar)  ; oops--that must be a literal constant operand
```

(1495) ADDFSR/SUBFSR instruction argument must be 0-3 (*Assembler*)

The operand to this instruction must be a literal constant and in the range 0 to 3, inclusive.

```
addfsr 1, 6  ; oops--the offset must be between 0 to 3
```

© 2012-2018 Microchip Technology Inc.

(1496) arithmetic on pointer to void yields Undefined Behavior (*Code Generator*)

Performing operations on pointers requires the size of the pointed-to object, which is not known in the case of generic (`void *`) pointers.

```
void * vp;

vp++;   // oops—how can this be incremented without knowing what it
points to?
```

(1497) more than one *interrupt function defined (*Code Generator*)

Only one interrupt function of the same priority can be defined.

```
void interrupt lo_isr(void) {  // oops — was this meant to be a
low_priority interrupt?
  …
}

void interrupt hi_isr(void) {
  …
}
```

(1498) pointer (*) in expression may have no targets (*Code Generator*)

A pointer that contains NULL has been dereferenced. Assign the pointer a valid address before doing so.

```
char * cp, c;

c = *cp;// oops —what is cp pointing to?
```

(1499) only decimal floating-point constants can be suffixed "f" or “F”

The floating-point constant suffix has been used with an integer value.

```
float myFloat = 100f*3.2;  // oops — is ‘100f’ mean to be a hex or
floating-point value?
```

MESSAGES 1500-1749

(1500) invalid token in #if expression (*Preprocessor*)

There is a malformed preprocessor expression.

```
#define LABEL
#define TEST 0

#if (LABEL == TEST) // oops--LABEL has no replacement text
```

(1504) the PIC18 extended instruction set was enabled but is not supported by this compiler (*Parser*)

The MPLAB XC8 compiler does not support generation of code using the PIC18 extended instruction set. The extended instruction set configuration bit must always be disabled.

```
#pragma config XINST=ON  // oops--this must be disabled at all times
```

(1505) interrupts not supported by this device (*Code Generator*)

You have attempted to define an interrupt function for a device that does not support interrupts.

```
void interrupt myIsr(void)  // oops--nothing will trigger this
{ ... }
```

(1506) multiple interrupt functions (* and *) defined at interrupt level * (*Code Generator*)

More than one interrupt function has been defined for the same priority.

```
void interrupt low_priority
isr(void)
{ ... }

void interrupt low_priority// oops--you can have two ISRs
loisr(void)  // with the same priority
{ ... }
```

(1507) asmopt state popped when there was no pushed state (*Assembler*)

The state of the assembler optimizers was popped in assembly code but there was no corresponding push.

```
movlw  20h
movwf  LATB
opt asmopt_pop; oops--there was never a state pushed
```

(1508) specifier "__ram" ignored (*Parser*)

This pointer-target specifier cannot be used with an ordinary variable, and it will be ignored. Confirm that this definition was not meant to indicate a pointer type.

```
__ram int ip;   // oops -- was this meant to be a pointer?
```

(1509) specifier "__rom" ignored (*Parser*)

This pointer-target specifier cannot be used with an ordinary variable, and it will be ignored. Confirm that this definition was not meant to indicate a pointer type.

```
const __rom int cip;   // oops -- was this meant to be a pointer?
```

© 2012-2018 Microchip Technology Inc.

(1510) non-reentrant function "*" appears in multiple call graphs and has been duplicated by the compiler (*Code Generator*)

This message indicates that the generated output for a function has been duplicated since it has been called from both main-line and interrupt code. It does not indicate a potential code failure. If you do not want function output duplicated, consider using the hybrid stack model, if possible, or restructure your source code.

(1511) stable/invariant mode optimizations no longer implemented; option will be ignored (*Driver*)

This option is no longer available and has been ignored.

(1512) stable/invariant mode optimizations no longer implemented; specifier will be ignored (*Code Generator*)

This specifier is no longer available and has been ignored.

(1513) target "*" of pointer "*" not in the memory space specified by * (*Code Generator*)

The pointer assigned an address by this statement was defined using a pointer-target specifier. This assignment might be assigning addresses to the pointer that conflict with that memory space specifier.

```
__rom int * ip;
int foobar;
ip = &foobar;  // oops -- foobar is in data memory, not program memory
```

(1514) "__ram" and "__rom" specifiers are mutually exclusive (*Parser*)

Use of both the `__ram` and `__rom` pointer-target specifiers with the same pointer does not make sense. If a pointer should be able to represent targets in any memory space, do not use either of these specifiers.

```
// oops -- you can’t limit ip to only point to objects in ram and
// also only point to objects in rom
__ram __rom int * ip;
```

(1515) disabling OCG optimizations for this device is not permitted (*Driver*)

Due to memory limits, projects targeting some devices cannot be built. Ensure that the OCG category of optimization is enabled.

(1516) compiler does not support 64-bit integers on the target architecture

Due to memory restrictions, the current device cannot support 64-bit integers, and a smaller integer will be used instead. Choose a type smaller than `long long` to suppress this warning.

```
long long int result;  // oops - this will not be 64-bits wide
```

(1517) peripheral library support only available for C90 (*Driver*)

The legacy peripheral library was build for the C90 standard and cannot reliably be used for other C standards.

(1518) * function call made with an incomplete prototype (*) **(*Code Generator*)**

A function has been called with the compiler not having seen a complete prototype for that function. Check for an empty parameter list in the declaration.

```
void foo();  // oops -- how will this call be encoded?
void main(void)
{
    foo();
}
```

© 2012-2018 Microchip Technology Inc.

MESSAGES 2000-2249

(2000) * attribute/specifier has a misplaced keyword (*) **(*Parser*)**

An attribute token has been used in a context where it was not expected.

```
// oops -- 'base' is a token which has specific meaning
void __interrupt(irq(base)) isr(void)
```

(2001) * attribute/specifier has a misplaced parenthesis **(*Parser*)**

The parentheses used in this attribute construct are not correctly formed. Check to ensure that you do not have extra brackets and that they are in the correct position.

```
void __interrupt(irq((TMR0)) isr(void) // oops -- one too many '('s
```

(2002) __interrupt attribute/specifier has conflicting priority-levels **(*Parser*)**

More than one priority has been assigned to an interrupt function definition.

```
//oops -- is it meant to be low or high priority?
void __interrupt(irq(TMR0), high_priority, low_priority) tc0Int(void)
```

(2003) * attribute/specifier has a duplicate keyword (*) **(*Parser*)**

The same token has been used more than once in this attribute. Check to ensure that one of these was not meant to be something else.

```
//oops -- using high_priority twice has no special meaning
void __interrupt(irq(TMR0), high_priority, high_priority) tc0Int(void)
```

(2004) __interrupt attribute/specifier has an empty "irq" list **(*Parser*)**

The `irq()` argument to the `__interrupt()` specifier takes a comma-separated list of interrupt vector numbers or symbols. At least one value or symbol must be present to link this function to the interrupt source.

```
//oops -- irq() does not indicate the interrupt source
void __interrupt(irq(),high_priority) tc0Int(void)
```

(2005) __interrupt attribute/specifier has an empty "base" list **(*Parser*)**

The `base()` argument to the `__interrupt()` specifier is optional, but when used it must take a comma-separated list of interrupt vector table addresses. At least one address must be present to position the vector table. If you do not specify the base address with an ISR, its vector will be located in an interrupt vector table located at an address equal to the reset value of the IVTBASE register.

```
//oops -- base() was used but did not indicate a vector table address
void __interrupt(irq(TMR0), base()) tc0Int(void)
```

(2006) __interrupt attribute/specifier has a duplicate "irq" (*) **(*Parser*)**

An `irq()` argument to the `__interrupt()` specifier has been used more than once.

```
//oops -- is one of those sources wrong?
void __interrupt(irq(TMR0,TMR0)) tc0Int(void)
```

(2007) __interrupt attribute/specifier has a duplicate "base" (*) **(*Parser*)**

The same `base()` argument to the `__interrupt()` specifier has been used more than once.

```
//oops -- is one of those base addresses wrong?
void __interrupt(irq(TMR0), base(0x100,0x100)) tc0Int(void)
```

(2008) unknown "irq" (*) in __interrupt attribute/specifier **(*Parser*)**

The interrupt symbol or number used with the irq() argument to the __interrupt() specifier does not correspond with an interrupt source on this device.

```
//oops -- what interrupt source is TODO?
void __interrupt(irq(TODO),high_priority) tc0Int(void)
```

(2009) * attribute/specifier has a misplaced number (*) **(*Parser*)**

A numerical value appears in an attribute where it is not expected.

```
//oops -- this specifier requires specific argument, not a number
void __interrupt(0) isr(void)
```

(2010) __interrupt attribute/specifier contains a misplaced interrupt source name (*) **(*Parser*)**

An interrupt source name can only be used as an argument to `irq()`.

```
//oops -- base() needs a vector table address
void __interrupt(irq(TMR0), base(TMR0)) tc0Int(void)
```

(2011) __interrupt attribute/specifier has a base (*) not supported by this device **(*Parser*)**

The address specified with the `base()` argument to the `__interrupt()` specifier is not valid for the target device. It cannot, for example, be lower than the reset value of the IVTBASE register.

```
//oops -- the base() address is too low
void __interrupt(irq(TMR0), base(0x00)) tc0Int(void)
```

(2012) * attribute/specifier is only applicable to functions **(*Parser*)**

The __interrupt() specifier has been used with something that is not a function.

```
// oops -- foobar is an int, not an ISR
__interrupt(irq(TMR0)) int foobar;
```

(2013) argument "*" used by "*" attribute/specifier not supported by this device **(*Parser*)**

The argument of the indicated specifier is not valid for the target device.

```
// oops -- base() can't be used with a device that does not
// support vectored interrupts
void __interrupt(base(0x100)) myMidrangeISR(void)
```

(2014) interrupt vector table @ 0x* already has a default ISR "*" **(*Code Generator*)**

You can indicate only one default interrupt function for any vector location not specified in a vector table. If you have specified this twice, check to make sure that you have specified the correct base() address for each default.

```
void __interrupt(irq(default), base(0x100)) tc0Int(void) { ...
void __interrupt(irq(default), base(0x100)) tc1Int(void) { ...
// oops -- did you mean to use different different base() addresses?
```

(2015) interrupt vector table @ 0x* already has an ISR (*) to service IRQ * (*) **(*Parser* or *Code Generator*)**

You have specified more than one interrupt function to handle a particular interrupt source in the same vector table.

```
void __interrupt(irq(TMR0), base(0x100)) tc0Int(void) { ...
void __interrupt(irq(TMR0), base(0x100)) tc1Int(void) { ...
```

© 2012-2018 Microchip Technology Inc.

```
// oops -- did you mean to use different different base() addresses?
```

(2016) interrupt function "*" does not service any interrupt sources (*Code Generator*)

You have defined an interrupt function but did not indicate which interrupt source this function should service. Use the `irq()` argument to indicate the source or sources.

```
//oops -- what interrupt does this service?
void __interrupt(low_priority, base(0x100)) tc0Int(void)
```

(2017) config programming has disabled multi-vectors, "irq" in __interrupt attribute/specifier is ignored (*Code Generator*)

An interrupt function has used the `irq()` argument to specify an interrupt source, but the vector table has been disabled via the configuration bits. Either re-enable vectored interrupts or use the priority keyword in the `__interrupt()` specifier to indicate the interrupt source.

```
#pragma config MVECEN=0
void __interrupt(irq(TMR0), base(0x100)) tc0Int(void)
// oops -- you cannot disable the vector table then allocate interrupt
// functions a vector source using irq()
```

(2018) interrupt vector table @ 0x* has multiple functions (* and *) defined at interrupt level * (*Code Generator*)

The program for a device operating in legacy mode has specified a vector table that contains more than one function at the same interrupt priority-level in the same table. In this mode, there can be at most one interrupt function for each priority level in each vector table.

```
#pragma config MVECEN=0
void __interrupt(high_priority) tc0Int(void) {...
void __interrupt(high_priority) tc1Int(void) {...
```

(2019) * interrupt vector in table @ 0x* is unassigned, will be programmed with a * (*Code Generator*)

In a program for a device operating in legacy mode, an interrupt vector in the indicated vector table has not been programmed with an address. The compiler will program this vector with an address as specified by the `--UNDEFINTS` option.

(2020) IRQ * (*) in vector table @ 0x* is unassigned, will be programmed with the address of a * (*Code Generator*)

The interrupt vector in the indicated vector table has not been programmed with an address. The compiler will program this vector with an address as specified by the `--UNDEFINTS` option.

(2021) invalid runtime "*" sub-option argument (*) (*Driver*)

The argument to a sub-option specified with the `--RUNTIME` option is not valid.

```
--RUNTIME=default,+ivt:reset
```

Oops, the `ivt` suboption requires a numeric address as its argument.

(2022) runtime sub-option "ivt" specifies a base address (0x*) not supported by this device (*Driver*)

The address specified with the `ivt` sub-option is not valid for the selected target device. It cannot, for example, be lower than the reset value of the IVTBASE register.

(2023) IVT @ 0x* will be selected at startup **(*Code Generator*)**

The source code defines more than one IVT and no address was specified with the `ivt` sub-option to the `--RUNTIME` option to indicate which table should be selected at startup. The IVT with the lowest address will be selected by the compiler. It is recommended that you always specify the table address when using this option.

(2024) runtime sub-option "ivt" specifies an interrupt table (@ 0x*) that has not been defined **(*Driver*)**

The `ivt` sub-option to the `--RUNTIME` option was used to specify a IVT address, but this address has not been specified in the source code with any ISR. Check that the address in the option is correct, or check that the `base()` arguments to the `__interrupt()` specifier are specified and are correct.

```
--RUNTIME=+ivt:0x100
```

Oops -- is this the right address? Nothing in the source code uses this base address.

(2025) qualifier * on local variable "*" is not allowed and has been ignored **(*Parser*)**

Some qualifiers are not permitted with `auto` or local `static` variables. This message indicates that the indicated qualifier has been ignored with the named variable.

```
near int foobar; // oops -- auto variables cannot use near
```

(2026) variables qualified "*" are not supported for this device **(*Parser*)**

Some variable qualifiers are not permitted with some devices.

```
eeprom int serialNo; // oops -- can't use eeprom with PIC18 devices
```

(2027) initialization of absolute variable "*" in * is not supported **(*Code Generator*)**

The variable indicated cannot be specified as absolute in the memory space.

```
eeprom char foobar @ 0x40 = 99; // oops - absolute can't be eeprom
```

(2028) external declaration for identifier "*" doesn't indicate storage location **(*Code Generator*)**

The declaration for an external object (e.g., one defined in assembly code) has no storage specifiers to indicate the memory space in which it might reside. Code produced by the compiler which accesses it might fail. Use `const` or a bank specifier as required.

```
extern int tapCounter;  // oops - how does the compiler access this?
```

(2029) a function pointer cannot be used to hold the address of data **(*Parser*)**

A function pointer must only hold the addresses of function, not variables or objects.

```
int (*fp)(int);
int foobar;
fp = &foobar;  // oops - a variable's address cannot be assigned
```

(2030) a data pointer cannot be used to hold the address of a function **(*Parser*)**

A data pointer (even a generic `void *` pointer) cannot be used to hold the address of a function.

```
void *gp;
int myFunc(int);
gp = foobar;  // oops - a function's address cannot be assigned
```

© 2012-2018 Microchip Technology Inc.

(2033) recursively called function might clobber a static register it has allocated in expression (*Code Generator*)

The compiler has encountered a situation where a register is used by an expression that is defined in a function that is called recursively, and that expression is part of a larger expression that requires this same function to be called. The register might be overwritten and the code may fail.

```
unsigned long fib_rec(unsigned long n)
{
    // the temporary result of the LHS call to fib_rec() might
    // store the result in a temp that is clobbered during the RHS
    // call to the same function
    return ((n > 1) ? (fib_rec(n-1) + fib_rec(n-2)) : n);
}
```

(2034) 24-bit floating-point types are not CCI compliant; use 32-bit setting for compliance (*Parser*)

The CCI does not permit the use of 24-bit floating point types. If you require compliance, use the `-no-short-float` and `-no-short-double` options, which will ensure the IEEE standard 32-bit floating-point type is used for `float` and `double` types.

(2035) use of sizeof() in preprocessor expressions is deprecated; use __SIZEOF_*__ macro to avoid this warning (*Preprocessor*)

The use of `sizeof()` in expressions that must be evaluated by the preprocess are no longer supported. Preprocessor macros defined by the compiler, such as `__SIZEOF_INT__`, can be used instead. This does not affect the C operator `sizeof()` which can be used in the usual way.

```
#if (sizeof(int) > 2)   // oops -- use (__SIZEOF_INT__ > 2) instead
```

(2036) use of @ is not compliant with CCI, use __at() instead (*Parser*)

The CCI does not permit the definition of absolute functions and objects that use the `@` *`address`* construct. Instead, place `__at(`*`address`*`)` after the identifier in the definition.

```
int foobar @ 0x100;  // oops -- use __at(0x100) instead
```

(2037) short long integer types are not compliant with CCI (*Parser*)

The CCI does not permit use of the 3-byte `short long` type. Instead consider an equivalent `long int` type.

```
short long input;  // oops -- consider input to be long when using CCI
```

(2038) use of short long integer types is deprecated; use __int24 or __uint24 to avoid this warning (*Parser*)

The `short long` type specifiers has been replaced with the more portable `__int24` (replacing *`short long`*) and `__uint24` (replacing `unsigned short long`) types.

```
short long input; // oops -- use __int24 as the type for input
```

(2039) __int24 integer type is not compliant with CCI (*Parser*)

The CCI does not permit use of the 3-byte `__int24` type. Instead the `long int` type.

```
__int24 input;  // oops -- use a long type when using CCI
```

(2040) __uint24 integer type is not compliant with CCI **(*Parser*)**

The CCI does not permit use of the 3-byte `__uint24` type. Instead `unsigned long int` type.

```
__uint24 input;  // oops -- use an unsigned long type when using CCI
```

(2041) missing argument after "*" **(*Driver*)**

The specified option requires an argument, but none was detected on the command line.

```
xc8-cc -mcpu=18f4520 -Wl,-Map main.c
```

Oops, the `-Map` option requires a map filename, e.g. `-Wl,-Map=proj.map`.

(2042) no target device specified; use the -mcpu option to specify a target device ***(Driver)***

The driver was invoked without selecting what chip to build for. Running the driver with the `-mprint-devices` option will display a list of all chips that could be selected to build for.

```
xc8 -cc main.c
```

Oops, use the `-mcpu` option to specify the device to build for.

(2043) target device was not recognized **(*Driver*)**

The top-level driver was not able to identify the family of device specified with the `-mcpu` option.

```
xc8-cc -mcpu=pic io.c
```

Oops, the device name must be exactly one of those shown by `-mprint-devices`.

(2044) unrecognized option "*" **(*Driver*)**

The option specified was not recognized by the top-level driver. The option in question will be passed further down the compiler tool chain, but this may cause errors or unexpected behavior.

(2045) could not find executable "*" **(*Driver*)**

The top-level driver was unable to locate the specified compiler tool in the usual locations. Ensure you have not moved files or directories inside the compiler install directory.

(2046) identifier length must be between * and *; using default length * **(*Driver*)**

The number of characters specified as the largest significant identifier length is illegal and the default length of 255 has been used.

```
-N=16
```

Oops, the identifier length must be between 32 and 255.

© 2012-2018 Microchip Technology Inc.

Appendix C. Implementation-Defined Behavior

C.1 INTRODUCTION

This chapter indicates the compiler's choice of behavior where that behavior is implementation defined.

Items discussed in this chapter are:

- Overview
- Translation
- Environment
- Identifiers
- Characters
- Integers
- Floating-Point
- Arrays and Pointers
- Hints
- Structures, Unions, Enumerations, and Bit Fields
- Qualifiers
- Library Functions
- Architecture

C.2 OVERVIEW

ISO C requires a conforming implementation to document the choices for behaviors defined in the standard as "implementation-defined." The following sections list all such areas, the choices made for the compiler, and the corresponding section number from the ISO/IEC 9899:1999 (aka C99) standard (or ISO/IEC 9899:1990 (aka C90)).

C.3 TRANSLATION

ISO Standard:	"How a diagnostic is identified (3.10, 5.1.1.3)."
Implementation:	By default, when compiling on the command-line the following formats are used. The string `(warning)` is only displayed for warning messages. *`filename`*: *`function`*() *`linenumber`*:*`source line`* ^ (*`ID`*) *`message`* `(warning)` or *`filename`*: *`linenumber`*: (*`ID`*) *`message`* `(warning)` where *`filename`* is the name of the file that contains the code (or empty if no particular file is relevant); *`linenumber`* is the line number of the code (or 0 if no line number is relevant); *`ID`* is a unique number that identifies the message; and *`message`* is the diagnostic message itself.
ISO Standard:	"Whether each nonempty sequence of white-space characters other than new-line is retained or replaced by one space character in translation phase 3 (5.1.1.2)."
Implementation:	Clang will replace each leading or interleaved whitespace character sequences with a space. A trailing sequence of whitespace characters is replaced with a new-line.

C.4 ENVIRONMENT

ISO Standard:	"The mapping between physical source file multibyte characters and the source character set in translation phase 1 (5.1.1.2)."
Implementation:	Multi-byte characters are not supported in source files.
ISO Standard:	"The name and type of the function called at program start-up in a freestanding environment (5.1.2.1)."
Implementation:	`int main (void);`
ISO Standard:	"The effect of program termination in a freestanding environment (5.1.2.1)."
Implementation:	A soft reset implemented by a branch to the reset vector location.
ISO Standard:	"An alternative manner in which the `main` function may be defined (5.1.2.2.1)."
Implementation:	`void main (void);`
ISO Standard:	"The values given to the strings pointed to by the `argv` argument to `main` (5.1.2.2.1)."
Implementation:	No arguments are passed to `main`. Reference to `argc` or `argv` is undefined.
ISO Standard:	"What constitutes an interactive device (5.1.2.3)."
Implementation:	Application defined.
ISO Standard:	"The set of signals, their semantics, and their default handling (7.14)."
Implementation:	Signals are not implemented.
ISO Standard:	"Signal values other than `SIGFPE`, `SIGILL`, and `SIGSEGV` that correspond to a computational exception (7.14.1.1)."
Implementation:	Signals are not implemented.
ISO Standard:	"Signals for which the equivalent of `signal(`*`sig, SIG_IGN`*`);` is executed at program start-up (7.14.1.1)."
Implementation:	Signals are not implemented.
ISO Standard:	"The set of environment names and the method for altering the environment list used by the `getenv` function (7.20.4.5)."
Implementation:	The host environment is application defined.
ISO Standard:	"The manner of execution of the string by the `system` function (7.20.4.6)."
Implementation:	The host environment is application defined.

C.5 IDENTIFIERS

ISO Standard:	"Which additional multibyte characters may appear in identifiers and their correspondence to universal character names (6.4.2)."
Implementation:	None.
ISO Standard:	"The number of significant initial characters in an identifier (5.2.4.1, 6.4.2)."
Implementation:	All characters are significant.

C.6 CHARACTERS

ISO Standard:	"The number of bits in a byte (C90 3.4, C99 3.6)."
Implementation:	8.
ISO Standard:	"The values of the members of the execution character set (C90 and C99 5.2.1)."
Implementation:	The execution character set is ASCII.
ISO Standard:	"The unique value of the member of the execution character set produced for each of the standard alphabetic escape sequences (C90 and C99 5.2.2)."
Implementation:	The execution character set is ASCII.
ISO Standard:	"The value of a `char` object into which has been stored any character other than a member of the basic execution character set (C90 6.1.2.5, C99 6.2.5)."
Implementation:	The value of the `char` object is the 8-bit binary representation of the character in the source character set. That is, no translation is done.
ISO Standard:	"Which of `signed char` or `unsigned char` has the same range, representation, and behavior as "plain" char (C90 6.1.2.5, C90 6.2.1.1, C99 6.2.5, C99 6.3.1.1)."
Implementation:	By default, `unsigned char` is functionally equivalent to plain `char`. The options `-funsigned-char` and `-fsigned-char` can be used to explicitly specify the type.
ISO Standard:	"The mapping of members of the source character set (in character constants and string literals) to members of the execution character set (C90 6.1.3.4, C99 6.4.4.4, C90 and C99 5.1.1.2)."
Implementation:	The binary representation of the source character set is preserved to the execution character set.
ISO Standard:	"The value of an integer character constant containing more than one character or containing a character or escape sequence that does not map to a single-byte execution character (C90 6.1.3.4, C99 6.4.4.4)."
Implementation:	The previous value is shifted left by eight, and the bit pattern of the next character is masked in. The final result is of type `int`. If the result is larger than can be represented by an `int`, a warning diagnostic is issued and the value truncated to `int` size.
ISO Standard:	"The value of a wide character constant containing more than one multibyte character, or containing a multibyte character or escape sequence not represented in the extended execution character set (C90 6.1.3.4, C99 6.4.4.4)."
Implementation:	Multi-byte characters are not supported in source files.
ISO Standard:	"The current locale used to convert a wide character constant consisting of a single multibyte character that maps to a member of the extended execution character set into a corresponding wide character code (C90 6.1.3.4, C99 6.4.4.4)."
Implementation:	Multi-byte characters are not supported in source files.

ISO Standard:	"The current locale used to convert a wide string literal into corresponding wide character codes (C90 6.1.4, C99 6.4.5)."
Implementation:	Wide strings are not supported.
ISO Standard:	"The value of a string literal containing a multibyte character or escape sequence not represented in the execution character set (C90 6.1.4, C99 6.4.5)."
Implementation:	Multi-byte characters are not supported in source files.

C.7 INTEGERS

ISO Standard:	"Any extended integer types that exist in the implementation (C99 6.2.5)."
Implementation:	The `__bit` keyword designates a single-bit integer type. The `__int24` and `__uint24` keywords designate a signed and unsigned, respectively, 24-bit integer type.
ISO Standard:	"Whether signed integer types are represented using sign and magnitude, two's complement, or one's complement, and whether the extraordinary value is a trap representation or an ordinary value (C99 6.2.6.2)."
Implementation:	All integer types are represented as two's complement, and all bit patterns are ordinary values.
ISO Standard:	"The rank of any extended integer type relative to another extended integer type with the same precision (C99 6.3.1.1)."
Implementation:	There are no extended integer types with the same precision.
ISO Standard:	"The result of, or the signal raised by, converting an integer to a signed integer type when the value cannot be represented in an object of that type (C90 6.2.1.2, C99 6.3.1.3)."
Implementation:	When converting value X to a type of width N, the value of the result is the Least Significant N bits of the 2's complement representation of X. That is, X is truncated to N bits. No signal is raised.
ISO Standard:	"The results of some bitwise operations on signed integers (C90 6.3, C99 6.5)."
Implementation:	The right shift operator sign extends signed values. Thus, an object with the signed int value 0x0124 shifted right one bit will yield the value 0x0092 and the value 0x8024 shifted right one bit will yield the value 0xC012. Right shifts of unsigned integral values always clear the MSb of the result. Left shifts (<< operator), signed or unsigned, always clear the LSb of the result. Other bitwise operations act as if the operand was unsigned.

© 2012-2018 Microchip Technology Inc.

C.8 FLOATING-POINT

ISO Standard:	"The accuracy of the floating-point operations and of the library functions in <`math.h`> and <`complex.h`> that return floating-point results (C90 and C99 5.2.4.2.2)."
Implementation:	The accuracy is unknown.
ISO Standard:	"The rounding behaviors characterized by non-standard values of `FLT_ROUNDS` (C90 and C99 5.2.4.2.2)."
Implementation:	No such values are used.
ISO Standard:	"The evaluation methods characterized by non-standard negative values of `FLT_EVAL_METHOD` (C90 and C99 5.2.4.2.2)."
Implementation:	No such values are used.
ISO Standard:	"The direction of rounding when an integer is converted to a floating-point number that cannot exactly represent the original value (C90 6.2.1.3, C99 6.3.1.4)."
Implementation:	The integer is rounded to the nearest floating point representation.
ISO Standard:	"The direction of rounding when a floating-point number is converted to a narrower floating-point number (C90 6.2.1.4, 6.3.1.5)."
Implementation:	A floating-point number is rounded down when converted to a narrow floating-point value.
ISO Standard:	"How the nearest representable value or the larger or smaller representable value immediately adjacent to the nearest representable value is chosen for certain floating constants (C90 6.1.3.1, C99 6.4.4.2)."
Implementation:	Not applicable; `FLT_RADIX` is a power of 2
ISO Standard:	"Whether and how floating expressions are contracted when not disallowed by the `FP_CONTRACT` pragma (C99 6.5)."
Implementation:	The pragma is not implemented.
ISO Standard:	"The default state for the `FENV_ACCESS` pragma (C99 7.6.1)."
Implementation:	This pragma is not implemented.
ISO Standard:	"Additional floating-point exceptions, rounding modes, environments, and classifications, and their macro names (C99 7.6, 7.12)."
Implementation:	None supported.
ISO Standard:	"The default state for the `FP_CONTRACT` pragma (C99 7.12.2)."
Implementation:	This pragma is not implemented.
ISO Standard:	"Whether the "inexact" floating-point exception can be raised when the rounded result actually does equal the mathematical result in an IEC 60559 conformant implementation (C99 F.9)."
Implementation:	The exception is not raised.
ISO Standard:	"Whether the "underflow" (and "inexact") floating-point exception can be raised when a result is tiny but not inexact in an IEC 60559 conformant implementation (C99 F.9)."
Implementation:	The exception is not raised.

C.9 ARRAYS AND POINTERS

ISO Standard:	"The result of converting a pointer to an integer or vice versa (C90 6.3.4, C99 6.3.2.3)."
Implementation:	When converting an integer to a pointer variable, if the pointer variable throughout the entire program is only assigned the addresses of objects in data memory or is only assigned the addresses of objects in program memory, the integer address is copied without modification into the pointer variable. If a pointer variable throughout the entire program is assigned addresses of objects in data memory and also addresses of objects in program memory, then the MSb of the integer value will be set if it is explicitly cast to a pointer to `const` type; otherwise the MSb is not set. The remaining bits of the integer are assigned to the pointer variable without modification. When converting a pointer to an integer, the value held by the pointer is assigned to the integer without modification. The usual integer truncation applies if the integer is larger than the size of the pointer.
ISO Standard:	"The size of the result of subtracting two pointers to elements of the same array (C90 6.3.6, C99 6.5.6)."
Implementation:	The signed integer result will have the same size as the pointer operands in the subtraction.

C.10 HINTS

ISO Standard:	"The extent to which suggestions made by using the register storage-class specifier are effective (C90 6.5.1, C99 6.7.1)."
Implementation:	The register storage class specifier has no effect.
ISO Standard:	"The extent to which suggestions made by using the inline function specifier are effective (C99 6.7.4)."
Implementation:	A function might be inlined if a PRO-licensed compiler has the optimizers set to level 2 or higher. In other situations, the function will not be inlined.

© 2012-2018 Microchip Technology Inc.

C.11 STRUCTURES, UNIONS, ENUMERATIONS, AND BIT FIELDS

ISO Standard:	"Whether a "plain" `int` bit-field is treated as a `signed int` bit-field or as an `unsigned int` bit-field (C90 6.5.2, C90 6.5.2.1, C99 6.7.2, C99 6.7.2.1)."
Implementation:	A plain `int` bit-field is treated as an unsigned integer. Signed integer bit-fields are not supported.
ISO Standard:	"Allowable bit-field types other than `_Bool`, `signed int`, and `unsigned int` (C99 6.7.2.1)."
Implementation:	The signed and unsigned `char` type is allowed.
ISO Standard:	"Whether a bit-field can straddle a storage unit boundary (C90 6.5.2.1, C99 6.7.2.1)."
Implementation:	A bit-field cannot straddle a storage unit. Any bit-field that would straddle a storage unit will be moved to the LSb position in a new storage unit.
ISO Standard:	"The order of allocation of bit-fields within a unit (C90 6.5.2.1, C99 6.7.2.1)."
Implementation:	The first bit-field defined in a structure is allocated the LSb position in the storage unit. Subsequent bit-fields are allocated higher-order bits.
ISO Standard:	"The alignment of non-bit-field members of structures (C90 6.5.2.1, C99 6.7.2.1)."
Implementation:	No alignment is performed.
ISO Standard:	"The integer type compatible with each enumerated type (C90 6.5.2.2, C99 6.7.2.2)."
Implementation:	The type chosen to represent an enumerated type depends on the enumerated values. A signed type is chosen if any value is negative; unsigned otherwise. If a `char` type is sufficient to hold the range of values, then this type is chosen; otherwise, an `int` type is chosen. Enumerated values must fit within an `int` type and will be truncated if this is not the case.

C.12 QUALIFIERS

ISO Standard:	"What constitutes an access to an object that has `volatile`-qualified type (C90 6.5.3, C99 6.7.3)."
Implementation:	Each reference to the identifier of a `volatile`-qualified object constitutes one access to the object.

C.13 PRE-PROCESSING DIRECTIVES

ISO Standard:	"How sequences in both forms of header names are mapped to headers or external source file names (C90 6.1.7, C99 6.4.7)."
Implementation:	The character sequence between the delimiters is considered to be a string which is a file name for the host environment.
ISO Standard:	"Whether the value of a character constant in a constant expression that controls conditional inclusion matches the value of the same character constant in the execution character set (C90 6.8.1, C99 6.10.1)."
Implementation:	Yes.
ISO Standard:	"Whether the value of a single-character `character` constant in a constant expression that controls conditional inclusion may have a negative value (C90 6.8.1, C99 6.10.1)."
Implementation:	Yes.

ISO Standard:	“The places that are searched for an included `< >` delimited header, and how the places are specified or the header is identified (C90 6.8.2, C99 6.10.2).”
Implementation:	The preprocessor searches any directory specified using the `-I` option, then, provided the `-nostdinc` option has not been used, the standard compiler include directory, `<install directory>/pic/include`
ISO Standard:	“How the named source file is searched for in an included `""` delimited header (C90 6.8.2, C99 6.10.2).”
Implementation:	The compiler first searches for the named file in the directory containing the including file, then the directories which are searched for a `< >` delimited header.
ISO Standard:	“The method by which preprocessing tokens are combined into a header name (C90 6.8.2, C99 6.10.2).”
Implementation:	All tokens, including whitespace, are considered part of the header file name. Macro expansion is not performed on tokens inside the delimiters.
ISO Standard:	“The nesting limit for `#include` processing (C90 6.8.2, C99 6.10.2).”
Implementation:	No limit.
ISO Standard:	"Whether the # operator inserts a \ character before the \ character that begins a universal character name in a character constant or string literal (6.10.3.2)."
Implementation:	No.
ISO Standard:	“The behavior on each recognized non-`STDC #pragma` directive (C90 6.8.6, C99 6.10.6).”
Implementation:	See Section 4.14.3 “Pragma Directives”
ISO Standard:	“The definitions for `__DATE__` and `__TIME__` when respectively, the date and time of translation are not available (C90 6.8.8, C99 6.10.8).”
Implementation:	The date and time of translation are always available.

© 2012-2018 Microchip Technology Inc.

C.14 LIBRARY FUNCTIONS

ISO Standard:	"Any library facilities available to a freestanding program, other than the minimal set required by clause 4 (5.1.2.1)."
Implementation:	See Appendix A. Library Functions.
ISO Standard:	"The format of the diagnostic printed by the `assert` macro (7.2.1.1)."
Implementation:	`Assertion failed: `*`expression`*` (`*`file`*`: `*`func`*`: `*`line`*`)`
ISO Standard:	"The representation of floating-point exception flags stored by the `fegetexceptflag` function (7.6.2.2)."
IImplementation:	Unimplemented.
ISO Standard:	"Whether the `feraiseexcept` function raises the inexact exception in addition to the overflow or underflow exception (7.6.2.3)."
Implementation:	Unimplemented.
ISO Standard:	"Strings other than `"C"` and `""` that may be passed as the second argument to the `setlocale` function (7.11.1.1)."
Implementation:	None.
ISO Standard:	"The types defined for `float_t` and `double_t` when the value of the `FLT_EVAL_METHOD` macro is less than 0 or greater than 2 (7.12)."
Implementation:	Unimplemented.
ISO Standard:	"Domain errors for the mathematics functions, other than those required by this International Standard (7.12.1)."
Implementation:	None.
ISO Standard:	"The values returned by the mathematics functions on domain errors (7.12.1)."
Implementation:	`errno` is set to `EDOM` on domain errors??
ISO Standard:	"Whether the mathematics functions set `errno` to the value of the macro `ERANGE` on overflow and/or underflow range errors (7.12.1)."
Implementation:	Yes
ISO Standard:	"Whether a domain error occurs or zero is returned when the `fmod` function has a second argument of zero (7.12.10.1)."
Implementation:	The first argument is returned.
ISO Standard:	"The base-2 logarithm of the modulus used by the `remquo` function in reducing the quotient (7.12.10.3)."
Implementation:	Unimplemented.
ISO Standard:	Whether the equivalent of signal(sig, SIG_DFL); is executed prior to the call of a signal handler, and, if not, the blocking of signals that is performed (7.14.1.1).
Implementation:	Signals are not implemented.
ISO Standard:	The null pointer constant to which the macro `NULL` expands (7.17).
Implementation:	`(0)`
ISO Standard:	"Whether the last line of a text stream requires a terminating new-line character (7.19.2)."
Implementation:	Streams are not implemented.
ISO Standard:	"Whether space characters that are written out to a text stream immediately before a new-line character appear when read in (7.19.2)."
Implementation:	Streams are not implemented.
ISO Standard:	"The number of null characters that may be appended to data written to a binary stream (7.19.2)."
Implementation:	Streams are not implemented.
ISO Standard:	"Whether the file position indicator of an append-mode stream is initially positioned at the beginning or end of the file (7.19.3)."

Implementation:	Streams are not implemented.
ISO Standard:	“Whether a write on a text stream causes the associated file to be truncated beyond that point (7.19.3).”
Implementation:	Streams are not implemented.
ISO Standard:	“The characteristics of file buffering (7.19.3).”
Implementation:	File handling is not implemented.
ISO Standard:	“Whether a zero-length file actually exists (7.19.3).”
Implementation:	File handling is not implemented.
ISO Standard:	“The rules for composing valid file names (7.19.3).”
Implementation:	File handling is not implemented.
ISO Standard:	“Whether the same file can be open multiple times (7.19.3).”
Implementation:	File handling is not implemented.
ISO Standard:	“The nature and choice of encodings used for multibyte characters in files (7.19.3).”
Implementation:	File handling is not implemented.
ISO Standard:	“The effect of the `remove` function on an open file (7.19.4.1).”
Implementation:	File handling is not implemented.
ISO Standard:	“The effect if a file with the new name exists prior to a call to the `rename` function (7.19.4.2).”
Implementation:	File handling is not implemented.
ISO Standard:	“Whether an open temporary file is removed upon abnormal program termination (7.19.4.3).”
Implementation:	File handling is not implemented.
ISO Standard:	“What happens when the `tmpnam` function is called more than `TMP_MAX` times (7.19.4.4).”
Implementation:	File handling is not implemented.
ISO Standard:	“Which changes of mode are permitted (if any), and under what circumstances (7.19.5.4).”
Implementation:	File handling is not implemented.
ISO Standard:	“The style used to print an infinity or NaN, and the meaning of the *n-char-sequence* if that style is printed for a NaN (7.19.6.1, 7.24.2.1).”
Implementation:	The values are printed as the nearest number.
ISO Standard:	“The output for `%p` conversion in the `fprintf` or `fwprintf` function (7.19.6.1, 7.24.2.1).”
Implementation:	Functionally equivalent to `%lx`.
ISO Standard:	“The interpretation of a `-` character that is neither the first nor the last character, nor the second where a `^` character is the first, in the scanlist for `%[` conversion in the `fscanf` or `fwscanf` function (7.19.6.2, 7.24.2.2).”
Implementation:	Streams are not implemented.
ISO Standard:	“The set of sequences matched by the `%p` conversion in the `fscanf` or `fwscanf` function (7.19.6.2, 7.24.2.2).”
Implementation:	Streams are not implemented.
ISO Standard:	“The value to which the macro `errno` is set by the `fgetpos`, `fsetpos`, or `ftell` functions on failure (7.19.9.1, 7.19.9.3, 7.19.9.4).”
Implementation:	Streams are not implemented.
ISO Standard:	“The meaning of the *n-char-sequence* in a string converted by the `strtod`, `strtof`, `strtold`, `wcstod`, `wcstof`, or `wcstold` function (7.20.1.3, 7.24.4.1.1).”
Implementation:	No meaning is attached to the sequence.

© 2012-2018 Microchip Technology Inc.

ISO Standard:	"Whether or not the `strtod`, `strtof`, `strtold`, `wcstod`, `wcstof`, or `wcstold` function sets `errno` to `ERANGE` when underflow occurs (7.20.1.3, 7.24.4.1.1)."
Implementation:	No.
ISO Standard:	"Whether the `calloc`, `malloc`, and `realloc` functions return a Null Pointer or a pointer to an allocated object when the size requested is zero (7.20.3)."
Implementation:	Memory allocation functions are not implemented.
ISO Standard:	"Whether open output streams are flushed, open streams are closed, or temporary files are removed when the `abort` function is called (7.20.4.1)."
Implementation:	Streams are not implemented.
ISO Standard:	"The termination status returned to the host environment by the `abort` function (7.20.4.1)."
Implementation:	The host environment is application defined.
ISO Standard:	"The value returned by the `system` function when its argument is not a Null Pointer (7.20.4.5)."
Implementation:	The host environment is application defined.
ISO Standard:	"The local time zone and Daylight Saving Time (7.23.1)."
Implementation:	Application defined.
ISO Standard:	"The range and precision of times representable in `clock_t` and `time_t` (7.23)"
Implementation:	the `time_t` type is used to hold a number of seconds and is defined as a `long` type; `clock_t` is not defined.
ISO Standard:	"The era for the `clock` function (7.23.2.1)."
Implementation:	Application defined.
ISO Standard:	"The replacement string for the `%Z` specifier to the `strftime`, `strfx-time`, `wcsftime`, and `wcsfxtime` functions in the "`C`" locale (7.23.3.5, 7.23.3.6, 7.24.5.1, 7.24.5.2)."
Implementation:	These functions are unimplemented.
ISO Standard:	"Whether or when the trigonometric, hyperbolic, base-*e* exponential, base-*e* logarithmic, error, and log gamma functions raise the inexact exception in an IEC 60559 conformant implementation (F.9)."
Implementation:	No.
ISO Standard:	"Whether the functions in `<math.h>` honor the Rounding Direction mode (F.9)."
Implementation:	The rounding mode is not forced.

C.15 ARCHITECTURE

ISO Standard:	"The values or expressions assigned to the macros specified in the headers `<float.h>`, `<limits.h>`, and `<stdint.h>` (C90 and C99 5.2.4.2, C99 7.18.2, 7.18.3)."
Implementation:	See Table A-4, Table A-7 and the header files in `<install directory>/pic/include/c99`.
ISO Standard:	"The number, order, and encoding of bytes in any object (when not explicitly specified in the standard) (C99 6.2.6.1)."
Implementation:	Little endian, populated from Least Significant Byte first.
ISO Standard:	"The value of the result of the `sizeof` operator (C90 6.3.3.4, C99 6.5.3.4)."
Implementation:	The type of the result is equivalent to `unsigned int`.

© 2012-2018 Microchip Technology Inc.

Glossary

A

Absolute Section

A GCC compiler section with a fixed (absolute) address that cannot be changed by the linker.

Absolute Variable/Function

A variable or function placed at an absolute address using the OCG compiler's `@ address` syntax.

Access Memory

PIC18 Only – Special registers on PIC18 devices that allow access regardless of the setting of the Bank Select Register (BSR).

Access Entry Points

Access entry points provide a way to transfer control across segments to a function which cannot be defined at link time. They support the separate linking of boot and secure application segments.

Address

Value that identifies a location in memory.

Alphabetic Character

Alphabetic characters are those characters that are letters of the Arabic alphabet (a, b, …, z, A, B, …, Z).

Alphanumeric

Alphanumeric characters are comprised of alphabetic characters and decimal digits (0,1, …, 9).

ANDed Breakpoints

Set up an ANDed condition for breaking, i.e., breakpoint 1 AND breakpoint 2 must occur at the same time before a program halt. This can only be accomplished if a data breakpoint and a program memory breakpoint occur at the same time.

Anonymous Structure

16-bit C Compiler **–** An unnamed structure.

PIC18 C Compiler **–** An unnamed structure that is a member of a C union. The members of an anonymous structure can be accessed as if they were members of the enclosing union. For example, in the following code, `hi` and `lo` are members of an anonymous structure inside the union `caster`.

```
union castaway {
 int intval;
 struct {
  char lo; //accessible as caster.lo
  char hi; //accessible as caster.hi
 };
} caster;
```

ANSI

American National Standards Institute is an organization responsible for formulating and approving standards in the United States.

Application

A set of software and hardware that can be controlled by a PIC microcontroller.

Archive/Archiver

An archive/library is a collection of relocatable object modules. It is created by assembling multiple source files to object files, and then using the archiver/librarian to combine the object files into one archive/library file. An archive/library can be linked with object modules and other archives/libraries to create executable code.

ASCII

American Standard Code for Information Interchange is a character set encoding that uses 7 binary digits to represent each character. It includes upper and lower case letters, digits, symbols and control characters.

Assembly/Assembler

Assembly is a programming language that describes binary machine code in a symbolic form. An assembler is a language tool that translates assembly language source code into machine code.

Assigned Section

A GCC compiler section which has been assigned to a target memory block in the linker command file.

Asynchronously

Multiple events that do not occur at the same time. This is generally used to refer to interrupts that can occur at any time during processor execution.

Asynchronous Stimulus

Data generated to simulate external inputs to a simulator device.

Attribute

GCC characteristics of variables or functions in a C program which are used to describe machine-specific properties.

Attribute, Section

GCC characteristics of sections, such as "executable", "readonly", or "data" that can be specified as flags in the assembler `.section` directive.

B

Binary

The base two numbering system that uses the digits 0-1. The rightmost digit counts ones, the next counts multiples of 2, then 2^2 = 4, etc.

Breakpoint

Hardware Breakpoint: An event whose execution will cause a halt.

Software Breakpoint: An address where execution of the firmware will halt. Usually achieved by a special break instruction.

Build

Compile and link all the source files for an application.

© 2012-2018 Microchip Technology Inc.

C

C\C++

C is a general-purpose programming language which features economy of expression, modern control flow and data structures, and a rich set of operators. C++ is the object-oriented version of C.

Calibration Memory

A special function register or registers used to hold values for calibration of a PIC microcontroller on-board RC oscillator or other device peripherals.

Central Processing Unit

The part of a device that is responsible for fetching the correct instruction for execution, decoding that instruction, and then executing that instruction. When necessary, it works in conjunction with the arithmetic logic unit (ALU) to complete the execution of the instruction. It controls the program memory address bus, the data memory address bus, and accesses to the stack.

Clean

Clean removes all intermediary project files, such as object, hex and debug files, for the active project. These files are recreated from other files when a project is built.

COFF

Common Object File Format. An object file of this format contains machine code, debugging and other information.

Command Line Interface

A means of communication between a program and its user based solely on textual input and output.

Compiled Stack

A region of memory managed by the compiler in which variables are statically allocated space. It replaces a software or hardware stack when such mechanisms cannot be efficiently implemented on the target device.

Compiler

A program that translates a source file written in a high-level language into machine code.

Conditional Assembly

Assembly language code that is included or omitted based on the assembly-time value of a specified expression.

Conditional Compilation

The act of compiling a program fragment only if a certain constant expression, specified by a preprocessor directive, is true.

Configuration Bits

Special-purpose bits programmed to set PIC microcontroller modes of operation. A Configuration bit can or cannot be preprogrammed.

Control Directives

Directives in assembly language code that cause code to be included or omitted based on the assembly-time value of a specified expression.

CPU

See Central Processing Unit.

Cross Reference File

A file that references a table of symbols and a list of files that references the symbol. If the symbol is defined, the first file listed is the location of the definition. The remaining files contain references to the symbol.

D

Data Directives

Data directives are those that control the assembler's allocation of program or data memory and provide a way to refer to data items symbolically; that is, by meaningful names.

Data Memory

On Microchip MCU and DSC devices, data memory (RAM) is comprised of General Purpose Registers (GPRs) and Special Function Registers (SFRs). Some devices also have EEPROM data memory.

Data Monitor and Control Interface (DMCI)

The Data Monitor and Control Interface, or DMCI, is a tool in MPLAB X IDE. The interface provides dynamic input control of application variables in projects. Application-generated data can be viewed graphically using any of 4 dynamically-assignable graph windows.

Debug/Debugger

See ICE/ICD.

Debugging Information

Compiler and assembler options that, when selected, provide varying degrees of information used to debug application code. See compiler or assembler documentation for details on selecting debug options.

Deprecated Features

Features that are still supported for legacy reasons, but will eventually be phased out and no longer used.

Device Programmer

A tool used to program electrically programmable semiconductor devices such as microcontrollers.

Digital Signal Controller

A A digital signal controller (DSC) is a microcontroller device with digital signal processing capability, i.e., Microchip dsPIC DSC devices.

Digital Signal Processing\Digital Signal Processor

Digital signal processing (DSP) is the computer manipulation of digital signals, commonly analog signals (sound or image) which have been converted to digital form (sampled). A digital signal processor is a microprocessor that is designed for use in digital signal processing.

Directives

Statements in source code that provide control of the language tool's operation.

Download

Download is the process of sending data from a host to another device, such as an emulator, programmer or target board.

DWARF

Debug With Arbitrary Record Format. DWARF is a debug information format for ELF files.

© 2012-2018 Microchip Technology Inc.

E

EEPROM

Electrically Erasable Programmable Read Only Memory. A special type of PROM that can be erased electrically. Data is written or erased one byte at a time. EEPROM retains its contents even when power is turned off.

ELF

Executable and Linking Format. An object file of this format contains machine code. Debugging and other information is specified in with DWARF. ELF/DWARF provide better debugging of optimized code than COFF.

Emulation/Emulator

See ICE/ICD.

Endianness

The ordering of bytes in a multi-byte object.

Environment

MPLAB PM3 **–** A folder containing files on how to program a device. This folder can be transferred to a SD/MMC card.

Epilogue

A portion of compiler-generated code that is responsible for deallocating stack space, restoring registers and performing any other machine-specific requirement specified in the runtime model. This code executes after any user code for a given function, immediately prior to the function return.

EPROM

Erasable Programmable Read Only Memory. A programmable read-only memory that can be erased usually by exposure to ultraviolet radiation.

Error/Error File

An error reports a problem that makes it impossible to continue processing your program. When possible, an error identifies the source file name and line number where the problem is apparent. An error file contains error messages and diagnostics generated by a language tool.

Event

A description of a bus cycle which can include address, data, pass count, external input, cycle type (fetch, R/W), and time stamp. Events are used to describe triggers, breakpoints and interrupts.

Executable Code

Software that is ready to be loaded for execution.

Export

Send data out of the MPLAB IDE in a standardized format.

Expressions

Combinations of constants and/or symbols separated by arithmetic or logical operators.

Extended Microcontroller Mode

In extended microcontroller mode, on-chip program memory as well as external memory is available. Execution automatically switches to external if the program memory address is greater than the internal memory space of the PIC18 device.

Extended Mode (PIC18 MCUs)

In Extended mode, the compiler will utilize the extended instructions (i.e., `ADDFSR`, `ADDULNK`, `CALLW`, `MOVSF`, `MOVSS`, `PUSHL`, `SUBFSR` and `SUBULNK`) and the indexed with literal offset addressing.

External Label

A label that has external linkage.

External Linkage

A function or variable has external linkage if it can be referenced from outside the module in which it is defined.

External Symbol

A symbol for an identifier which has external linkage. This can be a reference or a definition.

External Symbol Resolution

A process performed by the linker in which external symbol definitions from all input modules are collected in an attempt to resolve all external symbol references. Any external symbol references which do not have a corresponding definition cause a linker error to be reported.

External Input Line

An external input signal logic probe line (TRIGIN) for setting an event based upon external signals.

External RAM

Off-chip Read/Write memory.

F

Fatal Error

An error that will halt compilation immediately. No further messages will be produced.

File Registers

On-chip data memory, including General Purpose Registers (GPRs) and Special Function Registers (SFRs).

Filter

Determine by selection what data is included/excluded in a trace display or data file.

Fixup

The process of replacing object file symbolic references with absolute addresses after relocation by the linker.

Flash

A type of EEPROM where data is written or erased in blocks instead of bytes.

FNOP

Forced No Operation. A forced NOP cycle is the second cycle of a two-cycle instruction. Because the PIC microcontroller architecture is pipelined, it prefetches the next instruction in the physical address space while it is executing the current instruction. However, if the current instruction changes the program counter, this prefetched instruction is explicitly ignored, causing a forced NOP cycle.

Frame Pointer

A pointer that references the location on the stack that separates the stack-based arguments from the stack-based local variables. Provides a convenient base from which to access local variables and other values for the current function.

© 2012-2018 Microchip Technology Inc.

Free-Standing

An implementation that accepts any strictly conforming program that does not use complex types and in which the use of the features specified in the library clause (ANSI ‘89 standard clause 7) is confined to the contents of the standard headers `<float.h>`, `<iso646.h>`, `<limits.h>`, `<stdarg.h>`, `<stdbool.h>`, `<stddef.h>` and `<stdint.h>`.

G

GPR

General Purpose Register. The portion of device data memory (RAM) available for general use.

H

Halt

A stop of program execution. Executing Halt is the same as stopping at a breakpoint.

Heap

An area of memory used for dynamic memory allocation where blocks of memory are allocated and freed in an arbitrary order determined at runtime.

Hex Code\Hex File

Hex code is executable instructions stored in a hexadecimal format code. Hex code is contained in a hex file.

Hexadecimal

The base 16 numbering system that uses the digits 0-9 plus the letters A-F (or a-f). The digits A-F represent hexadecimal digits with values of (decimal) 10 to 15. The rightmost digit counts ones, the next counts multiples of 16, then $16^2 = 256$, etc.

High Level Language

A language for writing programs that is further removed from the processor than assembly.

I

ICE/ICD

In-Circuit Emulator/In-Circuit Debugger: A hardware tool that debugs and programs a target device. An emulator has more features than an debugger, such as trace.

In-Circuit Emulation/In-Circuit Debug: The act of emulating or debugging with an in-circuit emulator or debugger.

-ICE/-ICD: A device (MCU or DSC) with on-board in-circuit emulation or debug circuitry. This device is always mounted on a header board and used to debug with an in-circuit emulator or debugger.

ICSP

In-Circuit Serial Programming. A method of programming Microchip embedded devices using serial communication and a minimum number of device pins.

IDE

Integrated Development Environment, as in MPLAB IDE.

Identifier

A function or variable name.

IEEE

Institute of Electrical and Electronics Engineers.

Import

Bring data into the MPLAB IDE from an outside source, such as from a hex file.

Initialized Data

Data which is defined with an initial value. In C,

```
int myVar=5;
```

defines a variable which will reside in an initialized data section.

Instruction Set

The collection of machine language instructions that a particular processor understands.

Instructions

A sequence of bits that tells a central processing unit to perform a particular operation and can contain data to be used in the operation.

Internal Linkage

A function or variable has internal linkage if it cannot be accessed from outside the module in which it is defined.

International Organization for Standardization

An organization that sets standards in many businesses and technologies, including computing and communications. Also known as ISO.

Interrupt

A signal to the CPU that suspends the execution of a running application and transfers control to an Interrupt Service Routine (ISR) so that the event can be processed. Upon completion of the ISR, normal execution of the application resumes.

Interrupt Handler

A routine that processes special code when an interrupt occurs.

Interrupt Service Request (IRQ)

An event which causes the processor to temporarily suspend normal instruction execution and to start executing an interrupt handler routine. Some processors have several interrupt request events allowing different priority interrupts.

Interrupt Service Routine (ISR)

Language tools **–** A function that handles an interrupt.

MPLAB IDE **–** User-generated code that is entered when an interrupt occurs. The location of the code in program memory will usually depend on the type of interrupt that has occurred.

Interrupt Vector

Address of an interrupt service routine or interrupt handler.

L

L-value

An expression that refers to an object that can be examined and/or modified. An l-value expression is used on the left-hand side of an assignment.

Latency

The time between an event and its response.

Library/Librarian

See Archive/Archiver.

© 2012-2018 Microchip Technology Inc.

Linker

A language tool that combines object files and libraries to create executable code, resolving references from one module to another.

Linker Script Files

Linker script files are the command files of a linker. They define linker options and describe available memory on the target platform.

Listing Directives

Listing directives are those directives that control the assembler listing file format. They allow the specification of titles, pagination and other listing control.

Listing File

A listing file is an ASCII text file that shows the machine code generated for each C source statement, assembly instruction, assembler directive, or macro encountered in a source file.

Little Endian

A data ordering scheme for multibyte data whereby the LSB is stored at the lower addresses.

Local Label

A local label is one that is defined inside a macro with the LOCAL directive. These labels are particular to a given instance of a macro's instantiation. In other words, the symbols and labels that are declared as local are no longer accessible after the ENDM macro is encountered.

Logic Probes

Up to 14 logic probes can be connected to some Microchip emulators. The logic probes provide external trace inputs, trigger output signal, +5V, and a common ground.

Loop-Back Test Board

Used to test the functionality of the MPLAB REAL ICE in-circuit emulator.

LVDS

Low Voltage Differential Signaling. A low noise, low-power, low amplitude method for high-speed (gigabits per second) data transmission over copper wire.

With standard I/O signaling, data storage is contingent upon the actual voltage level. Voltage level can be affected by wire length (longer wires increase resistance, which lowers voltage). But with LVDS, data storage is distinguished only by positive and negative voltage values, not the voltage level. Therefore, data can travel over greater lengths of wire while maintaining a clear and consistent data stream.

Source: http://www.webopedia.com/TERM/L/LVDS.html.

M

Machine Code

The representation of a computer program that is actually read and interpreted by the processor. A program in binary machine code consists of a sequence of machine instructions (possibly interspersed with data). The collection of all possible instructions for a particular processor is known as its "instruction set".

Machine Language

A set of instructions for a specific central processing unit, designed to be usable by a processor without being translated.

Macro

Macro instruction. An instruction that represents a sequence of instructions in abbreviated form.

Macro Directives

Directives that control the execution and data allocation within macro body definitions.

Makefile

Export to a file the instructions to Make the project. Use this file to Make your project outside of MPLAB IDE, i.e., with a `make`.

Make Project

A command that rebuilds an application, recompiling only those source files that have changed since the last complete compilation.

MCU

Microcontroller Unit. An abbreviation for microcontroller. Also uC.

Memory Model

For C compilers, a representation of the memory available to the application. For the PIC18 C compiler, a description that specifies the size of pointers that point to program memory.

Message

Text displayed to alert you to potential problems in language tool operation. A message will not stop operation.

Microcontroller

A highly integrated chip that contains a CPU, RAM, program memory, I/O ports and timers.

Microcontroller Mode

One of the possible program memory configurations of PIC18 microcontrollers. In microcontroller mode, only internal execution is allowed. Thus, only the on-chip program memory is available in microcontroller mode.

Microprocessor Mode

One of the possible program memory configurations of PIC18 microcontrollers. In microprocessor mode, the on-chip program memory is not used. The entire program memory is mapped externally.

Mnemonics

Text instructions that can be translated directly into machine code. Also referred to as opcodes.

Module

The preprocessed output of a source file after preprocessor directives have been executed. Also known as a translation unit.

MPASM™ Assembler

Microchip Technology's relocatable macro assembler for PIC microcontroller devices, KeeLoq® devices and Microchip memory devices.

MPLAB *Language Tool* for *Device*

Microchip's C compilers, assemblers and linkers for specified devices. Select the type of language tool based on the device you will be using for your application, e.g., if you will be creating C code on a PIC18 MCU, select the MPLAB C Compiler for PIC18 MCUs.

© 2012-2018 Microchip Technology Inc.

MPLAB ICD

Microchip’s in-circuit debuggers that works with MPLAB IDE. *See* ICE/ICD.

MPLAB IDE

Microchip’s Integrated Development Environment. MPLAB IDE comes with an editor, project manager and simulator.

MPLAB PM3

A device programmer from Microchip. Programs PIC18 microcontrollers and dsPIC digital signal controllers. Can be used with MPLAB IDE or stand-alone. Replaces PRO MATE II.

MPLAB REAL ICE™ In-Circuit Emulator

Microchip’s next-generation in-circuit emulators that works with MPLAB IDE. *See* ICE/ICD.

MPLAB SIM

Microchip’s simulator that works with MPLAB IDE in support of PIC MCU and dsPIC DSC devices.

MPLIB™ Object Librarian

Microchip’s librarian that can work with MPLAB IDE. MPLIB librarian is an object librarian for use with COFF object modules created using either MPASM assembler (mpasm or mpasmwin v2.0) or MPLAB C18 C compiler.

MPLINK™ Object Linker

MPLINK linker is an object linker for the Microchip MPASM assembler and the Microchip C18 C compiler. MPLINK linker also can be used with the Microchip MPLIB librarian. MPLINK linker is designed to be used with MPLAB IDE, though it does not have to be.

MRU

Most Recently Used. Refers to files and windows available to be selected from MPLAB IDE main pull down menus.

N

Native Data Size

For Native trace, the size of the variable used in a Watch window must be of the same size as the selected device’s data memory: bytes for PIC18 devices and words for 16-bit devices.

Nesting Depth

The maximum level to which macros can include other macros.

Node

MPLAB IDE project component.

Non-Extended Mode (PIC18 MCUs)

In Non-Extended mode, the compiler will not utilize the extended instructions nor the indexed with literal offset addressing.

Non Real Time

Refers to the processor at a breakpoint or executing single-step instructions or MPLAB IDE being run in simulator mode.

Non-Volatile Storage

A storage device whose contents are preserved when its power is off.

NOP

No Operation. An instruction that has no effect when executed except to advance the program counter.

O

Object Code/Object File

Object code is the machine code generated by an assembler or compiler. An object file is a file containing machine code and, possibly, debug information. It can be immediately executable or it can be relocatable, requiring linking with other object files, e.g., libraries, to produce a complete executable program.

Object File Directives

Directives that are used only when creating an object file.

Octal

The base 8 number system that only uses the digits 0-7. The rightmost digit counts ones, the next digit counts multiples of 8, then 8^2 = 64, etc.

Off-Chip Memory

Off-chip memory refers to the memory selection option for the PIC18 device where memory can reside on the target board, or where all program memory can be supplied by the emulator. The **Memory** tab accessed from *Options>Development Mode* provides the Off-Chip Memory selection dialog box.

Opcodes

Operational Codes. *See* Mnemonics.

Operators

Symbols, like the plus sign ‘+’ and the minus sign ‘-’, that are used when forming well-defined expressions. Each operator has an assigned precedence that is used to determine order of evaluation.

OTP

One Time Programmable. EPROM devices that are not in windowed packages. Since EPROM needs ultraviolet light to erase its memory, only windowed devices are erasable.

P

Pass Counter

A counter that decrements each time an event (such as the execution of an instruction at a particular address) occurs. When the pass count value reaches zero, the event is satisfied. You can assign the Pass Counter to break and trace logic, and to any sequential event in the complex trigger dialog.

PC

Personal Computer or Program Counter.

PC Host

Any PC running a supported Windows operating system.

Persistent Data

Data that is never cleared or initialized. Its intended use is so that an application can preserve data across a device Reset.

Phantom Byte

An unimplemented byte in the dsPIC architecture that is used when treating the 24-bit instruction word as if it were a 32-bit instruction word. Phantom bytes appear in dsPIC hex files.

© 2012-2018 Microchip Technology Inc.

PIC MCUs

PIC microcontrollers (MCUs) refers to all Microchip microcontroller families.

PICkit 2 and 3

Microchip's developmental device programmers with debug capability through Debug Express. See the Readme files for each tool to see which devices are supported.

Plug-ins

The MPLAB IDE has both built-in components and plug-in modules to configure the system for a variety of software and hardware tools. Several plug-in tools can be found under the Tools menu.

Pod

The enclosure for an in-circuit emulator or debugger. Other names are "Puck", if the enclosure is round, and "Probe", not be confused with logic probes.

Power-on-Reset Emulation

A software randomization process that writes random values in data RAM areas to simulate uninitialized values in RAM upon initial power application.

Pragma

A directive that has meaning to a specific compiler. Often a pragma is used to convey implementation-defined information to the compiler. MPLAB C30 uses attributes to convey this information.

Precedence

Rules that define the order of evaluation in expressions.

Production Programmer

A production programmer is a programming tool that has resources designed in to program devices rapidly. It has the capability to program at various voltage levels and completely adheres to the programming specification. Programming a device as fast as possible is of prime importance in a production environment where time is of the essence as the application circuit moves through the assembly line.

Profile

For MPLAB SIM simulator, a summary listing of executed stimulus by register.

Program Counter

The location that contains the address of the instruction that is currently executing.

Program Counter Unit

16-bit assembler – A conceptual representation of the layout of program memory. The program counter increments by 2 for each instruction word. In an executable section, 2 program counter units are equivalent to 3 bytes. In a read-only section, 2 program counter units are equivalent to 2 bytes.

Program Memory

MPLAB IDE – The memory area in a device where instructions are stored. Also, the memory in the emulator or simulator containing the downloaded target application firmware.

16-bit assembler/compiler – The memory area in a device where instructions are stored.

Project

A project contains the files needed to build an application (source code, linker script files, etc.) along with their associations to various build tools and build options.

Prologue

A portion of compiler-generated code that is responsible for allocating stack space, preserving registers and performing any other machine-specific requirement specified in the runtime model. This code executes before any user code for a given function.

Prototype System

A term referring to a user's target application, or target board.

Psect

The OCG equivalent of a GCC section, short for program section. A block of code or data which is treated as a whole by the linker.

PWM Signals

Pulse Width Modulation Signals. Certain PIC MCU devices have a PWM peripheral.

Q

Qualifier

An address or an address range used by the Pass Counter or as an event before another operation in a complex trigger.

R

Radix

The number base, hex, or decimal, used in specifying an address.

RAM

Random Access Memory (Data Memory). Memory in which information can be accessed in any order.

Raw Data

The binary representation of code or data associated with a section.

Read Only Memory

Memory hardware that allows fast access to permanently stored data but prevents addition to or modification of the data.

Real Time

When an in-circuit emulator or debugger is released from the halt state, the processor runs in Real Time mode and behaves exactly as the normal chip would behave. In Real Time mode, the real time trace buffer of an emulator is enabled and constantly captures all selected cycles, and all break logic is enabled. In an in-circuit emulator or debugger, the processor executes in real time until a valid breakpoint causes a halt, or until the user halts the execution.

In the simulator, real time simply means execution of the microcontroller instructions as fast as they can be simulated by the host CPU.

Recursive Calls

A function that calls itself, either directly or indirectly.

Recursion

The concept that a function or macro, having been defined, can call itself. Great care should be taken when writing recursive macros; it is easy to get caught in an infinite loop where there will be no exit from the recursion.

Reentrant

A function that can have multiple, simultaneously active instances. This can happen due to either direct or indirect recursion or through execution during interrupt processing.

© 2012-2018 Microchip Technology Inc.

Relaxation

The process of converting an instruction to an identical, but smaller instruction. This is useful for saving on code size. MPLAB ASM30 currently knows how to RELAX a CALL instruction into an RCALL instruction. This is done when the symbol that is being called is within +/- 32k instruction words from the current instruction.

Relocatable

An object whose address has not been assigned to a fixed location in memory.

Relocatable Section

16-bit assembler – A section whose address is not fixed (absolute). The linker assigns addresses to relocatable sections through a process called relocation.

Relocation

A process performed by the linker in which absolute addresses are assigned to relocatable sections and all symbols in the relocatable sections are updated to their new addresses.

ROM

Read Only Memory (Program Memory). Memory that cannot be modified.

Run

The command that releases the emulator from halt, allowing it to run the application code and change or respond to I/O in real time.

Run-time Model

Describes the use of target architecture resources.

Runtime Watch

A Watch window where the variables change in as the application is run. See individual tool documentation to determine how to set up a runtime watch. Not all tools support runtime watches.

S

Scenario

For MPLAB SIM simulator, a particular setup for stimulus control.

Section

The GCC equivalent of an OCG psect. A block of code or data which is treated as a whole by the linker.

Section Attribute

A GCC characteristic ascribed to a section (e.g., an `access` section).

Sequenced Breakpoints

Breakpoints that occur in a sequence. Sequence execution of breakpoints is bottom-up; the last breakpoint in the sequence occurs first.

Serialized Quick Turn Programming

Serialization allows you to program a serial number into each microcontroller device that the Device Programmer programs. This number can be used as an entry code, password or ID number.

Shell

The MPASM assembler shell is a prompted input interface to the macro assembler. There are two MPASM assembler shells: one for the DOS version and one for the Windows version.

Simulator

A software program that models the operation of devices.

Single Step

This command steps though code, one instruction at a time. After each instruction, MPLAB IDE updates register windows, watch variables, and status displays so you can analyze and debug instruction execution. You can also single step C compiler source code, but instead of executing single instructions, MPLAB IDE will execute all assembly level instructions generated by the line of the high level C statement.

Skew

The information associated with the execution of an instruction appears on the processor bus at different times. For example, the executed opcodes appears on the bus as a fetch during the execution of the previous instruction, the source data address and value and the destination data address appear when the opcodes is actually executed, and the destination data value appears when the next instruction is executed. The trace buffer captures the information that is on the bus at one instance. Therefore, one trace buffer entry will contain execution information for three instructions. The number of captured cycles from one piece of information to another for a single instruction execution is referred to as the skew.

Skid

When a hardware breakpoint is used to halt the processor, one or more additional instructions can be executed before the processor halts. The number of extra instructions executed after the intended breakpoint is referred to as the skid.

Source Code

The form in which a computer program is written by the programmer. Source code is written in a formal programming language which can be translated into machine code or executed by an interpreter.

Source File

An ASCII text file containing source code.

Special Function Registers (SFRs)

The portion of data memory (RAM) dedicated to registers that control I/O processor functions, I/O status, timers or other modes or peripherals.

SQTP

See Serialized Quick Turn Programming.

Stack, Hardware

Locations in PIC microcontroller where the return address is stored when a function call is made.

Stack, Software

Memory used by an application for storing return addresses, function parameters, and local variables. This memory is dynamically allocated at runtime by instructions in the program. It allows for reentrant function calls.

Stack, Compiled

A region of memory managed and allocated by the compiler in which variables are statically assigned space. It replaces a software stack when such mechanisms cannot be efficiently implemented on the target device. It precludes reentrancy.

MPLAB Starter Kit for *Device*

Microchip's starter kits contains everything needed to begin exploring the specified device. View a working application and then debug and program you own changes.

© 2012-2018 Microchip Technology Inc.

Static RAM or SRAM

Static Random Access Memory. Program memory you can read/write on the target board that does not need refreshing frequently.

Status Bar

The Status Bar is located on the bottom of the MPLAB IDE window and indicates such current information as cursor position, development mode and device, and active tool bar.

Step Into

This command is the same as Single Step. Step Into (as opposed to Step Over) follows a CALL instruction into a subroutine.

Step Over

Step Over allows you to debug code without stepping into subroutines. When stepping over a `CALL` instruction, the next breakpoint will be set at the instruction after the `CALL`. If for some reason the subroutine gets into an endless loop or does not return properly, the next breakpoint will never be reached. The Step Over command is the same as Single Step except for its handling of `CALL` instructions.

Step Out

Step Out allows you to step out of a subroutine which you are currently stepping through. This command executes the rest of the code in the subroutine and then stops execution at the return address to the subroutine.

Stimulus

Input to the simulator, i.e., data generated to exercise the response of simulation to external signals. Often the data is put into the form of a list of actions in a text file. Stimulus can be asynchronous, synchronous (pin), clocked and register.

Stopwatch

A counter for measuring execution cycles.

Storage Class

Determines the lifetime of the memory associated with the identified object.

Storage Qualifier

Indicates special properties of the objects being declared (e.g., `const`).

Symbol

A symbol is a general purpose mechanism for describing the various pieces which comprise a program. These pieces include function names, variable names, section names, file names, struct/enum/union tag names, etc. Symbols in MPLAB IDE refer mainly to variable names, function names and assembly labels. The value of a symbol after linking is its value in memory.

Symbol, Absolute

Represents an immediate value such as a definition through the assembly `.equ` directive.

System Window Control

The system window control is located in the upper left corner of windows and some dialogs. Clicking on this control usually pops up a menu that has the items “Minimize,” “Maximize,” and “Close.”

T

Target

Refers to user hardware.

Target Application

Software residing on the target board.

Target Board

The circuitry and programmable device that makes up the target application.

Target Processor

The microcontroller device on the target application board.

Template

Lines of text that you build for inserting into your files at a later time. The MPLAB Editor stores templates in template files.

Tool Bar

A row or column of icons that you can click on to execute MPLAB IDE functions.

Trace

An emulator or simulator function that logs program execution. The emulator logs program execution into its trace buffer which is uploaded to MPLAB IDE's trace window.

Trace Memory

Trace memory contained within the emulator. Trace memory is sometimes called the trace buffer.

Trace Macro

A macro that will provide trace information from emulator data. Since this is a software trace, the macro must be added to code, the code must be recompiled or reassembled, and the target device must be programmed with this code before trace will work.

Trigger Output

Trigger output refers to an emulator output signal that can be generated at any address or address range, and is independent of the trace and breakpoint settings. Any number of trigger output points can be set.

Trigraphs

Three-character sequences, all starting with ??, that are defined by ISO C as replacements for single characters.

U

Unassigned Section

A section which has not been assigned to a specific target memory block in the linker command file. The linker must find a target memory block in which to allocate an unassigned section.

Uninitialized Data

Data which is defined without an initial value. In C,

```
int myVar;
```

defines a variable which will reside in an uninitialized data section.

Upload

The Upload function transfers data from a tool, such as an emulator or programmer, to the host PC or from the target board to the emulator.

USB

Universal Serial Bus. An external peripheral interface standard for communication between a computer and external peripherals over a cable using bi-serial transmission. USB 1.0/1.1 supports data transfer rates of 12 Mbps. Also referred to as high-speed USB, USB 2.0 supports data rates up to 480 Mbps.

© 2012-2018 Microchip Technology Inc.

V

Vector

The memory locations that an application will jump to when either a Reset or interrupt occurs.

Volatile

A variable qualifier which prevents the compiler applying optimizations that affect how the variable is accessed in memory.

W

Warning

MPLAB IDE – An alert that is provided to warn you of a situation that would cause physical damage to a device, software file, or equipment.

16-bit assembler/compiler – Warnings report conditions that can indicate a problem, but do not halt processing. In MPLAB C30, warning messages report the source file name and line number, but include the text '`warning`:' to distinguish them from error messages.

Watch Variable

A variable that you can monitor during a debugging session in a Watch window.

Watch Window

Watch windows contain a list of watch variables that are updated at each breakpoint.

Watchdog Timer (WDT)

A timer on a PIC microcontroller that resets the processor after a selectable length of time. The WDT is enabled or disabled and set up using Configuration bits.

Workbook

For MPLAB SIM stimulator, a setup for generation of SCL stimulus.

NOTES:

© 2012-2018 Microchip Technology Inc.

Index

Symbols

_ assembly label character 151, 186
__at address construct, see absolute variables/functions
__bank qualifier... 109
__bit type 96
__builtin_software_breakpoint builtin......266, 267, 268
__Bxxxx type symbols 178
__compiled qualifier 124
__conditional_software_breakpoint macro............. 268
__control qualifier.. 92
__DATABANK macro.. 162
__DATE__ macro 162
__DEBUG macro 224, 268, 269
__debug_break macro 269
__delay_ms macro.. 269
__delay_us macro... 269
__delaywdt_ms macro 269
__delaywdt_us macro 269
__eeprom qualifier 110, 118
__EEPROM_DATA macro.............................118, 270
__EXTMEM macro.. 162
__far qualifier 110
__FILE__ macro 162
__FLASHTYPE macro 162
__fpnormalize function.. 270
__Hxxxx type symbols 178
__interrupt qualifier 132
__LINE__ macro 162
__LOG macro (REAL ICE)...................................... 94
__Lxxxx type symbols... 178
__MPLAB_ICD__ macro....................................... 161
__near qualifier 110, 117
__nonreentrant qualifier 114, 124
__OPTIMIZE_SPEED__ macro 163
__osccal_val function.. 271
__persistent qualifier..............................111, 143, 144
__PICC__ macro 163
__PICCPRO__ macro... 163
__ram pointer-target specifier 102
__reentrant qualifier 114, 124
__RESETBITS_ADDR macro 163
__rom pointer-target specifier 102
__section qualifier 111, 175
__software qualifier 124
__TRACE macro (REAL ICE) 94
__XC macro 163
__XC8 macro 163
__XC8_VERSION macro...................................... 163
BANKBITS macro 161
_Bool type 96
COMMON macro 161
_delay function 32, 272
_EEPROM_INT macro.. 161
_EEPROMSIZE macro...........................118, 119, 161
_ERRATA_TYPES macro....................................... 62
_FLASH_ERASE_SIZE macro 161
_FLASH_WRITE_SIZE macro 161
GPRBITS macro 161
GPRCOUNT macro... 161
_HAS_OSCVAL macro 161
_HTC_EDITION_ macro 162
_PIC12 macro 162
_PIC14E macro... 162
_PIC18 macro 162
PROGMEM macro 162
_RAMSIZE macro 162
_READ_OSCCAL_DATA macro............................. 93
_ROMSIZE macro.. 162
;; macro comment suppress character.................. 200
? assembly label character 186
??nnnn type symbols 186, 200
. (dot) linker load address character...................... 222
.h files, see header files
.hxl files, see hexmate log files
.i files, see preprocessed files
.map files, see map files
.s files, see assembly files
.sx files, see assembly files
xxxx@yyyy type symbols 152
@ command file specifier................................ 46, 219
/ psect address symbol 222
& macro concatenation character 184, 199
&& bitwise AND operator 184
# preprocessor operator.. 160
## preprocessor operator...................................... 160
#pragma
    addrqual 165
    inline... 165
    interrupt_level 166
    intrinsic... 165
    printf_check.. 166
    regsused 167
    switch 167
% macro argument prefix 200
% message format placeholder character................ 55
<> macro argument characters 184, 200
$ assembly label character 186
$ location counter symbol 186

Numerics

0b binary radix specifier 106

A

abs PSECT flag 156, 193
ABS1 class 175
absolute functions 126
absolute object files 221
absolute psects 156, 193, 195
absolute variables 116, 198
activation, see compiler installation & activation
addressable unit, see delta PSECT flag
addrqual pragma directive 165
advisory messages 54
alignment
  of HEX file records 60
  of psects, see reloc PSECT flag
anonymous structures and unions 100
arg nodes 214
arrays
  and pointer sizes 101
  as dummy pointer targets 105
  maximum size of 113
ASCII characters 184
  extended 107
asm C statement 150
asmfile option 74
ASMOPT control 203
assembler controls 203–205
assembler directives 190–202
assembler macros 199
  disabling in listing 204
  expanding in listings 203
  repeat with argument 201
  repeating 201
  suppressing comments 200
  unnamed 201
assembler optimizations 206
assembler optimizer
  and list files 207
  enabling 203
  saving state 203
  selectively disabling 203
  stack depth considerations 213
assembler-generated symbols 186
assembly code
  called by C 148
  generating from C 69
  interaction with C 150
  mixing with C 25, 148
  stack overflow 43
  writing 25–27
assembly constants 185
assembly files 148
assembly language
  absolute variables 198
  access operands 180
  accessing C objects 150
  character set 184
  comments 184, 185
  common errors 27, 44
  conditional 199
  data types 186
  delimiters 184
  destination operands 180
  differences in 180
  expressions 188
  include files 204
  initializing locations 197, 198
  label scope 187, 191
  labels 184, 187
  location counter 186
  operators 188
  pseudo-ops 190
  registers 27, 152, 187
  relative jumps 186
  repeating instructions 201
  reserving memory 156, 198
  statement formats 184
  strings 185
  volatile objects 185
assembly list files 37, 52, 207–213
  blank lines 205
  content 207
  excluding conditional code 204
  format 204
  including conditional code 203
  macros 203, 204
  new page 205
  titles and subtitles 205
assembly variables
  C equivalent 150
  defining 198
  global 191
  identifiers 186
  initialized 197
  reserving memory 198
  type 186
assert function 273
auto variables 211
  initialization 143
  memory allocation 114
  size limits 115
AVR devices 86

B

banked memory 36, 112, 196
  linear addressing 37, 113, 117
  number of available banks 161
  qualifiers for 109
  selection in assembly code 26, 149, 181, 202
BANKMASK macro 26, 149
BANKSEL directive 26, 149
BANKx class 175
base __interrupt argument 133
base specifier, see radix specifier
biased exponent 98
big endian format 236
BIGRAM class 175
binary constants
  assembly 185
  C code 106
bit access of variables 22
bit data types 95

© 2012-2018 Microchip Technology Inc.

bit instructions 90, 96
bit PSECT flag 193
bit variables 117
bitclr macro 91
bit-fields 22, 99
bitset macro 91
bitwise complement operator 120
blinking an LED 42
bootloaders 29, 240
    requirements 142
bss psect 113, 173
btemp variables 122
building projects 49
byte addressable memory 193

C

C identifiers 95
C standard
    conformance 83
    divergence 83
C standard libraries 146, 251
C90 standard 45
call depth, see stack depth
call graph 87, 140, 211–213
call graph critical path 213
call graph graphs 214
call graph table 211
call grpah arg nodes 214
call instruction 183
casting 17, 120
CCI, see Common C Interface
character constants
    assembly 185
    in C 107
checksum psect 171
checksums 58, 236
cinit psect 171
Clang front end 70
class PSECT flag 193
classes
    linker 174
classes, see linker classes
clearing variables 144
clrwdt instruction 32
CLRWDT macro 274
CODE class 174
COFF files 52, 72
command files 46
    linker 219
command-line driver, see driver
commands, see building projects, command-line
Common C Interface 83
COMMON class 175
common memory 110, 112
compilation
    incremental builds 49
    make files, see make files
    sequence 48–49
    to assembly file 69
    to object file 68
    to preprocessed file 68
compiled specifier 124
compiled stack 87, 114, 140
compiler applications 48
compiler errors
    format 54
    list of 281–412
compiler installation & activation 13–14
compiler operating mode 11, 33
compiler options, see driver options
compiler selection 16
compiler-generated code 37
compiler-generated psects 170–173
COND control 203
conditional assembly 199
CONFIG class 175
config pragma 88
config psect 171
configuration bits 88
CONST class 174
const objects
    initialization 108
    storage location 115
const psect 171
const qualifier 108
constants
    assembly 185
    C specifiers 106
    character 107
    string, see string literals 107
context switch code 24, 36, 126, 138, 167
conversion between types 120
crystal frequency 269
cstack psect 173
Customer Notification Service 8
Customer Support 8

D

DABS directive 198
data memory 112, 173, 193, 196
data pointers 101
data psect 113, 173
data stack 87, 114
data types
    assembly 186
    floating point .... ??–99
    integer 95
    size of 95, 99
DB directive 197
DDW directive 198
debuggers 29, 60
Debugging Information 72
default psect 189
delay routine 32, 269
delaywdt function 272
delta PSECT flag 149, 193, 219
dependency files 76
device family macro 161
device macros 162
device selection 60, 222
device support 37, 69, 86
DI macro 274

diagnostic files 52
directives, see assembler directives
disabling interrupts 30, 139
Documentation
  Conventions 6
  Layout 5
double data type 82, 97
driver 45–82
  command format 46
  help on options 69
  input files 46
  long command lines 46
  single step compilation 49
driver option
  addrqual 58, 109, 110, 165
  ansi 70
  asmfile 74
  c 49, 68
  checksum 58
  codeoffset 29, 59, 136
  config 59
  cpu 60, 226
  D 76
  debugger 60
  default-config-bits 59
  dfp 60
  download 60
  download-hex 60
  E 68, 159
  emi 61
  errata 61
  ext 70
  fill 58, 79
  g 72
  help 69
  I 81
  instrument-functions 72, 94
  ivt 131
  L 81
  l 78
  local 74
  M 76
  max-errors 53, 71, 226
  maxichip 62
  MD 77
  MF 77
  MM 77
  MMD 77
  no-data-init 143
  nodefaultlibs 79
  nofallback 75
  no-keep-startup 63
  nostartfiles 79
  nostdinc 81
  nostdlib 79
  O 73
  o 52, 68
  O0 73
  O1 73
  O2 73
  O3 73
  Og 73
  Os 74
  osccal 63, 93
  oscval 63
  pedantic 71
  ram 63, 110
  reserve 59, 64
  resetbits 64, 145
  rom 64
  S 69
  save-resetbits 64
  save-temps 49, 72
  serial 79
  short-double 82, 97
  short-float 82, 97
  shroud 64
  signed-char 70
  stack 65, 88, 114, 124, 140
  stackcall 66, 129
  std 70
  target-help 37, 69
  U 77
  undefints 67, 131
  unsigned-char 70
  v 69
  version 69
  w 71
  Wa 78
  warn 55, 71
  Wl 79, 225, 227
  Wp 77
  x 69
  Xassembler 78
  Xclang 77
  Xl 79
  Xp1 77
  Xparser 77
  Xpreprocessor 77
driver options 16, 46, 56–82
DS directive 198
DW directive 197
dynamic memory allocation 119

E

EEDATA class 175
EEPROM data 118
EEPROM memory
  initializing 118
  reading 119
  writing 119
eeprom psect 171
eeprom_data psect 171
eeprom_read function 119
eeprom_write function 119
EI macro 274
ELF files 52, 72
ELSE directive 198
ELSIF directive 198
enabling interrupts 139
END directive 191

© 2012-2018 Microchip Technology Inc.

end_init psect 171
endianism 95, 97
ENDIF directive 198
ENDM directive 199
ENTRY class 174
entry point 191
entry__ type symbols 151
EQU directive 184, 187, 197
equating assembly symbols 197
errata workarounds 61
ERRATA_4000_BOUNDARY macro 161
errata.h header file 62
error counter 53
error files 220
error messages 41, 53–55
    format 54
    list of 281–412
    location 41
    maximum number of 71
eval_poly function 275
EXPAND control 200, 203
exponent 97
extended character set 107
extended instruction set 86
external functions 124
external memory 110
EXTRN directive 197

F

F constant suffix 107
fatal error messages 54
fcall pseudo instruction 26, 183
file extensions 47
file types
    command 46, 219
    input 46
    object, see object files
    preprocessed 68
    symbol 220
filling unused memory 30, 58
fixup overflow errors 44, 224, 225
Fletcher’s checksum algorithm 59, 237
float data type 82, 97
floating-point constant suffixes 107
floating-point types 82, 97–99
    biased exponent 98
    exponent 98
    relaxed 97, 270
    rounding 98
fpbase symbol 104
function
    calling convention 129
    duplication 140, 140–141
    parameters 114, 127, 128, 148
    pointers 104
    prototypes 177, 202
    return values 128
    signatures 177, 202
    size limits 127
    specifiers 123
    stack usage 129

functions
    absolute 126
    external 124
    inline 123
    interrupt, see interrupt functions
    location of 38
    reentrant 124
    size of 23
    static 123
    written in assembler 148

G

get_cal_data function 276
GIE SFR bit 139
glitches on ports 28
GLOBAL directive 25, 149, 187, 191
global PSECT flag 193
goto instruction 183

H

hardware errata 61
hardware multiply instructions 91
hardware stack 87
header files 147
    device 86
help! 13, 69
hex files 47, 233
    address alignment 60
    addresses 193
    data record 60, 236
    embedding serial numbers 241
    embedding strings 242
    extended address record 240
    format 240
    merging 29, 233
    multiple 220
    record length 60, 240
    statistics 240
hexadecimal constants
    assembly 185
hexmate application 233
hexmate log files 234, 240
hexmate options 235–242
high_priority __interrupt argument 132
hlink application 217
HTC_ERR_FORMAT environment variable 54
HTC_MSG_FORMAT environment variable 54
HTC_WARN_FORMAT environment variable 54

I

ICD, see debuggers
ID Locations 89
idata psect 171
identifiers
    assembly 186
    C 95
IDLOC class 175
idloc psect 171
IEEE floating-point format, see floating-point types . 97
IF directive 198
implementation-defined behaviour 85

INCLUDE control.. 204
include files, see header files
incremental builds 49
INHX32 hex files 235, 240
INHX8M hex files.. 235, 240
init psect 171
initialized variables 143
inline functions 123
inline pragma directive 165
inline PSECT flag 193
inline qualifier 94
input files 46
installation, see compiler installation & activation
instruction set 86
instrumented trace 93
intcode psect 171
integer constants.. 106
integer suffixes 106
integral promotion 120
Intel HEX files, see hex files
intentry psect.. 171
intermediate files 46, 48
 assembly.. 50
Internet Address 7
interrupt
 priority 132
 sources 132
 vectors 59, 136
interrupt functions
 context switching.................................. 138, 167
 moving 59, 126
 optimizations 36
interrupt_level pragma directive 166
interrupts 24
 context switching.................................24, 36, 126
 disabling 30, 139
 enabling 139
 unused vectors.. 67
intrinsic pragma directive....................................... 165
IRP directive.. 201
IRPC directive 201
irq __interrupt argument.. 133
ivt0xn psect 172
IVTBASE register 62

J

jmp_tab psect... 172

K

keep PSECT flag... 194

L

L constant suffix 106
labels, assembly... 184, 187
LED, blinking 42
lib directory 51
LIBR application, see librarian
librarian 147, 177, 232
libraries.. 51
 adding files to 232
 deleting modules from.................................... 232
 linking 217, 223
 object.. 225, 227
 p-code 51
 replacing modules in 147, 177
 search order 46
 user-defined 147
library functions 251
limit PSECT flag 194, 223
limits.h header file 96
linear data memory.................................. 37, 112, 117
link addresses 222
linker classes.....................................63, 64, 174, 193
 address limit 223
 address ranges 219
 adjusting... 63, 64
 boundary argument... 223
linker options 217, 217–224, 227
 viewing 227
linker scripts 170
linker-defined symbols... 178
linking projects... 170
LIST control 204
LITE mode, see compiler operating mode
little endian format 95, 97, 236
ljmp pseudo instruction.................................... 26, 183
load addresses 222
LOCAL directive 186
local PSECT flag 194
location counter 186, 196
long double types 97
low_priority__interrupt argument........................... 132
ltemp variables 122

M

Macro 76
macro concatenation 160
MACRO directive... 184, 199
main function 142
main-line code 132
maintext psect 125, 172
make files 46, 49
managed stack 129
mantissa... 97
map files 52, 221, 226–230
MDF.. 53
mediumconst psect 172
memory
 banks, see banked memory
 common 110, 112
 data 112, 173, 193, 196
 linear data 112
 pages 181, 183, 196, 202
 remaining 39
 reserving 21, 38, 59
 specifying ranges 219
 summary 39
 unbanked 112
memory allocation 112
 data memory 112
 dynamic.. 119
 function code.. 125

© 2012-2018 Microchip Technology Inc.

non-auto variables 112
program memory 115
memory models 119
merge PSECT flag 194, 196
merging hex files... 235
message description files....................................... 53
messages...53–55
advisory 54
disabling..53, 55, 168
error, see error messages
fatal error 54
format... 54
ID number 53
list of 281–412
meaning 41
placeholders in.. 55
types of 54
warning level of... 55
messaging system 53–55
default warning level 55
environment variables...................................... 54
message count 53
Microchip Internet Web Site 7
modules
generating... 68
movfw pseudo instruction 182
MPLAB IDE
compiler selection 16
search path 81
multi-byte SFRs 90
multiply instructions.. 91

N

native trace 93
NDEBUG macro.. 268
NOCOND control 204
noexec PSECT flag... 194
NOEXPAND control 204
NOLIST control 204
nonreentrant specifier 124
non-volatile RAM... 109
NOP function... 276
NOP macro 276
null macro operator 200
NULL pointers 104, 106
nv psect...113, 173

O

object code version number 226
object file libraries 225
object files 50, 68
absolute 221
contents 225
relocatable 225
symbol only.. 220
OBJTOHEX application 233
operator
cast 17
sizeof 84
OPT control directive 203
optim PSECT flag 195
optimizations 157
causing corruption... 30
code size... 34
data size.. 35
faster code 35
interrupt functions 36
option instruction 92
options, see driver options
ORG directive... 156, 196
osccal_val function 93
oscillator calibration constants 31, 93, 144
preserving 93
output files.. 68
names of 52
overlaid memory areas... 221
overlaid psects 195
ovrld PSECT flag.. 156, 195

P

PAGE control 205
paged memory 181, 183, 196, 202
selection in assembly code 26
PAGESEL directive 26, 181, 202
parameters, see function, parameters
PATH environment variable 47
p-code files.. 46
phase errors 193
pointer
comparisons.. 105
definitions.. 101
encoding 103
qualifiers.. 101
targets 101
types 101
pointer reference graph................................ 103, 210
pointers 101–105, 112
assigning dummy targets 105
assigning integers 105
data 101
function 104
powerup label... 143
powerup psect.. 145, 172
powerup routine 51, 145
powerup.S 145
pragma directives... 165
preprocessed files 68
preprocessing... 159
preprocessor
macro concatenation...................................... 160
types 160
preprocessor directives 159–160
in assembly files.. 184
preprocessor macros
containing strings 76
predefined 161
printf function.. 31, 146
format checking... 166
printf_check pragma directive 166
PRO mode, see compiler operating mode
processor selection 60, 222
program counter 186

program memory 193
  absolute variables 108, 117
project name 52
projects 49
psect
  absolute 156
  bss 113, 173
  checksum 171
  cinit 171
  config 171
  const 171
  cstack 173
  data 113, 173
  default 189
  eeprom 171
  eeprom_data 171
  end_init 171
  grouping 193, 194
  idata 171
  idloc 171
  init 171
  intcode 171
  intentry 171
  ivt0xn 172
  jmp_tab 172
  maintext 125, 172
  mediumconst 172
  powerup 145, 172
  reset_vec 172
  reset_wrap 172
  smallconst 172
  stack 173
  strings 172
  stringtext 172
  temp 173
  textn 125, 173
  xxx_text 126, 173
psect association 193
PSECT directive 27, 192
PSECT flags 193–196
psects 225
  absolute 193, 195
  alignment of, see reloc PSECT flag
  class 219, 223
  compiler-generated 170–173
  delta value 219
  function 125
  linking 225
  maximum address 194
  maximum size 196
  overlaid 195
  page boundaries and 196
  placing in memory 193, 222
  placing with others 196
  specifying addresses 219, 222
pseudo-ops, see assembler directives
pure PSECT flag 195
putch function 31
putchar function 277

Q

qualifier 110
  __bank 109
  __compiled 124
  __control 92
  __eeprom 110, 118
  __far 110
  __near 110, 117
  __nonreentrant 114, 124
  __persistent 111, 143, 144
  __reentrant 114, 124
  __section 111, 175
  __software 124
  const 102, 108
  special 109
  volatile 28, 30, 109, 139, 156, 185
qualifiers 108–111
  and structures 99

R

radix specifiers
  assembly 185
  C code 106
RAM banks, see banked memory
RAM class 175
reading timer registers 90
Reading, Recommended 7
Readme 7
read-modify-write problems 43
read-only variables 108
READTIMERx macro 278
REAL ICE In-Circuit Emulator 93
REALICE, see debuggers
recursion 84
reentrancy 84
reentrant functions 87, 124, 140
reentrant specifier 124
registers
  allocation to 119
  in assembly code 187
  special function 187
  temporary 122
  used by functions 38, 122, 150
regsused pragma directive 167
relative branch instructions 184
relative jump 186
relaxed floating-point rules 97, 270
reloc PSECT flag 195
relocatable object files 225
replacing library modules 177
REPT directive 201
reserving memory 38, 59
reset 111
  code executed after 30, 51, 145
  determining cause 145
  vector 59
RESET macro 278
reset_vec label 143
reset_vec psect 172
reset_wrap psect 172

© 2012-2018 Microchip Technology Inc.

retfie instruction........ 183
retlw instruction........ 116
return values, see function, return values
returning from interrupts........ 183
rotate operator........ 32, 121
runtime startup code........ 142, 171, 225
 preserving variables........ 111
 variable initialization........ 143

S

safeguarding code........ 30, 64
scale value........ 193
sections, see psects
segment selector........ 220
serial numbers........ 241
 embedding........ 241
SET directive........ 184, 197
SFRs........ 90
 accessing in assembly........ 152
SFRx class........ 175
shadow registers........ 138, 183
sign bit........ 97
SIGNAT directive........ 149, 177, 202
signatures........ 177, 202
signedness of plain char........ 70
silicon errata........ 61
single step compilation........ 49
size limits........ 36
 const variables........ 116
 non-auto variables........ 113
size of types........ 82, 95, 99
size PSECT flag........ 196
sizeof operator........ 84
SLEEP macro........ 279
smallconst psect........ 172
software breakpoint........ 268, 269
software specifier........ 124
software stack........ 88, 114
sources directory........ 145
SPACE control........ 205
space PSECT flag........ 196
special function registers, see SFRs
special type qualifiers........ 109
specifiers, see qualifiers
sports cars........ 186
stack
 compiled........ 87, 114, 140
 data........ 87, 114
 hardware........ 87
 managed........ 129
 software........ 88, 114
stack depth........ 212
stack overflow........ 43, 87
stack pointer........ 88
stack psect........ 87, 173
standard library files
start label........ 143, 145
start record........ 191
start_initialization........ 143
startup module........ 51
startup.s, see startup module
static functions........ 123, 151
static variables........ 143, 151
STATUS register, preserving........ 145
STD mode, see compiler operating mode
STRCODE class........ 174
STRING class........ 174
string literals........ 107
 assembly........ 185
 packing........ 242
 storage location........ 108, 242
 type of........ 107
strings psect........ 172
stringtext psect........ 172
struct types, see structures
structure bit-fields........ 99
structure qualifiers........ 99
structures........ 99
 anonymous........ 100
 bit-fields in........ 22, 99
 maximum size of........ 113
SUBTITLE control........ 205
supported devices, see device, support
switch pragma directive........ 167
switch statement........ 167
switch statements........ 121
symbol files........ 220, 221, 222
symbol table........ 215
symbol tables........ 223
 sorting........ 221
symbol-only object file........ 220
symbols
 assembler-generated........ 186
 linker defined........ 178
 undefined........ 223

T

target device, see device, selection
temp psect........ 173
temporary registers........ 122
textn psect........ 125, 173
TITLE control........ 205
trace features........ 93
translation units........ 68
tris instruction........ 92
ttemp variables........ 122
type conversions........ 17, 120
types, see data types

U

U constant suffix........ 106
unbanked memory, see memory, common
undefined symbols........ 156
 adding........ 223
uninitialized variables........ 144
unions
 anonymous........ 100
 qualifiers........ 99
unnamed bit-fields........ 100
unnamed psect........ 189
unnamed structure members........ 100
unused interrupt vectors........ 67

unused memory 39
    filling 58
unused variables 156
    removing 109
USB 442

V

value 161
variables
    absolute 116
    accessing from assembler 150
    in assembly 198
    in program memory 21, 115
    in registers 119
    initialization 143
    location of 38
    maximum size of 36
    sizes 95, 99
verbose output 69
volatile qualifier 28, 30, 109, 139, 156, 185

W

warning level 55
    setting 223
warning messages 41, 54
    disabling 168
    location 41
    suppressing 42, 223
Warranty Registration 7
watch dog timer 42
Watchdog Timer 443
with PSECT flag 196
withtotal 196
word addressable memory 193
word boundaries 195
WRITETIMERx macro 279
wtemp variables 122
WWW Address 7

X

xc.h header file 86
xc.inc assembly header file 148, 152, 153, 187
xc8-cc application 46
xtal frequency 269

© 2012-2018 Microchip Technology Inc.

Worldwide Sales and Service

AMERICAS

Corporate Office
2355 West Chandler Blvd.
Chandler, AZ 85224-6199
Tel: 480-792-7200
Fax: 480-792-7277
Technical Support:
http://www.microchip.com/support
Web Address:
www.microchip.com

Atlanta
Duluth, GA
Tel: 678-957-9614
Fax: 678-957-1455

Austin, TX
Tel: 512-257-3370

Boston
Westborough, MA
Tel: 774-760-0087
Fax: 774-760-0088

Chicago
Itasca, IL
Tel: 630-285-0071
Fax: 630-285-0075

Dallas
Addison, TX
Tel: 972-818-7423
Fax: 972-818-2924

Detroit
Novi, MI
Tel: 248-848-4000

Houston, TX
Tel: 281-894-5983

Indianapolis
Noblesville, IN
Tel: 317-773-8323
Fax: 317-773-5453
Tel: 317-536-2380

Los Angeles
Mission Viejo, CA
Tel: 949-462-9523
Fax: 949-462-9608
Tel: 951-273-7800

Raleigh, NC
Tel: 919-844-7510

New York, NY
Tel: 631-435-6000

San Jose, CA
Tel: 408-735-9110
Tel: 408-436-4270

Canada - Toronto
Tel: 905-695-1980
Fax: 905-695-2078

ASIA/PACIFIC

Asia Pacific Office
Suites 3707-14, 37th Floor
Tower 6, The Gateway
Harbour City, Kowloon

Hong Kong
Tel: 852-2943-5100
Fax: 852-2401-3431

Australia - Sydney
Tel: 61-2-9868-6733
Fax: 61-2-9868-6755

China - Beijing
Tel: 86-10-8569-7000
Fax: 86-10-8528-2104

China - Chengdu
Tel: 86-28-8665-5511
Fax: 86-28-8665-7889

China - Chongqing
Tel: 86-23-8980-9588
Fax: 86-23-8980-9500

China - Dongguan
Tel: 86-769-8702-9880

China - Guangzhou
Tel: 86-20-8755-8029

China - Hangzhou
Tel: 86-571-8792-8115
Fax: 86-571-8792-8116

China - Hong Kong SAR
Tel: 852-2943-5100
Fax: 852-2401-3431

China - Nanjing
Tel: 86-25-8473-2460
Fax: 86-25-8473-2470

China - Qingdao
Tel: 86-532-8502-7355
Fax: 86-532-8502-7205

China - Shanghai
Tel: 86-21-3326-8000
Fax: 86-21-3326-8021

China - Shenyang
Tel: 86-24-2334-2829
Fax: 86-24-2334-2393

China - Shenzhen
Tel: 86-755-8864-2200
Fax: 86-755-8203-1760

China - Wuhan
Tel: 86-27-5980-5300
Fax: 86-27-5980-5118

China - Xian
Tel: 86-29-8833-7252
Fax: 86-29-8833-7256

ASIA/PACIFIC

China - Xiamen
Tel: 86-592-2388138
Fax: 86-592-2388130

China - Zhuhai
Tel: 86-756-3210040
Fax: 86-756-3210049

India - Bangalore
Tel: 91-80-3090-4444
Fax: 91-80-3090-4123

India - New Delhi
Tel: 91-11-4160-8631
Fax: 91-11-4160-8632

India - Pune
Tel: 91-20-3019-1500

Japan - Osaka
Tel: 81-6-6152-7160
Fax: 81-6-6152-9310

Japan - Tokyo
Tel: 81-3-6880- 3770
Fax: 81-3-6880-3771

Korea - Daegu
Tel: 82-53-744-4301
Fax: 82-53-744-4302

Korea - Seoul
Tel: 82-2-554-7200
Fax: 82-2-558-5932 or
82-2-558-5934

Malaysia - Kuala Lumpur
Tel: 60-3-6201-9857
Fax: 60-3-6201-9859

Malaysia - Penang
Tel: 60-4-227-8870
Fax: 60-4-227-4068

Philippines - Manila
Tel: 63-2-634-9065
Fax: 63-2-634-9069

Singapore
Tel: 65-6334-8870
Fax: 65-6334-8850

Taiwan - Hsin Chu
Tel: 886-3-5778-366
Fax: 886-3-5770-955

Taiwan - Kaohsiung
Tel: 886-7-213-7830

Taiwan - Taipei
Tel: 886-2-2508-8600
Fax: 886-2-2508-0102

Thailand - Bangkok
Tel: 66-2-694-1351
Fax: 66-2-694-1350

EUROPE

Austria - Wels
Tel: 43-7242-2244-39
Fax: 43-7242-2244-393

Denmark - Copenhagen
Tel: 45-4450-2828
Fax: 45-4485-2829

Finland - Espoo
Tel: 358-9-4520-820

France - Paris
Tel: 33-1-69-53-63-20
Fax: 33-1-69-30-90-79

France - Saint Cloud
Tel: 33-1-30-60-70-00

Germany - Garching
Tel: 49-8931-9700
Germany - Haan
Tel: 49-2129-3766400

Germany - Heilbronn
Tel: 49-7131-67-3636

Germany - Karlsruhe
Tel: 49-721-625370

Germany - Munich
Tel: 49-89-627-144-0
Fax: 49-89-627-144-44

Germany - Rosenheim
Tel: 49-8031-354-560

Israel - Ra'anana
Tel: 972-9-744-7705

Italy - Milan
Tel: 39-0331-742611
Fax: 39-0331-466781

Italy - Padova
Tel: 39-049-7625286

Netherlands - Drunen
Tel: 31-416-690399
Fax: 31-416-690340

Norway - Trondheim
Tel: 47-7289-7561

Poland - Warsaw
Tel: 48-22-3325737

Romania - Bucharest
Tel: 40-21-407-87-50

Spain - Madrid
Tel: 34-91-708-08-90
Fax: 34-91-708-08-91

Sweden - Gothenberg
Tel: 46-31-704-60-40

Sweden - Stockholm
Tel: 46-8-5090-4654

UK - Wokingham
Tel: 44-118-921-5800
Fax: 44-118-921-5820

© 2012-2018 Microchip Technology Inc.

11/07/16