MPASM™ Assembler,
MPLINK™ Object Linker,
MPLIB™ Object Librarian
User’s Guide
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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 may 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 on-line help. Select the Help menu, and then Topics to open a list of available on-line help files.

INTRODUCTION

This chapter contains general information that will be useful to know before using Assembler/Linker/Librarian User’s Guide. Items discussed include:

• Document Layout
• Conventions Used
• Recommended Reading
• The Microchip Web Site
• myMicrochip Personalized Notification Service
• Customer Support

DOCUMENT LAYOUT

This document describes how to use the MPASM assembler, the MPLINK object linker, and the MPLIB object librarian to develop code for PIC® microcontroller (MCU) applications. All of these tools can work within the MPLAB® Integrated Development Environment (IDE). For a detailed discussion about basic MPLAB IDE functions, refer to MPLAB IDE documentation.

PIC1X MCU Language Tools and MPLAB X IDE – provides an overview of how to use all of the tools in this manual together under the MPLAB X IDE. This is how most developers will use these tools.

PIC1X MCU Language Tools and MPLAB IDE v.8 – provides an overview of how to use all of the tools in this manual together under the MPLAB IDE v.8.
Part 1 – “MPASM Assembler”
- Chapter 1. “MPASM Assembler Overview” – describes what the MPASM assembler is, what it does and how it works with other tools. Also, gives an overview of operation and discusses input/output files.
- Chapter 2. “Assembler Interfaces” – reviews how to use the MPASM assembler with MPLAB IDE and describes how to use the assembler on the command line or in a Windows shell interface.
- Chapter 4. “Directives” – lists each MPASM assembler directive alphabetically and describes the directive in detail, with examples.
- Chapter 5. “Assembler Examples, Tips and Tricks” – provides examples of how to use the MPASM assembler directives together in applications.
- Chapter 6. “Relocatable Objects” – describes how to use the MPASM assembler in conjunction with MPLINK object linker.
- Chapter 7. “Macro Language” – describes how to use the MPASM assembler’s built-in macro processor.
- Chapter 8. “Errors, Warnings, Messages, and Limitations” – contains a descriptive list of the errors, warnings, and messages generated by the MPASM assembler, as well as tool limitations.

Part 2 – “MPLINK Object Linker”
- Chapter 9. “MPLINK Linker Overview” – describes what the MPLINK object linker is, what it does and how it works with other tools. Also, gives an overview of operation and discusses input/output files.
- Chapter 10. “Linker Interfaces” – reviews how to use the MPLINK linker with MPLAB IDE and describes how to use the linker on the command line.
- Chapter 11. “Linker Scripts” – discusses how to generate and use linker scripts to control linker operation.
- Chapter 13. “Sample Applications” – provides examples of how to use the linker to create applications.
  - Sample Application 1 – explains how to find and use template files and when to modify the generic linker script file.
  - Sample Application 2 – explains how to place program code in different memory regions, how to place data tables in ROM memory and how to set configuration bits in C.
  - Sample Application 3 – explains how to partition memory for a boot loader and how to compile code that will be loaded into external RAM and executed.
  - Sample Application 4 – explains how to create new linker script memory section, how to declare external memory through #pragma code directive, and how to access external memories using C pointers.
- Chapter 14. “Errors, Warnings and Common Problems” – contains a descriptive list of the errors and warnings generated by the MPLINK linker, as well as common problems and tool limitations.
Part 3 – “MPLIB Object Librarian”
- Chapter 15. “MPLIB Librarian Overview” – describes what the MPLIB object librarian is, what it does and how it works with other tools. Also, gives an overview of operation and discusses input/output files.
- Chapter 16. “Librarian Interfaces” – reviews how to use the MPLIB librarian with MPLAB IDE and describes how to use the librarian on the command line.
- Chapter 17. “Errors” – contains a descriptive list of the errors generated by the MPLIB librarian.

Part 4 – “Utilities”
- Chapter 18. “Utilities Overview and Usage” – lists the available utilities and describes their usage.
- Chapter 19. “Errors and Warnings” – contains a descriptive list of the errors generated by the utilities.

Part 5 – “Appendices”
- Appendix A. “Instruction Sets” – lists PIC MCU device instruction sets.
- Appendix B. “Useful Tables” – provides some useful tables for code development.
  - ASCII Character Set – lists the ASCII Character Set.
  - Hexadecimal to Decimal Conversions – shows how to convert from hexadecimal to decimal numbers.
CONVENTIONS USED

The following conventions may appear in this documentation:

### DOCUMENTATION CONVENTIONS

<table>
<thead>
<tr>
<th>Description</th>
<th>Represents</th>
<th>Examples</th>
</tr>
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<td></td>
</tr>
<tr>
<td>Italic characters</td>
<td>Referenced books</td>
<td>MPLAB IDE User's Guide</td>
</tr>
<tr>
<td></td>
<td>Emphasized text</td>
<td>...is the only compiler...</td>
</tr>
<tr>
<td>Initial caps</td>
<td>A window</td>
<td>the Output window</td>
</tr>
<tr>
<td></td>
<td>A dialog</td>
<td>the Settings dialog</td>
</tr>
<tr>
<td></td>
<td>A menu selection</td>
<td>select Enable Programmer</td>
</tr>
<tr>
<td>Quotes</td>
<td>A field name in a window or dialog</td>
<td>“Save project before build”</td>
</tr>
<tr>
<td>Underlined, italic text with right angle bracket</td>
<td>A menu path</td>
<td>File&gt;Save</td>
</tr>
<tr>
<td><strong>Bold characters</strong></td>
<td>A dialog button</td>
<td>Click OK</td>
</tr>
<tr>
<td></td>
<td>A tab</td>
<td>Click the Power tab</td>
</tr>
<tr>
<td><strong>Text in angle brackets &lt; &gt;</strong></td>
<td>A key on the keyboard</td>
<td>Press &lt;Enter&gt;, &lt;F1&gt;</td>
</tr>
<tr>
<td><strong>Courier font:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plain Courier</td>
<td>Sample source code</td>
<td>#define START</td>
</tr>
<tr>
<td></td>
<td>Filenames</td>
<td>autoexec.bat</td>
</tr>
<tr>
<td></td>
<td>File paths</td>
<td>c:\mcc18\h</td>
</tr>
<tr>
<td></td>
<td>Keywords</td>
<td>_asm, _endasm, static</td>
</tr>
<tr>
<td></td>
<td>Command-line options</td>
<td>-Opa+, -Opa-</td>
</tr>
<tr>
<td></td>
<td>Bit values</td>
<td>0, 1</td>
</tr>
<tr>
<td></td>
<td>Constants</td>
<td>0xFF, ‘A’</td>
</tr>
<tr>
<td>Italic Courier</td>
<td>A variable argument</td>
<td>file.o, where file can be any valid filename</td>
</tr>
<tr>
<td><strong>Square brackets [ ]</strong></td>
<td>Optional arguments</td>
<td>mpasmwin [options] file [options]</td>
</tr>
<tr>
<td>**Curly brackets and pipe character: {</td>
<td>Choice of mutually exclusive arguments; an OR selection</td>
<td>errorlevel {0</td>
</tr>
<tr>
<td>Ellipses...</td>
<td>Replaces repeated text</td>
<td>var_name [, var_name...]</td>
</tr>
<tr>
<td></td>
<td>Represents code supplied by user</td>
<td>void main (void) { ... }</td>
</tr>
</tbody>
</table>
RECOMMENDED READING

This documentation describes how to use Assembler/Linker/Librarian User’s Guide. Other useful documents are listed below. The following Microchip documents are available and recommended as supplemental reference resources.

Readme Files - readme.asm and readme.lkr
For the latest tool information and known issues, see the MPASM assembler readme file (readme.asm) or the MPLINK object linker/MPLIB object librarian readme file (readme.lkr). These ASCII text files may be found in the Readme folder of the MPLAB IDE installation directory.

On-line Help Files
Comprehensive help files are available for MPASM assembler and MPLINK object linker/MPLIB object librarian. In addition, debug output format (COFF) information is also available in help.

C Compiler User’s Guides and Libraries
The MPLINK linker and MPLIB librarian also work with the MPLAB C Compiler for PIC18 MCUs (formerly MPLAB C18). For more information on the compiler, see:

• MPLAB® C Compiler for PIC18 MCUs Getting Started (DS51295)
• MPLAB® C Compiler for PIC18 MCUs User's Guide (DS51288)
• MPLAB® C Compiler for PIC18 MCUs Libraries (DS51297)
• PIC18 Configuration Settings Addendum (DS51537) or on-line help file

MPLAB IDE Documentation
Information on the integrated development environment MPLAB IDE may be found in:

• MPLAB® IDE User’s Guide (DS51519) – Comprehensive user’s guide.
• On-line help file – The most up-to-date information on MPLAB IDE.

PIC MCU Data Sheets and Application Notes
Data sheets contain information on device operation, as well as electrical specifications. Applications notes demonstrate how various PIC MCU’s may be used. Find both of these types of documents for your device on the Microchip website.
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

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Please visit http://www.microchip.com/pcn to begin the registration process and select your preferences to receive personalized notifications. A FAQ and registration details are available on the page, which can be opened by selecting the link above.

When you are selecting your preferences, choosing “Development Systems” will populate the list with available development tools. The main categories of tools are listed below:

- **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. These include the MPLAB REAL ICE™ and MPLAB ICE 2000 in-circuit emulators
- **In-Circuit Debuggers** – The latest information on Microchip in-circuit debuggers. These include the MPLAB ICD 2 and 3 in-circuit debuggers and PICkit™ 2 and 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 the device (production) programmers MPLAB REAL ICE in-circuit emulator, MPLAB ICD 3 in-circuit debugger, MPLAB PM3, and PRO MATE® II and development (nonproduction) programmers MPLAB ICD 2 in-circuit debugger, PICSTART® Plus and PICkit 1, 2 and 3.
- **Starter/Demo Boards** – These include MPLAB Starter Kit boards, PICDEM demo boards, and various other evaluation boards.
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://support.microchip.com.

Documentation errors or comments may be emailed to docerrors@microchip.com.
INTRODUCTION

The MPASM™ assembler, the MPLINK™ object linker and the MPLIB™ object librarian are typically used together under MPLAB® X Integrated Development Environment (IDE) to provide GUI development of application code for PIC1X MCU devices (PIC10/12/16/18 MCUs). The operation of these 8-bit language tools with MPLAB X IDE is discussed here.

Additionally, the MPLAB C Compiler for PIC18 MCUs (MPLAB C18) may be used with the above tools. For more on this compiler, see the Microchip website (http://www.microchip.com) for additional information and documentation.

These language tools were initially developed for use in Microsoft Windows®. However, the MPASMX toolchain does function in Linux and Mac OS (with support available for the “/” and “-” characters). The C18 toolchain also supports these operating systems.

Topics covered in this chapter:
• MPLAB X IDE and Tools Installation
• MPLAB X IDE Setup
• MPLAB X IDE Projects
• Project Setup
• Project Example

MPLAB X IDE AND TOOLS INSTALLATION

MPLAB IDE includes the MPASM Toolsuite which consists of the MPASM assembler, MPLINK linker, MPLIB librarian and other 8-bit utilities. Also, MPLAB IDE may be used with the C18 Toolsuite that consists of the MPLAB C18 Compiler and compiler versions of tools in the MPASM Toolsuite.

MPASM Toolsuite Installation

In order to use the PIC language tools with MPLAB IDE, you must first install MPLAB IDE. The latest version of this free software is available at our website (http://www.microchip.com) or from any sales office (back cover). When you install MPLAB IDE, you will be installing the MPASM assembler, the MPLINK object linker and the MPLIB object librarian as well.

The language tools will be installed, by default, in the directory:

- Windows OS - C:\Program Files\Microchip\MPLABX\mpasmx
- Linux OS - /opt/microchip/mplabx/mpasmx
- Mac OS - /Applications/microchip/mplabx/mpasmx

The executables for each tool will be:

- MPASM Assembler – mpasmx.exe
- MPLINK Object Linker – mplink.exe
- MPLIB Object Librarian – mplib.exe
- Other Utilities
All device include (.inc) files are also in this directory. For more on these files, see MPASM assembler documentation.

All device linker script (.lkr) files are in the LKR subdirectory. For more on these files, see MPLINK object linker documentation.

Template files are also included in the Template subdirectory for your use. Template files are provided for absolute code (Code) and relocatable code (Object) development.

Code examples are also included in the Example subdirectory.

**C18 Toolsuite Installation**

The MPLAB C18 compiler and related tools must be acquired from Microchip (standard, lite and evaluation versions available). The install includes the MPLAB C18 C compiler and compiler versions of tools in the MPASM Toolsuite.

The language tools will be installed, by default, in the directory:

- **Windows OS** - `C:\Program Files\Microchip\mplabc18\version`
- **Mac OS** - `/Applications/microchip/mplabc18/version`
- **Linux OS** - `/opt/microchip/mplabc18/version`

where version is the *version* of the compiler.

The executables for each tool will be:

- **MPLAB C18 C Compiler** - `bin\mcc18.exe`
- **MPASM Assembler** - `mpasm\mpasmx.exe`
- **MPLINK Object Linker** - `bin\mplink.exe`
- **MPLIB Object Librarian** - `bin\mplib.exe`
- **Other Utilities** - `bin subdirectory`

All device header (.h) files are in the *h* subdirectory. For more on these files, see MPLAB C18 documentation.

All device include (.inc) files are in the *mpasm* subdirectory. For more on these files, see MPASM assembler documentation.

All device linker script (.lkr) files are in the *bin\LKR* subdirectory. For more on these files, see MPLINK object linker documentation.

All device library (.lib) files and precompiled start-up code (.o) are in the *lib* subdirectory. For more on these files, see MPLAB C18 libraries documentation.

Code examples are also included in the *example* subdirectory.
MPLAB X IDE SETUP

Once MPLAB X IDE is installed on your PC, check the settings below to ensure that the PIC1X language tools are properly recognized under MPLAB X IDE.

1. From the MPLAB X IDE menu bar, select *Tools>Options* to open the Options dialog. Click on the "Embedded" button and select the "Build Tools" tab.

2. Click on “MPASMX” under “Tool Collection”. Ensure that the paths are correct for your installation of the MPASM assembler. This will ensure that the paths to the linker, librarian and utilities are correct as all of these tools are part of the MPASM Suite.

3. For the optional MPLAB C18 C compiler, click on “C18” under “Tool Collection”. Ensure that the paths are correct for your installation of the compiler. This will ensure that the paths to the compiler and related assembler, linker, librarian and utilities are correct as all of these tools are part of the C18 Suite.

4. Click OK.

FIGURE 1: MPASM SUITE TOOL LOCATIONS
MPLAB X IDE PROJECTS

A project in MPLAB X IDE is a group of files needed to build an application, along with their associations to various build tools. Below is a generic MPLAB X IDE project.

FIGURE 2: PROJECT RELATIONSHIPS

MPLAB X IDE Project

MPASM assembler

MPLAB C18

MPLINK linker

MPLIB librarian

source files

ASSEMBLER/COMPILER

list and object files

LIBRARIAN & library file

LINKER & linker script file (1)

LINKER output files

Utility & output file

(1) The linker can choose the correct linker script file for your project.
In this MPLAB X IDE project, an assembly source file (prog.asm) is shown with its associated assembler (MPASM assembler). MPLAB X IDE will use this information to generate the object file prog.o for input into the MPLINK object linker. For more information on the assembler, see the MPASM assembler documentation.

The C source file main.c is also shown with its associated MPLAB C18 C compiler. MPLAB X IDE will use this information to generate an object file (main.o) for input into the MPLINK object linker. For more information on the compiler, see the MPLAB C18 C compiler documentation listed in Recommended Reading.

In addition, precompiled object files (precomp.o) may be included in a project, with no associated tool required. MPLAB C18 requires the inclusion of a precompiled standard code module c018i.o, for example. For more information on available Microchip precompiled object files, see the MPLAB C18 C compiler documentation.

Some library files (math.lib) are available with the compiler. Others may be built using the librarian tool (MPLIB object librarian). For more information on the librarian, see the MPLIB librarian documentation. For more information on available Microchip libraries, see the MPLAB C18 C compiler documentation.

The object files, along with library files, are used to generate the project output files via the linker (MPLINK object linker). MPLAB X IDE will automatically add the correct linker script file (device.lkr) for your project. For more information on using linker script files and the linker, see the MPLINK linker documentation.

The main output file generated by the MPLINK linker is the COF file (prog.cof). The linker then uses the utility MP2HEX to generate the Hex file (prog.hex), used by simulators, emulators, debuggers and programmers. For more information on linker output files, see the MPLINK linker documentation. For more information on utilities, see the related documentation.

For more on projects, see MPLAB X IDE documentation.
PROJECT SETUP

To set up an MPLAB X IDE project for the first time, use the built-in Project Wizard (File>New Project). In this wizard, you will be able to select a language toolsuite. For more on the wizard, and MPLAB X IDE projects, see MPLAB X IDE documentation.

Once you have a project set up, you may then set up properties of the tools in MPLAB X IDE.

1. From the MPLAB X IDE menu bar, select File>Project Properties to open a dialog to set/check project build options.

2. **MPASM**: For “Conf: [default]” > “MPASMX”, select a tool from the tool collection to set up.
   a) MPASM (TOP)
   b) MPASM
   c) MPLINK

3. **MPLAB C18**: For “Conf: [default]” > “C18”, select a tool from the tool collection to set up.
   a) C18 (TOP)
   b) MPASM
   c) MCC18
   d) MPLINK

**MPASM (TOP)**

The top level of the MPASM toolchain contains the following options.

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
<th>Command Line</th>
</tr>
</thead>
<tbody>
<tr>
<td>Build in absolute mode</td>
<td>For assembly code projects, build using the assembler only, i.e., do not invoke the linker.</td>
<td>-ahex-format</td>
</tr>
</tbody>
</table>

**TABLE 1-2: ADDITIONAL CONTROLS**

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Additional Options</td>
<td>Enter additional command-line options. See the tool documentation for more options.</td>
</tr>
<tr>
<td>Option Description</td>
<td>Click on option text to see more information in this tab, if available.</td>
</tr>
<tr>
<td>Generated Command Line</td>
<td>For selectable options, click this tab to see the equivalent command line option.</td>
</tr>
</tbody>
</table>

**MPASM**

Select a category, and then set up assembler options. For additional options, see MPASM assembler documentation, Chapter 2. “Assembler Interfaces”.

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
<th>Command Line</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enable case sensitivity</td>
<td>The assembler will distinguish between upper- and lower-case letters. Note: Disabling case sensitivity will make all labels uppercase.</td>
<td>-c+</td>
</tr>
<tr>
<td>Default Radix</td>
<td>Set the default radix, either Hexadecimal, Decimal or Octal.</td>
<td>-rradix</td>
</tr>
<tr>
<td>Preprocessor Macro Definitions</td>
<td>Add macro directive definitions.</td>
<td>-dmacro</td>
</tr>
</tbody>
</table>
**TABLE 1-4: OUTPUT CATEGORY**

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
<th>Command Line</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cross-reference file</td>
<td>Create an cross-reference file. A cross-reference file contains a listing of all symbols used in the assembly code.</td>
<td>-x&quot;xrf&quot;</td>
</tr>
<tr>
<td>Diagnostic level</td>
<td>Select to display errors only; errors and warnings; or errors, warnings and messages. These will be shown in the Output window.</td>
<td>-w&quot;value&quot;</td>
</tr>
<tr>
<td>Hex file format (absolute assembly only)</td>
<td>When assembling a single file, the assembler may be used to generate a hex file. Choose the format here. When assembling multiple files, the assembler generates object files which must be linked with the linker to generate a hex file. Choose the hex file format for the linker in this case.</td>
<td>-ahex-format</td>
</tr>
</tbody>
</table>

**TABLE 1-5: ADDITIONAL CONTROLS**

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
<th>Generated Command Line</th>
</tr>
</thead>
<tbody>
<tr>
<td>Additional Options</td>
<td>Enter additional command-line options. See the tool documentation for more options.</td>
<td></td>
</tr>
<tr>
<td>Option Description</td>
<td>Click on option text to see more information in this tab, if available.</td>
<td></td>
</tr>
<tr>
<td>Generated Command Line</td>
<td>For selectable options, click this tab to see the equivalent command line option.</td>
<td></td>
</tr>
</tbody>
</table>

**TABLE 1-6: ALL OPTIONS CATEGORY**

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
<th>Command Line</th>
</tr>
</thead>
<tbody>
<tr>
<td>Generate map file</td>
<td>Create a map file. A map file provides information on the absolute location of source code symbols in the final output. It also provides information on memory use, indicating used/unused memory.</td>
<td>-m&quot;map&quot;</td>
</tr>
<tr>
<td>Hex file format</td>
<td>Choose the linker hex file format.</td>
<td>-ahex-format</td>
</tr>
<tr>
<td>Library directories</td>
<td>Browse to the path(s) of any libraries you want the linker to include in the output. Manage the list of paths in the dialog.</td>
<td>-l&quot;lib&quot;</td>
</tr>
</tbody>
</table>

**TABLE 1-7: ADDITIONAL CONTROLS**

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
<th>Generated Command Line</th>
</tr>
</thead>
<tbody>
<tr>
<td>Additional Options</td>
<td>Enter additional command-line options. See the tool documentation for more options.</td>
<td></td>
</tr>
<tr>
<td>Option Description</td>
<td>Click on option text to see more information in this tab, if available.</td>
<td></td>
</tr>
<tr>
<td>Generated Command Line</td>
<td>For selectable options, click this tab to see the equivalent command line option.</td>
<td></td>
</tr>
</tbody>
</table>
C18 (TOP)

The top level of the C18 toolchain contains the following options.

### TABLE 1-8:  ALL OPTIONS CATEGORY

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
<th>Command Line</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enable extended instruction set</td>
<td>Build in extended mode. The selected device must support extended mode and the correct configuration bit must be enabled. See “MPLAB C18: Setup for PIC18 Extended Instruction Set Use”.</td>
<td>--extended</td>
</tr>
<tr>
<td></td>
<td></td>
<td>--no-extended</td>
</tr>
<tr>
<td>Enable stack analysis</td>
<td>Generate a stack analysis report for use with third-party application “Understand,” from Scientific Toolworks, Inc. See their web site at <a href="http://www.scitools.com">www.scitools.com</a> for more information. This option is only supported on devices that support extended mode. The checkbox for Enable extended instruction set must be checked as well. (See the previous row in this table.)</td>
<td>-g</td>
</tr>
</tbody>
</table>

### TABLE 1-9:  ADDITIONAL CONTROLS

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Additional Options</td>
<td>Enter additional command-line options. See the tool documentation for more options.</td>
</tr>
<tr>
<td>Option Description</td>
<td>Click on option text to see more information in this tab, if available.</td>
</tr>
<tr>
<td>Generated Command Line</td>
<td>For selectable options, click this tab to see the equivalent command line option.</td>
</tr>
</tbody>
</table>

### MPLAB C18: Setup for PIC18 Extended Instruction Set Use

To use the PIC18 MCU Extended Instruction set in your MPLAB C18 project, do the following:

- Enable “Extended Instruction Set” in the configuration bits by doing one of the following:
  - In code, use `CONFIG XINST=ON`.
  - In the Configurations Bits window, under XINST select “Enabled”.
- Select File>Project Properties, click on C18, and check “Enable extended instruction set. Click OK.

For a list of available instructions in the Extended Instruction set, see Section A.9 “PIC18 Device Extended Instruction Set”.

### MCC18

Although the MPLAB C18 C compiler works with MPLAB X IDE, it must be acquired separately. The standard version may be purchased, or a free (limited-feature) version may be downloaded. See the Microchip website (www.microchip.com) for details. This compiler supports PIC18X MCU devices.

A subset of command-line options may be specified in MPLAB X IDE. Select a category, and then set up compiler options. For additional options, see the *MPLAB C Compiler for PIC18 MCUs User’s Guide* (DS51288), also available on the Microchip website.

### TABLE 1-10:  MEMORY MODEL CATEGORY

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
<th>Command Line</th>
</tr>
</thead>
<tbody>
<tr>
<td>Code model</td>
<td>Select a code (program memory/ROM) model. Choose from small (≤64K bytes) or large (&gt;64K bytes).</td>
<td>-mmodel</td>
</tr>
<tr>
<td>Data model</td>
<td>Select a data (data memory/RAM) model. Choose from large (all RAM banks) or small (access RAM only).</td>
<td>-Omodel</td>
</tr>
<tr>
<td>Enable multi-bank stack model</td>
<td>Select a stack model. Choose from single bank or multiple bank.</td>
<td>-Lmodel</td>
</tr>
</tbody>
</table>
### TABLE 1-11: GENERAL CATEGORY

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
<th>Command Line</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treat char as unsigned</td>
<td>Select to make 'char' types unsigned (0-256) instead of the default signed (-128 to 127).</td>
<td>-k</td>
</tr>
<tr>
<td>Enable integer promotions</td>
<td>Select to enable integer promotions (ISO-mandated arithmetic performed at int precision or greater.)</td>
<td>-oi</td>
</tr>
<tr>
<td>Enable verbose output</td>
<td>Display all compiler outputs.</td>
<td>--verbose</td>
</tr>
<tr>
<td>Default storage class</td>
<td>Select the storage class, either auto (ANSI standard), static (ANSI standard) or overlay (non-extended mode).</td>
<td>-sc class</td>
</tr>
<tr>
<td>Diagnostics level</td>
<td>Select to display errors only; errors and warnings; or errors, warnings and messages. These will be shown in the Output window.</td>
<td>-w value</td>
</tr>
<tr>
<td>Preprocessor macro definitions</td>
<td>Add macro directive definitions.</td>
<td>-D macro</td>
</tr>
<tr>
<td>Include directories</td>
<td>Enter a path to header (*.h) files.</td>
<td>-I &quot;inc&quot;</td>
</tr>
</tbody>
</table>

### TABLE 1-12: OPTIMIZATION CATEGORY

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
<th>Command Line</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optimizations</td>
<td>Select to:</td>
<td>-O level</td>
</tr>
<tr>
<td>Enable all optimizations</td>
<td>View whether all options enabled.</td>
<td>N/A</td>
</tr>
<tr>
<td>Enable duplicate string merging</td>
<td>Take two or more identical literal strings and combine them into a single string table entry with a single instance of the raw data stored in program memory.</td>
<td>-Om</td>
</tr>
<tr>
<td>Enable banking optimizer</td>
<td>Remove MOVLB instructions in instances where it can be determined that the Bank Select register already contains the correct value.</td>
<td>-On</td>
</tr>
<tr>
<td>Enable unreachable code removal</td>
<td>Attempt to remove any code that can be provably demonstrated to not execute during normal program flow.</td>
<td>-Ou</td>
</tr>
<tr>
<td>Enable code straightening</td>
<td>Attempt to reorder code sequences so that they appear in the order in which they will be executed.</td>
<td>-Os</td>
</tr>
<tr>
<td>Enable tail merging</td>
<td>Attempt to combine multiple sequences of identical instructions into a single sequence.</td>
<td>-Ot</td>
</tr>
<tr>
<td>Enable branch optimization</td>
<td>Optimize branching. Some of the branch optimizations save program space, while others may expose unreachable code.</td>
<td>-Ob</td>
</tr>
<tr>
<td>Enable WREG tracking</td>
<td>Remove MOVLW instructions in instances where it can be determined that the Working register already contains the correct value.</td>
<td>-Ow</td>
</tr>
<tr>
<td>Enable copy propagation</td>
<td>Replace uses of x with uses of y for x ← y, as long as intervening instructions have not changed the value of either x or y. This optimization by itself does not save any instructions, but enables dead code removal.</td>
<td>-Op</td>
</tr>
<tr>
<td>Enable redundant store elimination</td>
<td>Remove redundant assignments of the form x ← y when the assignment appears multiple times in an instruction sequence and the intervening code has not changed the value of x or y.</td>
<td>-Or</td>
</tr>
<tr>
<td>Enable dead code removal</td>
<td>Remove dead code, i.e., values computed in a function which are not used on any path to the function's exit or instructions which compute only dead values.</td>
<td>-Od</td>
</tr>
<tr>
<td>Enable procedural abstraction</td>
<td>Reduce the size of the generated code by creating a procedure containing the repeated code and replacing the copies with a call to the procedure.</td>
<td>-Opa</td>
</tr>
<tr>
<td>Procedural Abstraction passes</td>
<td>For &quot;Enable All&quot; and “Custom” optimizations, set the desired number of passes for procedural abstraction.</td>
<td>-pa=pass</td>
</tr>
<tr>
<td>Option</td>
<td>Description</td>
<td></td>
</tr>
<tr>
<td>-------------------------------</td>
<td>-----------------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>Additional Options</td>
<td>Enter additional command-line options. See the tool documentation for more options.</td>
<td></td>
</tr>
<tr>
<td>Option Description</td>
<td>Click on option text to see more information in this tab, if available.</td>
<td></td>
</tr>
<tr>
<td>Generated Command Line</td>
<td>For selectable options, click this tab to see the equivalent command line option.</td>
<td></td>
</tr>
</tbody>
</table>
PROJECT EXAMPLE

In this example, you will create an MPLAB X IDE project with multiple assembly files. Therefore, you will need to use the MPASM assembler and the MPLINK linker to create the final output executable (.hex) file.

• Run the Project Wizard
• Add Files to the Project
• Set Build Options
• Build the Project
• Build Errors
• Output Files
• Further Development

Run the Project Wizard

In MPLAB X IDE, select File>New Project to launch the wizard.

1. Choose Project: Select “Embedded” for the category and “C/ASM Standalone Project” for the project. Click Next> to continue.
2. Select Device: Select the PIC16F877. Click Next> to continue.
3. Select Header: There is no header for this device so this is skipped.
4. Select Tool: Choose a development tool from the list. Tool support for the selected device is shown as a colored circle next to the tool. Mouse over the circle to see the support as text. Click Next> to continue.
5. Select Compiler: Choose a version of the MPASMX assembler. Click Next> to continue.
6. Select Project Name and Folder: Enter a project name, such as MyAsmProject. Then select a location for the project folder. Click Finish to complete the project creation and setup.

Once the Project Wizard has completed, the Project window should contain the project tree. For more on projects, see the MPLAB X IDE documentation.

FIGURE 3: NEW PROJECT TREE
Add Files to the Project

Right click on the "Source Files" folder in the project tree. Select "New>Other" to open the File wizard.

1. **Choose File Type:** Expand "Microchip Embedded" to see available file types.
   Click "MPASM assembler" and select "main.asm". Click Next> to continue.

2. **Name and Location:** Enter the name for the new file, in this case example.asm. The location is the current project by default. Leave this for now.
   Click Finish to create file.

Repeat the above steps to add another file, example2.asm, to the project. When you are done, the project tree should now look as in Figure 4. The code for each file follows.

**FIGURE 4: PROJECT TREE WITH SOURCE FILES**

![Project Tree with Source Files]

**example.asm**

; File: example.asm
; This is the main file in the MPASM assembler/MPLINK linker example
; Use with example2.asm

#include p16f877.inc

PROG CODE ; Set the start of code from 16f877.lkr script

main ; Min code entry called from example2.asm
    global main ; Define as global so can be used in example2.asm
    nop ; Main does nothing -- Put your code here
    goto main ; Our sample "main" is just an infinite loop

service ; Interrupt routine, called from example2.asm
    global service ; Define as global so can be used in example2.asm
    nop ; Interrupt code would go here
    nop
    retfie

IDLOCS CODE ; ID location data, address is in 16f877.lkr
    dw 0x0102
    dw 0x0304

CONBITS CODE ; Set config bits from defines in p16f877.inc
    ; Config address for device programmer is
    ; in 16f877.lkr
    dw _LP_OSC & _PWRT_OFF & _WDT_OFF & _CP_OFF

end
example2.asm
; File: example2.asm
; This is the second file in the MPASM assembler/MPLINK linker example
; Use with example.asm

#include p16f877.inc

extern main, service ; These routines are in Example.asm

STARTUP CODE ; This area is defined in 16f877.lkr,
; the linker script

goto main ; Jump to main code defined in example.asm
nop ; Pad out so interrupt service routine gets
nop ; put at address 0x0004.

end

Set Build Options

Select File>Project Properties or right click on the project name and select “Properties”

to open the Project Properties dialog.

1. Under “default>MPASMX”, select “MPASMX”.
2. Select “General” from the “Option Categories”. Ensure that the “Default Radix” is
   “Hex”.
3. Select “Output” from the “Option Categories”. Ensure that the “Diagnostics level”
   is set to “Errors Only”. Then enter a file name for a “Cross-reference file”, i.e.,
   example.xrf.
4. Under “default>MPASMX”, select “MPLINK”.
5. Ensure that the “Hex File Format” is set to “INHX32”. Then enter a file name to
   “Generate map file”, i.e., example.map.
6. Click OK on the bottom of the dialog to accept the build options and close the
   dialog.
Build the Project

Right-click on the project name, “MyASMProject”, in the project tree and select “Build” from the pop-up menu.

The Output window should appear at the end of the build and display the build results.

FIGURE 5: OUTPUT WINDOW - BUILD RESULTS

Build Errors

If the build did not complete successfully, check these items:
1. Review the previous steps in this example. Make sure you have set up the language tools correctly and have all the correct project files and build options.
2. If you modified the sample source code, examine the Build results in the Output window for syntax errors in the source code. If you find any, correct the error, and then try to build again. Some errors provide links to go to the source code line that contains that error.

Output Files

View the project output files by opening the files in MPLAB X IDE.
1. Select File>Open File. In the Open dialog, find the project directory.
2. Under “Files of type” select “All Files” to see all project files.
3. Select “example.xrf”. Click Open to view the assembler cross-reference file in an MPLAB X IDE editor window. For more on this file, see the MPASM assembler documentation, Section 1.7.6 “Cross Reference File (.xrf)”.
4. Select File>Open File. In the Open dialog, select “example.map”. Click Open to view the linker map file in an MPLAB X IDE editor window. For more on this file, see the MPLINK linker documentation, Section 9.7.7 “Map File (.map)”.
5. Select File>Open File. In the Open dialog, go to the build>default>production directory. Select “example.lst”. Click Open to view the linker listing file in an MPLAB X IDE editor window. When MPASM assembler is used with MPLINK linker, this listing file may be generated. For more on this file, see the Utilities documentation, Section 18.3 “Utilities Operation”.
6. Select File>Open File. In the Open dialog, return to the project directory and then go to the dist>default>production directory. Notice that there is only one hex file, “example.hex”. This is the primary output file, used by various debug tools. Click Open to view the hex file in an MPLAB X IDE editor window. For more on this file, see the Utilities documentation, Section 18.3 “Utilities Operation”.

For this example, we used a multi-file project which requires the use of the linker (relocatable code). But if you have a project with one assembly file, you could use only the assembler (absolute code). The assembler is capable of generating its own list and hex file.
Further Development

Usually, your application code will contain errors and not work the first time. Therefore, you will need a debug tool to help you develop your code. Using the output files previously discussed, several debug tools exist that work with MPLAB X IDE to help you do this. You may choose from simulators, in-circuit emulators or in-circuit debuggers, either manufactured by Microchip Technology or third-party developers. Please see the documentation for these tools to learn how they can help you. When debugging, you will use *Debug* > *Debug Project* to run and debug your code. Please see MPLAB X IDE documentation for more information.

Once you have developed your code, you will want to program it into a device. Again, there are several programmers that work with MPLAB X IDE to help you do this. Please see the documentation for these tools to see how they can help you. When programming, you will use “Program Target Project” button on the debug toolbar. Please see MPLAB X IDE documentation concerning this control.

MPLAB C18 example code that may be used to create a C code project may be found in the compiler install example subdirectory. See also the *MPLAB C Compiler for PIC18 MCUs User’s Guide* (DS51288).
INTRODUCTION

The MPASM assembler, the MPLINK object linker and the MPLIB object librarian are typically used together under MPLAB IDE to provide GUI development of application code for PIC1X MCU devices (PIC10/12/16/18 MCUs). The operation of these 8-bit language tools with MPLAB IDE is discussed here.

Additionally, the MPLAB C Compiler for PIC18 MCUs (MPLAB C18) may be used with the above tools. For more on this compiler, see the Microchip website (http://www.microchip.com) for additional information and documentation.

Topics covered in this chapter:
- MPLAB IDE and Tools Installation
- MPLAB IDE Setup
- MPLAB IDE Projects
- Project Setup
- Project Example

MPLAB IDE AND TOOLS INSTALLATION

MPLAB IDE includes the MPASM Toolsuite which consists of the MPASM assembler, MPLINK linker, MPLIB librarian and other 8-bit utilities. Also, MPLAB IDE may be used with the C18 Toolsuite that consists of the MPLAB C18 C compiler and compiler versions of tools in the MPASM Toolsuite.

MPASM Toolsuite Installation

In order to use the PIC language tools with MPLAB IDE, you must first install MPLAB IDE. The latest version of this free software is available at our website (http://www.microchip.com) or from any sales office (back cover). When you install MPLAB IDE, you will be installing the MPASM assembler, the MPLINK object linker and the MPLIB object librarian as well.

The language tools will be installed, by default, in the directory:
- C:\Program Files\Microchip\MPASM Suite

The executables for each tool will be:
- MPASM Assembler - mpasmwin.exe
- MPLINK Object Linker - mplink.exe
- MPLIB Object Librarian - mplib.exe
- Other Utilities

All device include (.inc) files are also in this directory. For more on these files, see MPASM assembler documentation.

All device linker script (.lkr) files are in the LKR subdirectory. For more on these files, see MPLINK object linker documentation.

Code examples and template files are included in the Template subdirectory. Template files are provided for absolute code (Code) and relocatable code (Object) development. Code examples are also included in the Example subdirectory.
C18 Toolsuite Installation

The MPLAB C18 compiler and related tools must be acquired from Microchip (standard, lite and evaluation versions available). The install includes the MPLAB C18 C compiler and compiler versions of tools in the MPASM Toolsuite.

The language tools will be installed, by default, in the directory:

- C:\Program Files\Microchip\mplabc18\version

where version is the version of the compiler.

The executables for each tool will be:

- MPLAB C18 C Compiler - bin\mcc18.exe
- MPASM Assembler - mpasm\mpasmwin.exe
- MPLINK Object Linker - bin\mplink.exe
- MPLIB Object Librarian - bin\mplib.exe
- Other Utilities - bin subdirectory

All device header (.h) files are in the h subdirectory. For more on these files, see MPLAB C18 documentation.

All device include (.inc) files are in the mpasm subdirectory. For more on these files, see MPASM assembler documentation.

All device linker script (.lkr) files are in the bin\LKR subdirectory. For more on these files, see MPLINK object linker documentation.

All device library (.lib) files and precompiled start-up code (.o) are in the lib subdirectory. For more on these files, see MPLAB C18 libraries documentation.

Code examples are also included in the example subdirectory.
MPLAB IDE SETUP

Once MPLAB IDE is installed on your PC, check the settings below to ensure that the language tools are properly recognized under MPLAB IDE.

1. From the MPLAB IDE menu bar, select **Project>Set Language Tool Locations** to open a dialog to set/check language tool executable location.

![Set Language Tool Locations](image)

2. In the dialog, under “Registered Tools”, select “Microchip MPASM Toolsuite”. Click the “+” to expand.
3. Select “Executables”. Click the “+” to expand.
4. Select “MPASM Assembler (mpasmwin.exe)”. Under “Location”, a path to the executable file should be displayed. If no path is displayed, enter one or browse to the location of this file. The default location is listed in “MPASM Toolsuite Installation”.
5. Select “MPLINK Object Linker (mplink.exe)”. Under “Location”, a path to the executable file should be displayed. If no path is displayed, enter one or browse to the location of this file. The default location is listed in “MPASM Toolsuite Installation”.
6. Select “MPLIB Object Librarian (mplib.exe)”. Under “Location”, a path to the executable file should be displayed. If no path is displayed, enter one or browse to the location of this file. The default location is listed in “MPASM Toolsuite Installation”.
7. For the optional MPLAB C18 C compiler, select “Microchip C18 Toolsuite” and expand “Executables”. Select “MPLAB C18 C Compiler (mcc18.exe)” and check the install path. Ensure the other tools in this toolsuite point to the MPLAB C18 installation subdirectories and not the directories for the “Microchip MPASM Toolsuite”. The default location is listed in “C18 Toolsuite Installation”.
8. Click **OK**.
MPLAB IDE PROJECTS

A project in MPLAB IDE is a group of files needed to build an application, along with their associations to various build tools. Below is a generic MPLAB IDE project.

FIGURE 2: PROJECT RELATIONSHIPS

MPLAB IDE Project

source files

MPASM assembler

MPLAB C18

MPLINK linker

MP2HEX

SIMULATORS

EMULATORS

DEBUGGERS

PROGRAMMERS

source files

ASSEMBLER/COMPILER

list and object files

LIBRARIAN & library file

LINKER & linker script file(1)

LINKER output files

Utility & output file

prog.asm

main.c

prog.lst

prog.o

main.o

precomp.o

math.lib

device.lkr

prog.cof

prog.map

prog.hex

(1) The linker can choose the correct linker script file for your project.
In this MPLAB IDE project, an assembly source file (prog.asm) is shown with its associated assembler (MPASM assembler). MPLAB IDE will use this information to generate the object file prog.o for input into the MPLINK object linker. For more information on the assembler, see the MPASM assembler documentation.

The C source file main.c is also shown with its associated MPLAB C18 C compiler. MPLAB IDE will use this information to generate an object file (main.o) for input into the MPLINK object linker. For more information on the compiler, see the MPLAB C Compiler for PIC18 MCUs User's Guide (DS51288).

In addition, precompiled object files (precomp.o) may be included in a project, with no associated tool required. MPLAB C18 requires the inclusion of a precompiled standard code module c018i.o, for example. For more information on available Microchip precompiled object files, see the MPLAB C18 C compiler documentation.

Some library files (math.lib) are available with the compiler. Others may be built using the librarian tool (MPLIB object librarian). For more information on the librarian, see the MPLIB librarian documentation. For more information on available Microchip libraries, see the MPLAB C18 C compiler documentation.

The object files, along with library files, are used to generate the project output files via the linker (MPLINK object linker). Depending on your project, you may or may not need to add a linker script file (device.lkr). For more information on using linker script files and the linker, see the MPLINK linker documentation.

The main output file generated by the MPLINK linker is the COF file (prog.cof). The linker then uses the utility MP2HEX to generate the Hex file (prog.hex), used by simulators, emulators, debuggers and programmers. For more information on linker output files, see the MPLINK linker documentation. For more information on utilities, see the related documentation.

For more on projects, and related workspaces, see MPLAB IDE documentation.
**PROJECT SETUP**

To set up an MPLAB IDE project for the first time, it is advisable to use the built-in Project Wizard (*Project>*Project Wizard). In this wizard, you will be able to select a language toolsuite that uses MPASM assembler, e.g., the Microchip MPASM Toolsuite. For more on the wizard, and MPLAB IDE projects, see MPLAB IDE documentation.

When a project is set up, set up properties of the tools in MPLAB IDE.

1. From the MPLAB IDE menu bar, select *Project>*Build Options>*Project* to open a dialog to set/check project build options.

   **Note:** MPASM assembler does not recognize include path information specified in MPLAB IDE.

2. Click on the tool tab to modify tool settings.
   - Build Options Dialog, MPASM Assembler Tab
   - Build Options Dialog, MPLAB C17 Tab (If Installed)
   - Build Options Dialog, MPLAB C18 Tab (If Installed)
   - Build Options Dialog, MPLINK Linker Tab
   - Build Options Dialog, MPASM/C17/C18 Suite Tab

3. Perform additional setup as required.
   - MPLAB C18: Setup for PIC18 Extended Instruction Set Use

**Build Options Dialog, MPASM Assembler Tab**

Select a category, and then set up assembler options. For additional options, see MPASM assembler documentation, *Chapter 2. “Assembler Interfaces”*.

### General Category

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Generate Command Line</td>
<td>The assembler accepts upper- and lower-case letters equally. <strong>Note:</strong> Disabling case sensitivity will make all labels uppercase.</td>
</tr>
<tr>
<td>Disable case sensitivity</td>
<td></td>
</tr>
<tr>
<td>Extended mode</td>
<td>Enable PIC18F extended instruction support.</td>
</tr>
<tr>
<td>Default Radix</td>
<td>Set the default radix, either Hexadecimal, Decimal or Octal.</td>
</tr>
<tr>
<td>Macro Definitions</td>
<td>Add macro directive definitions.</td>
</tr>
<tr>
<td>Restore Defaults</td>
<td>Restore tab default settings.</td>
</tr>
</tbody>
</table>

### Use Alternate Settings

| Text Box                | Enter options in a command-line (non-GUI) format.                          |
|                        |                                                                             |

### Output Category

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Generate Command Line</td>
<td></td>
</tr>
<tr>
<td>Diagnostics level</td>
<td>Select to display errors only; errors and warnings; or errors, warnings and messages. These will be shown in the Output window.</td>
</tr>
<tr>
<td>Generate cross-reference file</td>
<td>Create an cross-reference file. A cross-reference file contains a listing of all symbols used in the assembly code.</td>
</tr>
<tr>
<td>Hex file format (for single-file assemblies)</td>
<td>When assembling a single file, the assembler may be used to generate a hex file. Choose the format here. When assembling multiple files, the assembler generates object files which must be linked with the linker to generate a hex file. Choose the hex file format for the linker in this case.</td>
</tr>
</tbody>
</table>

| Restore Defaults        | Restore tab default settings.                                               |

### Use Alternate Settings

| Text Box                | Enter options in a command-line (non-GUI) format.                          |
|                        |                                                                             |
Build Options Dialog, MPLAB C17 Tab (If Installed)

Although the MPLAB C17 C compiler works with MPLAB IDE, it is no longer sold or supported. See the Microchip website (www.microchip.com) for details.

| Note: | PIC17C MCUs are end-of-life devices. Consider migrating to PIC18X MCU devices. |

A subset of command-line options may be specified in MPLAB IDE in the Build Options dialog, MPLAB C17 tab. Select a category, and then set up compiler options.

### General Category

<table>
<thead>
<tr>
<th><strong>Generate Command Line</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Diagnostics level</strong></td>
</tr>
<tr>
<td><strong>Default storage class</strong></td>
</tr>
<tr>
<td><strong>Macro Definitions</strong></td>
</tr>
<tr>
<td><strong>Restore Defaults</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Use Alternate Settings</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>TextBox</strong></td>
</tr>
</tbody>
</table>

### Memory Model Category

<table>
<thead>
<tr>
<th><strong>Generate Command Line</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Small</strong></td>
</tr>
<tr>
<td><strong>Medium</strong></td>
</tr>
<tr>
<td><strong>Compact</strong></td>
</tr>
<tr>
<td><strong>Large</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Use Alternate Settings</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>TextBox</strong></td>
</tr>
</tbody>
</table>

### Optimization Category

<table>
<thead>
<tr>
<th><strong>Generate Command Line</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Bank Selection Optimiza-</strong></td>
</tr>
<tr>
<td><strong>tion</strong></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Use Alternate Settings</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>TextBox</strong></td>
</tr>
</tbody>
</table>
### Build Options Dialog, MPLAB C18 Tab (If Installed)

Although the MPLAB C18 C compiler works with MPLAB IDE, it must be acquired separately. The full version may be purchased, or a student (limited-feature) version may be downloaded for free. See the Microchip website (www.microchip.com) for details. This compiler supports PIC18X MCU devices.

A subset of command-line options may be specified in MPLAB IDE in the Build Options dialog, MPLAB C18 tab. Select a category, and then set up compiler options. For additional options, see the *MPLAB C Compiler for PIC18 MCUs User’s Guide* (DS51288), also available on the Microchip website.

#### General Category

<table>
<thead>
<tr>
<th>Generate Command Line</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Diagnostics level</strong></td>
</tr>
<tr>
<td><strong>Default storage class</strong></td>
</tr>
<tr>
<td><strong>Enable integer promotions</strong></td>
</tr>
<tr>
<td><strong>Treat \texttt{char} as unsigned</strong></td>
</tr>
<tr>
<td><strong>Extended mode</strong></td>
</tr>
<tr>
<td><strong>Macro Definitions</strong></td>
</tr>
<tr>
<td><strong>Restore Defaults</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Use Alternate Settings</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Text Box</strong></td>
</tr>
</tbody>
</table>

#### Memory Model Category

<table>
<thead>
<tr>
<th>Generate Command Line</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Code Model</strong></td>
</tr>
<tr>
<td><strong>Data Model</strong></td>
</tr>
<tr>
<td><strong>Stack Model</strong></td>
</tr>
<tr>
<td><strong>Restore Defaults</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Use Alternate Settings</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Text Box</strong></td>
</tr>
</tbody>
</table>

#### Optimization Category

<table>
<thead>
<tr>
<th>Generate Command Line</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Disable</strong></td>
</tr>
<tr>
<td><strong>Debug</strong></td>
</tr>
<tr>
<td><strong>Enable All</strong></td>
</tr>
<tr>
<td><strong>Custom</strong></td>
</tr>
<tr>
<td><strong>Procedural Abstraction passes</strong></td>
</tr>
<tr>
<td><strong>Restore Defaults</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Use Alternate Settings</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Text Box</strong></td>
</tr>
</tbody>
</table>
Build Options Dialog, MPLINK Linker Tab

Select a category, and then set up linker options. For additional options, see MPLINK object linker documentation, Chapter 10. “Linker Interfaces”.

All Options Category

<table>
<thead>
<tr>
<th>Generate Command Line</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hex file format</td>
</tr>
<tr>
<td>Generate map file</td>
</tr>
<tr>
<td>Output file root</td>
</tr>
<tr>
<td>Restore Defaults</td>
</tr>
<tr>
<td>Use Alternate Settings</td>
</tr>
</tbody>
</table>

Build Options Dialog, MPASM/C17/C18 Suite Tab

Select a category, and then set up output build options.

All Options Category

<table>
<thead>
<tr>
<th>Generate Command Line</th>
</tr>
</thead>
<tbody>
<tr>
<td>Library Output</td>
</tr>
</tbody>
</table>
| Build normal target (invoke MPLINK)           | The files in the project will be built for normal output using the MPLINK linker (hex file, etc.)  
To set linker options, see Build Options Dialog, MPLINK Linker Tab. |
| Build library target (invoke MPLIB)           | The files in the project will be built into a library using the MPLIB librarian (lib file.)  
Check “Build generic library” to build a library with the generic-device instead of the selected device. This means the library can be used with any device and not just the one currently selected.  
For more on libraries, see MPLIB object librarian documentation, Chapter 16. “Librarian Interfaces”. |

Single File Assembly Projects

| Ask me                                        | Pop up a dialog to ask me, when a project contains a single file, whether I want to generate absolute or relocatable code. |
| Generate absolute code                        | Always generate absolute code, i.e., code generated by the assembler not requiring a linker. |
| Generate relocatable code                     | Always generate relocatable code, i.e., code generated using a linker. |

Other Controls

| Extended mode                                | Build in extended mode. The selected device must support extended mode and the correct configuration bit must be enabled.  
See “MPLAB C18: Setup for PIC18 Extended Instruction Set Use”. |
| Generate stack analysis report               | Generate a stack analysis report for use with third-party application “Understand,” from Scientific Toolworks, Inc. See their web site at www.scitools.com for more information.  
This option is only supported on devices that support extended mode. The checkbox for Extended mode must be checked as well.  
(See the previous row in this table.) |
MPLAB C18: Setup for PIC18 Extended Instruction Set Use

To use the PIC18 MCU Extended Instruction set in your MPLAB C18 project, do the following:

• Enable “Extended Instruction Set” in the configuration bits.
  - In code, use CONFIG XINST=ON.
  - In the Configurations Bits window, under XINST select “Enabled”.
• Select Project>Build Options>Project. On the MPASM/C17/C18 Suite tab, check the “Extended Mode” checkbox.

For a list of available instructions in the Extended Instruction set, see Section A.9 “PIC18 Device Extended Instruction Set”.
PROJECT EXAMPLE

In this example, you will create an MPLAB IDE project with multiple assembly files. Therefore, you will need to use the MPASM assembler and the MPLINK linker to create the final output executable (.hex) file.

- Run the Project Wizard
- Set Build Options
- Build the Project
- Build Errors
- Output Files
- Further Development

Run the Project Wizard

In MPLAB IDE, select Project>Project Wizard to launch the wizard. Click Next> at the Welcome screen.

1. Select PIC16F84A as the Device. Click Next> to continue.
2. Set up the language tools, if you haven’t already. Refer to “MPLAB IDE Setup”. Click Next> to continue.
3. Enter “Example” for the name of the project. Then Browse to select a location for your project. Click Next> to continue.
4. Add files to the project. In the file listing box on the left of the dialog, find the following directory:
   C:\Program Files\Microchip\MPASM Suite\Example
   Select Example.asm and Example2.asm. Click Add>> to add these files to the project. Click Next> to continue.
5. Review the summary of information. If anything is in error, use <Back to go back and correct the entry. Click Finish to complete the project creation and setup.

Once the Project Wizard has completed, the Project window should contain the project tree. The workspace name is Example.mcw, the project name is Example.mcp, and all the project files are listed under their respective file type. For more on workspaces and projects, see MPLAB IDE documentation.

FIGURE 3: EXAMPLE PROJECT TREE
Set Build Options

Select **Project>Build Options>Project** to open the Build Options dialog.

1. Click on the **MPASM Assembler** tab. For “Categories: General”, check that the “Default Radix” is set to “Hexadecimal”. For “Categories: Output”, check that the “Diagnostics level” includes all errors, warnings and messages. Then check the checkbox for “Generate cross-reference file”.

2. Click on the **MPLINK Linker** tab. For “Categories: (All Options)”, check that the “Hex File Format” is set to “INHX32”. Then check the checkbox for “Generate map file”.

3. Click on the **MPASM/C17/C18 Suite** tab. For “Categories: (All Options)”, check that the “Build normal target (invoke MPLINK)” is selected.

4. Click **OK** on the bottom of the dialog to accept the build options and close the dialog.

5. Select **Project>Save Project** to save the current configuration of the Example project.

Build the Project

Select **Project>Build All** to build the project.

**Note:** You also may right-click on the project name, “Example.mcp”, in the project tree and select “Build All” from the pop-up menu.

The Output window should appear at the end of the build and display the build results.

**FIGURE 4: OUTPUT WINDOW - BUILD TAB**

Build Errors

If the build did not complete successfully, check these items:

1. Review the previous steps in this example. Make sure you have set up the language tools correctly and have all the correct project files and build options.

2. If you modified the sample source code, examine the Build tab of the Output window for syntax errors in the source code. If you find any, double-click on the error to go to the source code line that contains that error. Correct the error, and then try to build again.
Output Files

View the project output files by opening the files in MPLAB IDE.

1. Select File>Open. In the Open dialog, find the project directory.
2. Under “Files of type” select “All files (*.*)” to see all project files.
3. Select “Example.xrf”. Click Open to view the assembler cross-reference file for Example.asm in an MPLAB IDE editor window. For more on this file, see the MPASM assembler documentation, Section 1.7.6 “Cross Reference File (.xrf)”.
4. Repeat steps 1 and 2. Select “Example.map”. Click Open to view the linker map file in an MPLAB IDE editor window. For more on this file, see the MPLINK linker documentation, Section 9.7.7 “Map File (.map)”.
5. Repeat steps 1 and 2. Select “Example.lst”. Click Open to view the linker listing file in an MPLAB IDE editor window. When MPASM assembler is used with MPLINK linker, the listing file is generated by the linker. For more on this file, see the MPLINK linker documentation, Section 9.7.6 “Listing File (.lst)”.
6. Repeat steps 1 and 2. Notice that there is only one hex file, “Example.hex”. This is the primary output file, used by various debug tools. You do not view this file for debugging; use View>Program Memory or View>Disassembly Listing.

Further Development

Usually, your application code will contain errors and not build the first time. Therefore, you will need a debug tool to help you develop your code. Using the output files previously discussed, several debug tools exist that work with MPLAB IDE to help you do this. You may choose from simulators, in-circuit emulators or in-circuit debuggers, either manufactured by Microchip Technology or third-party developers. Please see the documentation for these tools to determine how they can help you. When debugging, you will need to set the Build Configuration to “Debug”. Please see MPLAB IDE documentation concerning this control.

Once you have developed your code, you will want to program it into a device. Again, there are several programmers that work with MPLAB IDE to help you do this. Please see the documentation for these tools to see how they can help you. When programming, you will need to set the Build Configuration to “Release”. Please see MPLAB IDE documentation concerning this control.

For more information on using MPLAB IDE, consult the on-line help that comes with this application or download printable documents from our website.

MPLAB C18 example code that may be used to create a C code project may be found in the MPLAB C Compiler for PIC18 MCUs User’s Guide (DS51288).
Part 1 – MPASM Assembler

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Chapter 1. MPASM Assembler Overview

1.1 INTRODUCTION

An overview of the MPASM assembler and its capabilities is presented.
Topics covered in this chapter:
• MPASM Assembler Defined
• How MPASM Assembler Helps You
• Assembler Migration Path
• Assembler Compatibility Issues
• Assembler Operation
• Assembler Input/Output Files

1.2 MPASM ASSEMBLER DEFINED

The MPASM assembler (the assembler) is a command-line or GUI application that provides a platform for developing assembly language code for Microchip's PIC1X microcontroller (MCU) families.

The assembler comes with and is used by MPLAB X IDE (mpasmx.exe) and MPLAB IDE v8 (mpasmwin.exe). The MPLAB IDE v8 assembler is also available with the MPLAB C Compiler for PIC18 MCUs (aka MPLAB C18). The assembler may also be used in a stand-alone application (Windows OS only) or on the command line.

The MPASM assembler supports all PIC1X MCU devices, as well as memory and KeeLoq® secure data products from Microchip Technology Inc. (Some memory and KeeLoq devices were not supported in MPLAB IDE after v5.70.40.)

1.3 HOW MPASM ASSEMBLER HELPS YOU

The MPASM assembler provides a universal solution for developing assembly code for all of Microchip's PIC1X MCUs. Notable features include:
• MPLAB X IDE and MPLAB IDE v8 Compatibility
• Windows/Command Line Interfaces
• Rich Directive Language
• Flexible Macro Language

1.4 ASSEMBLER MIGRATION PATH

Since the MPASM assembler is a universal assembler for all PIC1X MCU devices, application code developed for the PIC16F877A can be translated into a program for the PIC18F452. This may require changing the instruction mnemonics that are not the same between the devices (assuming that register and peripheral usage were similar).
Also, configuration settings may be different. The __CONFIG syntax with one operand is not recognized by PIC18 and PIC16F1XXX MCUs. The rest of the directive and macro language will be the same.
1.5 ASSEMBLER COMPATIBILITY ISSUES

The MPASM assembler is compatible with the MPLAB X IDE and MPLAB IDE v8 integrated development environments and all Microchip PIC1X MCU development systems currently in production.

The MPASM assembler supports a clean and consistent method of specifying radix (see Section 3.4 “Numeric Constants and Radix”). You are encouraged to develop using the radix and other directive methods described within this document, even though certain older syntaxes may be supported for compatibility reasons.

1.6 ASSEMBLER OPERATION

The MPASM assembler can be used in two ways:

• To generate absolute code that can be executed directly by a microcontroller.
• To generate relocatable code that can be linked with other separately assembled or compiled modules.

1.6.1 Generating Absolute Code

Absolute code is the default output from the MPASM assembler. This process is shown below.

When a source file is assembled in this manner, all variables and routines used in the source file must be defined within that source file, or in files that have been explicitly included by that source file. If assembly proceeds without errors, a hex file will be generated, containing the executable machine code for the target device. This file can then be used with a debugger to test code execution or with a device programmer to program the microcontroller.

1.6.2 Generating Relocatable Code

The MPASM assembler also has the ability to generate a relocatable object module that can be linked with other modules using Microchip's MPLINK linker to form the final executable code. This method is very useful for creating reusable modules.
Related modules can be grouped and stored together in a library using Microchip's MPLIB librarian. Required libraries can be specified at link time, and only the routines that are needed will be included in the final executable.

Refer to Chapter 6. “Relocatable Objects” for more information on the differences between absolute and relocatable object assembly.
1.7 ASSEMBLER INPUT/OUTPUT FILES

These are the default file extensions used by the assembler and the associated utility functions.

<table>
<thead>
<tr>
<th>TABLE 1-1: INPUT FILES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Source Code (.asm)</td>
</tr>
<tr>
<td>Include File (.inc)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TABLE 1-2: OUTPUT FILES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Listing File (.lst)</td>
</tr>
<tr>
<td>Error File (.err)</td>
</tr>
<tr>
<td>Hex File Formats (.hex, .hxl, .hxh)</td>
</tr>
<tr>
<td>Cross Reference File (.xrf)</td>
</tr>
<tr>
<td>Object File (.o)</td>
</tr>
</tbody>
</table>

1.7.1 Source Code (.asm)

Assembly is a programming language you may use to develop the source code for your application. The source code file may be created using any ASCII text file editor.

**Note:** Several example source code files are included free with the IDE.

Your source code should conform to the following basic guidelines.

Each line of the source file may contain up to four types of information:

- Labels
- Mnemonics, Directives and Macros
- Operands
- Comments

The order and position of these are important. For ease of debugging, it is recommended that labels start in column one and mnemonics start in column two or beyond. Operands follow the mnemonic. Comments may follow the operands, mnemonics or labels, and can start in any column. The maximum column width is 255 characters.

White space or a colon must separate the label and the mnemonic, and white space must separate the mnemonic and the operand(s). Multiple operands must be separated by commas.

White space is one or more spaces or tabs. White space is used to separate pieces of a source line. White space should be used to make your code easier for people to read. Unless within character constants, any white space means the same as exactly one space.
EXAMPLE 1-1: ABSOLUTE MPASM ASSEMBLER SOURCE CODE (SHOWS MULTIPLE OPERANDS)

<table>
<thead>
<tr>
<th>Labels</th>
<th>Mnemonics</th>
<th>Directives</th>
<th>Macros</th>
<th>Operands</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>list</td>
<td>p=18f452</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>#include</td>
<td>p18f452.inc</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dest</td>
<td>equ</td>
<td></td>
<td>0x0B</td>
<td></td>
<td>;Define constant</td>
</tr>
<tr>
<td>org</td>
<td>org</td>
<td></td>
<td>0x0000</td>
<td></td>
<td>;Reset vector</td>
</tr>
<tr>
<td>goto</td>
<td>org</td>
<td></td>
<td>0x0020</td>
<td></td>
<td>;Begin program</td>
</tr>
<tr>
<td>Start</td>
<td>movlw</td>
<td></td>
<td>0x0A</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>movwf</td>
<td></td>
<td>Dest</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>bcf</td>
<td></td>
<td>Dest, 3</td>
<td></td>
<td>;This line uses 2 operands</td>
</tr>
<tr>
<td></td>
<td>goto</td>
<td></td>
<td>Start</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1.7.1.1 LABELS

A label is used to represent a line or group of code, or a constant value. It is needed for branching instructions (Example 1-1.)

Labels should start in column 1. They may be followed by a colon (:), space, tab or the end of line. Labels must not begin with number.

Labels may be up to 32 characters long. By default they are case sensitive, but case sensitivity may be overridden by a command-line option (/c or -c). If a colon is used when defining a label, it is treated as a label operator and not part of the label itself.

1.7.1.2 MNEMONICS, DIRECTIVES AND MACROS

Mnemonics tell the assembler what machine instructions to assemble. For example, addition (add), branches (goto) or moves (movwf). Unlike labels that you create yourself, mnemonics are provided by the assembly language. Mnemonics are not case sensitive.

Directives are assembler commands that appear in the source code but are not usually translated directly into opcodes. They are used to control the assembler: its input, output, and data allocation. Directives are not case sensitive.

Macros are user-defined sets of instructions and directives that will be evaluated in-line with the assembler source code whenever the macro is invoked.

Assembler instruction mnemonics, directives and macro calls should begin in column two or greater. If there is a label on the same line, instructions must be separated from that label by a colon, or by one or more spaces or tabs.

1.7.1.3 OPERANDS

Operands give information to the instruction on the data that should be used and the storage location for the instruction.

Operands must be separated from mnemonics by one or more spaces, or tabs. Multiple operands must be separated by commas.
1.7.1.4 COMMENTS

Comments are text explaining the operation of a line or lines of code. The MPASM assembler treats anything after a semicolon as a comment. All characters following the semicolon are ignored through the end of the line. String constants containing a semicolon are allowed and are not confused with comments.

1.7.2 Include File (.inc)

An assembler include, or header, file is any file containing valid assembly code. Usually, the file contains device-specific register and bit assignments. This file may be "included" in the code so that it may be reused by many programs.

As an example, to add the standard header file for the PIC18F452 device to your assembly code, use:

```
#include p18f452.inc
```

Standard header files are located in:

```
C:\Program Files\Microchip\MPASM Suite
```

1.7.3 Listing File (.lst)

An MPASM assembler listing file provides a mapping of source code to object code. It also provides a list of symbol values, memory usage information, and the number of errors, warnings and messages generated.

This file may be viewed in MPLAB X IDE by:

1. selecting File>Open File to launch the Open dialog
2. selecting “All Files” from the “Files of type” drop-down list
3. locating the desired list file
4. clicking on the list file name
5. clicking Open

This file may be viewed in MPLAB IDE v8 by:

1. selecting File>Open to launch the Open dialog
2. selecting “List files (*.lst)” from the “Files of type” drop-down list
3. locating the desired list file
4. clicking on the list file name
5. clicking Open

Both the MPASM assembler and the MPLINK linker can generate listing files. For information on the MPLINK linker listing file, see 9.7.6 “Listing File (.lst)”.

To prevent assembler list file generation, use the /l- or -l- option or use with MPLINK linker. (The linker list file overwrites the assembler list file.) Set the size of tabs in the list file using the /t or -t option.
EXAMPLE 1-2: ABSOLUTE MPASM ASSEMBLER LISTING FILE

The product name and version, the assembly date and time, and the page number appear at the top of every page.

The first column contains the base address in memory where the code will be placed. The second column displays the 32-bit value of any symbols created with the `set`, `equ`, `variable`, `constant`, or `cblock` directives. The third column is reserved for the machine instruction. This is the code that will be executed by the PIC1X MCU. The fourth column lists the associated source file line number for this line. The remainder of the line is reserved for the source code line that generated the machine code.

Errors, warnings, and messages are embedded between the source lines and pertain to the following source line. Also, there is a summary at the end of the listing.

The symbol table lists all symbols defined in the program.

The memory usage map gives a graphical representation of memory usage. ‘X’ marks a used location and ‘-’ marks memory that is not used by this object. The map also displays program memory usage. The memory map is not printed if an object file is generated.

Note: Due to page width restrictions, some comments have been shortened, indicated by ‘...’ Also, some symbol table listings have been removed, indicated by ‘:’ See the standard header, p18f452.inc, for a complete list of symbols.
list p=18f452
#include p18f452.inc
LIST
; P18F452.INC  Standard Header File, Version 1.4..
LIST
 Dest equ        0x0B
org    0x0000
goto   Start
org    0x0020
movlw      0x0A
movwf  Dest
bcf    Dest, 3  ;This line uses 2 op..
movwf Dest
goto   Start
end

SYMBOL TABLE

LABEL                             VALUE

A                                 00000000
ACCESS                            00000000
:                                   :
_XT_OSC_1H                        000000F9
__18F452                           00000001

MEMORY USAGE MAP ('X' = Used, '-' = Unused)

0000 : XXXX--------------------- XXXXXXXXXXX-------- ----------------

All other memory blocks unused.

Program Memory Bytes Used: 14
Program Memory Bytes Free: 32754
1.7.4 Error File (.err)

The MPASM assembler, by default, generates an error file. This file can be useful when debugging your code. The IDE will display the error information in the Output window. The format of the messages in the error file is:

type[number] file line description

For example:

Error[113] C:\PROG.ASM 7 : Symbol not previously defined (start)

The error file may contain any number of MPASM assembler errors, warnings and messages. For more on these, see Chapter 8. “Errors, Warnings, Messages, and Limitations”.

To prevent error file generation, use the /e- or -e- option.

1.7.5 Hex File Formats (.hex, .hxl, .hxh)

The MPASM assembler and MPLINK linker are capable of producing ASCII text hex files in different formats.

<table>
<thead>
<tr>
<th>Format Name</th>
<th>Format Type</th>
<th>File Extension</th>
<th>Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intel Hex Format</td>
<td>INHX8M</td>
<td>.hex</td>
<td>8-bit core device programmers</td>
</tr>
<tr>
<td>Intel Split Hex Format</td>
<td>INHX8S</td>
<td>.hxl,.hxh</td>
<td>odd/even programmers</td>
</tr>
<tr>
<td>Intel Hex 32 Format</td>
<td>INHX32</td>
<td>.hex</td>
<td>16-bit core device programmers</td>
</tr>
</tbody>
</table>

This file format is useful for transferring PIC1X MCU series code to Microchip programmers and third party PIC1X MCU programmers.

1.7.5.1 INTEL HEX FORMAT

This format produces one 8-bit hex file with a low byte, high byte combination. Since each address can only contain 8 bits in this format, all addresses are doubled. Each data record begins with a 9-character prefix and ends with a 2-character checksum. Each record has the following format:

:BBBBBBAAAATTHHHH....HHHCC

where:

- **BB** A two digit hexadecimal byte count representing the number of data bytes that will appear on the line.
- **AAAA** A four digit hexadecimal address representing the starting address of the data record.
- **TT** A two digit record type that will always be '00' except for the end-of-file record, which will be '01'.
- **HH** A two digit hexadecimal data byte, presented in low byte/high byte combinations.
- **CC** A two digit hexadecimal checksum that is the two’s complement of the sum of all preceding bytes in the record.
EXAMPLE 1-3: INHX8M

file_name.hex :
:1000000000000000000000000000000000000000F0
:040010000000000EC
:10003200000280040006800A800E800C80028016D
:100042006801A901901EA01280208026A02BE02C5
:10005200E002E80228036803BF03E03C030804B8
:100062008040804030443050306E807E807FF0839
:06007200FF08FF08190A57
:00000001FF

1.7.5.2 INTEL SPLIT HEX FORMAT

The split 8-bit file format produces two output files: .hxl and .hxh. The format is the same as the normal 8-bit format, except that the low bytes of the data word are stored in the .hxl file, and the high bytes of the data word are stored in the .hxh file, and the addresses are divided by two. This is used to program 16-bit words into pairs of 8-bit EPROMs, one file for low byte, one file for high byte.

EXAMPLE 1-4: INHX8S

file_name.hxl :
:0A0000000000000000000000000000F6
:1000190000284068A8E8C8E2868A989EA28086ABFAA
:10002900E0E82868BFE8C808034303E8E8FFD0
:03003900FFFF19AD
:00000001FF

file_name.hxh :
:0A000000000000000000000101010101010101
:100019000000000000000000000000F6
:100029000202030303030304040405060707883
:0300390008080AAA
:00000001FF

1.7.5.3 INTEL HEX 32 FORMAT

The extended 32-bit address hex format is similar to the hex 8 format, except that the extended linear address record is output also to establish the upper 16 bits of the data address. This is mainly used for 16-bit core devices since their addressable program memory exceeds 64 kbytes.

Each data record begins with a 9-character prefix and ends with a 2-character checksum. Each record has the following format:

:BBAAATTHHHH....HHHCC

where:

BB  A two digit hexadecimal byte count representing the number of data bytes that will appear on the line.

AAAA A four digit hexadecimal address representing the starting address of the data record.

TT  A two digit record type:
00 - Data record
01 - End of File record
02 - Segment address record
04 - Linear address record

HH  A two digit hexadecimal data byte, presented in low byte/high byte combinations.

CC  A two digit hexadecimal checksum that is the two's complement of the sum of all preceding bytes in the record.
1.7.6 Cross Reference File (.xrf)

A cross reference file contains a listing of all symbols used in the assembly code. The file has the following format:

- The symbols are listed in the “Label” column, sorted by name.
- The “Type” column defines the type of symbol. A list of “Label Types” is provided at the end of the file.
- The “File Name” column lists the names of the files that use the symbol.
- The “Source File References” column lists the line number of the corresponding file in the “File Name” column where the symbol is defined/referenced. An asterisk means a definition.

To prevent cross-reference file generation, use the /x- or -x- option.

1.7.7 Object File (.o)

The assembler creates a relocatable object file from source code. This object file does not yet have addresses resolved and must be linked before it can be used as an executable.

To generate a file that will execute after being programmed into a device, see 1.7.5 “Hex File Formats (.hex, .hxl, .hxh)”.

To prevent object file generation, use the /o- or -o- option.
Chapter 2. Assembler Interfaces

2.1 INTRODUCTION

There are several interfaces with which you may use the MPASM assembler, depending on the assembler version. These interfaces are discussed here.

When MPLAB X IDE or MPLAB IDE v8 is installed, the MPASM assembler is also installed. In addition, the assembler may be obtained with the MPLAB C Compiler for PIC18 MCUs.

Topics covered in this chapter:
• MPLAB X IDE Interface
• MPLAB IDE v8 Interface
• Windows Interface
• Command Line Interface

2.2 MPLAB X IDE INTERFACE

The MPASM assembler is most commonly used with the MPLINK linker in an MPLAB X IDE project to generate relocatable code. However, the assembler may be used in MPLAB X IDE to generate absolute code (without the use of the MPLINK linker). For more information on this use, see “PIC1X MCU Language Tools and MPLAB X IDE”.

2.3 MPLAB IDE V8 INTERFACE

The MPASM assembler is most commonly used with the MPLINK linker in an MPLAB IDE project to generate relocatable code. For more information on this use, see “PIC1X MCU Language Tools and MPLAB IDE v8”.

The assembler may also be used in MPLAB IDE to generate absolute code (without the use of the MPLINK linker or MPLAB IDE project) by using the QuickBuild feature. To do this:

1. From the MPLAB IDE menu bar, select Project>Set Language Tool Locations to open a dialog to set/check language tool executable location.
2. In the dialog, under Registered Tools, select "Microchip MPASM Toolsuite". Click the "+" to expand.
3. Select Executables. Click the "+" to expand.
4. Select MPASM Assembler (mpasmwin.exe). Under Location, a path to the mpasmwin.exe file should be displayed. If no path is displayed, enter one or browse to the location of this file. By default, it is located at:
   C:\Program Files\Microchip\MPASM Suite\mpasmwin.exe
5. Click OK.
6. From the MPLAB IDE menu bar, select Project>Quickbuild to assemble the specified asm file using the MPASM assembler.
2.4 WINDOWS INTERFACE

MPASM assembler for Windows provides a graphical interface for setting assembler options. It is invoked by executing either `mpasmx.exe` (MPLAB X IDE) or `mpasmwin.exe` (MPLAB IDE v8) in Windows Explorer, or from a command prompt.

**FIGURE 2-1: MPASM ASSEMBLER WINDOWS SHELL INTERFACE**

Select a source file by typing in the name or using the Browse button. Set the various options as described below. (Default options are read from the source file.) Then click Assemble to assemble the source file.

**Note:** When MPASM assembler is invoked through an IDE, this options screen is not available. For MPLAB X IDE, use the project properties dialog (File>Properties) to set options. For MPLAB IDE v8, use the MPASM Assembler tab of the Build Options dialog in MPLAB IDE (Project>Build Options>Project) to set options.

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radix</td>
<td>Override any source file radix settings. Reference: *Section 4.43 “list - Listing Options”, Section 4.56 “radix - Specify Default Radix”, Section 3.4 “Numeric Constants and Radix”</td>
</tr>
<tr>
<td>Warning Level</td>
<td>Override any source file message level settings. Reference: *Section 4.48 “messg - Create User Defined Message”</td>
</tr>
<tr>
<td>Hex Output</td>
<td>Override any source file hex file format settings. Reference: *Section 1.7.5 “Hex File Formats (.hex, .hxl, .hxh)”</td>
</tr>
<tr>
<td>Generated Files</td>
<td>Enable/disable various output files. Reference: *Section 1.7 “Assembler Input/Output Files”</td>
</tr>
<tr>
<td>Case Sensitivity</td>
<td>Enable/disable case sensitivity. If enabled, the assembler will distinguish between upper- and lower-case letters.</td>
</tr>
</tbody>
</table>
Assembler Interfaces

2.5 COMMAND LINE INTERFACE

MPASM assembler can be invoked through the command line interface (command prompt). For the assembler included with MPLAB X IDE:

Windows OS: `mpasmx [/option1.../optionN] filename`

Linux OS and Mac OS: `mpasmx [-option1...-optionN] filename`

where

- `option` refers to one of the command line options
- `filename` is the file being assembled

For example, if `test.asm` exists in the current directory, it can be assembled with the following command:

`mpasmx /e /l test.asm`

If the source filename is omitted, the appropriate shell interface is invoked, i.e., a Windows OS interface is displayed, which includes a Help button.

<table>
<thead>
<tr>
<th>Option (Enter -o)</th>
<th>Default</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>? or h</td>
<td>N/A</td>
<td>Display the assembler help screen.</td>
</tr>
<tr>
<td>a hex-format</td>
<td>INHX32*</td>
<td>Generate .hex output directly from assembler, where <code>hex-format</code> is one of {INHX8M</td>
</tr>
<tr>
<td>c</td>
<td>On</td>
<td>Enable/Disable case sensitivity. If enabled, the assembler will distinguish between upper- and lower-case letters.</td>
</tr>
<tr>
<td>d label[=value]</td>
<td>N/A</td>
<td>Define a text string substitution, i.e., assign value to label.</td>
</tr>
<tr>
<td>e[+]</td>
<td>-</td>
<td>path</td>
</tr>
</tbody>
</table>

- e Enable
- e+ Enable
- e- Disable
- e path Enable/specify path
- e=CON Enable to console; no file output

* Default is dependent on processor selected.

* Default is dependent on processor selected.
<table>
<thead>
<tr>
<th>Option (/ or -)</th>
<th>Default</th>
<th>Description</th>
</tr>
</thead>
</table>
| ![image](https://via.placeholder.com/150) ![image](https://via.placeholder.com/150) ![image](https://via.placeholder.com/150) ![image](https://via.placeholder.com/150) | On | Enable/Disable/Set Path for list file.
| ![image](https://via.placeholder.com/150) ![image](https://via.placeholder.com/150) | 1 | Enable |
| ![image](https://via.placeholder.com/150) ![image](https://via.placeholder.com/150) | 1+ | Enable |
| ![image](https://via.placeholder.com/150) ![image](https://via.placeholder.com/150) | 1- | Disable |
| ![image](https://via.placeholder.com/150) ![image](https://via.placeholder.com/150) | \texttt{path} | Enable/specify path |
| ![image](https://via.placeholder.com/150) ![image](https://via.placeholder.com/150) | See Section 1.7.3 “Listing File (.lst)” for more information. |
| ![image](https://via.placeholder.com/150) ![image](https://via.placeholder.com/150) | m | On |
| ![image](https://via.placeholder.com/150) ![image](https://via.placeholder.com/150) | Enable/Disable macro expansion. See Section 4.32 “expand - Expand Macro Listing” for more information. |
| ![image](https://via.placeholder.com/150) ![image](https://via.placeholder.com/150) | o | Off |
| ![image](https://via.placeholder.com/150) ![image](https://via.placeholder.com/150) | Enable/Disable/Set Path for object file. |
| ![image](https://via.placeholder.com/150) ![image](https://via.placeholder.com/150) | o | Enable |
| ![image](https://via.placeholder.com/150) ![image](https://via.placeholder.com/150) | o+ | Enable |
| ![image](https://via.placeholder.com/150) ![image](https://via.placeholder.com/150) | o- | Disable |
| ![image](https://via.placeholder.com/150) ![image](https://via.placeholder.com/150) | o | Enable/specify path |
| ![image](https://via.placeholder.com/150) ![image](https://via.placeholder.com/150) | See Section 1.7.7 “Object File (.o)” for more information. |
| ![image](https://via.placeholder.com/150) ![image](https://via.placeholder.com/150) | processor_type | None |
| ![image](https://via.placeholder.com/150) ![image](https://via.placeholder.com/150) | Set the processor type, where processor_type is a PIC1X MCU device, e.g., PIC18F452. |
| ![image](https://via.placeholder.com/150) ![image](https://via.placeholder.com/150) | q | Off |
| ![image](https://via.placeholder.com/150) ![image](https://via.placeholder.com/150) | Enable/Disable quiet mode (suppress screen output.) |
| ![image](https://via.placeholder.com/150) ![image](https://via.placeholder.com/150) | radix | Hex |
| ![image](https://via.placeholder.com/150) ![image](https://via.placeholder.com/150) | Defines default radix, where \texttt{radix} is one of \{HEX | DEC | OCT\}. See Section 4.43 “\texttt{list} - Listing Options” or Section 4.56 “\texttt{radix} - Specify Default Radix” for more information. |
| ![image](https://via.placeholder.com/150) ![image](https://via.placeholder.com/150) | s | On |
| ![image](https://via.placeholder.com/150) ![image](https://via.placeholder.com/150) | Show progress window while assembling. For use only on the command line (not within MPLAB IDE). |
| ![image](https://via.placeholder.com/150) ![image](https://via.placeholder.com/150) | t | 8 |
| ![image](https://via.placeholder.com/150) ![image](https://via.placeholder.com/150) | Set the size of tabs in the list file. See Section 1.7.3 “Listing File (.lst)” for more information. |
| ![image](https://via.placeholder.com/150) ![image](https://via.placeholder.com/150) | w | 0 |
| ![image](https://via.placeholder.com/150) ![image](https://via.placeholder.com/150) | Set message level, where \texttt{value} is one of \{0|1|2\}. |
| ![image](https://via.placeholder.com/150) ![image](https://via.placeholder.com/150) | 0 | all messages |
| ![image](https://via.placeholder.com/150) ![image](https://via.placeholder.com/150) | 1 | errors and warnings |
| ![image](https://via.placeholder.com/150) ![image](https://via.placeholder.com/150) | 2 | errors only |
| ![image](https://via.placeholder.com/150) ![image](https://via.placeholder.com/150) | See Section 4.48 “\texttt{messg} - Create User Defined Message” for more information. |
| ![image](https://via.placeholder.com/150) ![image](https://via.placeholder.com/150) | x | Off |
| ![image](https://via.placeholder.com/150) ![image](https://via.placeholder.com/150) | x | Enable |
| ![image](https://via.placeholder.com/150) ![image](https://via.placeholder.com/150) | x+ | Enable |
| ![image](https://via.placeholder.com/150) ![image](https://via.placeholder.com/150) | x- | Disable |
| ![image](https://via.placeholder.com/150) ![image](https://via.placeholder.com/150) | x | Enable/specify path |
| ![image](https://via.placeholder.com/150) ![image](https://via.placeholder.com/150) | See Section 1.7.6 “Cross Reference File (.xrf)” for more information. |
| ![image](https://via.placeholder.com/150) ![image](https://via.placeholder.com/150) | y | Disabled |
| ![image](https://via.placeholder.com/150) ![image](https://via.placeholder.com/150) | Enable/Disable extended instruction set. |
| ![image](https://via.placeholder.com/150) ![image](https://via.placeholder.com/150) | y | Enable |
| ![image](https://via.placeholder.com/150) ![image](https://via.placeholder.com/150) | y+ | Enable |
| ![image](https://via.placeholder.com/150) ![image](https://via.placeholder.com/150) | y- | Disable |
| ![image](https://via.placeholder.com/150) ![image](https://via.placeholder.com/150) | See Section 4.43 “\texttt{list} - Listing Options”. |

* Default is dependent on processor selected.
Chapter 3. Expression Syntax and Operation

3.1 INTRODUCTION

Various expression formats, syntax, and operations used by MPASM assembler are described here.

Topics covered in this chapter:
• Text Strings
• Reserved Words and Section Names
• Numeric Constants and Radix
• Arithmetic Operators and Precedence

3.2 TEXT STRINGS

A “string” is a sequence of any valid ASCII character (of the decimal range of 0 to 127) enclosed by double quotes. It may contain double quotes or null characters.

The way to get special characters into a string is to escape the characters, preceding them with a backslash ‘\’ character. The same escape sequences that apply to strings also apply to characters.

Strings may be of any length that will fit within a 255 column source line. If a matching quote mark is found, the string ends. If none is found before the end of the line, the string will end at the end of the line. While there is no direct provision for continuation onto a second line, it is generally no problem to use a second dw directive for the next line.

The dw directive will store the entire string into successive words. If a string has an odd number of characters (bytes), the dw and data directives will pad the end of the string with one byte of zero (00).

If a string is used as a literal operand, it must be exactly one character long, or an error will occur.
3.2.1 Escape Characters

The assembler accepts the ANSI 'C' escape sequences to represent certain special control characters:

**TABLE 3-1: ANSI ‘C’ ESCAPE SEQUENCES**

<table>
<thead>
<tr>
<th>Escape Character</th>
<th>Description</th>
<th>Hex Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>\a</td>
<td>Bell (alert) character</td>
<td>07</td>
</tr>
<tr>
<td>\b</td>
<td>Backspace character</td>
<td>08</td>
</tr>
<tr>
<td>\f</td>
<td>Form feed character</td>
<td>0C</td>
</tr>
<tr>
<td>\n</td>
<td>New line character</td>
<td>0A</td>
</tr>
<tr>
<td>\r</td>
<td>Carriage return character</td>
<td>0D</td>
</tr>
<tr>
<td>\t</td>
<td>Horizontal tab character</td>
<td>09</td>
</tr>
<tr>
<td>\v</td>
<td>Vertical tab character</td>
<td>0B</td>
</tr>
<tr>
<td>&quot;</td>
<td>Backslash</td>
<td>5C</td>
</tr>
<tr>
<td>?</td>
<td>Question mark character</td>
<td>3F</td>
</tr>
<tr>
<td>'</td>
<td>Single quote (apostrophe)</td>
<td>27</td>
</tr>
<tr>
<td>&quot;</td>
<td>Double quote character</td>
<td>22</td>
</tr>
<tr>
<td>\000</td>
<td>Octal number (zero, Octal digit, Octal digit)</td>
<td></td>
</tr>
<tr>
<td>\xHH</td>
<td>Hexadecimal number</td>
<td></td>
</tr>
</tbody>
</table>

3.2.2 Code Examples

See the examples below for the object code generated by different statements involving strings.

```
7465 7374 696E  # define str “testing output string two”
6720 6F75 7470
7574 2073 7472
696E 6720 6F6E
650A
7465 7374 696E  # define str “testing output string two”
6720 6669 7273
7420 6F75 7470
7574 2073 7472
696E 6700
```
3.3 RESERVED WORDS AND SECTION NAMES

You may not use the following words for label, constant or variable names:

- Directives (see Chapter 4, “Directives”).
- Instructions (see Appendix A, “Instruction Sets”).
- The word “main” (when using the assembler with an IDE). Do not use a “main” label that cannot be reached by a simple reset and run, for example, a data label named “main” or a routine named “main” that will only be accessed under certain conditions, as with an interrupt.

In addition, the assembler has the following reserved section names:

<table>
<thead>
<tr>
<th>TABLE 3-2: RESERVED SECTION NAMES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Section Name</td>
</tr>
<tr>
<td>.access_ovr</td>
</tr>
<tr>
<td>.code</td>
</tr>
<tr>
<td>.idata</td>
</tr>
<tr>
<td>.idata_acs</td>
</tr>
<tr>
<td>.udata</td>
</tr>
<tr>
<td>.udata_acs</td>
</tr>
<tr>
<td>.udata_ovr</td>
</tr>
<tr>
<td>.udata_shr</td>
</tr>
</tbody>
</table>

3.4 NUMERIC CONSTANTS AND RADIX

MPASM assembler supports the following radix forms for constants: hexadecimal, decimal, octal, binary, and ASCII. The default radix is hexadecimal; the default radix determines what value will be assigned to constants in the object file when a radix is not explicitly specified by a base descriptor.

Note: The radix for numeric constants can be made different from the default radix specified with the directives radix or list r=. Also, allowable default radices are limited to hexadecimal, decimal, and octal.

Constants can be optionally preceded by a plus or minus sign. If unsigned, the value is assumed to be positive.

Note: Intermediate values in constant expressions are treated as 32-bit unsigned integers. Whenever an attempt is made to place a constant in a field for which it is too large, a truncation warning will be issued.
The following table presents the various radix specifications:

<table>
<thead>
<tr>
<th>Note</th>
<th>Type</th>
<th>Syntax</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Binary</td>
<td>B'binary_digits'</td>
<td>B'00111001'</td>
</tr>
<tr>
<td>2</td>
<td>Octal</td>
<td>O'octal_digits'</td>
<td>O'777'</td>
</tr>
<tr>
<td>3</td>
<td>Decimal</td>
<td>D'digits'</td>
<td>D'100'</td>
</tr>
<tr>
<td></td>
<td></td>
<td>.digits</td>
<td>.100</td>
</tr>
<tr>
<td>4</td>
<td>Hexadecimal</td>
<td>H'hex_digits'</td>
<td>H'9f'</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0xhex_digits</td>
<td>0x9f</td>
</tr>
<tr>
<td>5</td>
<td>ASCII</td>
<td>A'character'</td>
<td>A'C'</td>
</tr>
<tr>
<td></td>
<td></td>
<td>'character'</td>
<td>'C'</td>
</tr>
</tbody>
</table>

1. A binary integer is 'b' or 'B' followed by one or more of the binary digits '01' in single quotes. 
2. An octal integer is 'o' or 'O' followed by one or more of the octal digits '01234567' in single quotes. 
3. A decimal integer is 'd' or 'D' followed by one or more decimal digits '0123456789' in single quotes. Or, a decimal integer is '.' followed by one or more decimal digits '0123456789'. 
4. A hexadecimal integer is 'h' or 'H' followed by one or more hexadecimal digits '0123456789abcdefABCDEF' in single quotes. Or, a hexadecimal integer is '0x' or '0X' followed by one or more hexadecimal digits '0123456789abcdefABCDEF'. 
5. An ASCII character is 'a' or 'A' followed by one character in single quotes. Or, an ASCII character is one character in single quotes.
### 3.5 ARITHMETIC OPERATORS AND PRECEDENCE

Arithmetic operators may be used with directives and their variables as specified in the table below.

**Note:** These operators cannot be used with program variables. They are for use with directives only.

The operator order in the table also corresponds to its precedence, where the first operator has the highest precedence and the last operator has the lowest precedence. Precedence refers to the order in which operators are executed in a code statement.

#### TABLE 3-1: ARITHMETIC OPERATORS IN ORDER OF PRECEDENCE

<table>
<thead>
<tr>
<th>Operator</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>$</td>
<td>Current/Return program counter</td>
</tr>
<tr>
<td>(</td>
<td>Left Parenthesis</td>
</tr>
<tr>
<td>)</td>
<td>Right Parenthesis</td>
</tr>
<tr>
<td>!</td>
<td>Item NOT (logical complement)</td>
</tr>
<tr>
<td>-</td>
<td>Negation (2\’s complement)</td>
</tr>
<tr>
<td>~</td>
<td>Complement</td>
</tr>
<tr>
<td>low^1</td>
<td>Return low byte of address</td>
</tr>
<tr>
<td>high^1</td>
<td>Return high byte of address</td>
</tr>
<tr>
<td>upper^1</td>
<td>Return upper byte of address</td>
</tr>
<tr>
<td>*</td>
<td>Multiply</td>
</tr>
<tr>
<td>/</td>
<td>Divide</td>
</tr>
<tr>
<td>%</td>
<td>Modulus</td>
</tr>
<tr>
<td>+</td>
<td>Add</td>
</tr>
<tr>
<td>-</td>
<td>Subtract</td>
</tr>
<tr>
<td>&lt;&lt;</td>
<td>Left shift</td>
</tr>
<tr>
<td>&gt;&gt;</td>
<td>Right shift</td>
</tr>
<tr>
<td>&gt;=</td>
<td>Greater or equal</td>
</tr>
<tr>
<td>&gt;</td>
<td>Greater than</td>
</tr>
<tr>
<td>&lt;</td>
<td>Less than</td>
</tr>
<tr>
<td>&lt;=</td>
<td>Less or equal</td>
</tr>
<tr>
<td>==</td>
<td>Equal to</td>
</tr>
<tr>
<td>!=</td>
<td>Not equal to</td>
</tr>
<tr>
<td>&amp;</td>
<td>Bitwise AND</td>
</tr>
<tr>
<td>^</td>
<td>Bitwise exclusive OR</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>&amp;&amp;</td>
<td>Logical AND</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>=</td>
<td>Set equal to</td>
</tr>
<tr>
<td>+=</td>
<td>Add to, set equal</td>
</tr>
<tr>
<td>-=</td>
<td>Subtract, set equal</td>
</tr>
<tr>
<td>*=</td>
<td>Multiply, set equal</td>
</tr>
<tr>
<td>/=</td>
<td>Divide, set equal</td>
</tr>
<tr>
<td>%=</td>
<td>Modulus, set equal</td>
</tr>
<tr>
<td>&lt;&lt;=</td>
<td>Left shift, set equal</td>
</tr>
<tr>
<td>&gt;&gt;=</td>
<td>Right shift, set equal</td>
</tr>
<tr>
<td>&amp;=</td>
<td>AND, set equal</td>
</tr>
</tbody>
</table>

^1 These operators cannot be used with program variables. They are for use with directives only.
### TABLE 3-1: ARITHMETIC OPERATORS IN ORDER OF PRECEDENCE

<table>
<thead>
<tr>
<th>Operator</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>=</td>
</tr>
<tr>
<td>^=</td>
<td>flags ^= ERROR_FLAG</td>
</tr>
<tr>
<td>++</td>
<td>i ++</td>
</tr>
<tr>
<td>--</td>
<td>i --</td>
</tr>
</tbody>
</table>

**Note 1:** This precedence is the same for the low, high and upper operands which apply to sections. See Section 6.4 “Low, High and Upper Operators” for more information.

**2:** These operators can only be used on a line by themselves; they cannot be embedded within other expression evaluations.
Chapter 4. Directives

4.1 INTRODUCTION

Directives are assembler commands that appear in the source code but are not usually translated directly into opcodes. They are used to control the assembler: its input, output, and data allocation.

Note: Directives are not instructions (movlw, btfss, goto, etc.). For instruction set information, consult your device data sheet.

Many of the assembler directives have alternate names and formats. These may exist to provide backward compatibility with previous assemblers from Microchip and to be compatible with individual programming practices. If portable code is desired, it is recommended that programs be written using the specifications contained here.

Note: Although MPASM assembler is often used with MPLINK object linker, MPASM assembler directives are not supported in MPLINK linker scripts. See MPLINK object linker documentation for more information on linker options to control listing and hex file output.

Information on individual directives includes syntax, description, usage, and related directives, as well as simple and, in some cases, expanded examples of use. In most cases, simple examples may be assembled and run by adding an end statement. Expanded examples may be assembled and run as-is to give an demonstration of an application using the directive(s).

Individual directives may be found alphabetically (in the following sections) or by type (Section 4.2 “Directives by Type”).

Note: Directives are not case-sensitive, e.g., cblock may be executed as CBLOCK, cblock, Cblock, etc.

4.2 DIRECTIVES BY TYPE

There are six basic types of directives provided by the assembler.

1. Control Directives
2. Conditional Assembly Directives
3. Data Directives
4. Listing Directives
5. Macro Directives
6. Object File Directives
4.2.1 Control Directives

Control directives control how code is assembled.

- `#define` - Define a Text Substitution Label .............................................. p. 98
- `#include` - Include Additional Source File ............................................... p. 130
- `#undefine` - Delete a Substitution Label.................................................. p. 162
- `bankisel` - Generate Indirect Bank Selecting Code (PIC12/16 MCUs)...... p. 77
- `banksel` - Generate Bank Selecting Code ............................................... p. 80
- `constant` - Declare Symbol Constant ...................................................... p. 89
- `end` - End Program Block ........................................................................... p. 103
- `equ` - Define an Assembler Constant......................................................... p. 105
- `org` - Set Program Origin........................................................................... p. 141
- `pagesel` - Generate Page Selecting Code (PIC10/12/16 MCUs)............. p. 144
- `pageselw` - Generate Page Selecting Code Using WREG Commands (PIC10/12/16 MCUs) .................................................................................. p. 146
- `processor` - Set Processor Type ............................................................. p. 147
- `radix` - Specify Default Radix ................................................................... p. 148
- `set` - Define an Assembler Variable .......................................................... p. 152
- `variable` - Declare Symbol Variable ....................................................... p. 163

4.2.2 Conditional Assembly Directives

Conditional assembly directives permit sections of conditionally assembled code. These are not run-time instructions like their C language counterparts. They define which code is assembled, not how the code executes.

- `else` - Begin Alternative Assembly Block to if Conditional ..................... p. 102
- `endif` - End Conditional Assembly Block ................................................. p. 104
- `endw` - End a while Loop ......................................................................... p. 105
- `if` - Begin Conditionally Assembled Code Block....................................... p. 125
- `ifdef` - Execute If Symbol Has Been Defined .......................................... p. 127
- `ifndef` - Execute If Symbol Has Not Been Defined ................................. p. 129
- `while` - Perform Loop While Condition is True ......................................... p. 165

4.2.3 Data Directives

Data directives control the allocation of memory and provide a way to refer to data items symbolically, i.e., by meaningful names.

- `__badram` - Identify Unimplemented RAM ................................................ p. 75
- `__badrom` - Identify Unimplemented ROM ................................................ p. 76
- `__config` - Set Processor Configuration Bits ............................................ p. 86
- `__maxram` - Define Maximum RAM Location .......................................... p. 136
- `__maxrom` - Define Maximum ROM Location .......................................... p. 137
- `cblock` - Define a Block of Constants....................................................... p. 82
- `data` - Create Numeric and Text Data ....................................................... p. 92
- `db` - Declare Data of One Byte................................................................... p. 94
- `de` - Declare EEPROM Data Byte ......................................................... p. 96
- `dt` - Define Table (PIC12/16 MCUs) ......................................................... p. 100
4.2.4 Listing Directives

Listing directives control the MPASM assembler listing file format. These directives allow the specification of titles, pagination, and other listing control. Some listing directives also control how code is assembled.

- **error** - Issue an Error Message .......................................................... p. 106
- **errorlevel** - Set Message Level ............................................................ p. 108
- **list** - Listing Options .......................................................................... p. 131
- **messg** - Create User Defined Message ................................................ p. 138
- **nolist** - Turn off Listing Output .......................................................... p. 140
- **page** - Insert Listing Page Eject ........................................................... p. 144
- **space** - Insert Blank Listing Lines ....................................................... p. 153
- **subtitle** - Specify Program Subtitle .................................................... p. 153
- **title** - Specify Program Title ............................................................... p. 154

4.2.5 Macro Directives

Macro directives control the execution and data allocation within macro body definitions.

- **endm** - End a Macro Definition ............................................................ p. 104
- **exitm** - Exit from a Macro ................................................................. p. 111
- **expand** - Expand Macro Listing .......................................................... p. 113
- **local** - Declare Local Macro Variable ................................................ p. 132
- **macro** - Declare Macro Definition ...................................................... p. 134
- **noexpand** - Turn off Macro Expansion .............................................. p. 140

4.2.6 Object File Directives

Object file directives are used only when creating an object file.

- **access_ovr** - Begin an Object File Overlay Section in Access RAM (PIC18 MCUs) .......................................................... p. 74
- **code** - Begin an Object File Code Section ........................................... p. 84
- **code_pack** - Begin an Object File Packed Code Section (PIC18 MCUs).......................................................... p. 85
- **extern** - Declare an Externally Defined Label ........................................ p. 114
- **global** - Export a Label ....................................................................... p. 119
- **idata** - Begin an Object File Initialized Data Section ................................ p. 120
- **idata_acs** - Begin an Object File Initialized Data Section in Access RAM (PIC18 MCUs) .......................................................... p. 122
- **udata** - Begin an Object File Uninitialized Data Section ....................... p. 154
- **udata_acs** - Begin an Object File Access Uninitialized Data Section (PIC18 MCUs) .......................................................... p. 156
- **udata_ovr** - Begin an Object File Overlayed Uninitialized Data Section . p. 158
- **udata_shr** - Begin an Object File Shared Uninitialized Data Section (PIC12/16 MCUs) .......................................................... p. 160
4.3 access_ovr - BEGIN AN OBJECT FILE OVERLAY SECTION IN ACCESS RAM (PIC18 MCUs)

4.3.1 Syntax

[label] access_ovr [RAM_address]

4.3.2 Description

This directive declares the beginning of a section of overlay data in Access RAM. If label is not specified, the section is named .access_ovr. The starting address is initialized to the specified address or will be assigned at link time if no address is specified. The space declared by this section is overlayed by all other access_ovr sections of the same name. No code can be placed by the user in this segment.

4.3.3 Usage

This directive is used in the following types of code: relocatable. For information on types of code, see Section 1.6 "Assembler Operation".

access_ovr is similar to udata_acs and udata_ovr, except that it declares a PIC18 Access-RAM, uninitialized-data section that can be overlayed with other overlay access sections of the same name. Overlaying access sections allows you to reuse access-bank data space.

4.3.4 See Also

extern global udata udata_ovr udata_acs

4.3.5 Simple Example

;The 2 identically-named sections are overlayed in PIC18 Access RAM.
;In this example, u16a is overlaid with memory locations used
;by u8a and u8b. u16b is overlaid with memory locations used
;by u8c and u8d.

myaoscn       access_ovr
u8a:          res 1
u8b:          res 1
u8c:          res 1
u8d:          res 1

myaoscn       access_ovr
u16a:         res 2
u16b:         res 2
4.4 __badram - IDENTIFY UNIMPLEMENTED RAM

4.4.1 Syntax

__badram expr[-expr][, expr[-expr]]

4.4.2 Description

The __maxram and __badram directives together flag accesses to unimplemented registers. __badram defines the locations of invalid RAM addresses. This directive is designed for use with the __maxram directive. A __maxram directive must precede any __badram directive. Each expr must be less than or equal to the value specified by __maxram. Once the __maxram directive is used, strict RAM address checking is enabled, using the RAM map specified by __badram. To specify a range of invalid locations, use the syntax minloc-maxloc.

4.4.3 Usage

This directive is used in the following types of code: absolute or relocatable. For information on types of code, see Section 1.6 “Assembler Operation”.

__badram is not commonly used, as RAM and ROM details are handled by the include files (*.inc) or linker script files (*.lkr).

4.4.4 See Also

__maxram

4.4.5 Simple Example

#include p16c622.inc
__maxram 0x0BF
__badram 0x07-0x09, 0x0D-0xE
__badram 0x87-0x89, 0x8D, 0x8F-0x9E
movwf 0x07 ; Generates invalid RAM warning
movwf 0x87 ; Generates invalid RAM warning
; and truncation message
4.5 \texttt{__badrom} - IDENTIFY UNIMPLEMENTED ROM

4.5.1 Syntax

\texttt{__badrom expr[-expr][, expr[-expr]]}

4.5.2 Description

The \texttt{__maxrom} and \texttt{__badrom} directives together flag accesses to unimplemented registers. \texttt{__badrom} defines the locations of invalid ROM addresses. This directive is designed for use with the \texttt{__maxrom} directive. A \texttt{__maxrom} directive must precede any \texttt{__badrom} directive. Each \texttt{expr} must be less than or equal to the value specified by \texttt{__maxrom}. Once the \texttt{__maxrom} directive is used, strict ROM address checking is enabled, using the ROM map specified by \texttt{__badrom}. To specify a range of invalid locations, use the syntax \texttt{minloc-maxloc}.

Specifically, a warning will be raised in the following circumstances:

- the target of a \texttt{GOTO} or \texttt{CALL} instruction is evaluated by the assembler to a constant, and falls in a bad ROM region
- the target of an \texttt{LGOTO} or \texttt{LCALL} pseudo-op is evaluated by the assembler to a constant, and falls in a bad ROM region
- a \texttt{.hex} file is being generated, and part of an instruction falls in a bad ROM region

4.5.3 Usage

This directive is used in the following types of code: absolute or relocatable. For information on types of code, see Section 1.6 "Assembler Operation".

\texttt{__badrom} is not commonly used, as RAM and ROM details are handled by the include files (*.inc) or linker script files (*.lkr).

4.5.4 See Also

\texttt{__maxrom}

4.5.5 Simple Example

\begin{verbatim}
#include p12c508.inc
__maxrom 0x1FF
__badrom 0x2 - 0x4, 0xA
org 0x5
  goto 0x2 ; generates a warning
  call 0x3 ; generates a warning
org 0xA
  movlw 5 ; generates a warning
\end{verbatim}
4.6 bankisel - GENERATE INDIRECT BANK SELECTING CODE (PIC12/16 MCUs)

4.6.1 Syntax

`bankisel label`

4.6.2 Description

This directive is an instruction to the assembler or linker to generate the appropriate bank selecting code for an indirect access of the register address specified by `label`. Only one `label` should be specified. No operations can be performed on `label`. This label must have been previously defined.

The linker will generate the appropriate bank selecting code. For 14-bit instruction width (most PIC12/PIC16) devices, the appropriate bit set/clear instruction on the IRP bit in the STATUS register will be generated. But for PIC16 extended instructions, FSR0H is modified instead of IRP bit (as there is no IRP bit). If the indirect address can be specified without these instructions, no code will be generated.

4.6.3 Usage

This directive is used in the following types of code: absolute or relocatable. For information on types of code, see Section 1.6 “Assembler Operation”.

This directive may be used with 14-bit instruction width PIC1X devices. This excludes 12-bit instruction width devices and PIC18 devices.

4.6.4 See Also

`banksel` `pagesel`

4.6.5 Simple Example

```
movlw Var1
movwf FSR       ;Load the address of Var1 info FSR
bankisel Var1   ;Select the correct bank for Var1
    ;
movwf INDF      ;Indirectly write to Var1
```
4.6.6 Application Example - bankisel

This program demonstrates the bankisel directive. This directive generates the appropriate code to set/clear the IRP bit of the STATUS register for an indirect access.

```assembly
#include p16f877a.inc  ;Include standard header file for the selected device.

group1 udata 0x20 ;group1 data stored at locations starting at 0x20 (IRP bit 0).
group1_var1 res 1 ;group1_var1 located at 0x20.
group1_var2 res 1 ;group1_var2 located at 0x21.

group2 udata 0x120 ;group2 data stored at locations starting at 0x120 (IRP bit 1).
group2_var1 res 1 ;group2_var1 located at 0x120.
group2_var2 res 1 ;group2_var2 located at 0x121.

RST CODE 0x0 ;The code section named RST is placed at program memory location 0x0. The next two instructions are placed in code section RST.

pagesel start ;Jumps to the location labelled 'start'.
goto start ;'start'.

PGM CODE ;This is the beginning of the code section named PGM. It is a relocatable code section since no absolute address is given along with directive CODE.

start

movlw 0x20 ;This part of the code addresses variables group1_var1 & group1_var2 indirectly.
movwf FSR
bankisel group1_var1
clrf INDF
incf FSR,F
clrf INDF

movwf FSR
bankisel group2_var1
clrf INDF
incf FSR,F
clrf INDF

goto $ ;Go to current line (loop here)
end
```
4.6.7 Application Example 2 - bankisel

```c
#include p16f877a.inc ;Include standard header file
 ;for the selected device.

bankisel EEADR ;This register is at location 100h
 ;in banks 2 or 3 so the IRP bit
 ;must be set. bankisel will set it
 ;but only where it is used.
movlw EEADR,W ;Put the address of the register to
 ;be accessed indirectly into W.
movwf FSR ;Copy address from W to FSR to set
 ;up pointer to EEADR.
clr INDF ;Clear EEADR through indirect
 ;accessing of EEADR through FSR/INDF.
 ;It would have cleared PIR2 (00Dh)
 ;if bankisel had not been used to
 ;set the IRP bit.
goto $ ;Prevents fall off end of code.
end ;All code must have an end statement.
```
4.7 banksel - GENERATE BANK SELECTING CODE

4.7.1 Syntax

```
banksel label
```

4.7.2 Description

This directive is an instruction to the assembler and linker to generate bank selecting code to set the bank to the bank containing the designated `label`. Only one `label` should be specified. No operations can be performed on `label`. This label must have been previously defined.

The linker will generate the appropriate bank selecting code:
- For 12-bit instruction width (PIC10F, some PIC12/PIC16) devices, the appropriate bit set/clear instructions on the FSR will be generated.
- For 14-bit instruction width (most PIC12/PIC16) devices, bit set/clear instructions on the STATUS register will be generated.
- For PIC16 extended and PIC18 devices, a `movlb` will be generated. If the device contains only one bank of RAM, no instructions will be generated.

4.7.3 Usage

This directive is used in the following types of code: absolute or relocatable. For information on types of code, see Section 1.6 “Assembler Operation”.

This directive may be used with all PIC1X devices. This directive is not needed for variables in access RAM (PIC18 devices.)

4.7.4 See Also

```
bankisel pagesel
```

4.7.5 Simple Example

```
banksel Var1 ;Select the correct bank for Var1
movwf Var1 ;Write to Var1
```
4.7.6 Application Example - banksel

This program demonstrates thebanksel directive. This directive generates the appropriate code to set/clear the RP0 and RP1 bits of the STATUS register.

```c
#include p16f877a.inc ;Include standard header file
;for the selected device.

group1 udata 0x20 ;group1 data stored at locations
;starting at 0x20 (bank 0).
group1_var1 res 1 ;group1_var1 located at 0x20.
group1_var2 res 1 ;group1_var2 located at 0x21.

group2 udata 0xA0 ;group2 data stored at locations
;starting at 0xA0 (bank 1)
group2_var1 res 1
group2_var2 res 1

RST CODE 0x0 ;The code section named RST
;is placed at program memory
;location 0x0. The next two
;instructions are placed in
;code section RST.

groupsel start ;Jumps to the location labelled
goto start ;'start'.

PGM CODE ;This is the beginning of the
;code section named PGM. It is
;a relocatable code section
;since no absolute address is
;given along with directive CODE.

start
banksel group1_var1 ;This directive generates code
;to set/clear bank select bits
;RP0 & RP1 of STATUS register
;depending upon the address of
;group1_var1.

clrf group1_var1
clrf group1_var2

banksel group2_var1 ;This directive generates code
;to set/clear bank select bits
;RP0 & RP1 of STATUS register
;depending upon the address of
;group2_var1.

clrf group2_var1
clrf group2_var2

goto $ ;Go to current line (loop here)
end
```
4.7.7 Application Example 2 - banksel

```asm
#include p16f877a.inc ;Include standard header file
                     ;for the selected device.

banksel TRISB       ;Since this register is in bank 1,
                     ;not default bank 0, banksel is
                     ;used to ensure bank bits are correct.

clrf TRISB          ;Clear TRISB. Sets PORTB to outputs.
banksel PORTB       ;banksel used to return to bank 0,
                     ;where PORTB is located.
movlw 0x55           ;Set PORTB value.
movwf PORTB
goto $               ;All programs must have an end.
```

4.8 cblock - DEFINE A BLOCK OF CONSTANTS

4.8.1 Syntax

cblock [expr]

```asm
type1[::increment][,type2[::increment]]
```

endc

4.8.2 Description

Defines a list of named sequential symbols. The purpose of this directive is to assign
address offsets to many labels. The list of names end when an endc directive is
encountered.

`expr` indicates the starting value for the first name in the block. If no expression is
found, the first name will receive a value one higher than the final name in the previous
cblock. If the first cblock in the source file has no `expr`, assigned values start with
zero.

If `increment` is specified, then the next `label` is assigned the value of `increment`
higher than the previous `label`.

Multiple names may be given on a line, separated by commas.

cblock is useful for defining constants in program and data memory for absolute code
generation.

4.8.3 Usage

This directive is used in the following types of code: absolute. For information on types
of code, see Section 1.6 “Assembler Operation”.

Use this directive in place of or in addition to the `equ` directive. When creating
non-relocatable (absolute) code, cblock is often used to define variable address
location names. Do not use cblock or `equ` to define variable location names for
relocatable code.

4.8.4 See Also

endc equ
4.8.5  Simple Example

cblock 0x20 ; name_1 will be assigned 20
    name_1, name_2 ; name_2, 21 and so on
    name_3, name_4 ; name_4 is assigned 23.
endc

cblock 0x30
    TwoByteVar: 0, TwoByteHigh, TwoByteLow ;TwoByteVar =0x30
        ;TwoByteHigh=0x30
        ;TwoByteLow =0x31
Queue: QUEUE_SIZE
    QueueHead, QueueTail
    Double1:2, Double2:2
endc

4.8.6  Application Example - cblock/endc

This example shows the usage of CBLOCK and ENDC directives for defining constants or variables in data memory space. The same directives can be used for program memory space also.

The program calculates the perimeter of a rectangle. Length and width of the rectangle will be stored in buffers addressed by length (22H) and width (23H). The calculated perimeter will be stored in the double-precision buffer addressed by perimeter (i.e., 20H and 21H).

#include p16f877a.inc   ;Include standard header file
    ;for the selected device.
CBLOCK  0x20            ;Define a block of variables
    ;starting at 20H in data memory.
    perimeter:2          ;The label perimeter is 2 bytes
        ;wide. Address 20H and 21H is assigned to the label perimeter.
    length                ;Address 22H is assigned to the
        ;label length.
    width                  ;Address 23H is assigned to the
        ;label width.
ENDC                ;This directive must be supplied
        ;to terminate the CBLOCK list.
clrf    perimeter+1     ;Clear perimeter high byte
        ;at address 21H.
movf    length,w        ;Move the data present in the
        ;register addressed by 'length'
    ;to 'w'
addwf   width,w         ;Add data in 'w' with data in the
        ;register addressed by 'width'.
        ;STATUS register carry bit C
    ;may be affected.
movwf   perimeter        ;Move 'w' to the perimeter low
        ;byte at address 20H. Carry bit
    ;is unaffected.
rlf     perimeter+1      ;Increment register 21H if carry
        ;was generated. Also clear carry
    ;if bit was set.
rlf     perimeter        ;Multiply register 20H by 2.
        ;Carry bit may be affected.
rlf     perimeter+1      ;Again, increment register 21H
        ;if carry was generated.
goto  $                 ;Go to current line (loop here)
end
4.9  code - BEGIN AN OBJECT FILE CODE SECTION

4.9.1 Syntax

[label] code [ROM_address]

4.9.2 Description

This directive declares the beginning of a section of program code. If label is not specified, the section is named .code. The starting address is initialized to the specified address or will be assigned at link time if no address is specified.

Note: Two sections in a source file may not have the same name.

4.9.3 Usage

This directive is used in the following types of code: relocatable. For information on types of code, see Section 1.6 “Assembler Operation”.

There is no “end code” directive. The code of a section ends automatically when another code or data section is defined or when the end of the file is reached.

4.9.4 See Also

extern code_pack global idata udata udata_acs udata_ovr udata_shr

4.9.5 Simple Example

RESET code 0x01FF
    goto START

4.9.6 Application Example - code

This program demonstrates the code directive, which declares the beginning of a section of program code.

    #include p16f877a.inc  ;Include standard header file
    ;for the selected device.

RST     CODE     0x0     ;The code section named RST
    ;is placed at program memory
    ;location 0x0. The next two
    ;instructions are placed in
    ;code section RST.
    pagesel start
    goto     start
    ;Jumps to the location labelled
    ;‘start’.

PGM     CODE             ;This is the beginning of the
    ;code section named PGM. It is
    ;a relocatable code section
    ;since no absolute address is
    ;given along with directive CODE.

    start
    clrw
    goto  $                ;Go to current line (loop here)

    CODE             ;This is a relocatable code
    ;section since no address is
    ;specified. The section name will
    ;be, by default, .code.

    end
4.10  code_pack - BEGIN AN OBJECT FILE PACKED CODE SECTION (PIC18 MCUs)

4.10.1  Syntax

[label] code_pack [ROM_address]

4.10.2  Description

This directive declares the beginning of a section of program code or ROM data where
a padding byte of zero is not appended to an odd number of bytes. If label is not
specified, the section is named .code. The starting address is initialized to
ROM_address or will be assigned at link time if no address is specified. If
ROM_address is specified, it must be word-aligned. If padded data is desired, use db.

Note: Two sections in a source file may not have the same name.

4.10.3  Usage

This directive is used in the following types of code: relocatable. For information on
types of code, see Section 1.6 “Assembler Operation”.

This directive is commonly used when storing data into program memory (use with db)
or the EEPROM data memory (use with de) of a PIC18 device.

4.10.4  See Also

extern code global idata udata udata_acs udata_ovr udata_shr

4.10.5  Simple Example

000001 LIST P=18Cxx
000002
000003 packed code_pack 0x1F0
0001F0 01 02 03       000004   DB 1, 2, 3
0001F3 04 05          000005   DB 4, 5
000006
000007 padded code
000000 0201 0003      000008   DB 1, 2, 3
000004 0504           000009   DB 4, 5
000010
000011 END
4.11  __config - SET PROCESSOR CONFIGURATION BITS

4.11.1 Syntax

Preferred:

__config expr
__config addr, expr

Note: PIC18FXXJ devices do not support this directive. Use config directive (no underline characters.)

Supported:

__fuses expr

4.11.2 Description

Sets the processor's configuration bits. Before this directive is used, the processor must be declared through the command line, the list directive, the processor directive, a project if using MPLAB X IDE or Configure>Select Device if using MPLAB IDE. Refer to individual PIC1X microcontroller data sheets for a description of the configuration bits.

MCUs with a single configuration register
Sets the processor's configuration bits to the value described by expr.

MCUs with multiple configuration registers
For the address of a valid configuration byte specified by addr, sets the configuration bits to the value described by expr.

Note: Configuration bits must be listed in ascending order.

Although this directive may be used to set configuration bits for PIC18 MCU devices, it is recommended that you use the config directive (no underline characters). For PIC18FXXJ devices, you must use the config directive.

Note: Do not mix __config and config directives in the same code.

4.11.3 Usage

This directive is used in the following types of code: absolute or relocatable. For information on types of code, see Section 1.6 “Assembler Operation”.

This directive is placed in source code so that, when the code is assembled into a hex file, the configuration values are preset to desired values in your application. This is useful when giving your files to a third-party programming house, as this helps insure the device is configured correctly when programmed.

Place configuration bit assignments at the beginning of your code. Use the configuration options (names) in the standard include (*.inc) file. These names can be bitwise ANDed together using & to declare multiple configuration bits.

4.11.4 See Also

config __idlocs list processor
4.11.5  Simple Examples

Example 1: PIC16 Devices

```c
#include p16f877a.inc   ;include file with config bit definitions
__config _HS_OSC & _WDT_OFF & _LVP_OFF  ;Set oscillator to HS,
;watchdog time off,
;low-voltage prog. off
```

Example 2: PIC17X Devices (MPLAB IDE v8 Support Only)

```c
#include p17c42.inc   ;include file with config bit definitions
__config 0xFFFF       ;default configuration bits
```

Example 3: PIC18 Devices

```c
#include p18c452.inc   ;Include standard header file
;for the selected device.

;code protect disabled.
__CONFIG __CONFIG0, _CP_OFF_0

;Oscillator switch disabled, RC oscillator with OSC2
;as I/O pin.
__CONFIG __CONFIG1, _OSCS_OFF_1 & _RCIO_OSC_1

;Brown-OutReset enabled, BOR Voltage is 2.5v
__CONFIG __CONFIG2, _BOR_ON_2 & _BORV_25_2

;Watch Dog Timer enable, Watch Dog Timer PostScaler
;count - 1:128
__CONFIG __CONFIG3, _WDT_ON_3 & _WDTPS_128_3

;CCP2 pin Mux enabled
__CONFIG __CONFIG5, _CCP2MX_ON_5

;Stack over/underflow Reset enabled
__CONFIG __CONFIG6, _STVR_ON_6
```
4.12 config - SET PROCESSOR CONFIGURATION BITS (PIC18 MCUs)

4.12.1 Syntax

```
cfg setting=value [, setting=value]
```

4.12.2 Description

Defines a list of Configuration bit setting definitions. This list sets the PIC18 processor’s Configuration bits represented by `setting` to a value described by `value`. Refer to individual PIC18 microcontroller data sheets for a description of the Configuration bits. Available settings and values maybe found in both the standard processor include (*.inc) files and the PIC18 Configuration Settings Addendum (DS51537).

Multiple settings may be defined on a single line, separated by commas. Settings for a single Configuration byte may also be defined on separate lines. Before this directive is used, a PIC18 MCU must be declared through the command line, the list directive, the processor directive, a project if using MPLAB X IDE or Configure>Select Device if using MPLAB IDE.

Another directive that may be used to set configuration bits for PIC18 MCU devices is the `__config` directive, but this is not recommended for new code.

```
Note: Do not mix `__config` and `config` directives in the same code.
```

4.12.3 Usage

This directive is used in the following types of code: absolute or relocatable. For information on types of code, see Section 1.6 “Assembler Operation”.

This directive is placed in source code so that, when the code is compiled/assembled into a hex file, the configuration values are preset to desired values in your application. This is useful when giving your files to a third-party programming house, as this helps insure the device is configured correctly when programmed.

Place configuration bit assignments at the beginning of your code. Use the configuration options (`setting=value` pairs) listed in the standard include (*.inc) file or the addendum. The `config` directive can be used multiple times in the source code, but an error will be generated if the same bit is assigned a value more than once, i.e.,

```
CONFIG CP0=OFF, WDT=ON
CONFIG CP0=ON ; (An error will be issued since CP0 is assigned twice)
```

4.12.4 See Also

`__config`, `__idlocs`, `list processor`
4.12.5 Simple Example

#include p18f452.inc ;Include standard header file
;for the selected device.

;code protect disabled
CONFIG CP0=OFF

;Oscillator switch enabled, RC oscillator with OSC2 as I/O pin.
CONFIG OSCS=ON, OSC=LP

;Brown-OutReset enabled, BOR Voltage is 2.5v
CONFIG BOR=ON, BORV=25

;Watch Dog Timer enable, Watch Dog Timer PostScaler count = 1:128
CONFIG WDT=ON, WDTPS=128

;CCP2 pin Mux enabled
CONFIG CCP2MUX=ON

;Stack over/underflow Reset enabled
CONFIG STVR=ON

4.13 constant - DECLARE SYMBOL CONSTANT

4.13.1 Syntax
constant label=expr [..., label=expr]

4.13.2 Description
Creates symbols for use in MPASM assembler expressions. Constants may not be
reset after having once been initialized, and the expression must be fully resolvable at
the time of the assignment. This is the principal difference between symbols declared
as constant and those declared as variable, or created by the set directive. Otherwise,
constants and variables may be used interchangeably in absolute code expressions.

4.13.3 Usage
This directive is used in the following types of code: absolute or relocatable. For
information on types of code, see Section 1.6 “Assembler Operation”.
Although equ or cblock is more generally used to create constants, the constant
directive also works.

4.13.4 See Also
set variable equ cblock

4.13.5 Examples
See the examples under variable.
4.14  da - STORE STRINGS IN PROGRAM MEMORY (PIC12/16 MCUs)

4.14.1  Syntax

[la bel] da expr [, expr2, ..., exprn]

4.14.2  Description

da - Data ASCII.
Generates a packed 14-bit number representing two 7-bit ASCII characters.

4.14.3  Usage

This directive is used in the following types of code: absolute or relocatable. For information on types of code, see Section 1.6 "Assembler Operation".
This directive is useful for storing strings in memory for PIC16 MCU devices.

4.14.4  Simple Examples

•  da "abcdef"
   will put 30E2 31E4 32E6 into program memory
•  da "12345678",0
   will put 18B2 19B4 1AB6 1BB8 0000 into program memory
•  da 0xFFFF
   will put 0x3FFF into program memory

4.14.5  Application Example - da

This example shows the usefulness of directive da in storing a character string in the program memory of 14-bit architecture devices. This directive generates a packed 14-bit number representing two 7-bit ASCII characters.

```assembly
#include p16f877a.inc ;Include standard header file for the selected device.

ORG   0x0000 ;The following code will be programmed in reset address 0.
goto  start ;Jump to an address labelled 'start'.

start ;Write your main program here.

goto $ ;Go to current line (loop here)

ORG 0x1000 ;Store the string starting from 1000H.

Ch_stng da "PICmicro"
```


Directive `da` produces four 14-bit numbers: 2849, 21ED, 34E3, and 396F representing the ASCII equivalent of PI, Cm, ic, and ro. See below for more information.

```plaintext
Sngl_ch     da  "A"       ;7-bit ASCII equivalents of 'A'
             ;and a NULL character will be packed
             ;in a 14-bit number.

da  0xff55      ;Places 3f55 in program memory.
             ;No packing.
end
```

### Determining 14-Bit Numbers

For the following statement:

```plaintext
Ch_stng     da  "PICmicro"
```

`directive` `da` produces four 14-bit numbers: 2849, 21ED, 34E3 and 396F representing the ASCII equivalent of PI, Cm, ic and ro.

To see how the 14-bit numbers are determined, look at the ASCII values of P and I, which are 50h(01010000) and 49h(01001001) respectively. Each is presented in 7-bit as (0)1010000 and (0)1001001 respectively. The packed 14-bit number is 101000 01001001, which is stored as (00)101000 01001001 or 2849.
4.15 data - CREATE NUMERIC AND TEXT DATA

4.15.1 Syntax

[label] data expr[,expr,...,expr]
[label] data "text_string"[,"text_string",...]

4.15.2 Description

Initialize one or more words of program memory with data. The data may be in the form of constants, relocatable or external labels, or expressions of any of the above. The data may also consist of ASCII character strings, text_string, enclosed in single quotes for one character or double quotes for strings. Single character items are placed into the low byte of the word, while strings are packed two to a word. If an odd number of characters are given in a string, the final byte is zero. On all families except the PIC18 device family, the first character is in the most significant byte of the word. On the PIC18 device family, the first character is in the least significant byte of the word.

4.15.3 Usage

This directive is used in the following types of code: absolute or relocatable. For information on types of code, see Section 1.6 “Assembler Operation”.

When generating a linkable object file, this directive can also be used to declare initialized data values. Refer to the idata directive for more information.

db and other data directives are more commonly used than data.

4.15.4 See Also

db de dt dtm dw idata

4.15.5 Simple Example

data reloc_label+10 ; constants
data 1,2,ext_label ; constants, externals
data "testing 1,2,3" ; text string
data 'N' ; single character
data start_of_program ; relocatable label

4.15.6 PIC16 Application Example - data

This example shows the usefulness of directive data in storing one or more words in program memory.

```assembly
#include pl6f877a.inc ;Include standard header file
;for the selected device.

ORG 0x0000 ;The following code will be
;programmed in reset address 0.
goto start ;Jump to an address labelled
; 'start'.

start ;Write your main program here.
goto $ ;Go to current line (loop here)

ORG 0x1000 ;Store the string starting from
;1000H.

Ch_stng data "M","C","U" ;3 program memory locations
;will be filled with ASCII
;equivalent of "M", "C" and
;"U".
```
Directive **data** produces three 14-bit numbers: 004Dh, 0043h, and 0055h. 4Dh, 43h and 55h are ASCII equivalents of “M”, “C” and “U”, respectively.

```plaintext
tbl_dta    data  0xffff,0xaa55 ;Places 3fffh and 2a55h in ;two consecutive program ;memory locations. As program ;memory is 14-bit wide, ;the last nibble can store ;a maximum value 3.

end
```

### 4.15.7 PIC18 Application Example - **data**

This example shows the usefulness of directive **data** in storing one or more words in program memory.

```plaintext
#include p18f452.inc ;Include standard header file ;for the selected device.

ORG 0x0000 ;The following code will be ;programmed in reset address 0.
goto start ;Jump to an address labelled ;'start'.

start ;Write your main program here.
goto $ ;Go to current line (loop here)

ORG 0x1000 ;Store the string starting from ;1000H. In PIC18 devices, the ;first character is in least ;significant byte.

Ch_stng    data    "M","C","U" ;3 program memory locations ;will be filled with ASCII ;equivalent of "M", "C" and ;"U".

Directive **data** produces two 16-bit numbers: 004Dh, 0043h, and 0055h. 4Dh, 43h and 55h are ASCII equivalents of “M”, “C” and “U”, respectively. See **Section 4.10 “code_pack - Begin an Object File Packed Code Section (PIC18 MCUs)”** for better use of memory.

```plaintext
Ch_stgl    data    "MCU" ;2 program memory locations ;will be filled with two ;words (16-bit numbers), ;each representing ASCII ;equivalent of two ;characters. The last ;character will be taken as ;NULL in case odd number of ;characters are specified.

Directive **data** produces two words: 434Dh and 0055h. 434Dh represents “C” and “M”.

```plaintext
tbl_dta    data  0xffff,0xaa55 ;Places ffff and aa55 in ;two consecutive program ;memory locations.

end
```
4.16  **db - DECLARE DATA OF ONE BYTE**

### 4.16.1 Syntax

\[ [\text{label}] \text{ db expr[, expr...]} \]

### 4.16.2 Description

**db - Data Byte.**

Reserve program memory words with 8-bit values. Multiple expressions continue to fill bytes consecutively until the end of expressions. Should there be an odd number of expressions, the last byte will be zero unless in a PIC18 code_pack section.

### 4.16.3 Usage

This directive is used in the following types of code: absolute or relocatable. For information on types of code, see Section 1.6 “Assembler Operation”.

When generating a linkable object file, this directive can also be used to declare initialized data values. In this case, the values will be padded with 34 (RETLW) instead of 00 as in examples. Refer to the idata directive for more information.

For PIC18 devices, use code_pack with db, since it is desired to not have bytes padded with zeroes. See the description of code_pack for more information.

### 4.16.4 See Also

data de dt dtm dw idata code_pack

### 4.16.5 Simple Examples

**Example 1: PIC16 Devices**

```
db 0x0f, "t", 0x0f, "e", 0x0f, "s", 0x0f, "t", "\n"
ASCII: 0x0F74 0x0F65 0x0F73 0x0F74 0x0a00
```

**Example 2: PIC18 Devices**

```
db "t", "e", "s", "t", "\n"
ASCII: 0x6574 0x7473 0x000a
```

### 4.16.6 PIC16 Application Example - db

This example shows the usefulness of directive db in storing one or more bytes or characters in program memory.

```
#include p16f877a.inc ;Include standard header file
 ;for the selected device.

ORG 0x0000 ;The following code will be
 ;programmed in reset address 0.
goto start ;Jump to an address labelled
 ;'start'.

start ;Write your main program here.
goto $ ;Go to current line (loop here)

ORG 0x1000 ;Store the string starting from
 ;1000H.
```
4.16.7 PIC18 Application Example - db

This example shows the usefulness of directive db in storing one or more byte or character in program memory.

```
#include p18f452.inc ;Include standard header file ;for the selected device.

ORG 0x0000 ;The following code will be ;programmed in reset address 0.
goto start ;Jump to an address labelled ;’start’.

start ;Write your main program here.
goto $ ;Go to current line (loop here)

ORG 0x1000 ;Store the string starting from ;1000H. In PIC18 devices, the ;first character is in least ;significant byte.

Ch_stng db "M","C","U" ;Ch_string contains three 16-bit numbers: ;004Dh, 0043h, and 0055h. These are ASCII ;equivalents of "M", "C" and "U", ;respectively. Information on storing data ;in both bytes of a program word on the ;PIC18 architecture can be found under the ;code_pack directive*.

tbl_dta db 0,0xff ;Places 00ff in program memory ;location.

end
```

* Section 4.10 “code_pack - Begin an Object File Packed Code Section (PIC18 MCUs)”
4.17  de - DECLARE EEPROM DATA BYTE

4.17.1  Syntax

[label] de expr [, expr, ... , expr]

4.17.2  Description

de - Data EEPROM.

This directive can be used at any location for any processor.

For PIC18 devices, reserve memory word bytes are packed. If an odd number of bytes is specified, a 0 will be added unless in a code_pack section. See the description for code_pack for more information.

For all other PIC1X MCU devices, reserve memory words with 8-bit data. Each expr must evaluate to an 8-bit value. The upper bits of the program word are zeroes. Each character in a string is stored in a separate word.

4.17.3  Usage

This directive is used in the following types of code: absolute or relocatable. For information on types of code, see Section 1.6 “Assembler Operation”.

This directive is designed mainly for initializing data in the EE data memory region of PIC1X MCU devices with EE data FLASH.

Make sure to specify the start of EEPROM data memory in your code. The table below shows start addresses for different device families. However, always check your device programming specification for the correct address.

<table>
<thead>
<tr>
<th>TABLE 4-1: EEPROM START ADDRESS BY DEVICE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Device</td>
</tr>
<tr>
<td>Most PIC1X MCUs</td>
</tr>
<tr>
<td>PIC18 MCUs</td>
</tr>
<tr>
<td>PIC16F19XX MCUs</td>
</tr>
</tbody>
</table>

4.17.4  See Also

data db dt dtm dw code_pack

4.17.5  Simple Example

Initialize EEPROM data on a PIC16 device:

org 0x2100
de "My Program, v1.0", 0
4.17.6  PIC16 Application Example - de

```plaintext
#include p16f877a.inc ;Include standard header file
 ;for the selected device.

org 0x2100 ;The absolute address 2100h is
 ;mapped to the 0000 location of
 ;EE data memory.

;You can create a data or character table starting from any
 ;address in EE data memory.

ch_tbl2 de "PICmicro" ;8 EE data memory locations
 ;(starting from 0) will be filled
 ;with 8 ASCII characters.

end
```

4.17.7  PIC18 Application Example - de

```plaintext
#include p18f452.inc ;Include standard header file
 ;for the selected device.

org 0xF00000 ;The absolute address F00000h is
 ;mapped to the 0000 location of
 ;EE data memory for PIC18 devices.

;You can create a data or character table starting from any
 ;address in EE data memory.

ch_tbl2 de "PICmicro" ;8 EE data memory locations
 ;(starting from 0) will be filled
 ;with 8 ASCII characters.

end
```
4.18  #define - DEFINE A TEXT SUBSTITUTION LABEL

4.18.1 Syntax
#define name [string]

4.18.2 Description
This directive defines a text substitution string. Wherever name is encountered in the assembly code, string will be substituted.

Using the directive with no string causes a definition of name to be noted internally and may be tested for using the ifdef directive.

This directive emulates the ANSI 'C' standard for #define. Symbols defined with this method are not available for viewing using MPLAB X IDE or MPLAB IDE v8.

4.18.3 Usage
This directive is used in the following types of code: absolute or relocatable. For information on types of code, see Section 1.6 “Assembler Operation”.

#define is useful for defining values for constants in your program.

Note: A processor-specific include file exists with predefined SFR names. It is recommended that you use this file instead of defining the variables yourself. See #include for how to include a file in your program.

This directive is also useful with the ifdef and ifndef directives, which look for the presence of an item in the symbol table.

4.18.4 See Also
#undef define ifdef ifndef

4.18.5 Simple Example
#define length 20
#define control 0x19,7
#define position(X,Y,Z) (Y-(2 * Z +X))
:
:
test_label dw position(1, length, 512)
bsf control ; set bit 7 in f19
4.18.6 Application Example - `#define/#undefine`

This example shows the usage of `#define` and `#undefine` directives. A symbol name previously defined with the `#define` directive, is removed from the symbol table if `#undefine` directive is used. The same symbol may be redefined again.

```
#include p16f877a.inc ;Include standard header file
;for the selected device.

area set 0 ;The label 'area' is assigned
 ;the value 0.
#define lngth 50H ;Label 'lngth' is assigned
 ;the value 50H.
#define wdth 25H ;Label 'wdth' is assigned
 ;the value 25H
area set lngth*wdth ;Reassignment of label 'area'.
 ;So 'area' will be reassigned a
 ;value equal to 50H*25H.

#undef lngth ;Undefine label 'lngth'.
#undef wdth ;Undefine label 'wdth'
#define lngth 0 ;Define label 'lngth' to '0'.
end
```

By using the above directives, `lngth` will be reassigned a value '0' and `wdth` will be removed from the symbol list in the list (.lst) file. The label `lngth` must be undefined before it can be defined as '0'.

4.19  dt - DEFINE TABLE (PIC12/16 MCUs)

4.19.1  Syntax

[label] dt expr [, expr, ..., expr]

4.19.2  Description

dt - Define data Table.

Generates a series of RETLW instructions, one instruction for each expr. Each expr must be an 8-bit value. Each character in a string is stored in its own RETLW instruction.

4.19.3  Usage

This directive is used in the following types of code: absolute or relocatable. For information on types of code, see Section 1.6 “Assembler Operation”.

This directive is used when generating a table of data for the PIC12/16 device family. If you are using a PIC18 device, it is recommended that you use the table read/write (TBLRD/TBLWT) features. See the device data sheet for more information.

4.19.4  See Also

data db de dtm dw

4.19.5  Simple Example

dt "A Message", 0
dt FirstValue, SecondValue, EndOfValues

4.20  dtm - DEFINE TABLE (EXTENDED PIC16 MCUS ONLY)

4.20.1  Syntax

[label] dtm expr [, expr, ..., expr]

4.20.2  Description

dtm - Define data Table using MOVLW.

Generates a series of MOVLW instructions, one instruction for each expr. Each expr must be an 8-bit value. Each character in a string is stored in its own MOVLW instruction.

4.20.3  Usage

This directive is used in the following types of code: absolute or relocatable. For information on types of code, see Section 1.6 “Assembler Operation”. This directive is used when generating a table of data for the PIC16 extended device family.

4.20.4  See Also

data db de dt dw

4.20.5  Simple Example

dtm "A Message", 0
dtm FirstValue, SecondValue, EndOfValues
4.21 \texttt{dw} - DECLARE DATA OF ONE WORD

4.21.1 Syntax

\begin{verbatim}
[label] dw expr[,expr,...,expr]
\end{verbatim}

4.21.2 Description

\texttt{dw} - Data Word.

Reserve program memory words for data, initializing that space to specific values. For PIC18 devices, \texttt{dw} functions like \texttt{db}. Values are stored into successive memory locations and the location counter is incremented by one. Expressions may be literal strings and are stored as described in the \texttt{db} data directive.

4.21.3 Usage

This directive is used in the following types of code: absolute or relocatable. For information on types of code, see Section 1.6 “Assembler Operation”.

When generating a linkable object file, this directive can also be used to declare initialized data values. Refer to the \texttt{idata} directive for more information.

While \texttt{db} is more common to use, you may use \texttt{dw} to store data in Flash PIC16FXXX devices, as many of these devices can read all 14 bits of a program memory word at run-time. See the PIC16F877A data sheet for examples and more information.

4.21.4 See Also

\texttt{data db idata}

4.21.5 Simple Example

\begin{verbatim}
dw 39, "diagnostic 39", 0x123
dw diagbase-1
\end{verbatim}
4.22 else - BEGIN ALTERNATIVE ASSEMBLY BLOCK TO if CONDITIONAL

4.22.1 Syntax

Preferred:
else

Supported:
#else
.else

4.22.2 Description

Used in conjunction with an if directive to provide an alternative path of assembly code should the if evaluate to false. else may be used inside a regular program block or macro.

4.22.3 Usage

This directive is used in the following types of code: absolute or relocatable. For information on types of code, see Section 1.6 “Assembler Operation”.

This directive is not an instruction. It is used to perform conditional assembly of code.

4.22.4 See Also

def if

4.22.5 Simple Example

if rate < 50
   incf speed, F
else
   decf speed, F
endif

4.22.6 Application Example - if/else/endif

See this example under if.
4.23 end - END PROGRAM BLOCK

4.23.1 Syntax
end

4.23.2 Description
Indicates the end of the program.

4.23.3 Usage
This directive is used in the following types of code: absolute or relocatable. For information on types of code, see Section 1.6 “Assembler Operation”.

You will need at least one end directive in any assembly program to indicate the end of a build. In a single assembly file program, one and only one end must be used.

Be careful not to include files which contain end as assembly will be prematurely stopped.

4.23.4 See Also
org

4.23.5 Simple Example
#include p18f452.inc
: ; executable code
: ;
end ; end of instructions

4.24 endc - END AN AUTOMATIC CONSTANT BLOCK

4.24.1 Syntax
endc

4.24.2 Description
endc terminates the end of a cblock list. It must be supplied to terminate the list.

4.24.3 Usage
This directive is used in the following types of code: absolute. For information on types of code, see Section 1.6 “Assembler Operation”.

For every cblock directive used, there must be a corresponding endc.

4.24.4 See Also
cblock

4.24.5 Examples
See the examples under cblock.
4.25  endif - END CONDITIONAL ASSEMBLY BLOCK

4.25.1  Syntax

Preferred:
endif

Supported:
#endif
.endif
.fi

4.25.2  Description

This directive marks the end of a conditional assembly block. endif may be used inside a regular program block or macro.

4.25.3  Usage

This directive is used in the following types of code: absolute or relocatable. For information on types of code, see Section 1.6 “Assembler Operation”.
For every if directive used, there must be a corresponding endif.
if and endif are not instructions, but used for code assembly only.

4.25.4  See Also

else if

4.25.5  Examples

See the examples under if.

4.26  endm - END A MACRO DEFINITION

4.26.1  Syntax

endm

4.26.2  Description

Terminates a macro definition begun with macro.

4.26.3  Usage

This directive is used in the following types of code: absolute or relocatable. For information on types of code, see Section 1.6 “Assembler Operation”.
For every macro directive used, there must be a corresponding endm.

4.26.4  See Also

macro exitm

4.26.5  Simple Example

make_table macro arg1, arg2
   dw arg1, 0 ; null terminate table name
   res arg2   ; reserve storage
   endm

4.26.6  Application Example - macro/endm

See this example under macro.
4.27 endw - END A while LOOP

4.27.1 Syntax

Preferred:
endw

Supported:
.endw

4.27.2 Description

endw terminates a while loop. As long as the condition specified by the while directive remains true, the source code between the while directive and the endw directive will be repeatedly expanded in the assembly source code stream. This directive may be used inside a regular program block or macro.

4.27.3 Usage

This directive is used in the following types of code: absolute or relocatable. For information on types of code, see Section 1.6 “Assembler Operation”. For every while directive used, there must be a corresponding endw. while and endw are not instructions, but used for code assembly only.

4.27.4 See Also

while

4.27.5 Examples

See the example under while.

4.28 equ - DEFINE AN ASSEMBLER CONSTANT

4.28.1 Syntax

label equ expr

4.28.2 Description

The value of expr is assigned to label.

4.28.3 Usage

This directive is used in the following types of code: absolute or relocatable. For information on types of code, see Section 1.6 “Assembler Operation”. In a single assembly file program, equ is commonly used to assign a variable name to an address location in RAM. Do not use this method for assigning variables when building a linked project; use a res directive inside a data section directive (idata, udata).

4.28.4 See Also

set cblock res idata udata udata_acs udata_ovr udata_shr

4.28.5 Simple Example

four equ 4 ; assigned the numeric value of 4 to label four

4.28.6 Application Example - set/equ

See this example under set.
4.29  error - ISSUE AN ERROR MESSAGE

4.29.1  Syntax

error "text_string"

4.29.2  Description

`text_string` is printed in a format identical to any MPASM assembler error message. `text_string` may be from 1 to 80 characters.

4.29.3  Usage

This directive is used in the following types of code: absolute or relocatable. For information on types of code, see Section 1.6 "Assembler Operation".

You can use this directive to generate errors for yourself or others who build your code. You can create any error message you wish, as long as it is no longer than 80 characters.

4.29.4  See Also

messg if

4.29.5  Simple Example

```assembly
error_checking macro arg1
  if arg1 >= 55 ; if arg is out of range
    error "error_checking-01 arg out of range"
  endif
endm
```

4.29.6  Application Example - error

This program demonstrates the `error` assembler directive, which sets an error message to be printed in the listing file and error file.

```assembly
#include p16f877a.inc ;Include standard header file
 ;for the selected device.

variable baudrate ;variable used to define
 ;required baud rate

baudrate set D'5600' ;Enter the required value of
 ;baud rate here.

if (baudrate!=D'1200')&& (baudrate!=D'2400')&&
 (baudrate!=D'4800')&& (baudrate!=D'9600')&&
 (baudrate!=D'19200')
  error "Selected baud rate is not supported"
endif
```
The if-endif code above outputs error if the baud rate selected is other than 1200, 2400, 4800, 9600 or 19200 Hz.

RST CODE 0x0 ;The code section named RST
;is placed at program memory
;location 0x0. The next two
;instructions are placed in
;code section RST.
pagesel start ;Jumps to the location labelled
goto start ;'start'.

PGM CODE ;This is the beginning of the
;code section named PGM. It is
;a relocatable code section
;since no absolute address is
;given along with directive CODE.

start
goto $ ;Go to current line (loop here)
end
4.30  errorlevel - SET MESSAGE LEVEL

4.30.1 Syntax

errorlevel {0|1|2|+msgnum|-msgnum} [, ...]

4.30.2 Description

Sets the types of messages that are printed in the listing file and error file.

<table>
<thead>
<tr>
<th>Setting</th>
<th>Affect</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Messages, warnings, and errors printed</td>
</tr>
<tr>
<td>1</td>
<td>Warnings and errors printed</td>
</tr>
<tr>
<td>2</td>
<td>Errors printed</td>
</tr>
<tr>
<td>-msgnum</td>
<td>Inhibits printing of message msgnum</td>
</tr>
<tr>
<td>+msgnum</td>
<td>Enables printing of message msgnum</td>
</tr>
</tbody>
</table>

4.30.3 Usage

This directive is used in the following types of code: absolute or relocatable. For information on types of code, see Section 1.6 “Assembler Operation”.

Errors cannot be disabled. Warnings may be disabled using setting 2. Messages may be disabled using settings 1 or 2. Also, messages may be disabled individually. However, the setting of 0, 1, or 2 overrides individual message disabling or enabling.

Be careful about disabling warnings and messages, as this can make debugging of your code more difficult.

The most common usage for this directive is to suppress “MESSAGE 302 - Operand Not in bank 0, check to ensure bank bits are correct”. See the Simple Example for how to do this.

4.30.4 See Also

list error

4.30.5 Simple Example

errorlevel -302 ; Turn off banking message
               ; known tested (good) code
               :
errorlevel +302 ; Enable banking message
               ; untested code
               :
end

4.30.6 Application Example - errorlevel

This program demonstrates the errorlevel assembler directive, which sets the type of messages that are printed in the listing file and error file.

```
#include pl6f877a.inc ;Include standard header file
                   ;for the selected device.

errorlevel 0       ;Display/print messages, 
                   ;warnings and errors.

messg "CAUTION: This program has errors" ;display on build
```
This message will display/print for error level 0.

```markdown
errorlevel 1 ;Display/print only warnings
               ;and errors.
```

```markdown
messg "CAUTION: This program has errors" ;display message
```

This message will NOT display/print for error level 1 or 2.

```markdown
group1  udata  0x20
        group1_var1  res  1 ;Label of this directive is not
               ;at column 1. This will generate
               ;a warning number 207.
```

**Warning #207 will display/print for error level 0 or 1.**

```markdown
errorlevel  -207 ;This disables warning whose
                  ;number is 207.
```

```markdown
group1_var2  res  1 ;label of this directive is also
               ;not at column 1, but no warning
               ;is displayed/printed.
```

```markdown
errorlevel  +207 ;This enables warning whose
               ;number is 207
```

```markdown
group2  udata
```

```markdown
errorlevel 2 ;Display/print only errors
```

```markdown
group2_var1 res  1 ;label of this directive is not
               ;at column 1. This will generate
               ;a warning number 207.
```

**Warning #207 will NOT display/print for error level 2.**

```markdown
errorlevel 1 ;Display/print warnings
               ;and errors.
```

```markdown
group2_var2 res  1 ;label of this directive is not
               ;at column 1. This will generate
               ;a warning number 207.
```

```markdown
RST    CODE  0x0 ;The code section named RST
               ;is placed at program memory
               ;location 0x0. The next two
               ;instructions are placed in
               ;code section RST.
```

```markdown
pagesel  start
        goto     start
```

```markdown
INTRT  CODE  0x4 ;The code section named INTRT is
               ;placed at 0x4. The next two
               ;instructions are placed in
               ;code section INTRT
```

```markdown
pagesel  service_int
        goto     service_int
```

**Label 'service_int' is not defined. Hence this generates
error[113].**
Error 113 will always display/print, regardless of error level.

PGM CODE

;This is the beginning of the code
;section named 'PGM'. It is a
;relocatable code section since
;no absolute address is given along
;with directive CODE.

start
     movwf group1_var1
     goto $
     goto $
     end

;Go to current line (loop here)
4.31 exitm - EXIT FROM A MACRO

4.31.1 Syntax

exitm

4.31.2 Description

Force immediate return from macro expansion during assembly. The effect is the same as if an endm directive had been encountered.

4.31.3 Usage

This directive is used in the following types of code: absolute or relocatable. For information on types of code, see Section 1.6 “Assembler Operation”.

Use this directive to prematurely end a macro, usually for a specific condition. This is similar to the C language command break.

4.31.4 See Also

endm macro

4.31.5 Simple Example

```assembly
test macro filereg
    if filereg == 1 ; check for valid file
        exitm
    else
        error "bad file assignment"
    endif
endm
```

4.31.6 Application Example - exitm

This program demonstrates the exitm assembler directive, which causes an immediate exit from a macro. It is used in the example to exit from the macro when certain conditions are met.

```assembly
#include p16f877a.inc ;Include standard header file
            ;for the selected device.
result equ 0x20        ;Assign value 20H to label result.
RST CODE 0x0         ;The code section named RST
            ;is placed at program memory location 0x0. The next two
            ;instructions are placed in code section RST.
pagesel start         ;Jumps to the location labelled 'start'.
goto start
add MACRO num1,num2 ;'add' is a macro. The values of num1 and num2 must be passed
            ;to this macro.
```
if num1>0xff ;If num1>255 decimal, 
exitm   ;force immediate return from 
;macro during assembly.
else
  if num2>0xff ;If num2>255 decimal, 
extim    ;force immediate return from 
;macro during assembly.
  else
    movlw num1 ;Load W register with a literal 
     ;value assigned to the label 
     ;'num1'.
    movwf result ;Load W register to an address 
     ;location assigned to the label 
     ;'result'.
    movlw num2 ;Load W register with a literal 
     ;value assigned to the label 
     ;'num2'.
    addwf result ;Add W register with the memory 
     ;location addressed by 'result' 
     ;and load the result back to 
     ;'result'.
  endif
endif
endm     ;End of 'add' MACRO
org 0010 ;My main program starts at 10H.
start    ;The label 'start' is assigned an 
         ;address 10H.
add .100,.256 ;Call 'add' MACRO with decimal 
             ;numbers 100 and 256 assigned to 
             ;'num1' and 'num2' labels, 
             ;respectively. EXITM directive in 
             ;macro will force return. 
             ;Remember '.' means decimal, not 
             ;floating point.
end
4.32 expand - EXPAND MACRO LISTING

4.32.1 Syntax
expand

4.32.2 Description
Expand all macros in the listing file. (This is the default behavior.) This directive is roughly equivalent to the /m or -m- MPASM assembler command line option, but may be disabled by the occurrence of a subsequent noexpand.

4.32.3 Usage
This directive is used in the following types of code: absolute. For information on types of code, see Section 1.6 "Assembler Operation".
This directive may be useful when exploring a small range of code with many macros in it.

4.32.4 See Also
macro noexpand

4.32.5 Simple Example

Code example:
:
;Define a macro to add two numbers
add macro num1,num2
movlw num1
movwf result
movlw num2
addwf result
endm
:
expand
;Use macro add
add .100,.90

Resulting listing file:

```
00029    expand    
00030    add .100,.90  
0010 3064 M movlw .100  
0011 00A0 M movwf result  
0012 305A M movlw .90  
0013 07A0 M addwf result  
00031
```
4.33 extern - DECLARE AN EXTERNALLY DEFINED LABEL

4.33.1 Syntax
extern label [, label...]

4.33.2 Description
This directive declares symbol names that may be used in the current module but are defined as global in a different module.

The `extern` statement must be included before the `label` is used. At least one label must be specified on the line. If `label` is defined in the current module, MPASM assembler will generate a duplicate label error.

4.33.3 Usage
This directive is used in the following types of code: relocatable. For information on types of code, see Section 1.6 “Assembler Operation”.

As soon as you have more than one file in your project, you may use this directive. `extern` will be used in a file when a label (usually a variable) is used by that file. `global` will be used in another file so that the label may be seen by other files. You must use both directives as specified or the label will not be visible to other files.

4.33.4 See Also
global idata udata udata_acs udata_ovr udata_shr

data

4.33.5 Simple Example
extern Function
:
call Function

4.33.6 Application Example - `extern/global`
The program `main.asm`, along with `sub.asm`, demonstrate the `global` and `extern` directives, which make it possible to use symbols in modules other than where they are defined. This allows a project to be split up into multiple files (two in this example) for code reuse.

```
;******************************************************
;main.asm
;******************************************************
#include p16f877a.inc ;Include standard header file
;for the selected device.

UDATA
delay_value res 1

GLOBAL delay_value ;The variable 'delay_value',
;declared GLOBAL in this
;module, is included in an
;EXTERN directive in the module
;sub.asm.

EXTERN delay ;The variable 'delay', declared
;EXTERN in this module, is
;declared GLOBAL in the module
;sub.asm.
```
RST CODE 0x0 ;The code section named RST is placed at program memory location 0x0. The next two instructions are placed in code section RST.
pagesel start ;Jumps to the location labelled 'start'.
goto start ;'start'.

PGM CODE ;This is the beginning of the code section named PGM. It is a relocatable code section since no absolute address is given along with directive CODE.

start
movlw D'10'
movwf delay_value
xorlw 0x80
call delay

goto start
end

*******************************************************************************
;sub.asm
*******************************************************************************
#include p16f877a.inc ;Include standard header file for the selected device.

GLOBAL delay ;The variable 'delay' declared GLOBAL in this module is included in an EXTERN directive in the module main.asm.

EXTERN delay_value ;The variable 'delay_value' declared EXTERN in this module is declared GLOBAL in the module main.asm.

PGM CODE

delay
  decfsz delay_value,1
  goto delay
  return

end
4.34 \texttt{fill} - SPECIFY PROGRAM MEMORY FILL VALUE

4.34.1 Syntax

\[\texttt{label} \texttt{fill expr,count} \]

4.34.2 Description

Generates \textit{count} occurrences of the program word or byte (PIC18 devices), \textit{expr}. If bounded by parentheses, \textit{expr} can be an assembler instruction.

4.34.3 Usage

This directive is used in the following types of code: absolute or relocatable. For information on types of code, see Section 1.6 "Assembler Operation".

\begin{tabular}{|p{0.9\textwidth}|}
\hline
\textbf{Note:} & For relocatable code, do not use a symbol in another section in the expression \textit{expr}. \\
\hline
\end{tabular}

This directive is often used to force known data into unused program memory. This helps ensure that if code ever branches to an unused area at run-time, a fail-safe condition occurs. For example, it is not uncommon to see this used with the watchdog timer (WDT) on a PIC16 device. Unused program memory would be filled with goto or branch instructions to prevent execution of the \texttt{clrwdt} instruction in code, which would cause the device to reset. See the device data sheet for more information on the WDT.

4.34.4 See Also

data dw org

4.34.5 Simple Examples

Example 1: PIC10/12/16 MCU's

\begin{verbatim}
fill 0x1009, 5 ; fill with a constant
fill (GOTO RESET_VECTOR), NEXT_BLOCK-$
\end{verbatim}

Example 2: PIC18 Devices

\begin{verbatim}
#include p18f252.inc

org 0x12
failsafe goto $

org 0x100
fill (goto failsafe), (0x8000-$)/2 ;Divide by 2 for ;2-word instructions
end
\end{verbatim}
### 4.34.6 PIC16 Application Example - fill

The **fill** directive is used to specify successive program memory locations with a constant or an assembly instruction.

```assembly
#include p16f877a.inc ;Include standard header file for the selected device.

RST  CODE   0x0000 ;The code section named RST is placed at program memory location 0x0. The next two instructions are placed in code section RST.
pagesel start ;Jumps to the location labelled 'start'.
goto start  ;'start'.
fill  0, INTRPT-$ ;Fill with 0 up to address 3 - INTRPT addr. minus current addr.

INTRPT CODE  0x0004 ;The code section named INTRPT is placed at program memory location 0x4. The next two instructions are placed in code section INTRPT.
pagesel ISR ;Jumps to the location labelled ISR.
goto ISR   ;ISR.
fill  (goto start), start-$ ;Fill up to address 0Fh with instruction <goto start>.

CODE  0x0010
start    ;Write your main program here.

fill  (nop),  5 ;Fill 5 locations with NOPs.
goto $ ;Go to current line (loop here)

ISR
retfie ;Write your interrupt service routine here.
end
```
4.34.7 PIC18 Application Example - fill

The `fill` directive is used to specify successive program memory locations with a constant or an assembly instruction. For PIC18 devices, only an even number is allowed to be specified as a count of locations to be filled.

```assembly
#include p18f452.inc ;Include standard header file
 ;for the selected device.

RST CODE 0x0000 ;The code section named RST
 ;is placed at program memory
 ;location 0x0. The instruction
 ;'goto start' is placed in
 ;code section RST.

goto start ;Jumps to the location labelled
 ;'start'.

fill 0, HI_INT-$ ;Fills 0 in 2 program memory
 ;locations: 0004 and 0006 -
 ;HI_INT addr. minus current addr.

HI_INT CODE 0x0008
goto INTR_H
fill (goto start),6 ;Fills 6 locations (each location
 ;is 2 bytes wide) with 3 numbers
 ;of 2 word wide instructions
 ;<goto start>

LO_INT CODE 0x0018
goto INTR_L
fill 10a9, start-$ ;Fills address 1Ch and 1Eh with
 ;10a9h

CODE 0x0020
start ;Write your main program here

fill (nop), 4 ;Fills 2 locations (4 bytes) with
 ;NOP

goto $ ;Go to current line (loop here)

INTR_H
retfie

INTR_L
retfie

end ;Write your low interrupt ISR here
```
4.35 global - EXPORT A LABEL

4.35.1 Syntax

global label [, label ...]

4.35.2 Description

This directive declares symbol names that are defined in the current module and should be available to other modules. At least one label must be specified on the line.

4.35.3 Usage

This directive is used in the following types of code: relocatable. For information on types of code, see Section 1.6 “Assembler Operation”.

When your project uses more than one file, you will be generating linkable object code. When this happens, you may use the global and extern directives.

global is used to make a label visible to other files. extern must be used in the file that uses the label to make it visible in that file.

4.35.4 See Also

extern idata udata udata_acs udata_ovr udata_shr

4.35.5 Simple Example

    global Var1, Var2
    global AddThree

    udata
    Var1  res 1
    Var2  res 1
    code
    AddThree
        addlw 3
    return

4.35.6 Application Example - extern/global

See this example under extern.
4.36  idata - BEGIN AN OBJECT FILE INITIALIZED DATA SECTION

4.36.1  Syntax

[label] idata [RAM_address]

4.36.2  Description

This directive declares the beginning of a section of initialized data. If label is not specified, the section is named .idata. The starting address is initialized to the specified address or will be assigned at link time if no address is specified. No code can be placed by the user in this segment.

The linker will generate a look-up table entry for each byte specified in an idata section. You must then link or include the appropriate initialization code. Examples of initialization code that may be used and modified as needed may be found with MPLINK linker sample application examples.

Note: This directive is not available for 12-bit instruction width (PIC10, some PIC12/PIC16) devices.

The res, db and dw directives may be used to reserve space for variables. res will generate an initial value of zero. db will initialize successive bytes of RAM. dw will initialize successive bytes of RAM, one word at a time, in low-byte/high-byte order.

Data initialized using db or dw will be padded with 34 (RETLW) instead of 00. This is because the idata directive reserves space in data memory while putting the initialization values in program memory and the application code must then copy the initialization values from program memory to data memory at runtime.

4.36.3  Usage

This directive is used in the following types of code: relocatable. For information on types of code, see Section 1.6 “Assembler Operation”.

Use this directive to initialize your variables, or use a udata directive and then initialize your variables with values in code. It is recommended that you always initialize your variables. Relying on RAM initialization can cause problems, especially when using an emulator, as behavioral differences between the emulator and the actual part may occur.

This directive cannot be used across banks.

4.36.4  See Also

extern global udata udata_acs udata_ovr udata_shr

4.36.5  Simple Example

idata
LimitL dw 0
LimitH dw D'300'
Gain  dw D'5'
Flags  db 0
String db 'Hi there!'
4.36.6 Application Example - idata

This directive reserves RAM locations for variables and directs the linker to generate a lookup table that may be used to initialize the variables specified in this section. The Starting Address of the lookup table can be obtained from the Map (.map) file. If you don’t specify a value in the idata section, the variables will be initialized with 0.

```
#include p16f877a.inc ;Include standard header file for the selected device.

group1 IDATA 0x20 ;Initialized data at location 20h.
group1_var1 res 1 ;group1_var1 located at 0x20, initialized with 0.
group1_var2 res 1 ;group1_var2 located at 0x21, initialized with 0.

group2 IDATA ;Declaration of group2 data. The addresses for variables under this data section are allocated automatically by the linker.

group2_var1 db 1,2,3,4 ;4 bytes in RAM are reserved. ;Values will be padded with 34(RETLW).
group2_var2 dw 0x1234 ;1 word in RAM is reserved. ;Values will be padded with 34(RETLW).

RST CODE 0x0 ;The code section named RST is placed at program memory location 0x0. The next two instructions are placed in ;code section RST.

pagesel start ;Jumps to the location labelled ‘start’.

goto start

PGM CODE ;This is the beginning of the ;code section named PGM. It is ;a relocatable code section ;since no absolute address is ;given along with directive CODE.

start

goto $ ;Go to current line (loop here)

end
```
4.37  idata_acs - BEGIN AN OBJECT FILE INITIALIZED DATA SECTION IN ACCESS RAM (PIC18 MCUs)

4.37.1 Syntax

[label] idata_acs [RAM_address]

4.37.2 Description

This directive declares the beginning of a section of initialized data in Access RAM. If label is not specified, the section is named .idata_acs. The starting address is initialized to the specified address or will be assigned at link time if no address is specified. No code can be placed by the user in this segment.

The linker will generate a look-up table entry for each byte specified in an idata section. You must then link or include the appropriate initialization code. Examples of initialization code that may be used and modified as needed may be found with MPLINK linker sample application examples.

The res, db and dw directives may be used to reserve space for variables. res will generate an initial value of zero. db will initialize successive bytes of RAM. dw will initialize successive bytes of RAM, one word at a time, in low-byte/high-byte order.

4.37.3 Usage

This directive is used in the following types of code: relocatable. For information on types of code, see Section 1.6 “Assembler Operation”.

Use this directive to initialize your variables, or use a udata directive and then initialize your variables with values in code. It is recommended that you always initialize your variables. Relying on RAM initialization can cause problems, especially when using an emulator, as behavioral differences between the emulator and the actual part may occur.

4.37.4 See Also

extern global udata udata_acs udata_ovr udata_shr

4.37.5 Simple Example

idata_acs
LimitL dw 0
LimitH dw D'300'
Gain  dw D'5'
Flags  db 0
String db 'Hi there!'
4.38  __idlocs - SET PROCESSOR ID LOCATIONS

4.38.1 Syntax

__idlocs  expr
__idlocs  addr,  expr  (PIC18 Only)

4.38.2 Description

For PIC12 and PIC16 devices, __idlocs sets the four ID locations to the hexadecimal value of expr. For example, if expr evaluates to 1AF, the first (lowest address) ID location is zero, the second is one, the third is ten, and the fourth is fifteen.

For PIC18 devices, __idlocs sets the two-byte device ID at location addr to the hexadecimal value of expr.

Before this directive is used, the processor must be declared through the command line, the list directive, or the processor directive.

4.38.3 Usage

This directive is used in the following types of code: absolute or relocatable. For information on types of code, see Section 1.6 “Assembler Operation”.

This directive is not commonly used, but does provide an easy method of serializing devices. __idlocs can be read by a programmer. PIC18 devices can read this value at run-time, but PIC12/16 devices cannot.

4.38.4 See Also

__config  config  list  processor

4.38.5 Simple Example

Example 1: PIC16 Devices

```
#include p16f877a.inc   ;Include standard header file
                   ;for the selected device.
__idlocs  0x1234     ;Sets device ID to 1234.
```
Example 2: PIC18 Devices

Note: The most significant nibble of _idlocs is always 0x0, according to the programming specification.

```
#include p18f452.inc ;Include standard header file
                   ;for the selected device.

_idlocs  _IDLOC0, 0x1 ;IDLOC register 0 will be
                   ;programmed to 1.
_idlocs  _IDLOC1, 0x2 ;IDLOC register 1 will be
                   ;programmed to 2.
_idlocs  _IDLOC2, 0x3 ;IDLOC register 2 will be
                   ;programmed to 3.
_idlocs  _IDLOC3, 0x4 ;IDLOC register 3 will be
                   ;programmed to 4.
_idlocs  _IDLOC4, 0x5 ;IDLOC register 4 will be
                   ;programmed to 5.
_idlocs  _IDLOC5, 0x6 ;IDLOC register 5 will be
                   ;programmed to 6.
_idlocs  _IDLOC6, 0x7 ;IDLOC register 6 will be
                   ;programmed to 7.
_idlocs  _IDLOC7, 0x8 ;IDLOC register 7 will be
                   ;programmed to 8.
```
4.39  if - BEGIN CONDITIONALLY ASSEMBLED CODE BLOCK

4.39.1 Syntax

Preferred:
if expr

Supported:
#if expr
.if expr

4.39.2 Description

Begin execution of a conditional assembly block. If expr evaluates to true, the code immediately following the if will assemble. Otherwise, subsequent code is skipped until an else directive or an endif directive is encountered.

An expression that evaluates to zero is considered logically FALSE. An expression that evaluates to any other value is considered logically TRUE. The if and while directives operate on the logical value of an expression. A relational TRUE expression is guaranteed to return a nonzero value, FALSE a value of zero.

if's may be nested up to 16 deep.

4.39.3 Usage

This directive is used in the following types of code: absolute or relocatable. For information on types of code, see Section 1.6 “Assembler Operation”.

This directive is not an instruction, but used to control how code is assembled, not how it behaves at run-time. Use this directive for conditional assembly or to check for a condition, such as to generate an error message.

4.39.4 See Also

else endif

4.39.5 Simple Example

if version == 100; check current version
  movlw 0x0a
  movwf io_1
else
  movlw 0x01a
  movwf io_2
endif
4.39.6 Application Example - if/else/endif

This program demonstrates the utility of if, else and endif assembly directives.

```assembly
#include p16f877a.inc ;Include standard header file ;for the selected device.

variable cfab ;variable used to define ;required configuration of ;PORTA & PORTB
cfab set .1 ;Set config to decimal .1

RST CODE 0x0 ;The code section named RST ;is placed at program memory ;location 0x0. The next two ;instructions are placed in ;code section RST.

pagesel start ;Jumps to the location labelled ;’start’.
go to start ;’start’.

PGM CODE ;This is the beginning of the ;code section named PGM. It is ;a relocatable code section ;since no absolute address is ;given along with directive CODE.

start
banksel TRISA ;If config==0x0 is true,
if cfab==0x0 ;assemble the mnemonics up to
clrw ;the directive 'else'. Set up PORTA
movwf TRISA
movlw 0xff
movwf TRISB

else
  clrw ;If config==0x0 is false,
movwf TRISB ;assemble the mnemonics up to
movlw 0xff ;the directive 'endif'. Set up PORTB
movwf TRISA ;as output.
endif

go to $ ;Go to current line (loop here)
end
```

This program demonstrates the utility of if, else and endif assembly directives.
4.40 ifdef - EXECUTE IF SYMBOL HAS BEEN DEFINED

4.40.1 Syntax

Preferred:
ifdef label

Supported:
#ifdef label

4.40.2 Description

If label has been previously defined, usually by issuing a #define directive or by setting the value on the MPASM assembler command line, the conditional path is taken. Assembly will continue until a matching else or endif directive is encountered.

4.40.3 Usage

This directive is used in the following types of code: absolute or relocatable. For information on types of code, see Section 1.6 “Assembler Operation”.

This directive is not an instruction, but used to control how code is assembled, not how it behaves at run-time. Use this directive for removing or adding code during debugging, without the need to comment out large blocks of code.

4.40.4 See Also

#define #undefine else endif ifndef

4.40.5 Simple Example

#define testing 1     ; set testing "on"
ifdef testing
    <execute test code> ; this path would be executed.
endif

4.40.6 Application Example - ifdef

#include p16f877a.inc
#define AlternateASM ;Comment out with ; if extra
                   ;features not desired.
#elifdef AlternateASM
MyPort equ PORTC  ;Use Port C if AlternateASM defined.
MyTris equ TRISC  ;TRISC must be used to set data
                  ;direction for PORTC.
#else
MyPort equ PORTB  ;Use Port B if AlternateASM not defined.
MyTris equ TRISB  ;TRISB must be used to set data
                  ;direction for PORTB.
#endif

banksel MyTris
clrf    MyTris    ;Set port to all outputs.
banksel MyPort
movlw   55h       ;Move arbitrary value to W reg.
movwf   MyPort    ;Load port selected with 55h.
end
4.40.7 Application Example 2 - ifdef

This program uses the control directive \#define, along with the ifdef, else and endif directives to selectively assemble code for use with either an emulator or an actual part. The control directive \#define is used to create a “flag” to indicate how to assemble the code - for the emulator or for the actual device.

```
#include p18f452.inc
#define EMULATED ;Comment out with ; if actual part

INIT
#ifdef EMULATED ;If emulator used, add lines of
movlw 0xb0 ;initialization code to work around
movwf 0xf9c ;table read limitation.
#endif
```
4.41 ifndef - EXECUTE IF SYMBOL HAS NOT BEEN DEFINED

4.41.1 Syntax

Preferred:
ifndef label

Supported:
 ifndef label

4.41.2 Description

If label has not been previously defined, or has been undefined by issuing an
#undef define directive, then the code following the directive will be assembled.
Assembly will be enabled or disabled until the next matching else or endif directive
is encountered.

4.41.3 Usage

This directive is used in the following types of code: absolute or relocatable. For
information on types of code, see Section 1.6 “Assembler Operation”.

This directive is not an instruction, but used to control how code is assembled, not how
it behaves at run-time. Use this directive for removing or adding code during
debugging, without the need to comment out large blocks of code.

4.41.4 See Also

#define #undefine else endif ifdef

4.41.5 Simple Example

#define testing1 ; set testing on
:
#undef define testing1 ; set testing off
 ifndef testing ; if not in testing mode
 : ; execute this path
 endif
 end ; end of source

4.41.6 Application Example - ifndef

#include p16f877a.inc
#define UsePORTB ;Comment out with ; to use PORTC

 ifndef UsePORTB
    MyPort equ PORTC ;Use Port C if UsePORTB not defined.
    MyTris equ TRISC ;TRISC must be used to set data
       ;direction for PORTC.
    
#else
    MyPort equ PORTB ;Use Port B if UsePORTB defined.
    MyTris equ TRISB ;TRISB must be used to set data
       ;direction for PORTB.
    
#endif

banksel MyTris
    clrf MyTris ;Set port to all outputs.
 banksel MyPort ;Return to bank used for port.
 movlw  55h ;Move arbitrary value to W reg.
 movwf MyPort ;Load port selected with 55h.
 end
4.42  #include - INCLUDE ADDITIONAL SOURCE FILE

4.42.1  Syntax

Preferred:

#include include_file
#include "include_file"
#include <include_file>

Supported:

include include_file
include "include_file"
include <include_file>

4.42.2  Description

The specified file is read in as source code. The effect is the same as if the entire text of the included file were inserted into the file at the location of the include statement. Upon end-of-file, source code assembly will resume from the original source file. Up to 5 levels of nesting are permitted. Up to 255 include files are allowed.

If include_file contains any spaces, it must be enclosed in quotes or angle brackets. If a fully qualified path is specified, only that path will be searched. Otherwise, the search order is:
• current working directory
• source file directory
• MPASM assembler executable directory

4.42.3  Usage

This directive is used in the following types of code: absolute or relocatable. For information on types of code, see Section 1.6 “Assembler Operation”.

You should use the include directive once to include that standard header file for your selected processor. This file contains defined register, bit and other names for a specific processor, so there is no need for you to define all of these in your code.

4.42.4  See Also

#define #undefine

4.42.5  Simple Example

#include p18f452.inc  ;standard include file
#include "c:\Program Files\mydefs.inc"  ;user defines
4.43 list - LISTING OPTIONS

4.43.1 Syntax

list [list_option, ..., list_option]

4.43.2 Description

Occurring on a line by itself, the list directive has the effect of turning listing output on, if it had been previously turned off. Otherwise, one of a list of options can be supplied to control the assembly process or format the listing file.

4.43.3 Usage

This directive is used in the following types of code: absolute or relocatable. For information on types of code, see Section 1.6 “Assembler Operation”.

<table>
<thead>
<tr>
<th>Option</th>
<th>Default</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>b=nnn</td>
<td>8</td>
<td>Set tab spaces.</td>
</tr>
<tr>
<td>c=nnn</td>
<td>132</td>
<td>Set column width.</td>
</tr>
<tr>
<td>f=format</td>
<td>INHX8M</td>
<td>Set the hex file output. format can be INHX32, INHX8M, or INHX8S. Note: Hex file format is set in the IDE (Build Options dialog.)</td>
</tr>
<tr>
<td>free</td>
<td>FIXED</td>
<td>Use free-format parser. Provided for backward compatibility.</td>
</tr>
<tr>
<td>fixed</td>
<td>FIXED</td>
<td>Use fixed-format parser.</td>
</tr>
<tr>
<td>mm=(ON</td>
<td>OFF)</td>
<td>On</td>
</tr>
<tr>
<td>n=nnn</td>
<td>60</td>
<td>Set lines per page.</td>
</tr>
<tr>
<td>p=type</td>
<td>None</td>
<td>Set processor type; for example, PIC16F877. See also processor. Note: Processor type is set in MPLAB IDE or MPLAB X IDE projects.</td>
</tr>
<tr>
<td>pe=type</td>
<td>None</td>
<td>Set processor type and enable extended instruction set, for example; LIST pe=PIC18F4620 Only valid with processors which support the extended instruction set and the generic processor PIC18XXX. is overridden by command-line option /y- or -y- (disable extended instruction set). Note: Processor type is set in MPLAB IDE or MPLAB X IDE projects.</td>
</tr>
<tr>
<td>r=radix</td>
<td>hex</td>
<td>Set radix: hex, dec, oct. See also radix.</td>
</tr>
<tr>
<td>st=(ON</td>
<td>OFF)</td>
<td>On</td>
</tr>
<tr>
<td>t=(ON</td>
<td>OFF)</td>
<td>Off</td>
</tr>
<tr>
<td>w={0</td>
<td>1</td>
<td>2}</td>
</tr>
<tr>
<td>x=(ON</td>
<td>OFF)</td>
<td>On</td>
</tr>
</tbody>
</table>

**Note:** All list options are evaluated as decimal numbers by default.

4.43.4 See Also

errorlevel expand noexpand nolist processor radix

4.43.5 Simple Example

Set the processor type to PIC18F452, the hex file output format to INHX32 and the radix to decimal.

list p=18f452, f=INHX32, r=DEC
4.44 local - DECLARE LOCAL MACRO VARIABLE

4.44.1 Syntax

Preferred:
local label[,label...]

Supported:
.local label[,label...]

4.44.2 Description

Declares that the specified data elements are to be considered in local context to the macro. label may be identical to another label declared outside the macro definition; there will be no conflict between the two.

If the macro is called recursively, each invocation will have its own local copy.

4.44.3 Usage

This directive is used in the following types of code: absolute or relocatable. For information on types of code, see Section 1.6 “Assembler Operation”.

If you use a macro more than once and there is a label in it, you will get a “Duplicate Label” error unless you use this directive.

4.44.4 See Also

endm macro

4.44.5 Simple Example

<main code segment>

len   equ 10           ; global version
size  equ 20           ; note that a local variable
                 ; may now be created and modified
test macro size
          local len, label ; local len and label
          len   set size     ; modify local len
          label res len     ; reserve buffer
          len   set len-20
endm                   ; end macro

4.44.6 Application Example - local

This code demonstrates the utility of local directive, which declares that the specified data elements are to be considered in local context to the macro.

#include p16f877a.inc ;Include standard header file
                   ;for the selected device.
incr  equ  2          ;Assembler variable incr is set
to equal to 2.

add_incr macro       ;Declaration of macro 'add_incr'.
          local incr ;Local assembler variable 'incr'.


The same name `incr` is used in the main code, where its value is set to 2.

```assembly
incr set 3 ; Local 'incr' is set to 3, in contrast to 'incr' value of 2 in main code.
clrw ; w register is set to zero
addlw incr ; w register is added to incr and result placed back
endm ; in w register.

RST   CODE   0x0 ; The code section named RST is placed at program memory location 0x0. The next two instructions are placed in code section RST.
pagesel start ; Jumps to the location labelled 'start'.
goto start ; 'start'.

PGM   CODE
; This is the beginning of the code section named PGM. It is a relocatable code section since no absolute address is given along with directive CODE.

start
clrw ; W register set to zero.
addlw incr ; W register is added with the value of incr which is now equal to 2.
add_incr ; W register is added with the value of incr which is now equal to 3 (value set locally in the macro add_incr).
clrw ; W register is set to zero again.
addlw incr ; incr is added to W register and result placed in W register. incr value is again 2, not affected by the value set in the macro.
goto $ ; Go to current line (loop here)
end```

```
4.45 macro - DECLARE MACRO DEFINITION

4.45.1 Syntax

    label macro [arg, ..., arg]

4.45.2 Description

A macro is a sequence of instructions that can be inserted in the assembly source code by using a single macro call. The macro must first be defined, then it can be referred to in subsequent source code.

Arguments are read in from the source line, stored in a linked list and then counted. The maximum number of arguments would be the number of arguments that would fit on the source line, after the label and macro terms. Therefore, the maximum source line length is 200 characters.

A macro can call another macro, or may call itself recursively. The maximum number of nested macro calls is 16.

Please refer to Chapter 7. "Macro Language" for more information.

4.45.3 Usage

This directive is used in the following types of code: absolute or relocatable. For information on types of code, see Section 1.6 "Assembler Operation".

4.45.4 See Also

endm exitm local

4.45.5 Simple Example

;Define macro Read
Read macro device, buffer, count
    movlw device
    movwf ram_20
    movlw buffer  ; buffer address
    movwf ram_21
    movlw count   ; byte count
    call sys_21   ; subroutine call
endm

;Use macro Read
Read 0x0, 0x55, 0x05
4.45.6 Application Example - macro/endm

This code demonstrates the utility of macro directive, which is used to define a macro.

```
#include p16f877a.inc ;Include standard header file for the selected device.

result equ 0x20 ;Assign value 20H to label result.

ORG 0x0000 ;The following code will be placed in reset address 0.
goto start ;Jump to an address whose label is 'start'.

add MACRO num1,num2 ;'add' is a macro. The values of 'num1' and 'num2' must be passed to this macro.

movlw num1 ;Load W register with a literal value assigned to the label 'num1'.

movwf result ;Load W register to an address location assigned to the label 'result'.

movlw num2 ;Load W register with a literal value assigned to the label 'num2'.

addwf result ;Add W register with the memory location addressed by 'result' and load the result back to 'result'.

endm ;end of 'add' MACRO

ORG 0x0010 ;Main program starts at 10H.

start ;The label 'start' is assigned an address 10H.

add .100,.90 ;Call 'add' MACRO with decimal numbers 100 and 90 assigned to 'num1' and 'num2' labels, respectively. 100 and 90 will be added and the result will be in 'result'.

end
```
4.46 __maxram - DEFINE MAXIMUM RAM LOCATION

**Note:** `maxram` is preceded by two underline characters.

### 4.46.1 Syntax

```
__maxram expr
```

### 4.46.2 Description

The `__maxram` and `__badram` directives together flag accesses to unimplemented registers. `__maxram` defines the absolute maximum valid RAM address and initializes the map of valid RAM addresses to all addresses valid at and below `expr`. `expr` must be greater than or equal to the maximum page 0 RAM address and less than 1000H. This directive is designed for use with the `__badram` directive. Once the `__maxram` directive is used, strict RAM address checking is enabled, using the RAM map specified by `__badram`. `__maxram` can be used more than once in a source file. Each use redefines the maximum valid RAM address and resets the RAM map to all locations.

### 4.46.3 Usage

This directive is used in the following types of code: absolute or relocatable. For information on types of code, see Section 1.6 “Assembler Operation”.

This directive is not commonly used in user code, as RAM and ROM details are handled by the include files (`*.inc`) or linker script files (`*.lkr`).

### 4.46.4 See Also

`__badram`

### 4.46.5 Simple Example

See the examples for `badram`. 

---

**Note:** `maxram` is preceded by two underline characters.
4.47  __maxrom - DEFINE MAXIMUM ROM LOCATION

Note: maxrom is preceded by two underline characters.

4.47.1 Syntax
__maxrom expr

4.47.2 Description
The __maxrom and __badrom directives together flag accesses to unimplemented registers. __maxrom defines the absolute maximum valid ROM address and initializes the map of valid ROM addresses to all addresses valid at and below expr. expr must be greater than or equal to the maximum ROM address of the target device. This directive is designed for use with the __badrom directive. Once the __maxrom directive is used, strict ROM address checking is enabled, using the ROM map specified by __badrom.

__maxrom can be used more than once in a source file. Each use redefines the maximum valid ROM address and resets the ROM map to all locations.

4.47.3 Usage
This directive is used in the following types of code: absolute or relocatable. For information on types of code, see Section 1.6 “Assembler Operation”.

This directive is not commonly used in user code, as RAM and ROM details are handled by the include files (*.inc) or linker script files (*.lkr).

4.47.4 See Also
__badrom

4.47.5 Simple Example
See the examples for badrom.
4.48  **messg - CREATE USER DEFINED MESSAGE**

4.48.1  **Syntax**

    messg "message_text"

4.48.2  **Description**

Causes an informational message to be printed in the listing file. The message text can be up to 80 characters. Issuing a messg directive does not set any error return codes.

4.48.3  **Usage**

This directive is used in the following types of code: absolute or relocatable. For information on types of code, see Section 1.6 “Assembler Operation”.

This directive may be used to generate any desired message. It can be useful with conditional assembly, to verify in the assembled program which code was built.

4.48.4  **See Also**

error

4.48.5  **Simple Example**

    mssg_macro macro
        messg "mssg_macro-001 invoked without argument"
    endm

4.48.6  **Application Example - messg**

This program demonstrates the messg assembler directive, which sets a message to be printed in the listing file and error file.

    #include pl6f877a.inc ;Include standard header file
                          ;for the selected device.

    variable baudrate     ;variable used to define
                          ;required baud rate

    baudrate set D'5600'  ;Enter the required value of
                          ;baud rate here.

    if (baudrate!=D'1200')&&
        (baudrate!=D'2400')&&
        (baudrate!=D'4800')&&
        (baudrate!=D'9600')&&
        (baudrate!=D'19200')
        error "Selected baud rate is not supported"
        messg "only baud rates 1200,2400,4800,9600 & 19200 Hz "&&
        "are supported"
    endif
The if-endif code outputs error and messg if the baud rate selected is other than 1200, 2400, 4800, 9600 or 19200 Hz.

RST CODE 0x0 ;The code section named RST ;is placed at program memory ;location 0x0. The next two ;instructions are placed in ;code section RST.
pagesel start ;Jumps to the location labelled goto start ;’start’.

PGM CODE ;This is the beginning of the ;code section named PGM. It is ;a relocatable code section ;since no absolute address is ;given along with directive CODE.

start goto $ ;Go to current line (loop here)
end
4.49 noexpand - TURN OFF MACRO EXPANSION

4.49.1 Syntax

noexpand

4.49.2 Description and Usage

Turns off macro expansion in the listing file.

This directive is used in the following types of code: absolute. For information on types of code, see Section 1.6 “Assembler Operation”.

4.49.3 See Also

expand

4.49.4 Simple Example

Code example:

```
;Define a macro to add two numbers
add   macro  num1,num2
   movlw  num1
   movwf  result
   movlw  num2
   addwf  result
   endm

:noexpand

;Use macro add
add   .100,.90
```

Resulting listing file:

```
00029   noexpand
00030     add   .100,.90
00031
```

4.50 nolist - TURN OFF LISTING OUTPUT

4.50.1 Syntax

nolist

4.50.2 Description and Usage

Turn off listing file output.

This directive suppresses the information required for the listing file and source-level debugging. This will prevent the ability to debug the source code.

This directive is used in the following types of code: absolute or relocatable. For information on types of code, see Section 1.6 “Assembler Operation”.

4.50.3 See Also

list
4.51  org - SET PROGRAM ORIGIN

4.51.1 Syntax

[label]  org  expr

4.51.2 Description

Set the program origin for subsequent code at the address defined in expr. If label is specified, it will be given the value of the expr. If no org is specified, code generation will begin at address zero.

For PIC18 devices, only even-numbered expr values are allowed.

When generating an object file, the org directive is interpreted as introducing an absolute CODE section with an internally generated name. For example:

    L1:  org 0x200

is interpreted as:

    .scnname  CODE 0x200
    L1:

where .scnname is generated by the assembler, and will be distinct from every name previously generated in this context.

4.51.3 Usage

This directive is used in the following types of code: absolute. For information on types of code, see Section 1.6 "Assembler Operation".

org is commonly used in single-file assembly programs whenever code needs to be placed at a particular location. Commonly used values are 0x0 (reset), 0x4 (PIC16 device interrupt vector), 0x8 (PIC18 device high-priority interrupt vector) and 0x18 (PIC18 device low-priority interrupt vector).

4.51.4 See Also

fill res end

4.51.5 Simple Example

int_1 org 0x20
    ; Vector 20 code goes here
int_2 org int_1+0x10
    ; Vector 30 code goes here
4.51.6 PIC16 Application Example - org

This example shows the usage of the org directive. Code generation begins at an address specified by org address. The origin of a data table also can be specified by this directive. A data table may be placed either in a program memory region or in an EE data memory region, as in case of a PIC1X device with EE data FLASH.

```
#include p16f877a.inc ;Include standard header file ;for the selected device.
/org 0x0000 ;The following code will be ;placed in reset address 0.
goto Main ;Jump to an address whose label ;is 'Main'.

/org 0x0004 ;The following code will be ;placed in interrupt address 4.
goto int_routine ;Jump to an address whose label ;is 'int_routine'.

/org 0x0010 ;The following code section will ;placed starting from address 10H.
Main
;
; ;
goto Main ;Loop back to 'Main'.

/org 0x0100 ;The following code section will ;be placed starting from address ;100H.
int_routine
;
;
; ; ;
/write your interrupt service ;routine here.
; ;
retfie ;Return from interrupt.

/org 0x1000 ;You can create a data or ;character table starting from ;any address in program memory. ;In this case the address is ;1000h.

/ch_tbl1 da "PICwithFLASH" ;6 program memory locations ;starting from 1000h will ;be filled with six 14-bit ;packed numbers, each ;representing two 7-bit ASCII ;characters.

/org 0x2100 ;The absolute address 2100h is ;mapped to the 0000 location of ;EE data memory in PIC16Fxxx. ;You can create a data or ;character table starting from ;any address in EE data memory.

/ch_tbl2 de "PICwithFLASH" ;12 EE data memory locations ;starting from 0 will be ;filled with 12 ASCII ;characters.

end
```
4.51.7  PIC18 Application Example - org

This example shows the usage of the org directive. Code generation begins at an address specified by org address. The origin of a data table also can be specified by this directive. A data table may be placed either in a program memory region or in an EE data memory region, as in case of a PIC1X device with EE data FLASH.

```assembly
#include p18f452.inc ;Include standard header file for the selected device.

org 0x0000 ;The following code will be programmed in reset address 0.
goto Main ;Jump to an address whose label is 'Main'.

org 0x0008 ;The following code will be programmed in high priority interrupt address 8.
goto int_hi ;Jump to an address whose label is 'int_hi'.

org 0x0018 ;The following code will be programmed in low priority interrupt address 18h.
goto int_lo ;Jump to an address whose label is 'int_lo'.

org 0x0020 ;The following code section will be programmed starting from address 20H.

Main ;Write your main program here.
;
;
goto Main ;Loop back to 'Main'

org 0x0100 ;The following code section will be programmed starting from address 100H.

int_hi
;
;
retfie ;Return from interrupt.

org 0x0200 ;The following code section will be programmed starting from address 200H.

int_lo
;
;
retfie ;Return from interrupt.

org 0x1000 ;You can create a data or character table starting from any address in program memory. In this case the address is 1000h.

ch_tbl1 db "PICwithFLASH"

end
```
4.52 page - INSERT LISTING PAGE EJECT

4.52.1 Syntax

page

4.52.2 Description and Usage

Inserts a page eject into the listing file. This directive is used in the following types of code: absolute or relocatable. For information on types of code, see Section 1.6 “Assembler Operation”.

4.52.3 See Also

list subtitle title

4.53 pagesel - GENERATE PAGE SELECTING CODE (PIC10/12/16 MCUs)

4.53.1 Syntax

pagesel label

4.53.2 Description

An instruction to the linker to generate page selecting code to set the page bits to the page containing the designated label. Only one label should be specified. No operations can be performed on label. label must have been previously defined.

The linker will generate the appropriate page selecting code:
For 12-bit instruction width (PIC10F, some PIC12/PIC16) devices, the appropriate bit set/clear instructions on the STATUS register will be generated.
For 14-bit instruction width (most PIC12/PIC16) devices, a combination of BSF and BCF commands will be used to adjust bits 3 and 4 of the PCLATH register. For PIC16 extended devices, a movlp instruction is generated to set the page. If the device contains only one page of program memory, no code will be generated.
For PIC18 devices, this command will do nothing as these devices do not use paging.

4.53.3 Usage

This directive is used in the following types of code: absolute or relocatable. For information on types of code, see Section 1.6 “Assembler Operation”.

This directive saves you from having to manually code page bit changes. Also, since it automatically generates code, the code is much more portable.

If you are using relocatable code and your device has more than 2k program memory (or 0.5K for 12-bit instruction width devices), it is recommended that you use this directive, especially when code must jump between two or more code sections.

If you wish to indicate the start address of a RETLW table or a jump table for computed GOTOs, you must use the pageselw directive.

4.53.4 See Also

bankisel banksel

4.53.5 Simple Example

pagesel GotoDest
goto GotoDest:
pagesel CallDest
call CallDest
4.53.6 Application Example - pagesel

This program demonstrates the pagesel directive, which generates the appropriate code to set/clear PCLATH bits. This allows easier use of paged memory such as found on PIC16 devices.

```
#include p16f877a.inc

RST     CODE     0x0
         ;The code section named RST is placed at program memory location 0x0. The next two instructions are placed in code section RST.
      pagesel start
      goto     start
         ;Jumps to the location labelled 'start'.

PGM0    CODE     0x500
      start
      pagesel pagel_pgm
      goto     pagel_pgm
         ;address bits 12 & 11 of pagel_pgm are copied to PCLATH 4 & 3 respectively.

PGM1    CODE     0x900
      pagel_pgm
      goto $
         ;Go to current line (loop here)
```
4.54  pageselw - GENERATE PAGE SELECTING CODE USING WREG COMMANDS (PIC10/12/16 MCUs)

4.54.1 Syntax

    pageselw label

4.54.2 Description

An instruction to the linker to generate page selecting code to set the page bits to the page containing the designated label. Only one label should be specified. No operations can be performed on label. label must have been previously defined.

The linker will generate the appropriate page selecting code. For 12-bit instruction width (PIC10F, some PIC12/PIC16) devices, the appropriate bit set/clear instructions on the STATUS register will be generated. For 14-bit instruction width (most PIC12/PIC16) devices, MOVWL and MOVWF instructions will be generated to modify the PCLATH. If the device contains only one page of program memory, no code will be generated.

For PIC18 devices, this command will do nothing as these devices do not use paging.

4.54.3 Usage

This directive is used in the following types of code: absolute or relocatable. For information on types of code, see Section 1.6 “Assembler Operation”.

This directive saves you from having to manually code page bit changes. Also, since it automatically generates code, the code is much more portable.

If you are using relocatable code and your device has more than 2k program memory (or 0.5K for 12-bit instruction width devices), it is recommended that you use this directive, especially when code must jump between two or more code sections.

You must use this directive instead of pagesel if you wish to indicate the start address of a RETLW table or a jump table for computed GOTOs. Only then will all the 5 top-most bits of the PC will be loaded with the appropriate value when an 8-bit offset is added to the PC. The 256-word boundaries will still have to be considered, as discussed in Application Note AN586.

4.54.4 See Also

bankisel banksel

4.54.5 Simple Example

    pageselw CommandTableStart ;Get the byte read and use it to
    movlw CommandTableStart       ;index into our jump table. If
    addwf Comm.RxTxByte,w         ;we crossed a 256-byte boundary,
    btfsC STATUS,C                ;then increment PCLATH. Then load the
    incf PCLATH,f                 ;program counter with computed goto.
    movwf PCL

    CommandTableStart
    goto GetVersion   ;0x00 - Get Version
    goto GetRTSample ;0x01 - Get Real Time sample
    goto Configure   ;0x02 - stub
    goto Go          ;0x03 - stub
    goto ReadBuffer  ;0x04 - Read Buffer, just sends Vout
    goto AreYouThroughYet ;0x05
    goto CommDone    ;0x06
    goto CommDone    ;0x07
4.55  processor - SET PROCESSOR TYPE

4.55.1 Syntax

processor  processor_type

4.55.2 Description

Sets the processor type to processor_type.

4.55.3 Usage

This directive is used in the following types of code: absolute or relocatable. For information on types of code, see Section 1.6 “Assembler Operation”.

This directive is not generally used as the processor is set in MPLAB IDE or MPLAB X IDE projects. If it must be set in code, use processor or the list directive option p= to set the processor.

4.55.4 See Also

list

4.55.5 Simple Example

processor 16f877a ;Sets processor to PIC16F877A
4.56  radix - SPECIFY DEFAULT RADIX

4.56.1  Syntax

radix default_radix

4.56.2  Description

Sets the default radix for data expressions. The default radix is hex. Valid radix values are:

• hex - hexadecimal (base 16)
• dec - decimal (base 10)
• oct - octal (base 8)

You may also specify a radix using the list directive. For specifying the radix of constants, see Section 3.4 “Numeric Constants and Radix”.

4.56.3  Usage

This directive is used in the following types of code: absolute or relocatable. For information on types of code, see Section 1.6 “Assembler Operation”.

For many programs, the default radix, hex, is used and there is no need to set the radix. However, if you need to change the radix in your program, you should exercise care, as all numeric values following the radix declaration will use that radix value. See the radix example for more on the implications of changing the radix.

Use the radix directive or the list directive option r= to change the radix in your code.

4.56.4  See Also

list

4.56.5  Simple Example

radix dec

4.56.6  Application Example - radix

This example shows the usage of the radix directive for data presentation. If not declared, then the default radix is in hexadecimal.

list r=dec ;Set the radix as decimal.
#include p16f877a.inc ;Include standard header file for the selected device.

movlw  50H ;50 is in hex
movlw  0x50 ;Another way of declaring 50 hex
movlw  500 ;50 is in octal
movlw  50 ;50 is not declared as hex or octal or decimal. So by default, it is in decimal as default radix is declared as decimal.

radix oct ;Use ’radix’ to declare default radix as octal.

movlw  50H ;50 is in hex.
movlw  0x50 ;Another way of declaring 50 hex.
movlw  .50 ;50 is in decimal.
movlw 50 ; 50 is not declared as hex or octal or decimal. So by default it is in octal as default radix is declared as octal.

radix hex ; Now default radix is in hex.

movlw .50 ; 50 is declared in decimal.
movlw 500 ; 50 is declared in octal
movlw 50 ; 50 is not declared as hex or octal or decimal. So by default it is in hex as default radix is declared as hex.

end
4.57 res - RESERVE MEMORY

4.57.1 Syntax

[label] res mem_units

4.57.2 Description

Causes the memory location pointer to be advanced from its current location by the value specified in mem_units. In relocatable code (using MPLINK linker), res can be used to reserve data storage. In non-relocatable code, label is assumed to be a program memory address.

Address locations are defined in words for PIC12/16 MCUs, and bytes for PIC18 MCUs.

4.57.3 Usage

This directive is used in the following types of code: absolute or relocatable. For information on types of code, see Section 1.6 “Assembler Operation”.

The most common usage for res is for data storage in relocatable code.

4.57.4 See Also

fill org equ cblock

4.57.5 Simple Example

buffer res 64 ; reserve 64 address locations of storage

4.57.6 Application Example - res

This example shows the advantage of res directive in developing relocatable code. The program calculates the perimeter of a rectangle. Length and width of the rectangle will be stored in buffers addressed by length and width. The calculated perimeter will be stored in the double-precision buffer addressed by perimeter.

```
#include p18f452.inc ;Include standard header file
 ;for the selected device.

UDATA ;This directive allows the
 ;following data to be placed only
 ;in the data area.

perimeter res 2 ;Two locations of memory are
 ;reserved for the label
 ;'perimeter'. Addresses of the
 ;memory locations will be
 ;allocated by the linker.

length res 1 ;One location of memory is
 ;reserved for the label 'length'.
 ;Address of the memory location
 ;will be allocated by the linker.

width res 1 ;One location of memory is
 ;reserved for the label 'width'.
 ;Address of the memory location
 ;will be allocated by the linker.

Start CODE 0x0000 ;Following code will be placed in
 ;address 0.
```
Here the directive \texttt{code} has the same effect as \texttt{org}. But \texttt{org} is used with MPASM assembler to generate absolute code and \texttt{code} is used with MPLINK linker to generate an object file. \texttt{code} is also different in that an address is not normally specified; the linker handles the allocation of space, both in program Flash and data RAM memory.

\begin{verbatim}
  goto PER_CAL ;Jump to label PER_CAL

  CODE ;CODE directive here dictates that
         ;the following lines of code will
         ;be placed in program memory, but
         ;the starting address will be
         ;decided by the linker.

  PER_CAL
  clrf perimeter+1 ;Clear the high byte of the label
                   ;'perimeter'.
  movf length,w ;Move the data present in the
                 ;register addressed by 'length'
                 ;to 'w'.
  addwf width,w ;Add data in 'w' with data in the
                 ;register addressed by 'width'.
                 ;STATUS register carry bit C
                 ;may be affected.
  movwf perimeter ;Move 'w' to the perimeter low
                   ;byte at address 20H. Carry bit
                   ;is unaffected.
  rlf perimeter+1 ;Increment register 21H if carry
                  ;was generated. Also clear carry
                  ;if bit was set.
  rlf perimeter ;Multiply register 20H by 2.
                ;Carry bit may be affected.
  rlf perimeter+1 ;Again, increment register 21H
                  ;if carry was generated.

  The previous two lines of code will multiply (by left-shifting one bit) the intermediate result by 2.

  goto $ ;Go to current line (loop here)
end
\end{verbatim}
4.58 set - DEFINE AN ASSEMBLER VARIABLE

4.58.1 Syntax

Preferred:

```
label set expr
```

Supported:

```
label .set expr
```

4.58.2 Description

`label` is assigned the value of the valid MPASM assembler expression specified by `expr`. The `set` directive is functionally equivalent to the `equ` directive except that `set` values may be subsequently altered by other `set` directives.

4.58.3 Usage

This directive is used in the following types of code: absolute or relocatable. For information on types of code, see Section 1.6 “Assembler Operation”.

Because `set` directive values may be altered by later `set` directives, `set` is particularly useful when defining a variable in a loop (e.g., a `while` loop.)

4.58.4 See Also

equ variable while

4.58.5 Simple Example

```
area   set 0
width  set 0x12
length set 0x14
area   set length * width
length set length + 1
```

4.58.6 Application Example - set/equ

This example shows the usage of the `set` directive, used for creating symbols which may be used in MPASM assembler expressions only. The symbols created with this directive do not occupy any physical memory location on the microcontroller.

```
#include p16f877a.inc ;Include standard header file for the selected device.

perimeter set 0 ;The label 'perimeter' is assigned value 0.
area      set 0 ;The label 'area' is assigned value 0.

The value assigned by the `set` directive may be reassigned later.

lngth     equ 50H ;The label 'lngth' is assigned the value 50H.
wdth      equ 25H ;The label 'wdth' is assigned the value 25H.

The value assigned by the `equ` directive may not be reassigned later.

perimeter set 2*(lngth+wdth) ;Both 'perimeter' and
area      set lngth*wdth    ;'area' values are
                 ;reassigned.
```

end
4.59 space - INSERT BLANK LISTING LINES

4.59.1 Syntax

Preferred:

space expr

Supported:

spac expr

4.59.2 Description and Usage

Insert expr number of blank lines into the listing file.

This directive is used in the following types of code: absolute or relocatable. For information on types of code, see Section 1.6 “Assembler Operation”.

4.59.3 See Also

list

4.59.4 Simple Example

space 3 ; Inserts three blank lines

4.60 subtitle - SPECIFY PROGRAM SUBTITLE

4.60.1 Syntax

Preferred:

subtitle "sub_text"

Supported:

stitle "sub_text"

subtitl "sub_text"

4.60.2 Description and Usage

sub_text is an ASCII string enclosed in double quotes, 60 characters or less in length. This directive establishes a second program header line for use as a subtitle in the listing output.

This directive is used in the following types of code: absolute or relocatable. For information on types of code, see Section 1.6 “Assembler Operation”.

4.60.3 See Also

list title

4.60.4 Simple Example

subtitle "diagnostic section"
4.61 title - SPECIFY PROGRAM TITLE

4.61.1 Syntax

```
title "title_text"
```

4.61.2 Description and Usage

`title_text` is a printable ASCII string enclosed in double quotes. It must be 60 characters or less. This directive establishes the text to be used in the top line of each page in the listing file.

This directive is used in the following types of code: absolute or relocatable. For information on types of code, see Section 1.6 “Assembler Operation”.

4.61.3 See Also

list subtitle

4.61.4 Simple Example

```
title "operational code, rev 5.0"
```

4.62 udata - BEGIN AN OBJECT FILE UNINITIALIZED DATA SECTION

4.62.1 Syntax

```
[label] udata [RAM_address]
```

4.62.2 Description

This directive declares the beginning of a section of uninitialized data. If `label` is not specified, the section is named `.udata`. The starting address is initialized to the specified address or will be assigned at link time if no address is specified. No code can be generated in this segment. The `res` directive should be used to reserve space for data.

```
Note: Two sections in the same source file are not permitted to have the same name.
```

4.62.3 Usage

This directive is used in the following types of code: relocatable. For information on types of code, see Section 1.6 “Assembler Operation”.

For relocatable code, this directive is used to create a data (RAM) section. For absolute code, do not use this directive. Use directives `equ` or `cblock`.

This directive cannot be used across banks.

4.62.4 See Also

extern global idata udata_acs udata_ovr udata_shr

4.62.5 Simple Example

```
udata
Var1    res 1
Double res 2
```
4.62.6 Application Example - udata

This program demonstrates the udata directive, which declares the beginning of a section of uninitialized data. udata does not set (initialize) the starting value of the variables; you must do this in code.

```c
#include p16f877a.inc ;Include standard header file ;for the selected device.

group1 udata 0x20 ;group1 data stored at locations ;starting at 0x20.
group1_var1 res 1 ;group1_var1 located at 0x20.
group1_var2 res 1 ;group1_var2 located at 0x21.

group2 udata ;Declaration of group2 data. The ;addresses for variables under
  group2_var1 res 1 ;this data section are allocated
  group2_var2 res 1 ;automatically by the linker.

RST CODE 0x0 ;The code section named RST ;is placed at program memory ;location 0x0. The next two ;instructions are placed in ;code section RST.
  pagesel start ;Jumps to the location labelled ;'start'.
  goto start ;'start'.

PGM CODE ;This is the beginning of the ;code section named PGM. It is ;a relocatable code section ;since no absolute address is ;given along with directive CODE.

start
  banksel group1_var1
  clrf group1_var1
  clrf group1_var2

  banksel group2_var1
  clrf group2_var1
  clrf group2_var2

goto $ ;Go to current line (loop here)
end
```
4.63  udata_acs - BEGIN AN OBJECT FILE ACCESS UNINITIALIZED DATA SECTION (PIC18 MCUs)

4.63.1 Syntax

[label] udata_acs [RAM_address]

4.63.2 Description

This directive declares the beginning of a section of access uninitialized data. If label is not specified, the section is named .udata_acs. The starting address is initialized to the specified address or will be assigned at link time if no address is specified. This directive is used to declare variables that are allocated in access RAM of PIC18 devices. No code can be generated in this segment. The res directive should be used to reserve space for data.

Note: Two sections in the same source file are not permitted to have the same name.

4.63.3 Usage

This directive is used in the following types of code: relocatable. For information on types of code, see Section 1.6 “Assembler Operation”.

This directive is similar to udata, except that it is used only for PIC18 devices and will only place variables in access RAM. PIC18 devices have an area of RAM known as access RAM. Variables in access memory can be used no matter where the bank select register (BSR) is pointing. It is very useful for frequently-used and global variables.

4.63.4 See Also

extern global idata udata udata_ovr udata_shr

4.63.5 Simple Example

    udata_acs
    Var1   res 1
    Double res 2

4.63.6 Application Example - udata_acs

This program demonstrates the udata_acs directive. This directive declares the beginning of a section of uninitialized data.

    #include p18f452.inc ;Include standard header file
                         ;for the selected device.
    group1  udata_acs   0x20  ;group1 data stored at access
                         ;RAM locations starting at 0x20.
    group1_var1 res 1    ;group1_var1 located at 0x20.
    group1_var2 res 1    ;group1_var2 located at 0x21.
    group2  udata_acs
                         ;Declaration of group2 data. The
                         ;addresses for data under this
                         ;section are allocated
                         ;automatically by the linker.
    group2_var1 res 1    ;All addresses be will allocated
    group2_var2 res 1    ;in access RAM space only.
RST CODE 0x0

; The code section named RST is placed at program memory location 0x0. The instruction 'goto start' is placed in code section RST.

goto start

; Jumps to the location labelled 'start'.

PGM CODE

; This is the beginning of the code section named PGM. It is a relocatable code section since no absolute address is given along with directive CODE.

start

clrf group1_var1,A

; group1_var1 initialized to zero

clrf group1_var2,A

; group1_var2 initialized to zero

clrf group2_var1,A

; group2_var1 initialized to zero

clrf group2_var2,A

; group2_var2 initialized to zero

goto $

; Go to current line (loop here)
end

In the code above, “A” references the access RAM. This A designation can be explicitly stated by the code, but is not needed since the assembler will automatically locate variables in access memory, if possible.
4.64 udata_ovr - BEGIN AN OBJECT FILE OVERLAYED UNINITIALIZED DATA SECTION

4.64.1 Syntax

[label] udata_ovr [RAM_address]

4.64.2 Description

This directive declares the beginning of a section of overlayed uninitialized data. If label is not specified, the section is named .udata_ovr. The starting address is initialized to the specified address or will be assigned at link time if no address is specified. The space declared by this section is overlayed by all other udata_ovr sections of the same name. It is an ideal way of declaring temporary variables since it allows multiple variables to be declared at the same memory location. No code can be generated in this segment. The res directive should be used to reserve space for data.

**Note:** Two sections in the same source file are not permitted to have the same name.

4.64.3 Usage

This directive is used in the following types of code: relocatable. For information on types of code, see Section 1.6 “Assembler Operation”.

This directive is similar to udata, except that it allows you to reuse data space by "overlaying" one data area on another. It is used for temporary variables, as each data section may overwrite (and thus share) the same RAM address locations.

4.64.4 See Also

extern global idata udata udata_acs udata_shr

4.64.5 Simple Example

Temps     udata_ovr
Temp1     res 1
Temp2     res 1
Temp3     res 1
Temps     udata_ovr
LongTemp1 res 2  ; this will be a variable at the
          ; same location as Temp1 and Temp2
LongTemp2 res 2  ; this will be a variable at the
          ; same location as Temp3
4.64.6 Application Example - udata_ovr

This program demonstrates the udata_ovr directive. This directive declares the beginning of a section of overlayed uninitialized data.

```assembly
#include p16f877a.inc ;Include standard header file ;for the selected device.
same_var udata_ovr 0x20  ;Declares an overlayed ;uninitialized data section ;named 'same_var' starting at
var1 res 1         ;location 0x20.
same_var udata_ovr 0x20  ;Declares an overlayed ;uninitialized data section
var2 res 1         ;with the same name as the one ;declared above. Thus variables ;var1 and var2 are allocated ;at the same address.
RST CODE 0x0     ;The code section named RST ;is placed at program memory ;location 0x0. The next two ;instructions are placed in ;code section RST.
   pagesel start ;Jumps to the location labelled ;'start'.
goto start      ;'start'.

PGM CODE            ;This is the beginning of the ;code section named PGM. It is ;a relocatable code section ;since no absolute address is ;given along with directive CODE.

start
   banksel var1 ;Any operation on var1 affects
   movlw 0xFF   ;var2 also since both variables
   movwf var1   ;are overlaid.
   movf var2
   goto $      ;Go to current line (loop here)
end
```
4.65 **udata\_shr** - BEGIN AN OBJECT FILE SHARED UNINITIALIZED DATA SECTION (PIC12/16 MCUs)

### 4.65.1 Syntax

`[label] udata\_shr [RAM\_address]`

### 4.65.2 Description

This directive declares the beginning of a section of shared uninitialized data. If `label` is not specified, the section is named `.udata\_shr`. The starting address is initialized to the specified address or will be assigned at link time if no address is specified. This directive is used to declare variables that are allocated in RAM that is shared across all RAM banks (i.e. unbanked RAM). No code can be generated in this segment. The `res` directive should be used to reserve space for data.

**Note:** Two sections in the same source file are not permitted to have the same name.

### 4.65.3 Usage

This directive is used in the following types of code: relocatable. For information on types of code, see Section 1.6 "Assembler Operation".

This directive is similar to `udata`, except that it is only used on parts with memory accessible from multiple banks. `udata\_shr` sections are used with SHAREBANK locations in the linker script, whereas `udata` sections are used with DATABANK locations in the linker script. See the data sheet for the PIC16F873A for a specific example.

### 4.65.4 See Also

`extern global idata udata udata\_acs udata\_ovr`

### 4.65.5 Simple Example

```
Temps udata\_shr
Temp1 res 1
Temp2 res 1
Temp3 res 1
```

### 4.65.6 Application Example - `udata\_shr`

This program demonstrates the `udata\_shr` directive. This directive declares the beginning of a section of shared uninitialized data. This directive is used to declare variables that are allocated in RAM that is shared across all RAM banks (i.e. unbanked RAM.)

```
#include pl6f877a.inc ;Include standard header file
;for the selected device.

shared_data udata\_shr ;Declares the beginning of a data
;section named 'shared data',
var res 1 ;which is shared by all banks.
; 'var' is the location which can
;be accessed irrespective of
;banksel bits.

bank0\_var udata 0X20 ;Declares beginning of a data
var0 res 1 ;section named 'bank0\_var',
; which is in bank0. var0 is
;allocated the address 0x20.
```
bank1_var  udata  0xa0 ;Declares beginning of a data
       var1  res    1 ;section named 'bank1_var',
       ;which is in bank1. var1 is
       ;allocated the address 0xa0

bank2_var  udata  0x120 ;Declares beginning of a data
       var2  res    1 ;section named 'bank2_var',
       ;which is in bank2. var2 is
       ;allocated the address 0x120

bank3_var  udata  0x1a0 ;Declares beginning of a data
       var3  res    1 ;section named 'bank3_var',
       ;which is in bank3. var3 is
       ;allocated the address 0x1a0

RST     CODE     0x0     ;The code section named RST
       ;is placed at program memory
       ;location 0x0. The next two
       ;instructions are placed in
       ;code section RST.

       pagesel  start ;Jumps to the location labelled
       goto     start ;'start'.

PGM     CODE             ;This is the beginning of the
       ;code section named PGM. It is
       ;a relocatable code section
       ;since no absolute address is
       ;given along with directive CODE.

start
       banksel var0    ;Select bank0.
       movlw  0x00
       movwf  var       ;var is accessible from bank0.

       banksel var1    ;Select bank1.
       movlw  0x01
       movwf  var       ;var is accessible from bank1
       ;also.

       banksel var2    ;Select bank2.
       movlw  0x02
       movwf  var       ;var is accessible from bank2
       ;also.

       banksel var3    ;Select bank3.
       movlw  0x03
       movwf  var       ;var is accessible from bank3
       ;also.

       goto  $        ;Go to current line (loop here)
end
4.66  #undefine - DELETE A SUBSTITUTION LABEL

4.66.1 Syntax

#define label

4.66.2 Description

label is an identifier previously defined with the #define directive. The symbol named is removed from the symbol table.

4.66.3 Usage

This directive is used in the following types of code: absolute or relocatable. For information on types of code, see Section 1.6 “Assembler Operation”.

This directive is most often used with the ifdef and ifndef directives, which look for the presence of an item in the symbol table.

4.66.4 See Also

#define  #include ifdef ifndef

4.66.5 Simple Example

#define length 20
 :
#define undef length

4.66.6 Application Example - #define/#undefine

See this example under #define.
4.67 variable - DECLARE SYMBOL VARIABLE

4.67.1 Syntax

variable label[=expr][, label[=expr]...]

4.67.2 Description

Creates symbols for use in MPASM assembler expressions. Variables and constants may be used interchangeably in expressions.

The variable directive creates a symbol that is functionally equivalent to those created by the set directive. The difference is that the variable directive does not require that symbols be initialized when they are declared.

The variable values cannot be updated within an operand. You must place variable assignments, increments, and decrements on separate lines.

4.67.3 Usage

This directive is used in the following types of code: absolute or relocatable. For information on types of code, see Section 1.6 “Assembler Operation”.

This directive is most used for conditional assembly code.

Note: variable is not used to declare a run-time variable, but a variable that is used by the assembler. To create a run-time variable, refer to the directives res, equ or cblock.

4.67.4 See Also

constant set

4.67.5 Simple Example

variable RecLength=64 ; Set Default  
                         ; RecLength
constant BufLength=512  ; Init BufLength
                         ; RecLength may
                         ; be reset later
                         ; in RecLength=128
constant MaxMem=RecLength+BufLength ;CalcMaxMem
4.67.6 Application Example - variable/constant

This example shows the usage of the variable directive, used for creating symbols which may be used in MPASM assembler expressions only. The symbols created with this directive do not occupy any physical memory location of microcontroller.

```
#include p16f877a.inc ;Include standard header file
                ;for the selected device.

variable perimeter=0 ;The symbol 'perimeter' is
                ;initialized to 0
variable area       ;If a symbol is declared as
                ;variable, then initialization
                ;is optional, i.e. it may or may
                ;not be initialized.

constant lngth=50H  ;The symbol 'lngth' is
                ;initialized to 50H.
constant wdth=25H   ;The symbol 'wdth' is
                ;initialized to 25H.
                ;A constant symbol always needs
                ;to be initialized.
perimeter=2*(lngth+wdth);The value of a CONSTANT cannot
                ;be reassigned after having been
                ;initialized once. So 'lngth' and
                ;'wdth' cannot be reassigned. But
                ;'perimeter' has been declared
                ;as variable, and so can be
                ;reassigned.

area=lngth*wdth

end
```
4.68 while - PERFORM LOOP WHILE CONDITION IS TRUE

4.68.1 Syntax

Preferred:
```
while expr :
endw
```

Supported:
```
.while expr :
.endw
```

4.68.2 Description

The lines between the while and the endw are assembled as long as `expr` evaluates to TRUE. An expression that evaluates to zero is considered logically FALSE. An expression that evaluates to any other value is considered logically TRUE. A relational TRUE expression is guaranteed to return a non-zero value; FALSE a value of zero.

A `while` loop can contain at most 100 lines and be repeated a maximum of 256 times. `while` loops can be nested up to 8 deep.

4.68.3 Usage

This directive is used in the following types of code: absolute or relocatable. For information on types of code, see Section 1.6 “Assembler Operation”.

This directive is not an instruction, but used to control how code is assembled, not how it behaves at run-time. Use this directive for conditional assembly.

4.68.4 See Also

endw if

4.68.5 Simple Example

`while` is not executed at run-time, but produces assembly code based on a condition. View the list file (*.lst) or disassembly window to see the results of this example.

```
test_mac macro count
    variable i
    i = 0
    while i < count
        movlw i
    i += 1
    endw
endm

start
    test_mac 5
end
```
4.68.6 Application Example - while/endw

This example shows the usefulness of directive while to perform a loop while a certain condition is true. This directive is used with the endw directive.

```
#include p16f877a.inc ;Include standard header file
;for the selected device.

variable i ;Define the symbol 'i' as a
;variable.

mydata udata 0x20 ;Allocate RAM for labels
reg_hi res 1 ;reg_hi and reg_lo.
reg_lo res 1

RST CODE 0x0 ;The code section named RST
;is placed at program memory
;location 0x0. The next two
;instructions are placed in
;code section RST.

pagesel start ;Jumps to the location labelled
goto start ;'start'.

shift_right macro by_n ;Beginning of a macro, which
;shifts register data n times.
;Code length generated after
;assembly, varies depending upon
;the value of parameter 'by_n'.

i=0 ;Initialize variable i.
while i< by_n ;Following 3 lines of assembly
;code are repeated as long as
;i< by_n.

Up to 100 lines of codes are allowed inside a while loop.

bcf STATUS,C ;Clear carry bit.
rrf reg_hi,F ;reg_hi and reg_lo contains
rrf reg_lo,F ;16-bit data which is rotated
i+=1 ;Increment loop counter i.

i cannot increment to more than 255 decimal.

endw ;End while loop. The loop will
;break here after i=by_n.
endm ;End of 'shift_right' macro.

PGM CODE ;This is the beginning of the
;code section named PGM. It is
;a relocatable code section
;since no absolute address is
;given along with directive CODE.

start
movlw 0x88 ;Initialize reg_hi and
movwf reg_hi ;reg_lo for observation.
movlw 0x44
movwf reg_lo
```
shift_right 3; Shift right 3 times the 16-bit
data in reg_hi and reg_lo. This
is an example. A value 8 will
shift data 8 times.
goto $; Go to current line (loop here)
end
5.1 INTRODUCTION

The usage of multiple MPASM assembler directives is shown through examples. Directives are assembler commands that appear in the source code but are not opcodes. They are used to control the assembler: its input, output, and data allocation.

Many of the assembler directives have alternate names and formats. These may exist to provide backward compatibility with previous assemblers from Microchip and to be compatible with individual programming practices. If portable code is desired, it is recommended that programs be written using the specifications contained within this document.

For a reference listing of all directives discussed in examples here, please see Chapter 4. “Directives”.

Note: Although MPASM assembler is often used with MPLINK object linker, MPASM assembler directives are not supported in MPLINK linker scripts. See MPLINK object linker documentation for more information on linker options to control listing and hex file output.

Topics covered are:
- Example of Displaying Count on Ports
- Example of Port B Toggle and Delay Routines
- Example of Calculations with Variables and Constants
- Example of a 32-Bit Delay Routine
- Example of SPI Emulated in Firmware
- Example of Hexadecimal to ASCII Conversion
- Other Sources of Examples
- Tips and Tricks
5.2 EXAMPLE OF DISPLAYING COUNT ON PORTS

Directives highlighted in this example are:

- #include
- end

5.2.1 Program Functional Description

This simple program continually increases the count on PORTA and PORTB. This count may be displayed in software in the SFR or Watch(es) window of the IDE, or in hardware on connected LEDs or a scope. The count may be slowed down using a delay routine (see other examples.)

Once the count has increased to 0xFF, it will roll over to 0x00 and begin again.

The application is written as absolute code, i.e., you use only the assembler to generate the executable (not the assembler and linker).

The standard header file for the processor selected is included using #include. The port output data latches are then cleared. Port A must be set up for digital I/O as, on power-up, several pins are analog. Data direction registers (TRISx) are cleared to set port pins to outputs. A loop named Loop is entered where the value of each port is increased indefinitely until the program is halted. Finally, the program is finished with an end.

5.2.2 Commented Code Listing

;Toggles Port pins with count on PIC18F8720
;PortA pins on POR:
; RA5, RA3:0 = analog inputs
; RA6, RA4 = digital inputs
;PortB pins on POR:
; RB7:0 = digital inputs

#include p18f8720.inc  ;Include file needed to reference
;data sheet names.

clrfr  PORTA          ;Clear output data latches on Ports
clrfr  PORTB
movlw  0x0F            ;Configure Port A for digital I/O
movwf  ADCON1
clrfr  TRISA           ;Set data direction of Ports as outputs
clrfr  TRISB

Loop
incf  PORTA,F         ;Read PORTA, add 1 and save back.
incf  PORTB,F         ;Read PORTB, add 1 and save back.
goto  Loop            ;Do this repeatedly - count.
end                    ;All programs must have an end directive.
5.3 EXAMPLE OF PORT B TOGGLE AND DELAY ROUTINES

Directives highlighted in this example are:

- udata, res
- equ
- code
- banksel, pagesel

Items covered in this example are:

- Program Functional Description
- Commented Code Listing
- Header Files
- Register and Bit Assignments
- Program Memory CODE Sections and Paging
- Banking
- Interrupts

5.3.1 Program Functional Description

This program continually alternates the output on the Port B pins from 1’s to 0’s. Two delay routines using interrupts provide the timing for the alternating output. If LEDs were attached to Port B, they would flash (1=on, 0=off).

The type of PIC1X MCU is set in the IDE, so does not need to be set in code. However, if you wish to specify the MCU, as well as radix, in code, you may do so using the processor and radix directives, or list command, i.e., list p=16f877a, r=hex.

The application is written as relocatable code, i.e., you must use both the assembler and linker to generate the executable. See PIC1X MCU Language Tools and MPLAB X IDE or PIC1X MCU Language Tools and MPLAB IDE v8 for information on how to set up a project using assembler files and a linker script.

The standard header file for the processor selected is included using #include. Registers are assigned using the udata, res and equ directives. Sections of code are created using the code statement. Data memory banking and program memory paging is accomplished as needed using banksel and pagesel directives. Finally, the program is finished with an end.

5.3.2 Commented Code Listing

;**************************************
;* MPASM Assembler Control Directives *
;* Example Program 1                  *
;* Alternate output on Port B between *
;* 1's and 0's                        *
;**************************************

#include p16f877a.inc ;Include header file
MPLAB X IDE and MPLAB IDE v8 have many header files (*.inc) available for supported devices. These can be found in the installation directory. See Section 5.3.3 “Header Files” for more on headers.

`udata` ; Declare storage of RAM variables
`DTEMP res 1` ; Reserve 1 address location
`DFLAG res 1` ; Reserve 1 address location

`DFL0 equ 0x00` ; Set flag bit - 0 bit of DFLAG

Set DTEMP to be a temporary register at a location in RAM determined at by the linker. Set DFLAG to be the flag register at a location following the DTEMP register. Set DFL0 to a value to represent a bit in the DFLAG register, in this case 0. See the Additional Comments section for more information.

```
rst   code  0x00 ; Reset Vector
      pagesel Start ; Ensure correct page selected
      goto  Start   ; Jump to Start code
```

Place the reset vector at program memory location 0x00. When the program resets, the program will branch to `Start`.

```
intrpt code  0x04 ; Interrupt Vector
      goto ServInt ; Jump to service interrupt
```

Place interrupt vector code at program memory location 0x04, since this device automatically goes to this address for interrupts. When an interrupt occurs, the program will branch to the `ServInt` routine.

```
isr   code  0x08 ; Interrupt Service Routine
      ServInt

      banksel OPTION_REG ; Select Option Reg Bank (1)
      bsf  OPTION_REG, T0CS ; Stop Timer0

      banksel INTCON ; Select INTCON Bank (0)
      bcf  INTCON, T0IF ; Clear overflow flag
      bcf  DFLAG, DFL0 ; Clear flag bit

      retfie ; Return from interrupt
```

For the PIC16F877A, there is not enough memory to add a `pagesel ServInt` statement to insure proper paging. Therefore, the ISR code needs to be specifically placed on page 0. See Section 5.3.7 “Interrupts” for more on the ISR code.

```
;*********************************************************************************
;* Main Program                                                             *
;*********************************************************************************

      code               ; Start Program
```
Begin program code. Because no address is specified, the program memory location will be determined by the linker. See Section 5.3.5 “Program Memory CODE Sections and Paging” for more on code.

Start
    clrf PORTB ;Clear PortB

banksel TRISB ;Select TRISB Bank (1)
    clrf TRISB ;Set all PortB pins as outputs

banksel INTCON ;Select INTCON Bank (0)
    bsf INTCON, GIE ;Enable Global Int's
    bsf INTCON, T0IE ;Enable Timer0 Int

First, set up Port B pins to be all outputs using the data direction (TRISB) register. Then set up Timer 0 and interrupts for later use.

Loop
    movlw 0xFF
    movwf PORTB ;Set PortB
    call Delay1 ;Wait

    clrf PORTB ;Clear PortB
    pagesel Delay2 ;Select Delay2 Page
    call Delay2 ;Wait

    pagesel Loop ;Select Loop Page
    goto Loop ;Repeat

Set all Port B pins high and wait Delay 1. Then, set all Port B pins low and wait Delay 2. Repeat until program halted. This will have the effect of “flashing” the pins of Port B.

;***********************************************************************
;* Delay 1 Routine - Timer0 delay loop    *
;***********************************************************************

Delay1
    movlw 0xF0 ;Set Timer0 value
    movwf TMR0 ;0x00-longest delay
        ;0xFF-shortest delay
    clrf DFLAG ;Set flag bit
    bsf DFLAG, DFL0 ;Set flag bit

banksel OPTION_REG ;Select Option Reg Bank (1)
    bcf OPTION_REG, T0CS ;Start Timer0

banksel DFLAG ;Select DFLAG Bank (0)

TLoop ;Wait for overflow: 0xFF->0x00
    btfsc DFLAG, DFL0 ;After interrupt, DFL0 = 0
    goto TLoop

return
Use Timer 0 to create Delay 1. First, give the timer an initial value. Then, enable the timer and wait for it to overflow from 0xFF to 0x00. This will generate an interrupt, which will end the delay. See Section 5.3.7 “Interrupts” for more information.

```
;**************************************************
;* Delay 2 Routine - Decrement delay loop *          
;**************************************************

decly code 0x1000 ;Page 2

Place Delay2 routine at program memory location 0x1000, on page 2. (See Section 5.3.5 “Program Memory CODE Sections and Paging” for more on code.) This code was placed on a page other than 0 to demonstrate how a program functions across pages.

Delay2

```

movlw 0xFF ;Set DTEMP value
movwf DTEMP ;0x00-shortest delay
            ;0xFF-longest delay

DLoop        ;Use a simple countdown to
    decfsz DTEMP, F ;create delay.
goto DLoop   ;End loop when DTEMP=0

return

```

Use the time it takes to decrement a register DTEMP from an initial value to 0x00 as Delay 2. This method requires no timers or interrupts.

```
end

End of the program, i.e., tells the assembler no further code needs to be assembled.

5.3.3 Header Files

A header file is included in the program flow with the #include directive.

```
#include p16f877a.inc ;Include header file
```

Angle brackets, quotes or nothing at all may used to enclose the name of the header file. You may specify the complete path to the included file, or let the assembler search for it. For more on search order, see the discussion of the #include directive in Section 4.42 “#include - Include Additional Source File”

A header file is extremely useful for specifying often-used constants, such as register and pin names. This information can be typed in once, and then the file can be included in any code using the processor with those registers and pins.
5.3.4 Register and Bit Assignments

You can specify your own registers and bits by using the `udata, res and equ` directives, as is done in the following lines.

```assembly
udata ;Declare storage of RAM variables
DTEMP res 1 ;Reserve 1 address location
DFLAG res 1 ;Reserve 1 address location
DFL0 equ 0x00 ;Set flag bit - 0 bit of DFLAG
```

`DTEMP` and `DFLAG` are assigned one address location in RAM each by the linker. For illustrative purposes, suppose the locations selected by the linker are the general purpose registers (GPRs) 0x20 and 0x21. `DFL0` is assigned the value `0x00` and will be used as the name for pin 0 in the `DFLAG` register.

**FIGURE 5-1: PIC16F877A REGISTER FILE MAP**

The directives `udata` and `res` are used in relocatable code to define multiple registers instead of `equ`. For more on these directives, see:

- Section 4.62 “`udata` - Begin an Object File Uninitialized Data Section”
- Section 4.57 “`res` - Reserve Memory”
- Section 4.28 “`equ` - Define an Assembler Constant”

5.3.5 Program Memory CODE Sections and Paging

The `code` directive is used to specify sections of relocatable code. For absolute code, the `org` directive is used. See Chapter 6, “Relocatable Objects” for more on the differences between relocatable and absolute code. For more on these directives, see:

- Section 4.9 “`code` - Begin an Object File Code Section”
- Section 4.51 “`org` - Set Program Origin”

If no `code` directive is used, code generation will begin at address zero. For this example, `code` is used to specify code at 0x00 (reset address), 0x04 (interrupt address), 0x08 (interrupt service routine) and 0x1000 (Delay 2 address). It does not explicitly set the program start address, but allows the linker to place the code appropriately. Since the linker places addressed code first, and then attempts to place the relocatable code, based on size, the likely program memory usage is shown below.
Since the actual location of the main code (.code section) is unknown, pagesel directives must be used to ensure that program branches to other sections are correct.

```assembly
rst code 0x00 ;Reset Vector
pagesel Start
goto Start
:
    code ;Start Program
    pagesel Delay2 ;Select Delay2 Page
call Delay2 ;Wait
    pagesel Loop ;Select Loop Page
    goto Loop ;Repeat
:
```

For more on this directive, see Section 4.53 “pagesel - Generate Page Selecting Code (PIC10/12/16 MCUs)”

### 5.3.6 Banking

In this example, Port B must be configured, causing a switch to data memory bank 1 to access the TRISB register. This change to bank 1, and subsequent return to bank 0, is easily accomplished using the banksel directive.

```assembly
banksel TRISB ;Select TRISB Bank (1)
clrf TRISB ;Set PortB as output

banksel INTCON ;Select INTCON Bank (0)
bsf INTCON, GIE ;Enable Global Int's
bsf INTCON, T0IE ;Enable Timer0 Int
```

Two other routines also use banksel to access the Option register (OPTION_REG). For more on this directive, see Section 4.7 “banksel - Generate Bank Selecting Code”
5.3.7 Interrupts

The Delay 1 routine in this program uses the Timer 0 overflow interrupt as a timing mechanism. Once the interrupt occurs, the program branches to the interrupt vector. Here code is located to jump to a location where interrupt-handling code is found.

```
intrpt code 0x04 ;Interrupt Vector
goto ServInt   ;Jump to service interrupt
```

The interrupt-handling code, also known as the interrupt service routine or ISR, is generated by the programmer to handle the specific requirements of the peripheral interrupt and the program. In this case, Timer 0 is stopped and its flag bit is cleared, so it may be run again. Then, the program-defined flag bit is cleared. Finally, retfie takes the program back to the instruction that was about to be executed when the interrupt occurred.

```
isr code 0x08 ;Interrupt Service Routine
ServInt

banksel OPTION_REG ;Select Option Reg Bank (1)
bsf OPTION_REG, T0CS ;Stop Timer0

banksel INTCON ;Select INTCON Bank (0)
bcf INTCON, T0IF ;Clear overflow flag
bcf DFLAG, DFL0 ;Clear flag bit

retfie ;Return from interrupt
```

When the program code begins to execute again, the cleared flag bit DFL0 now causes the delay loop TLOOP to end, thus ending Delay 1 routine.
5.4 EXAMPLE OF CALCULATIONS WITH VARIABLES AND CONSTANTS

Directives highlighted in this example are:
• #define, #undefine
• set
• constant, variable

Items covered in this example are:
• Program Functional Description
• Commented Code Listing
• Using Watch(es) Windows

5.4.1 Program Functional Description

This program performs several calculations using defined constants and variables. The application is written as relocatable code, i.e., you must use both the assembler and linker to generate the executable.

The standard header file for the processor selected is included using #include. Sections of code are created using the code statement.

5.4.2 Commented Code Listing

;*******************************
;* MPASM Assembler Control Directives *
;* Example Program 2               *
;* Perform calculations            *
;*******************************
#include p16f877a.inc ;Include header file
#define Tdistance1 50 ;Define the symbol
#define Tdistance2 25 ;Define the symbol
#undefine Tdistance2 ;Remove Tdistance2 from

The #define directive was used to define two substitution strings: Tdistance1 to substitute for 50 and Tdistance2 to substitute for 25. Then #undefine was used to remove Tdistance2 from the symbol table, i.e., Tdistance2 can no longer be used to substitute for 25.

udata 0x20 ;Set up distance_reg
distance_reg res 1 ;at GPR 0x20

The udata and res directives are used to assign distance_reg to register 0x20. For more on these directives, see example 1.

rst code 0x00 ;Reset Vector
pagesel Start
goto Start

code ;Start Program
Start
cclf distance_reg ;Clear register
movlw Tdistance1 ;Move value of Tdistance1
movwf distance_reg ;into distance_reg
constant distance1=10 ;Declare distance1
;a constant symbol
Declare a constant symbol, \texttt{distance1}, with a value of 10. Once a constant is declared, its value cannot be altered.

\begin{verbatim}
variable distance2 ;Declare distance2
                   ;a variable symbol
\end{verbatim}

Declare a variable symbol, \texttt{distance2}. The \texttt{variable} directive does not require the symbol to be initialized when declared.

\begin{verbatim}
distance3 set 10 ;Define a value for
                 ;the symbol distance3
\end{verbatim}

Define symbol \texttt{distance3} as 10.

\begin{verbatim}
distance2=15        ;Give distance2 an
                   ;initial value
distance2=distance1+distance2 ;Add distance1
                               ;to distance2
\end{verbatim}

Variable assignments, increments and decrements must be placed on separate lines.

\begin{verbatim}
distance3 set 15 ;Change value of distance3
distance2=distance2+distance3 ;Add distance3
                               ;to distance2
movlw distance2 ;Move value of distance2
movwf distance_reg ;into distance_reg
goto Start ;Loop back to Start
end
\end{verbatim}

\subsection{5.4.3 Using Watch(es) Windows}

Once the program begins, the value of \texttt{Tdistance1} is placed into \texttt{distance_reg}. This can be observed in a Watches window in MPLAB X IDE or a Watch window in MPLAB IDE v8. The value of \texttt{distance_reg} will become 50. The symbol \texttt{Tdistance1} will not be found in the Watch(es) window symbol list, as symbols defined using the \texttt{#define} directive are not available for viewing in the IDE because they are not RAM variables.

The final lines of the example program write the final value of \texttt{distance2} to \texttt{distance_reg}. If you had a Watch(es) window open to see \texttt{distance_reg} loaded with the value of 50, you will see it change to 3A. Remember that the radix is hexadecimal, so hex addition was used to determine the \texttt{distance2} value.
5.5 EXAMPLE OF A 32-BIT DELAY ROUTINE

Directives highlighted in this example are:

- macro, endm
- banksel

5.5.1 Program Functional Description

A delay routine is needed in many applications. For this example, delay increments are 20 us, with the routine having a range of 40 us to 23.8 hours. (This assumes a 4 MHz clock.)

5.5.2 Commented Code Listing

; Each loop takes 20 clocks, or 20 us per loop, at 4MHz or 1MIPS clock.
; Turn off in config bits WDT for long simulations

#include p16F877A.inc
udata 0x20
Dly0 res 1 ; Stores 4 bytes of data for the delay count
Dly1 res 1 ; Dly0 is the least significant byte
Dly2 res 1 ; while Dly3 is the most significant byte
Dly3 res 1

Dly32 MACRO DLY
  goto $+1 ; delay 2 cycles
  goto $+1 ; delay total of 4 cycles

; Take the delay value argument from the macro, precalculate the required 4 RAM values and load the RAM values Dly3 through Dly0.
  BANKSEL Dly3
  movlw (DLY-1) & H'FF'
  movwf Dly0
  movlw (DLY-1) >>D'08' & H'FF'
  movwf Dly1
  movlw (DLY-1) >>D'16' & H'FF'

  ; Bytes are shifted and ANDed by the assembler to make user calculations easier.
  movwf Dly2
  movlw (DLY-1) >>D'24' & H'FF'

; Call DoDly32 to run the delay loop.
  movwf Dly3
  call DoDly32
ENDM ; End of Macro definition

RST CODE 0x00 ; Reset Vector

pagesel TestCode
  goto TestCode

CODE ; Code starts here

TestCode
  Dly32 D'50000' ; Max 4 billion+ (runs Dly32 Macro, 1 sec in this case).
  nop ; ZERO STOPWATCH, put breakpoint here.
goto TestCode ;Go back to top of program and
;run the delay again.

;Subroutine, called by the Macro Dly32 (20 Tcy per loop)
DoDly32
movlw H'FF' ;Start with -1 in W
addwf Dly0,F ;LSB decrement
btfsc STATUS,C ;was the carry flag set?
clrw ;If so, 0 is put in W
addwf Dly1,F ;Else, we continue.
btfsc STATUS,C
clrw ;0 in W
addwf Dly2,F
btfsc STATUS,C
clrw ;0 in W
addwf Dly3,F
btfsc STATUS,C
clrw ;0 in W
iorwf Dly0,W ;Inclusive-OR all variables
iorwf Dly1,W ;together to see if we have reached
iorwf Dly2,W ;0 on all of them.
iorwf Dly3,W
btfss STATUS,Z ;Test if result of Inclusive-OR's is 0
goto DoDly32 ;It was NOT zero, so continue counting
retlw 0 ;It WAS zero, so exit this subroutine.

END
5.6  EXAMPLE OF SPI EMULATED IN FIRMWARE

Directives highlighted in this example are:

- list
- #define
- udata, res
- global

5.6.1  Program Functional Description

This program is used to emulate SPI function in firmware.

The application is written as relocatable code, i.e., you must use both the assembler and linker to generate the executable.

The list directive is used to define the processor and set listing file formatting. The standard header file for the processor selected is included using #include. SPI variables are declared using #define. Program registers are assigned using the udata and res directives. Sections of code are created using the code statement. External code is accessed using global.

5.6.2  Commented Code Listing

;********************************************************************
; Emulates SPI in firmware
; Place byte in Buffer, call SPI_Out - sends MSB first
;********************************************************************
LIST        P=18F4520       ;define processor
#include    <P18F4520.INC>  ;include file
list        c=132, n=0      ;132 col, no paging

;********************************************************************
#define Clk LATB,0  ; SPI clock output
#define Dat LATB,1  ; SPI data output
#define Bus LATB,2  ; busy indicator

;********************************************************************
;Variable definitions
udata
Buffer      res 1   ; SPI transmit data
Counter     res 1   ; SPI transmit bit counter
DelayCtr    res 1

;********************************************************************
code
SPI_Out
  clrf    Counter                 ; init bit counter
  bsf     Counter,7
  bcf     Clk                     ; clear clock
  bcf     Dat                     ; clear data out
  bsf     Bus                     ; indicate busy
Lup     movf    Counter,W               ; get mask
        andwf   Buffer,W                ; test selected bit
        btfss   STATUS,Z                ; was result zero?
        bsf     Dat                     ; set data
        bsf     Clk                     ; set clock
        bcf     Clk                     ; clear clock
        bcf     Dat                     ; clear data
        rrcf   Counter,F               ; test next bit
        btfss   Counter,7               ; done with byte?
        bra     Lup                     ; no
        bcf     Bus                     ; indicate not busy
        return

;********************************************************************

    global  SPI_Out, Buffer
    end
5.7 EXAMPLE OF HEXADECIMAL TO ASCII CONVERSION

Directives highlighted in this example are:

- udata, res
- global

5.7.1 Program Functional Description

This program converts a hexadecimal byte into two ASCII bytes.

The application is written as relocatable code, i.e., you must use both the assembler and linker to generate the executable.

Program registers are assigned using the udata and res directives. Sections of code are created using the code statement. External code is accessed using global.

5.7.2 Commented Code Listing

```
;********************************************************************
; get a hex byte in W, convert to 2 ASCII bytes in ASCIIH:ASCIIL
; req 2 stack levels
;
;********************************************************************
Variables udata
HexTemp    res 1
ASCIIH     res 1
ASCIIL     res 1

;********************************************************************
code
Hex2ASC
    movf    HexTemp,W
    andlw   0x0F            ; get low nibble
    call    DecHex
    movwf   ASCIIL

    swapf   HexTemp,F
    movf    HexTemp,W
    andlw   0x0F            ; get high nibble
    call    DecHex
    movwf   ASCIIH

    return

;********************************************************************
DecHex
    sublw   0x09            ; 9-WREG
    btfss   STATUS,C        ; is nibble Dec?
    goto    HexC            ; no, convert hex

Dec
    movf    HexTemp,W       ; convert DEC nibble to ASCII
    andlw   0x0F
    addlw   A'0'
    return

HexC
    movf    HexTemp,W       ; convert HEX nibble to ASCII
    andlw   0x0F
    addlw   A'A' - 0x0A
    return
```

5.8 OTHER SOURCES OF EXAMPLES

Short examples of use for each directive are listed under each directive topic. See Chapter 4. “Directives”.

Examples of use for multiple directives are available from the following sources:

• readme.asm - Serial EEPROM Support
• Application Notes, Technical Briefs
  - Website - http://www.microchip.com
• Code Examples and Templates
  - MPLAB X IDE/MPLAB IDE v8 installation directory
  - Website - http://www.microchip.com
5.9 TIPS AND TRICKS

To reduce costs, designers need to make the most of the available program memory in MCUs. Program memory is typically a large portion of the MCU cost. Optimizing the code helps to avoid buying more memory than needed. Here are some ideas that can help reduce code size. For more information, see Tips 'n Tricks (DS40040).

- **TIP #1: Delay Techniques**
- **TIP #2: Optimizing Destinations**
- **TIP #3: Conditional Bit Set/Clear**
- **TIP #4: Swap File Register with W**
- **TIP #5: Bit Shifting Using Carry Bit**
- **TIP #6: Using External Memory**

5.9.1 TIP #1: Delay Techniques

- Use `GOTO Next Instruction` instead of two `NOP`.
- Use `CALL Rtrn` as quad, 1 instruction NOP (where `Rtrn` is the exit label from existing subroutine).

```plaintext
;*************************************************
NOP
NOP              ;2 instructions, 2 cycles
;*************************************************
GOTO $+1         ;1 instruction, 2 cycles
;*************************************************
Call Rtrn        ;1 instruction, 4 cycles
:                
Rtrn  RETURN
;*************************************************
```

MCUs are commonly used to interface with the “outside world” by means of a data bus, LED’s, buttons, latches, etc. Because the MCU runs at a fixed frequency, it will often need delay routines to meet setup/hold times of other devices, pause for a handshake or decrease the data rate for a shared bus.

Longer delays are well-suited for the DECFSZ and INCFSZ instructions where a variable is decremented or incremented until it reaches zero when a conditional jump is executed. For shorter delays of a few cycles, here a few ideas to decrease code size.

For a two cycle delay, it is common to use two NOP instructions which uses two program memory locations. The same result can be achieved by using `GOTO $+1`. The `§` represents the current program counter value in MPASM assembler. When this instruction is encountered, the MCU will jump to the next memory location. This is what it would have done if two NOP’s were used, but since the GOTO instruction uses two instruction cycles to execute, a two-cycle delay was created. This created a two-cycle delay using only one location of program memory.

To create a four cycle delay, add a label to an existing RETURN instruction in the code. In this example, the label `Rtrn` was added to the RETURN of subroutine that already existed somewhere in the code. When executing `CALL Rtrn`, the MCU delays two instruction cycles to execute the CALL and two more to execute the RETURN. Instead of using four NOP instructions to create a four cycle delay, the same result was achieved by adding a single CALL instruction.
5.9.2 TIP #2: Optimizing Destinations

- Destination bit determines \( W \) or \( F \) for result
- Look at data movement and restructure

Example: \( A + B \rightarrow A \)

MOVF A, W
ADDWF B, W
MOVWF A

3 instructions → 2 instructions

Careful use of the destination bits in instructions can save program memory. Here, register A and register B are summed and the result is put into the A register. A destination option is available for logic and arithmetic operations. In the first example, the result of the ADDWF instruction is placed in the working register. A MOVWF instruction is used to move the result from the working register to register A. In the second example, the ADDWF instruction uses the destination bit to place the result into the A register saving an instruction.

5.9.3 TIP #3: Conditional Bit Set/Clear

- To move single bit of data from REGA to REGB
- Precondition REGB bit
- Test REGA bit and fix REGB if necessary

BTFSS REGA, 2
BCF REGB, 5
BTFSC REGA, 2
BSF REGB, 5

4 instructions → 3 instructions

One technique for moving one bit from the REGA register to REGB is to perform bit tests. In the first example, the bit in REGA is tested using a BTFSS instruction. If the bit is clear, the BCF instruction is executed and clears the REGB bit, and if the bit is set, the instruction is skipped. The second bit test determines if the bit is set, and if so, will execute the BSF and set the REGB bit, otherwise the instruction is skipped. This sequence requires four instructions.

A more efficient technique is to assume the bit in REGA is clear, and clear the REGB bit, and test if the REGA bit is clear. If so, the assumption was correct and the BSF instruction is skipped, otherwise the REGB bit is set. The sequence in the second example uses three instructions because one bit test was not needed.

One important point is that the second example will create a two cycle glitch if REGB is a port outputting a high. This is caused by the BCF and BTFSC instructions that will be executed regardless of the bit value in REGA.
5.9.4  TIP #4: Swap File Register with W

The following macro swaps the contents of W and REG without using a second register.

```
SWAPWF MACRO REG
    XORWF REG,F
    XORWF REG,W
    XORWF REG,F
ENDM
```

Needs: 0 TEMP registers, 3 Instructions, 3 Tcy

An efficient way of swapping the contents of a register with the working register is to use three XORWF instructions. It requires no temporary registers and three instructions. Here’s an example:

```
W     REG     Instruction
10101100 01011100 XORWF REG,F
10101100 11110000 XORWF REG,W
01011100 11110000 XORWF REG,F
01011100 10101100 Result
```

5.9.5  TIP #5: Bit Shifting Using Carry Bit

Rotate a byte through carry without using RAM variable for loop count:

- Easily adapted to serial interface transmit routines.
- Carry bit is cleared (except last cycle) and the cycle repeats until the zero bit sets indicating the end.

```
list p=12f629
#include pl2f629.inc

buffer equ 0x20

bsf STATUS,C ;Set 'end of loop' flag
rlf buffer,F ;Place first bit into C
Send_Loop
  bcf GPIO,Dout ;Precondition output
  btfsc STATUS,C ;Check data - 0 or 1?
  bsf GPIO,Dout
  bcf STATUS,C ;Clear data in C
  rlf buffer,F ;Place next bit into C
  movf buffer,F ;Force Z bit
  btfss STATUS,Z ;Exit?
  goto Send_Loop
```

Related Topic: TIP #3: Conditional Bit Set/Clear

5.9.6  TIP #6: Using External Memory

To use external memory, the maximum allowable address must be redefined by using the _MAXROM directive. For example, when using the PIC18F87J10 in extended microcontroller mode, the _MAXROM directive must be used as follows:

```
#include <P18cxxx.inc>

_MAXROM 0x1FFFFF
```

; 87J10 Configuration for external memory
CONFIG MODE=XM20, EASHFT=OFF, BW = 16, WAIT=OFF

org 0x0000
goto 0x10000
END
Chapter 6. Relocatable Objects

6.1 INTRODUCTION

MPASM assembler, used with MPLINK object linker, has the ability to generate and link precompiled object modules. Writing source code that will be assembled to an object module is slightly different from writing code used to generate an executable (hex) file directly. MPASM assembler routines designed for absolute address assembly will require minor modifications to compile correctly into relocatable object modules.

Topics covered in this chapter:
- Header Files
- Program Memory
- Low, High and Upper Operators
- RAM Allocation
- Configuration Bits and ID Locations
- Accessing Labels From Other Modules
- Paging and Banking Issues
- Generating the Object Module
- Code Example

6.2 HEADER FILES

The Microchip-supplied standard header files (e.g., p18f8720.inc) should be used when generating object modules. These header files define the special function registers for the target processor.

EXAMPLE 6-1: INCLUDE HEADER FILE

```
#include p18f8720.inc
```

See 4.42 “#include - Include Additional Source File” for more information.
6.3 PROGRAM MEMORY

Program memory code must be organized into a logical code section. To do this, the code must be preceded by a code section declaration (See 4.9 “code - Begin an Object File Code Section”) to make it relocatable.

<table>
<thead>
<tr>
<th>Absolute Code</th>
<th>Equivalent Relocatable Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Start clrw</td>
<td>code ;Address determined ;by the linker.</td>
</tr>
<tr>
<td>option</td>
<td>Start clrw option</td>
</tr>
<tr>
<td>Progl org 0x0100</td>
<td>Progl code 0x0100 ;Start at 0x0100</td>
</tr>
<tr>
<td>movlw 0x0A</td>
<td>movlw 0x0A</td>
</tr>
<tr>
<td>movwf varl</td>
<td>movwf varl</td>
</tr>
</tbody>
</table>

If more than one code section is defined in a source file, each section must have a unique name. If the name is not specified, it will be given the default name .code.

Each program memory section must be contiguous within a single source file. A section may not be broken into pieces within a single source file.

The physical address of the code can be fixed by supplying the optional address parameter of the code directive. Situations where this might be necessary are:

- Specifying Reset and interrupt vectors
- Ensuring that a code segment does not overlap page boundaries

**EXAMPLE 6-2: RELOCATABLE CODE**

Reset code 0x01FF ;Fixed address
goto Start
Pgm code ;Address determined by the linker
clrw
option
6.4 LOW, HIGH AND UPPER OPERATORS

Low, high and upper operators are used to return one byte of a multi-byte label value. If low is used, only bits 0 through 7 of the expression will be used. If high is used, only bits 8 through 15 of the expression will be used. If upper is used, only bits 16 through 21 of the expression will be used.

<table>
<thead>
<tr>
<th>Operator</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>low</td>
<td>Return low byte of operand.</td>
</tr>
<tr>
<td>high</td>
<td>Return high byte of operand.</td>
</tr>
<tr>
<td>upper</td>
<td>Return upper byte of operand.</td>
</tr>
<tr>
<td>scnsz_low</td>
<td>Return low byte of section size.</td>
</tr>
<tr>
<td>scnsz_high</td>
<td>Return high byte of section size.</td>
</tr>
<tr>
<td>scnsz_upper</td>
<td>Return upper byte of section size.</td>
</tr>
<tr>
<td>scnend_low</td>
<td>Return low byte of section end operand.</td>
</tr>
<tr>
<td>scnend_high</td>
<td>Return high byte of section end operand.</td>
</tr>
<tr>
<td>scnend_upper</td>
<td>Return upper byte of section end operand.</td>
</tr>
<tr>
<td>scnstart_low</td>
<td>Return low byte of section start operand.</td>
</tr>
<tr>
<td>scnstart_high</td>
<td>Return high byte of section start operand.</td>
</tr>
<tr>
<td>scnstart_upper</td>
<td>Return upper byte of section start operand.</td>
</tr>
</tbody>
</table>

Operator precedence information may be found in 3.5 “Arithmetic Operators and Precedence”.

There are some restrictions involving these operators with relocatable symbols. For example, the low, high and upper operators must be of the form:

```
[low|high|upper] (relocatable_symbol + constant_offset)
```

where:

- `relocatable_symbol` is any label that defines a program or data memory address
- `constant_offset` is an expression that is resolvable at assembly time to a value between -32768 and 32767

Either `relocatable_symbol` or `constant_offset` may be omitted.

Operands of the form:

```
relocatable_symbol - relocatable_symbol
```

will be reduced to a constant value if both symbols are defined in the same code or data section.

In addition to section operators, there are section pseudo-instructions.

<table>
<thead>
<tr>
<th>Pseudo-Instruction</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>scnend_lfsr</td>
<td>scndend_lfsr n,s, where n is 0, 1, or 2 (as with the LFSR instruction) and s is a string which is taken to be the name of a section. This instruction loads LFSR with the end address of the section.</td>
</tr>
<tr>
<td>scnstart_lfsr</td>
<td>scnstart_lfsr n,s, where n is 0, 1, or 2 (as with the LFSR instruction) and s is a string which is taken to be the name of a section. This instruction loads LFSR with the start address of the section.</td>
</tr>
</tbody>
</table>

These operators and instructions only have meaning when an object file is generated; they cannot be used when generating absolute code.
EXAMPLE 6-3: GENERAL OPERATOR USE

The general operators, low, high and upper, may be used to access data in tables. The following code example was taken the pl8demo.asm file provided with PICDEM 2 Plus demo board. The excerpt shows how “Microchip” is read from the table and displayed on the demo board LCD.

```assembly
#include p18f452.inc

PROG1 CODE

stan_table                     ;table for standard code
; "XXXXXXXXXXXXXXXXXX"
; ptr:
data " Voltmeter " ;0
data " Buzzer " ;16
data " Temperature " ;32
data " Clock " ;48
data " RA4=Next RB0=Now" ;64
data " Microchip " ;80
data " PICDEM 2 PLUS " ;96
data " RA4=Set RB0=Menu" ;112
data " RA4= --> RB0= ++" ;128
data " RB0 = Exit " ;144
data " Volts = " ;160
data " Prd.=128 DC=128 " ;176

;**************** STANDARD CODE MENU SELECTION *******************
movlw   .80                 ;send "Microchip" to LCD
movwf   ptr_pos
call    stan_char_1

;----Standard code, Place characters on line-1----
stan_char_1
    call    LCDLine_1           ;move cursor to line 1
movlw   .16                 ;1-full line of LCD
movwf   ptr_count
movlw   UPPER stan_table    ;use operators to load
movwf   TBLPTRU             ;table pointer values
movlw   HIGH stan_table
movwf   TBLPTRH
movlw   LOW stan_table
movwf   TBLPTRL
movf    ptr_pos,W
addwf   TBLPTRL,F
clrf    WREG
addwf   TBLPTRH,F
addwf   TBLPTRU,F
```

```
```assembly
; Relocatable Objects

stan_next_char_1
  tblrd *
  movff TABLAT,temp_wr
  call d_write        ; send character to LCD
  decfsz ptr_count,F ; move pointer to next char
  bra stan_next_char_1

  movlw "\n"         ; move data into TXREG
  movwf TXREG      ; next line
  btfss TXSTA,TRMT ; wait for data TX
  goto $-2
  movlw "\r"       ; move data into TXREG
  movwf TXREG      ; carriage return
  btfss TXSTA,TRMT ; wait for data TX
  goto $-2

return
```
6.5 RAM ALLOCATION

RAM space must be allocated in a data section. Five types of data sections are available:

- **udata** - Uninitialized data. This is the most common type of data section. Locations reserved in this section are not initialized and can be accessed only by the labels defined in this section or by indirect accesses. See 4.62 "**udata** - Begin an Object File Uninitialized Data Section".
- **udata_acs** - Uninitialized access data. This data section is used for variables that will be placed in access RAM of PIC18 devices. Access RAM is used as quick data access for specified instructions. See 4.63 "**udata_acs** - Begin an Object File Access Uninitialized Data Section (PIC18 MCUs)".
- **udata_ovr** - Uninitialized overlaid data. This data section is used for variables that can be declared at the same address as other variables in the same module or in other linked modules. A typical use of this section is for temporary variables. See 4.64 "**udata_ovr** - Begin an Object File Overlaid Uninitialized Data Section".
- **udata_shr** - Uninitialized shared data. This data section is used for variables that will be placed in RAM of PIC12/16 devices that is unbanked or shared across all banks. See 4.65 "**udata_shr** - Begin an Object File Shared Uninitialized Data Section (PIC12/16 MCUs)".
- **idata** - Initialized data. The linker will generate a lookup table that can be used to initialize the variables in this section to the specified values. When linked with MPLAB C17 or C18 code, these locations will be initialized during execution of the startup code. The locations reserved by this section can be accessed only by the labels defined in this section or by indirect accesses. See 4.36 "**idata** - Begin an Object File Initialized Data Section".

The following example shows how a data declaration might be created.

EXAMPLE 6-4: RAM ALLOCATION

**Absolute Code**

Use **cblock** to define variable register locations (See 4.8 "**cblock** - Define a Block of Constants"). Variable values will need to be specified in code.

```assembly

cblock 0x20
    HistoryVector ;Must be initialized to 0
    InputGain, OutputGain ;Control loop gains
    Temp1, Temp2, Temp3 ;Used for internal calculations
endc
```

Note: The ability to use access, overlaid or shared data varies by device. Consult your device data sheet for more information.

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Equivalent Relocatable Code

Use data declarations to define register locations and initialize.

```assembly
idata
    HistoryVector db 0 ;Initialized to 0
udata
    InputGain res 1 ;Control loop gains
    OutputGain res 1
udata_ovr
    Temp1 res 1 ;Used for internal calculations
    Temp2 res 1
    Temp3 res 1
```

If necessary, the location of the section may be fixed in memory by supplying the optional address parameter. If more than one of each section type is specified, each section must have a unique name. If a name is not provided, the default section names are: `.idata`, `.udata`, `.udata_acs`, `.udata_shr`, and `.ucdata_ovr`.

When defining initialized data in an `idata` section, the directives `db`, `dw`, and `data` can be used. `db` will define successive bytes of data memory. `dw` and `data` will define successive words of data memory in low-byte/high-byte order. The following example shows how data will be initialized.

**EXAMPLE 6-5: RELOCATABLE CODE LISTING**

```assembly
00001 IDATA
0000 01 02 03 00002 Bytes DB 1,2,3
0003 34 12 78 56 00003 Words DW 0x1234,0x5678
0007 41 42 43 00 00004 String DB "ABC", 0
```

### 6.6 CONFIGURATION BITS AND ID LOCATIONS

Configuration bits and ID locations can still be defined in a relocatable object using the following directives:

- **Section 4.11 “__config - Set Processor Configuration Bits”**
- **Section 4.12 “config - Set Processor Configuration Bits (PIC18 MCUs)”**
- **Section 4.38 “__idlocs - Set Processor ID Locations”**

Only one linked module can specify these directives. They should be used prior to declaring any code sections. After using these directives, the current section is undefined.
6.7 ACCESSING LABELS FROM OTHER MODULES

Labels that are defined in one module for use in other modules must be exported using the `global` directive (see 4.35 “global - Export a Label”). Modules that use these labels must use the `extern` directive (see 4.33 “extern - Declare an Externally Defined Label”) to declare the existence of these labels. An example of using the `global` and `extern` directives is shown below.

**EXAMPLE 6-6: RELOCATABLE CODE, DEFINING MODULE**

```assembly
udata
   InputGain res 1
   OutputGain res 1
   global InputGain, OutputGain
code
Filter
   global Filter
   : ; Filter code
```

**EXAMPLE 6-7: RELOCATABLE CODE, REFERENCING MODULE**

```assembly
extern InputGain, OutputGain, Filter
udata
   Reading res 1

code
   : 
   movlw GAIN1
   movwf InputGain
   movlw GAIN2
   movwf OutputGain
   movf Reading,W
   call Filter
```
6.8 PAGING AND BANKING ISSUES

In many cases, RAM allocation will span multiple banks, and executable code will span multiple pages. In these cases, it is necessary to perform proper bank and page set-up to properly access the labels. However, since the absolute addresses of these variable and address labels may not be known at assembly time, it is not always possible to place the proper code in the source file. For these situations two directives, banksel (4.7 “banksel - Generate Bank Selecting Code”) and pagesel (4.53 “pagesel - Generate Page Selecting Code (PIC10/12/16 MCUs)”), have been added. These directives instruct the linker to generate the correct bank or page selecting code for a specified label. An example of how code should be converted is shown below.

EXAMPLE 6-8: BANKSEL AND PAGESEL

Hard-Coded Banking and Paging

Use indirect addressing (FSR) and the Status register for banking and paging, respectively.

```assembly
#include p12f509.inc
Var1 equ 0x10 ;Declare variables
Var2 equ 0x30

movlw InitialValue
bcf FSR, 5 ;Data memory Var1 bank (0)
movwf Var1
bsf FSR, 5 ;Data memory Var2 bank (1)
movwf Var2
bsf STATUS, PA0 ;Program memory page 1
call Subroutine
...
Subroutine clrw ;On Page 1
...
retlw 0
```

BANKSEL for Banking and PAGESEL for Paging

Use banksel and pagesel for banking and paging, respectively.

```assembly
#include p12f509.inc
extern Var1, Var2 ;Declare variables
code
movlw InitialValue
banksel Var1 ;Select data memory Var1 bank
movwf Var1
banksel Var2 ;Select data memory Var2 bank
movwf Var2
pagesel Subroutine ;Select program memory page
call Subroutine
...
Subroutine clrw ;Page unknown at assembly time
...
retlw 0
```
6.9 GENERATING THE OBJECT MODULE

Once the code conversion is complete, the object module is generated automatically in the IDE or by requesting an object file on the command line or in the shell interface. When using MPASM assembler for Windows, check the checkbox labeled "Object File." When using the command line interface, specify the /o or -o- option. The output file will have a .o extension.

6.10 CODE EXAMPLE

Since an eight-by-eight bit multiply is a useful, generic routine, it would be handy to break this off into a separate object file that can be linked in when required. The absolute code file can be broken into two relocatable code files: a calling file representing an application and a generic routine that could be incorporated in a library.

This code was adapted from application note AN617. Please see the Microchip website for a downloadable pdf of this app note.

EXAMPLE 6-9: ABSOLUTE CODE

; Input: fixed point arguments in AARGB0 and BARGB0
; Output: product AARGxBARG in AARGB0:AARGB1
; Other comments truncated. See AN617.
;********************************************************************
#include   p16f877a.inc ;Use any PIC16 device you like

LOOPCOUNT  EQU   0x20  ;7 loops needed to complete routine
AARGB0     EQU   0x21  ;MSB of result out,
AARGB1     EQU   0x22  ;operand A in (8 bits)
BARGB0     EQU   0x23  ;LSB of result out,
;operand B in (8 bits)

TestCode
    clrf    AARGB1      ;Clear partial product before testing
    movlw   D'11'
    movwf   AARGB0
    movlw   D'30'
    movwf   BARGB0
    call    UMUL0808L   ;After loading AARGB0 and BARGB0,
    ;call routine
    goto    $           ;Result now in AARGB0:AARGB1,
    ;where (B0 is MSB)

END

UMUL0808L
    movlw   0x08
    movwf   LOOPCOUNT
    movf    AARGB0,W
    LOOPUM0808A
    rrf     BARGB0, F
    btfsc   STATUS,C
    goto    LUM0808NAP
    decfsz  LOOPCOUNT, F
    goto    LOOPUM0808A
    clrf    AARGB0
    retlw   0x00
LUM0808NAP
    bcf     STATUS,C
    goto    LUM0808NA
LOOPUM0808
    rrf    BARGB0, F
    btfsc  STATUS,C
    addwf  AARGB0, F
LUM0808NA
    rrf    AARGB0, F
    rrf    AARGB1, F
    decfsz LOOPCOUNT, F
    goto   LOOPUM0808
    retlw  0
END

EXAMPLE 6-10: RELOCATABLE CODE, CALLING FILE

; Input: fixed point arguments in AARGB0 and BARGB0
; Output: product AARGxBARG in AARGB0:AARGB1
; Other comments truncated. See AN617.
;********************************************************************
#include   p16f877a.inc ;Use any PIC16 device you like
EXTERN   UMUL0808L, AARGB0, AARGB1, BARGB0

Reset   CODE   0x0
    pagesel  TestCode
    goto     TestCode

CODE
    TestCode
    banksel  AARGB1
    clrf     AARGB1      ;Clear partial product before testing
    movlw    D'11'       ;Load in 2 test values
    movwf     AARGB0
    movlw    D'30'
    movwf     BARGB0
    pagesel  UMUL0808L
    call     UMUL0808L   ;After loading AARGB0 and BARGB0,
    ;call routine
    goto     $           ;Result now in AARGB0:AARGB1,
    ;where (AARGB0 is MSB)
END

EXAMPLE 6-11: RELOCATABLE CODE, LIBRARY ROUTINE

; Input: fixed point arguments in AARGB0 and BARGB0
; Output: product AARGxBARG in AARGB0:AARGB1
; Other comments truncated. See AN617.
;********************************************************************
#include   p16f877a.inc ;Use any PIC16 device you like
GLOBAL   UMUL0808L, AARGB0, AARGB1, BARGB0
UDATA
    LOOPCOUNT  RES   1   ;7 loops needed to complete routine
    AARGB0     RES   1   ;MSB of result out,
    AARGB1     RES   1   ;operand A in (8 bits)
    BARGB0     RES   1   ;LSB of result out,
    ;operand B in (8 bits)

CODE
UMUL0808L
    movlw   0x08
    movwf   LOOPCOUNT
    movf    AARGB0,W
LOOPUM0808A
    rrf     BARGB0, F
    btfsc   STATUS,C
    goto    LUM0808NAP
    decfsz  LOOPCOUNT, F
    goto    LOOPUM0808A
    clrf    AARGB0
    retlw   0x00
LUM0808NAP
    bcf     STATUS,C
    goto    LUM0808NA
LOOPUM0808
    rrf     BARGB0, F
    btfsc   STATUS,C
    addwf   AARGB0, F
LUM0808NA
    rrf     AARGB0, F
    rrf     AARGB1, F
    decfsz  LOOPCOUNT, F
    goto    LOOPUM0808
    retlw   0

END
Chapter 7. Macro Language

7.1 INTRODUCTION

Macros are user defined sets of instructions and directives that will be evaluated in-line with the assembler source code whenever the macro is invoked.

Macros consist of sequences of assembler instructions and directives. They can be written to accept arguments, making them quite flexible. Their advantages are:

- Higher levels of abstraction, improving readability and reliability.
- Consistent solutions to frequently performed functions.
- Simplified changes.
- Improved testability.

Applications might include creating complex tables, frequently used code, and complex operations.

Topics covered in this chapter:

- Macro Syntax
- Macro Directives Defined
- Macro Definition
- Macro Invocation
- Macro Code Examples

7.2 MACRO SYNTAX

MPASM assembler macros are defined according to the following syntax:

```
label macro [arg1, arg2 ..., argn]
  :
  :
  endm
```

where `label` is a valid assembler label that will be the macro name and `arg` is any number of optional arguments supplied to the macro (that will fit on the source line.) The values assigned to these arguments at the time the macro is invoked will be substituted wherever the argument name occurs in the body of the macro.

The body of a macro may be comprised of MPASM assembler directives, PIC1X MCU assembly instructions, or MPASM assembler macro directives (local for example.) The assembler continues to process the body of the macro until an `exitm` or `endm` directive is encountered.

**Note:** Macros must be defined before they are used, i.e., forward references to macros are not permitted.
7.3 MACRO DIRECTIVES DEFINED

There are directives that are unique to macro definitions. They cannot be used out of
the macro context.

- 4.45 “macro - Declare Macro Definition”
- 4.31 “exitm - Exit from a Macro”
- 4.26 “endm - End a Macro Definition”
- 4.32 “expand - Expand Macro Listing”
- 4.49 “noexpand - Turn off Macro Expansion”
- 4.44 “local - Declare Local Macro Variable”

When writing macros, you can use any of these directives PLUS any other directives supported by the assembler.

Note: The previous syntax of the “dot” format for macro specific directives is no longer supported.

7.4 MACRO DEFINITION

String replacement and expression evaluation may appear within the body of a macro.

<table>
<thead>
<tr>
<th>Command</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>arg</td>
<td>Substitute the argument text supplied as part of the macro invocation.</td>
</tr>
<tr>
<td>#v(expr)</td>
<td>Return the integer value of expr. Typically, used to create unique variable</td>
</tr>
<tr>
<td></td>
<td>names with common prefixes or suffixes. Cannot be used in conditional</td>
</tr>
<tr>
<td></td>
<td>assembly directives (e.g. ifdef, while).</td>
</tr>
</tbody>
</table>

Arguments may be used anywhere within the body of the macro, except as part of normal expression.

The exitm directive provides an alternate method for terminating a macro expansion. During a macro expansion, this directive causes expansion of the current macro to stop and all code between the exitm and the endm directives for this macro to be ignored. If macros are nested, exitm causes code generation to return to the previous level of macro expansion.
7.5 MACRO INVOCATION

Once the macro has been defined, it can be invoked at any point within the source module by using a macro call, as described below:

```
macro_name [arg, ..., arg]
```

where `macro_name` is the name of a previously defined macro and arguments are supplied as required.

The macro call itself will not occupy any locations in memory. However, the macro expansion will begin at the current memory location. Commas may be used to reserve an argument position. In this case, the argument will be an empty string. The argument list is terminated by white space or a semicolon.

EXAMPLE 7-1: MACRO CODE GENERATION

The following macro:

```
define_table macro
    local a = 0
    while a < 3
        entry#v(a) dw 0
        a += 1
    endw
endm
```

When invoked, would generate:

```
entry0 dw 0
entry1 dw 0
entry2 dw 0
entry3 dw 0
```
7.6 MACRO CODE EXAMPLES

The following are examples of macros:

- Literal to RAM Conversion
- Constant Compare

7.6.1 Literal to RAM Conversion

This code converts any literal of 32 bits to 4 separate RAM data values. In this example, the literal 0x12345678 is put in the desired 8 bit registers as 0x12, 0x34, 0x56, and 0x78. Any literal can be “unpacked” this way using this macro.

```assembly
#include   p16F877A.inc
udata 0x20
Out0   res   1   ; LSB
Out1   res   1   ; :
Out2   res   1   ; :
Out3   res   1   ; MSB

Unpack32   MACRO Var, Address ;Var = 32 bit literal to be unpacked
  BANKSEL Address ;Address specifies the LSB start
  movlw Address ;Use FSR and INDF for indirect
  movwf FSR ;access to desired address

  movlw Var & H'FF' ;Mask to get LSB
  movwf INDF ;Put in first location

  movlw Var >>D'08' & H'FF';Mask to get next byte of literal
  incf FSR,F ;Point to next byte
  movwf INDF ;Write data to next byte

  movlw Var >>D'16' & H'FF';Mask to get next byte of literal
  incf FSR,F ;Point to next byte
  movwf INDF ;Write data to next byte

  movlw Var >>D'24' & H'FF';Mask to get last byte of literal
  incf FSR,F ;Point to last byte
  movwf INDF ;Write data to last byte

ENDM ;End of the Macro Definition

ORG     0
Start                        ;TEST CODE for Unpack32 MACRO
  Unpack32 0x12345678,Out0 ;Put Unpack Macro here
  goto $ ;Do nothing (loop forever)
END
```
7.6.2 Constant Compare

As another example, if the following macro were written:

```c
#include "pic16f877a.inc"
#endif

; compare file to constant and jump if file >= constant.
;
cfl_jge macro file, con, jump_to
    movlw con & 0xff
    subwf file, w
    btfsc status, carry
    goto jump_to
endm
```

and invoked by:

```c
cfl_jge switch_val, max_switch, switch_on
```

it would produce:

```asm
movlw max_switch & 0xff
subwf switch_val, w
btfsc status, carry
goto switch_on
```
Chapter 8. Errors, Warnings, Messages, and Limitations

8.1 INTRODUCTION

Error messages, warning messages and general messages produced by the MPASM assembler are listed and detailed here. These messages always appear in the listing file directly above each line in which the error occurred. Limitations of the assembler tool are also listed.

The messages are stored in the error file (.err) if no MPASM assembler options are specified. If the /e- or -e- option is used (turns error file off), then the messages will appear on the screen. If the /q or -q (quiet mode) option is used with the /e- or -e-, then the messages will not display on the screen or in an error file. The messages will still appear in the listing file.

Topics covered in this chapter:

• Assembler Errors
• Assembler Warnings
• Assembler Messages
• Assembler Limitations
8.2 ASSEMBLER ERRORS

MPASM assembler errors are listed numerically below:

101 ERROR
User error, invoked with the error directive.

102 Out of memory
Not enough memory for macros, #define's or internal processing.

103 Symbol table full
No more memory available for the symbol table.

104 Temp file creation error
Could not create a temporary file. Check the available disk space.

105 Cannot open file
Could not open a file. If it is a source file, the file may not exist. If it is an output file, the old version may be write protected.

To check for write-protect, right-click on the file named by MPLAB X IDE or MPLAB IDE v8 in Windows. Choose “Properties” and see if “read-only” is checked. If it is, it cannot be modified by the IDE and will generate this error message. This often happens when you save your project to a CD-R or similar write-once media as a backup, and then copy the data to your computer. Copying to a CD marks all files as read-only (they cannot be changed on a CD-R), and when you copy the files, the attributes move with them making them all read-only on your hard drive. A good way to prevent this is to archive all of the files in one file, such as a *.ZIP, and then restore them from CD. The archive will preserve the original file attributes.

106 String substitution too complex
A string substitution was attempted that was too complex. Check for nesting of #define's.

107 Illegal digit
An illegal digit in a number. Valid digits are 0-1 for binary, 0-7 for octal, 0-9 for decimal, and 0-9, a-f, and A-F for hexadecimal.

108 Illegal character
An illegal character in a label. Valid characters for labels are alphabetic (a..f, A..F), numeric (0-9), the underscore (_), and the question mark (?). Labels may not begin with a numeric.

109 Unmatched ( 
An open parenthesis did not have a matching close parenthesis. For example, DATA (1+2.

110 Unmatched)
An close parenthesis did not have a matching open parenthesis. For example, DATA 1+2).

111 Missing symbol
An equ or set directive did not have a symbol to which to assign the value.
112 **Missing operator**

An arithmetic operator was missing from an expression. For example, `DATA 1 2`.

113 **Symbol not previously defined**

A symbol was referenced that has not yet been defined. Check the spelling and location of the declaration of any symbols used in your code. Only addresses may be used as forward references. Constants and variables must be declared before they are used.

This sometimes happens when `#include` files are used in your project. Since the text from an include file is inserted at the location of the `#include` statement, and you may have labels used before that point, you can get this error. Also, the error may occur due to a typing error, spelling mistake or case change in your label. `MyLabel` is not the same as `Mylabel` unless case sensitivity is turned off (it is on by default). Additionally, `goto MyLabel` will never locate the code at `Mylabl` or `Mylable`. Check for these sorts of mistakes first. As a general rule, put your include files at the top of each file. If this seems to cluttered, you may include files within other include files.

114 **Divide by zero**

Division by zero encountered during an expression evaluation.

115 **Duplicate label**

A label was declared as a constant (e.g., with the `equ` or `cblock` directive) in more than one location.

116 **Address label duplicated or different in second pass**

The same label was used in two locations. Alternately, the label was used only once but evaluated to a different location on the second pass. This often happens when users try to write page-bit setting macros that generate different numbers of instructions based on the destination.

117 **Address wrapped around 0**

For PIC12/16 devices, the location counter can only advance to 0xFFFF. After that, it wraps back to 0. Error 117 is followed by error 118.

118 **Overwriting previous address contents**

Code was previously generated for this address.

119 **Code too fragmented**

The code is broken into too many pieces. This error is very rare, and will only occur in source code that references addresses above 32K (including configuration bits).

120 **Call or jump not allowed at this address**

A call or jump cannot be made to this address. For example, CALL destinations on the PIC16C5x family must be in the lower half of the page.

121 **Illegal label**

Labels are not allowed on certain directive lines. Simply put the label on its own line, above the directive. Also, high, low, page, and bank are not allowed as labels.

122 **Illegal opcode**

Token is not a valid opcode.
123 Illegal directive
Directive is not allowed for the selected processor; for example, the \_idlocs directive on devices with ID locations.

124 Illegal argument
An illegal directive argument; for example, list foobar.

125 Illegal condition
A bad conditional assembly. For example, an unmatched endif.

126 Argument out of range
Opcode or directive argument out of the valid range; for example, TRIS 10.

127 Too many arguments
Too many arguments specified for a macro call.

128 Missing argument(s)
Not enough arguments for a macro call or an opcode.

129 Expected
Expected a certain type of argument. The expected list will be provided.

130 Processor type previously defined
A different family of processor is being selected.

131 Processor type is undefined
Code is being generated before the processor has been defined. Note that until the processor is defined, the opcode set is not known.

132 Unknown processor
The selected processor is not a valid processor.

133 Hex file format INHX32 required
An address above 32K was specified.

134 Illegal hex file format
An illegal hex file format was specified in the list directive.

135 Macro name missing
A macro was defined without a name.

136 Duplicate macro name
A macro name was duplicated.

137 Macros nested too deep
The maximum macro nesting level was exceeded.

138 Include files nested too deep
The maximum include file nesting level was exceeded.
139 Maximum of 100 lines inside WHILE-ENDW
A `while-endw` can contain at most 100 lines.

140 WHILE must terminate within 256 iterations
A `while-endw` loop must terminate within 256 iterations. This is to prevent infinite assembly.

141 WHILEs nested too deep
The maximum `while-endw` nesting level was exceeded.

142 IFs nested too deep
The maximum `if` nesting level was exceeded.

143 Illegal nesting
Macros, `if`'s and `while`'s must be completely nested; they cannot overlap. If you have an `if` within a `while` loop, the `endif` must come before the `endw`.

144 Unmatched ENDC
`endc` found without a `cblock`.

145 Unmatched ENDM
`endm` found without a `macro` definition.

146 Unmatched EXITM
`exitm` found without a `macro` definition.

147 Directive/operation only allowed when generating an object file
The instruction/operand shown only has meaning when a linkable object file is generated. It cannot be used when generating absolute code.

148 Expanded source line exceeded 200 characters
The maximum length of a source line, after `#define` and macro parameter substitution, is 200 characters. Note that `#define` substitution does not include comments, but macro parameter substitution does.

149 Directive only allowed when generating an object file
Certain directives, such as `global` and `extern`, only have meaning when a linkable object file is generated. They cannot be used when generating absolute code.

150 Labels must be defined in a code or data section when making an object file
When generating a linkable object file, all data and code address labels must be defined inside a data or code section. Symbols defined by the `equ` and `set` directives can be defined outside of a section.

151 Operand contains unresolvable labels or is too complex
When generating an object file, operands must be of the form `[high|low][relocatable address label]+[offset]`.
152 Executable code and data must be defined in an appropriate section
When generating a linkable object file, all executable code and data declarations must be placed within appropriate sections.

153 Page or Bank bits cannot be evaluated for the operand
The operand of a pagesel, banksel or bankisel directive must be a relocatable address label or a constant.

154 Each object file section must be contiguous
Object file sections, except udata_ovr sections, cannot be stopped and restarted within a single source file. To resolve this problem, either name each section with its own name or move the code and data declarations such that each section is contiguous. This error will also be generated if two sections of different types are given the same name.

155 All overlaid sections of the same name must have the same starting address
If multiple udata_ovr sections with the same name are declared, they must all have the same starting address.

156 Operand must be an address label
When generating object files, only address labels in code or data sections may be declared global. Variables declared by the set or equ directives may not be exported.

157 ORG at odd address
For PIC18 devices, you cannot place org at an odd address, only even. Consult your device data sheet.

158 Cannot use RES directive with odd number of bytes
For PIC18 devices, you cannot use res to specify an odd number of bytes, only even. Consult your device data sheet.

159 Cannot use FILL directive with odd number of bytes
For PIC18 devices, you cannot use fill to fill with data an odd number of bytes, only even. Consult your device data sheet.

160 CODE_PACK directive not available for this part; substituting CODE
The code_pack directive can only be used with byte-addressable ROM.

161 Non-negative value required for this context.
Some contexts require non-negative values.

162 Expected a section name
Some operators and pseudo-operators take section names as operands. The lexical form of a section name is that of an identifier, optionally prefixed with a '.'.

163 __CONFIG directives must be contiguous
Do not place other code between __config directive declarations.

164 __IDLOC directives must be contiguous
Do not place other code between __idloc directive declarations.
165 extended mode not available for this device
This PIC18 device does not support extended mode.

166 left bracket missing from offset operand
The left bracket is missing from an offset, e.g., [0x55.

167 right bracket missing from offset operand
The right bracket is missing from an offset, e.g., 0x55].

168 square brackets required around offset operand
Square brackets are required around an offset, e.g., [0x55]

169 access bit cannot be specified with indexed mode
When using indexed mode, the access bit cannot be specified.

170 expression within brackets must be constant
The expression specified within brackets is not a constant value.

171 address specified is not in access ram range of [0x60, 0xFF]
When making use of Access RAM, addressing must occur within the specified Access Bank range.

172 PCL, TOSL, TOSH, or TOSU cannot be destination of MOVFF or MOVSF
These registers cannot be written to with movff or movsf commands.

174 __CONFIG directives must be listed in ascending order
List config directive configuration registers in ascending order, e.g.,
__CONFIG _CONFIG0, _CP_OFF_0
__CONFIG _CONFIG1, _OSCS_OFF_1 & _RCIO_OSC_1
__CONFIG _CONFIG2, _BOR_ON_2 & _BORV_25_2

175 __IDLOCS directives must be listed in ascending order
List __idlocs directive ID registers in ascending order, e.g.,
__idlocs IDLOC0, 0x1
__idlocs IDLOC1, 0x2
__idlocs IDLOC2, 0x3

176 CONFIG Directive Error:
An error was found in the config directive syntax.

177 __CONFIG directives cannot be used with CONFIG directives
Do not mix __config directives and config directives when assigning configuration bits in your code.

178 __CONFIG Directive Error
An error was found in the __config directive syntax.
179 Instruction is not supported on this device

This error would occur when an instruction is used in code which is not supported on the particular family/architecture.

180 RES directive cannot reserve odd number of bytes in PIC18 absolute mode

This error would occur if you try to reserve an odd number of bytes using a PIC18 device and assemble in absolute mode (Quickbuild). For example:

```
org 0x0
a res 1
end
```

If you try to Quickbuild the above PIC18 MCU program, you will see error 180 and warning 231.

### UNKNOWN ERROR

An internal application error has occurred. (### is the value of the last defined error plus 1.)

Contact your Microchip Field Application Engineer (FAE) or Microchip support if you cannot debug this error.
8.3 ASSEMBLER WARNINGS

MPASM assembler warnings are listed numerically below:

201 Symbol not previously defined
The symbol being undefined was not previously defined.

202 Argument out of range. Least significant bits used
Argument did not fit in the allocated space. For example, literals must be 8 bits.

203 Found opcode in column 1
An opcode was found in column one, which is reserved for labels.

204 Found pseudo-op in column 1
A pseudo-op was found in column one, which is reserved for labels.

205 Found directive in column 1
A directive was found in column one, which is reserved for labels.

206 Found call to macro in column 1
A macro call was found in column one, which is reserved for labels.

207 Found label after column 1
A label was found after column one, which is often due to a misspelled opcode.

208 Label truncated at 32 characters
Maximum label length is 32 characters.

209 Missing quote
A text string or character was missing a quote. For example, DATA 'a.

210 Extra ","
An extra comma was found at the end of the line.

211 Extraneous arguments on the line
Extra arguments were found on the line.

212 Expected (ENDIF)
Expected an endif statement, i.e., an if statement was used without an endif.

213 The EXTERN directive should only be used when making a .o file
The extern directive only has meaning if an object file is being created. This warning has been superseded by Error 149.

214 Unmatched ()
An unmatched parenthesis was found. The warning is used if the parenthesis is not used for indicating order of evaluation.
215 Processor superseded by command line. Verify processor symbol
The processor was specified on the command line as well as in the source file. The command line has precedence.
If you are using an IDE with the assembly, set the device to match the source file from File>Project Properties (MPLAB X IDE) or Configure>Select Device (MPLAB IDE v8).

216 Radix superseded by command line
The radix was specified on the command line as well as in the source file. The command line has precedence.

217 Hex file format specified on command line
The hex file format was specified on the command line as well as in the source file. The command line has precedence.

218 Expected DEC, OCT, HEX. Will use HEX
Bad radix specification.

219 Invalid RAM location specified
If the __maxram and __badram directives are used, this warning flags use of any RAM locations declared as invalid by these directives. Note that the provided header files include __maxram and __badram for each processor.

220 Address exceeds maximum range for this processor
A ROM location was specified that exceeds the processor's memory size.

221 Invalid message number
The message number specified for displaying or hiding is not a valid message number.

222 Error messages cannot be disabled
Error messages cannot be disabled with the errorlevel command.

223 Redefining processor
The selected processor is being reselected by the list or processor directive.

224 Use of this instruction is not recommended
The instruction is being obsoleted and is not recommended for current use. However, it is still supported for legacy reasons.

225 Invalid label in operand
Operand was not a valid address. For example, if the user tried to issue a CALL to a MACRO name.

226 Destination address must be word aligned
The destination address is not aligned with the start of a program memory word. For this device, use even bytes to specify address.

227 Substituting RETLW 0 for RETURN pseudo-op
Using retlw 0 instead of return to resume program execution.
228 Invalid ROM location specified
The data memory location specified is not valid for the operation specified or is non-existent.

229 extended mode is not in effect -- overridden by command line
A command-line option has disabled extended mode operation.

230 __CONFIG has been deprecated for PIC18 devices. Use directive CONFIG.
Although you may still use the __config directive for PIC18 MCU devices, it is strongly recommended that you use the config directive (no leading underscores) instead. For PIC18FXXJ MCUs, you must use the config directive.

231 No memory has been reserved by this instruction
This warning would appear if an instruction which is meant to reserve memory cannot actually reserve that memory. For example:

```assembly
org 0x0
a res 1
end
```
The above PIC18 assembly program is attempting to reserve one byte (a res 1) but this is not valid for a PIC18 MCU as each word size is two bytes.

232 STATUS register has no IRP or RP1 or RP0 bits
For PIC16 extended instruction devices, you are trying to access a non-existent bit of the STATUS register (IRP or RP1 or RP0 bits).

### UNKNOWN WARNING
An internal application error has occurred. (### is the value of the last defined warning plus 1.)
However, it is not severe enough to keep your code from assembling, i.e., it is a warning, not an error.
8.4 ASSEMBLER MESSAGES

MPASM assembler messages are listed numerically below:

301 MESSAGE
User-definable message, invoked with the `messg` directive (see Section 4.48 “messg - Create User Defined Message”).

302 Register in operand not in bank 0. Ensure that bank bits are correct.
This is a commonly seen reminder message to tell you that a variable that is being accessed in not in bank 0. This message was added to remind you to check your code, particularly code in banks other than 0. Review the section on `banksel` (Section 4.7 “banksel - Generate Bank Selecting Code”) and `bankisel` (Section 4.6 “bankisel - Generate Indirect Bank Selecting Code (PIC12/16 MCUs)”) and ensure that your code uses bank bits whenever changing from ANY bank to ANY other bank (including bank 0).
Since the assembler or linker can't tell which path your code will take, you will always get this message for any variable not in bank 0. You can use the `errorlevel` command to turn this and other messages on and off, but be careful as you may not spot a banking problem with this message turned off. For more about `errorlevel`, see Section 4.30 “errorlevel - Set Message Level”.
A similar message is 306 for paging.

303 Program word too large. Truncated to core size.
The program word (instruction width) is too large for the selected device’s core (program memory) size. Therefore the word has been truncated to the proper size.
For example, a 14-bit instruction would be truncated to 12 bits to be used by a PIC16F54.

304 ID Locations value too large. Last four hex digits used.
Only four hex digits are allowed for the ID locations.

305 Using default destination of 1 (file).
If no destination bit is specified, the default is used. Usually code that causes this message is missing the `,W` or `,F` after the register name, but sometimes the bug is due to typing `movf` instead of `movwf`.
It is best to fix any code that is causing this message. The default destination could not be where you want the value stored, and could cause the code to operate strangely.

306 Crossing page boundary -- ensure page bits are set.
Generated code is crossing a page boundary. This is a reminder message to tell you that code is being directed to a label that is on a page other than page 0. It is not an error or warning, but a reminder to check your page bits. Use the `pagesel` directive (Section 4.53 “pagesel - Generate Page Selecting Code (PIC10/12/16 MCUs)”) before this point and remember to use another `pagesel` if returning to page 0.
The assembler can't tell what path your code will take, so this message is generated for any label in a page other than 0. You can use the `errorlevel` command to turn this and other messages on and off, but be careful as you may not spot a paging problem with this message turned off. For more about `errorlevel`, see Section 4.30 “errorlevel - Set Message Level”.
A similar message is 302 for banking.
307 Setting page bits.
Page bits are being set with the LCALL or LGOTO pseudo-op.

308 Warning level superseded by command line value.
The warning level was specified on the command line as well as in the source file. The command line has precedence.

309 Macro expansion superseded by command line.
Macro expansion was specified on the command line as well as in the source file. The command line has precedence.

310 Superseding current maximum RAM and RAM map.
The __maxram directive has been used previously.

311 Operand of HIGH operator was larger than H'FFFF'.
High byte of address returned by high directive was greater than 0xFFFF.

312 Page or Bank selection not needed for this device. No code generated.
If a device contains only one ROM page or RAM bank, no page or bank selection is required, and any pagesel, banksel, or bankisel directives will not generate any code.

313 CBLOCK constants will start with a value of 0.
If the first cblock in the source file has no starting value specified, this message will be generated.

314 LFSR instruction is not supported on some versions of the 18Cxx2 devices.
See message 315 for more information.

315 Please refer to Microchip document DS80058A for more details
A downloadable pdf of this document, PIC18CXX2 Silicon/Data Sheet Errata, is available from the Microchip website.

316 W Register modified.
The working (W) register has been modified

317 W Register not modified. BSF/BCF STATUS instructions used instead.
The working (W) register has not been modified

318 Superseding current maximum ROM and ROM map.
Operation will cause maximum ROM to be exceeded.

### UNKNOWN MESSAGE
An internal application error has occurred. (### is the value of the last defined message plus 1.)
However, it is not severe enough to keep your code from assembling, i.e., it is a message, not an error.
8.5 ASSEMBLER LIMITATIONS

8.5.1 General Limitations

- If a fully qualified path is specified, only that path will be searched. Otherwise, the search order is: (1) current working directory, (2) source file directory, and (3) MPASM assembler executable directory.
- There is a source file line limit (expanded) of 200 characters.
- MPLAB X IDE v1.40 and above has a parallel make facility and will attempt to compile multiple source files simultaneously if your PC has a multi-core processor. The assembler is not compatible with parallel make and you should disable parallel make when using the assembler by itself or as part of MPLAB C18 (see Tools>Options, Embedded tab, Project options sub-tab).

8.5.2 Directive Limitations

- Do not use #includes in macros.
- if directive limits
  - Maximum nesting depth = 16
- include directive limits
  - Maximum nesting depth = 5
  - Maximum number of files = 255
- macro directive limits
  - Maximum nesting depth = 16
- while directive limits
  - Maximum nesting depth = 8
  - Maximum number of lines per loop = 100
  - Maximum iterations = 256

8.5.3 MPASM Assembler Versions before v5.39 (MPLAB IDE v8)

There is an assembler command-line length limit of 255 characters.

8.5.4 MPASM Assembler Versions before v3.30 (MPLAB IDE v8)

Assembler versions before v3.30 (v3.2x and earlier) have limitations based on the generation a COD file for debugging and the support of a command-line version, mpasm.exe.

- There is a 62 character length restriction for file and path names in the debug (COD) file produced by MPASM assembler. This can cause problems when assembling single files with long file names and/or path names.
  Work-arounds:
  - Shorten your file name or move your file into a directory closer to the root directory (shorten the path name), and try assembling your file again.
  - Create a Mapped drive for the long directory chain.
  - Use the linker with the assembler, and not the assembler alone, to generate your output. There is no character restriction with MPLINK linker.
- The command-line version of the assembler (mpasm.exe) has the following limitations:
  - File names are limited to 8.3 format.
  - config directive not supported.
Chapter 9. MPLINK Linker Overview

9.1 INTRODUCTION

An overview of the MPLINK object linker and its capabilities is presented.

Topics covered in this chapter:
• MPLINK Linker Defined
• How MPLINK Linker Works
• How MPLINK Linker Helps You
• Linker Platforms Supported
• Linker Operation
• Linker Input/Output Files

9.2 MPLINK LINKER DEFINED

MPLINK object linker (the linker) combines object modules generated by the MPASM assembler or the MPLAB C18 C compiler into a single executable (hex) file. The linker also accepts libraries of object files as input, as generated by the MPLIB object librarian. The linking process is controlled by a linker script file, which is also input into MPLINK linker.

For more information on MPASM assembler, see Chapter 1. “MPASM Assembler Overview”. For more information on MPLAB C18, see C compiler documentation listed in “Recommended Reading”.

9.3 HOW MPLINK LINKER WORKS

MPLINK linker performs many functions:
• Locates Code and Data. The linker takes as input relocatable object files. Using the linker script, it decides where the code will be placed in program memory and where variables will be placed in RAM.
• Resolves Addresses. External references in a source file generate relocation entries in the object file. After the linker locates code and data, it uses this relocation information to update all external references with the actual addresses.
• Generates an Executable. Produces a .hex file that can be programmed into a PIC1X MCU or loaded into an emulator or simulator to be executed.
• Configures Stack Size and Location. Allows MPLAB C18 to set aside RAM space for dynamic stack usage.
• Identifies Address Conflicts. Checks to ensure that program/data do not get assigned to space that has already been assigned or reserved.
• Provides Symbolic Debug Information. Outputs a file that the IDE uses to track address labels, variable locations, and line/file information for source level debugging.
9.4 HOW MPLINK LINKER HELPS YOU

MPLINK linker allows you to produce modular, reusable code. Control over the linking process is accomplished through a linker script file and with command line options. The linker ensures that all symbolic references are resolved and that code and data fit into the available PIC1X MCU device.

MPLINK linker can help you with:

• Reusable Source Code. You can build up your application in small, reusable modules.
• Libraries. You can make libraries of related functions which can be used in creating efficient, readily compilable applications.
• MPLAB C18. The Microchip compiler for PIC18 devices requires the use of MPLINK linker and can be used with precompiled libraries and MPASM assembler.
• Centralized Memory Allocation. By using application-specific linker scripts, precompiled objects and libraries can be combined with new source modules and placed efficiently into available memory at link time.
• Accelerated Development. Since tested modules and libraries don't have to be recompiled each time a change is made in your code, compilation time may be reduced.

9.5 LINKER PLATFORMS SUPPORTED

MPLINK linker is supported under Windows 2000/XP, Windows Vista, Linux and Mac platforms.
9.6 LINKER OPERATION

The MPLINK linker combines multiple input object modules and library files, per the linker script file, into a single output COF file. Utilities can be used to generate executable code (.hex) or a linker listing file (.lst) from the COF file. A map file can also be generated to aid in debugging.

FIGURE 9-1: MPLINK LINKER OPERATION

The linker is executed after assembling or compiling relocatable object modules with the MPASM assembler and/or MPLAB C18 C compiler. The actual addresses of data and the location of functions will be assigned when the MPLINK linker is executed. This means that you may instruct the linker, via a linker script, to place code and data somewhere within named regions of memory, or, if not specified, to place into any available memory.

The linker script must also tell the MPLINK linker about the ROM and RAM memory regions available in the target PIC1X MCU device. Then, it can analyze all the input files and try to fit the application's routines into ROM and assign its data variables into available RAM. If there is too much code or too many variables to fit, the linker will give an error message.

The MPLINK linker also provides flexibility for specifying that certain blocks of data memory are reusable, so that different routines (which never call each other and which don't depend upon this data to be retained between execution) can share limited RAM space.

When using a C compiler, libraries are available for most PIC MCU peripheral functions as well as for many standard C functions. The linker will only extract and link individual object files that are needed for the current application from the included libraries. This means that relatively large libraries can be used in a highly efficient manner.

The MPLINK linker combines all input files and ensure that all addresses are resolved. Any function in the various input modules that attempts to access data or call a routine that has not been allocated or created will cause the linker to generate an error.

Finally the linker calls the MP2HEX utility to generate the executable output. The MPLINK linker also generates symbolic information for debugging your application with the IDE (.cof and .map files). A list file (.lst) can also be generated by calling the MP2COD utility.
9.7 LINKER INPUT/OUTPUT FILES

The MPLINK linker combines multiple object files into one executable hex file.

### Input Files

<table>
<thead>
<tr>
<th>File Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Object File (.o)</td>
<td>Relocatable code produced from a source file.</td>
</tr>
<tr>
<td>Library File (.lib)</td>
<td>A collection of object files grouped together for convenience.</td>
</tr>
<tr>
<td>Linker Script File (.lkr)</td>
<td>Description of memory layout for a particular processor/project.</td>
</tr>
</tbody>
</table>

### Output Files

<table>
<thead>
<tr>
<th>File Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>COFF Object Module File (.cof, .out)</td>
<td>Debug file used by MPLAB IDE v6.xx and later.</td>
</tr>
<tr>
<td>Hex File Formats (.hex, .hxl, .hxh)</td>
<td>Hexadecimal file with no debug information. Suitable for use in programming. This file is generated by the utility MP2HEX.</td>
</tr>
<tr>
<td>Listing File (.lst)</td>
<td>Original source code, side-by-side with final binary code. <strong>Note:</strong> Requires linker can find original source files. This file is generated by the utility MP2COD.</td>
</tr>
<tr>
<td>Map File (.map)</td>
<td>Shows the memory layout after linking. Indicates used and unused memory regions.</td>
</tr>
</tbody>
</table>

#### 9.7.1 Object File (.o)

Object files are the relocatable code produced from source files. The MPLINK linker combines object files and library files, according to a linker script, into a single output file.

Object files may be created from source files by MPASM assembler and library files may be created from object files by MPLIB librarian.

#### 9.7.2 Library File (.lib)

Libraries are a convenient way of grouping related object modules. A library file may be created from object files by MPLIB librarian. For more on the librarian, see **Chapter 15. “MPLIB Librarian Overview”**.

#### 9.7.3 Linker Script File (.lkr)

Linker script files are the command files of MPLINK linker. For more information on linker scripts, see **Chapter 11. “Linker Scripts”**.

Standard linker script files are located in:

C:\Program Files\Microchip\MPASM Suite\LKR

During the link process, if MPLINK linker is unable to resolve a reference to a symbol, it will search libraries specified on the command line or in the linker script in an attempt to resolve the reference. If a definition is found in a library file, the object file containing that definition will be included in the link.
9.7.4  COFF Object Module File (.cof, .out)
MPLINK linker generates a COFF file which provides debugging information to MPLAB IDE v6.xx or later.

9.7.5  Hex File Formats (.hex, .hxl, .hxh)
Both the MPASM assembler and the MPLINK linker can generate a hex file. For more information on this format, see Section 1.7.5 “Hex File Formats (.hex, .hxl, .hxh)”.
For MPLINK linker, mp2hex.exe uses the COF file to generate the hex file. To prevent hex file generation, use the /x or –x option.

9.7.6  Listing File (.lst)
An MPLINK linker listing file provides a mapping of source code to object code. It also provides a list of symbol values, memory usage information, and the number of errors, warnings and messages generated.
This file may be viewed in MPLAB X IDE by:
1. selecting File>Open File to launch the Open dialog
2. selecting “All Files” from the “Files of type” drop-down list
3. locating the desired list file
4. clicking on the list file name
5. clicking Open
This file may be viewed in MPLAB IDE v8 by:
1. selecting File>Open to launch the Open dialog
2. selecting “List files (*.lst)” from the “Files of type” drop-down list
3. locating the desired list file
4. clicking on the list file name
5. clicking Open
Both the MPASM assembler and the MPLINK linker can generate listing files. For information on the MPASM assembler listing file, see Section 1.7.3 “Listing File (.lst)”.
An alternative to a listing file would be to use the information in the Disassembly window, View>Disassembly in MPLAB IDE v8 or Window>Debugging>Disassembly in MPLAB X IDE.
The MPLINK linker uses the mp2cod.exe utility to generate the linker list file from the COF file. To prevent linker list file generation, use the /w or –w- option.
EXAMPLE 9-1: MPLINK LINKER LISTING FILE

The MP2COD utility version and list file generation data appear at the top of each page.

The first column contains the base address in memory where the code will be placed.
The second column is reserved for the machine instruction. This is the code that will be
executed by the PIC MCU. The third column displays disassembly code. The fourth
column lists the associated source code line. The fifth column lists the file associated
for the source code line.

<table>
<thead>
<tr>
<th>Address</th>
<th>Value</th>
<th>Disassembly</th>
<th>Source</th>
<th>File</th>
</tr>
</thead>
<tbody>
<tr>
<td>000000</td>
<td>ef16</td>
<td>GOTO 0x2c</td>
<td>#include p18f452.inc</td>
<td>(1)</td>
</tr>
<tr>
<td>000002</td>
<td>f000</td>
<td></td>
<td>LIST</td>
<td>(2)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>; P18F452.INC  Standard Header File,...</td>
<td>(2)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>LIST</td>
<td>(2)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>udata</td>
<td>(1)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Dest res 1</td>
<td>(1)</td>
</tr>
</tbody>
</table>

RST code 0x0

goto Start

<table>
<thead>
<tr>
<th>Address</th>
<th>Value</th>
<th>Disassembly</th>
<th>Source</th>
<th>File</th>
</tr>
</thead>
<tbody>
<tr>
<td>000002c</td>
<td>0e0a</td>
<td>MOVlw 0xa</td>
<td>PGM code</td>
<td>(1)</td>
</tr>
<tr>
<td>000002e</td>
<td>6f80</td>
<td>MOVWF 0x80,0x1</td>
<td>Start movlw 0x0A</td>
<td>(1)</td>
</tr>
<tr>
<td>000030</td>
<td>9780</td>
<td>BCF 0x80,0x3,0x1</td>
<td>movwf Dest</td>
<td>(1)</td>
</tr>
<tr>
<td>000032</td>
<td>ef16</td>
<td>GOTO 0x2c</td>
<td>bcf Dest, 3</td>
<td>(1)</td>
</tr>
<tr>
<td>000034</td>
<td>f000</td>
<td></td>
<td>goto Start</td>
<td>(1)</td>
</tr>
</tbody>
</table>

end

where:

(1) = D:\Projects32\PIC18F452\SourceReloc.asm
(2) = C:\Program Files\Microchip\MPASM Suite\p18f452.inc

Note: Due to page width restrictions, some comments have been shortened, indicated by ".." Also, associated file names have been replaced by numbers, i.e., (1) and (2). See the end of the listing of the actual file paths and names.
9.7.7 Map File (.map)

The map file generated by MPLINK linker can be viewed by selecting File>Open File in MPLAB X IDE (or File>Open in MPLAB IDE v8) and choosing the file you specified in the MPLINK linker options. It provides information on the absolute location of source code symbols in the final output. It also provides information on memory use, indicating used/unused memory. This window is automatically reloaded after each rebuild.

The map file contains four tables. The first table (Section Info) displays information about each section. The information includes the name of the section, its type, beginning address, whether the section resides in program or data memory, and its size in bytes.

There are four types of sections:
- code
- initialized data (idata)
- uninitialized data (udata)
- initialized ROM data (romdata)

The following table is an example of the section table in a map file:

<table>
<thead>
<tr>
<th>Section</th>
<th>Type</th>
<th>Address</th>
<th>Location</th>
<th>Size(Bytes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reset</td>
<td>code</td>
<td>0x000000</td>
<td>program</td>
<td>0x000002</td>
</tr>
<tr>
<td>.cinit</td>
<td>romdata</td>
<td>0x000021</td>
<td>program</td>
<td>0x000004</td>
</tr>
<tr>
<td>.code</td>
<td>code</td>
<td>0x000023</td>
<td>program</td>
<td>0x000026</td>
</tr>
<tr>
<td>.udata</td>
<td>udata</td>
<td>0x000020</td>
<td>data</td>
<td>0x000005</td>
</tr>
</tbody>
</table>

The second table (Program Memory Usage) lists program memory addresses that were used and provides a total usage statistic. For example:

<table>
<thead>
<tr>
<th>Program Memory Usage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Start</td>
</tr>
<tr>
<td>0x000000</td>
</tr>
<tr>
<td>0x00002a</td>
</tr>
<tr>
<td>0x0000bc</td>
</tr>
<tr>
<td>0x001176</td>
</tr>
</tbody>
</table>

10209 out of 32786 program addresses used, program memory utilization is 31%

The third table in the map file (Symbols - Sorted by Name) provides information about the symbols in the output module. The table is sorted by the symbol name and includes the address of the symbol, whether the symbol resides in program or data memory, whether the symbol has external or static linkage, and the name of the file where defined. The following table is an example of the symbol table sorted by symbol name in a map file:

<table>
<thead>
<tr>
<th>Name</th>
<th>Address</th>
<th>Location</th>
<th>Storage</th>
<th>File</th>
</tr>
</thead>
<tbody>
<tr>
<td>call_m</td>
<td>0x000026</td>
<td>program</td>
<td>static</td>
<td>C:\PROGRA~1\MPLAB\ASMFOO\sampobj.asm</td>
</tr>
<tr>
<td>loop</td>
<td>0x00002e</td>
<td>program</td>
<td>static</td>
<td>C:\MPASM assemblerV2\MUL8X8.ASM</td>
</tr>
<tr>
<td>main</td>
<td>0x000024</td>
<td>program</td>
<td>static</td>
<td>C:\PROGRA~1\MPLAB\ASMFOO\sampobj.asm</td>
</tr>
<tr>
<td>mpy</td>
<td>0x000028</td>
<td>program</td>
<td>extern</td>
<td>C:\MPASM assemblerV2\MUL8X8.ASM</td>
</tr>
<tr>
<td>start</td>
<td>0x000023</td>
<td>program</td>
<td>static</td>
<td>C:\PROGRA~1\MPLAB\ASMFOO\sampobj.asm</td>
</tr>
<tr>
<td>H_byte</td>
<td>0x000022</td>
<td>data</td>
<td>extern</td>
<td>C:\MPASM assemblerV2\MUL8X8.ASM</td>
</tr>
<tr>
<td>L_byte</td>
<td>0x000023</td>
<td>data</td>
<td>extern</td>
<td>C:\MPASM assemblerV2\MUL8X8.ASM</td>
</tr>
<tr>
<td>count</td>
<td>0x000024</td>
<td>data</td>
<td>static</td>
<td>C:\MPASM assemblerV2\MUL8X8.ASM</td>
</tr>
<tr>
<td>mulcnd</td>
<td>0x000020</td>
<td>data</td>
<td>extern</td>
<td>C:\MPASM assemblerV2\MUL8X8.ASM</td>
</tr>
<tr>
<td>mulplr</td>
<td>0x000021</td>
<td>data</td>
<td>extern</td>
<td>C:\MPASM assemblerV2\MUL8X8.ASM</td>
</tr>
</tbody>
</table>
The fourth table in the map file (Symbols - Sorted by Address) provides the same information that the third table provides, but it is sorted by symbol address rather than symbol name.

If a linker error is generated, a complete map file can not be created. However, if the /m or -m option was supplied, an error map file will be created. The error map file contains only section information; no symbol information is provided. The error map file lists all sections that were successfully allocated when the error occurred. This file, in conjunction with the error message, should provide enough context to determine why a section could not be allocated.
10.1 INTRODUCTION

MPLINK object linker usage is discussed.

When MPLAB X IDE/MPLAB IDE v8 or MPLAB C18 is installed, the MPLINK linker (mplink.exe) is also installed.

Topics covered in this chapter:

• IDE Interface
• Command Line Interface
• Command Line Example

10.2 IDE INTERFACE

The MPLINK linker is commonly used with the MPASM assembler in an MPLAB X IDE or MPLAB IDE v8 project to generate relocatable code. For more information on this use, see the MPASM assembler on-line Help file.

The linker may also be used in the IDE with the MPLAB C18 C compiler. For more information on Microchip compilers, see the MPLAB C18 C compiler documentation listed in “Recommended Reading”.

10.3 COMMAND LINE INTERFACE

MPLINK linker can be used in the IDE or directly from a command line.

When used in an IDE, all of MPLINK linker’s options are available through the Project Properties dialog (File>Project Properties) for MPLAB X IDE or MPLINK Linker tab, accessed from the Project>Build Options dialog, in MPLAB IDE v8.

When using MPLINK linker in a batch file, or directly from the command line, the linker is invoked with the following two syntaxes:

mplink lkrsctipt partnumber objfiles [libfiles] [options]
mplink partnumber objfiles [libfiles] [options]

lkrsctipt is the name of a linker script file. All linker script files must have the extension .lkr. It is not necessary to add the linker script file name to the command line if you will be using the generic linker script, as described in the next paragraph. However if you have your own modified script, you must include the name on the command line.

partnumber indicates the part number for the device, as in 18f4520 for PIC18F4520. For Windows OS, you specify the part number by /ppartnumber. For Linux or Mac OS, you specify the part number by -ppartnumber.

If no linker script name is provided, the part number will be used to determine the generic linker script to build the project. The linker will search the lkr directory to find the generic linker script for that part. The lkr directory is located at the same location as the MPLINK linker executable. The linker will construct the name of the generic linker script by adding an ‘_g.lkr’ to the string value of the part number, as in 18f4520_g.lkr.

As of MPLINK linker v4.38, even if a linker script is provided, the part number must also be provided.

objfile is the name of an assembler or compiler generated object file. All object files must have the extension .o.

libfile is the name of a librarian-created library file. All library files must have the extension .lib.

option is one of the linker command-line options described below. For Windows OS, use a backslash and then the option. For Linux or Mac OS, use a dash and then the option.
There is no required order for the command line arguments; however, changing the order can affect the operation of the linker. Specifically, additions to the library/object directory search path are appended to the end of the current library/object directory search path as they are encountered on the command line and in command files.

Library and object files are searched for in the order in which directories occur in the library/object directory search path. Therefore, changing the order of directories may change which file is selected.

The /o or -o option is used to supply the name of the generated output COFF file for the IDE debugging. Also generated is an Intel format hex file for programming. This file has the same name as the output COFF file but with the file extension .hex. If this option is not supplied, the default output COFF file is named a.out and the corresponding hex file is named a.hex.
10.4 COMMAND LINE EXAMPLE

An example of an MPLINK linker command line is shown below.

Windows OS:

mplink myscript.lkr /p18f452 main.o funct.o math.lib /m main.map /o main.out

Linux or Mac OS:

mplink myscript.lkr -p18f452 main.o funct.o math.lib -m main.map -o main.out

This instructs MPLINK linker to use the myscript.lkr linker script file to link the input modules main.o, funct.o, and the precompiled library math.lib. It also instructs the linker to produce a map file named main.map. main.o and funct.o must have been previously compiled or assembled. The output files main.cof and main.hex will be produced if no errors occur during the link process. The project applies to a PIC18F452 device.
Chapter 11. Linker Scripts

11.1 INTRODUCTION

Linker script files are used by the linker to generate application code. You no longer need to add a device-specific linker script file to the command line or your MPLAB X IDE or MPLAB IDE v8 project; the linker will find the appropriate file for you as long as a device has been specified. However, if you want to use a non-standard linker script file, you will have to add that manually.

Depending on the hardware debug tool you want to use, you may need to set certain conditional symbols on the command line (see Example 11.8.4) or to select the Build Configuration as “Debug” in MPLAB IDE v8 only.

Linker script files are the command files of the linker. They specify:

- Program and data memory regions for the target part
- Stack size and location (for MPLAB C18)
- A mapping of logical sections in source code into program and data regions

Linker script directives form the command language that controls the linker’s behavior. There are four basic categories of linker script directives. Each of these directives, plus some useful linker script caveats, are discussed in the topics listed below.

**Note:** Linker script comments are specified by ‘//’, i.e., any text between a ‘//’ and the end of a line is ignored.

Topics covered in this chapter:

- Standard Linker Scripts
- Linker Script Command Line Information
- Linker Script Caveats
- Memory Region Definition
- Logical Section Definition
- STACK Definition
- Conditional Linker Statements
11.2 STANDARD LINKER SCRIPTS

Standard linker script files are provided for each device and are located, by default, in the directory: `C:\Program Files\Microchip\MPASM Suite\LKR`.

Standard linker scripts are named with the following convention `partnumber_g.lkr`. For example, the standard linker script for PIC16F872 is `16F872_g.lkr`. The standard linker scripts contain conditional linker statements and the IDE uses the `/u` command line flag to utilize these statements for different builds such as debug or no debug. You can modify a local copy of the standard linker script and use it in your project.
11.3 LINKER SCRIPT COMMAND LINE INFORMATION

The MPLAB Project Manager can set this information directly. You probably only need to use these if you are linking from the command line.

- LIBPATH
- LKRPATH
- FILES
- INCLUDE

11.3.1 LIBPATH

Library and object files which do not have a path are searched using the library/object search path. The following directive appends additional search directories to the library/object search path:

LIBPATH libpath

where libpath is a semicolon-delimited list of directories.

EXAMPLE 11-1: LIBPATH EXAMPLE

To append the current directory and the directory C:\PROJECTS\INCLUDE to the library/object search path, the following line should be added to the linker script file:

LIBPATH .;C:\PROJECTS\INCLUDE

11.3.2 LKRPATH

Linker script files that are included using a linker script INCLUDE directive are searched for using the linker script file search path. The following directive appends additional search directories to the linker script file search path:

LKRPATH lkrpath

where lkrpath is a semicolon-delimited list of directories.

EXAMPLE 11-2: LKRPATH EXAMPLE

To append the current directory’s parent and the directory C:\PROJECTS\SCRIPTS to the linker script file search path, the following line should be added to the linker script file:

LKRPATH ..;C:\PROJECTS\SCRIPTS

11.3.3 FILES

The following directive specifies object or library files for linking:

FILES objfile/libfile [objfile/libfile...]

where objfile/libfile is either an object or library file.

Note: More than one object or library file can be specified in a single FILES directive.

EXAMPLE 11-3: FILES EXAMPLE

To specify that the object module main.o be linked with the library file math.lib, the following line should be added to the linker script file:

FILES main.o math.lib
11.3.4 INCLUDE

The following directive includes an additional linker script file:

```
INCLUDE cmdfile
```

where `cmdfile` is the name of the linker script file to include.

**EXAMPLE 11-4: INCLUDE EXAMPLE**

To include the linker script file named `mylink.lkr`, the following line should be added to the linker script file:

```
INCLUDE mylink.lkr
```

11.4 LINKER SCRIPT CAVEATS

Some linker script caveats:

- You may need to modify the linker script files included with MPLINK linker before using them.
- You may wish to reconfigure stack size to use MPLAB C18 with MPLINK linker.
- You will need to split up memory pages if your code contains `goto` or `call` instructions without `pagesel` pseudo-instructions (directives.)
- You must not combine data memory regions when using MPLINK linker with MPLAB C18 C compiler. MPLAB C18 requires that any section be located within a single bank. See MPLAB C18 documentation for directions on creating variables larger than a single bank.
11.5 MEMORY REGION DEFINITION

The linker script describes the memory architecture of the PIC1X MCU. This allows the linker to place code in available ROM space and variables in available RAM space. Regions that are marked PROTECTED will not be used for general allocation of program or data. Code or data will only be allocated into these regions if an absolute address is specified for the section, or if the section is assigned to the region using a SECTION directive in the linker script file.

11.5.1 Defining RAM Memory Regions

The following directives are used for variable data in internal RAM. The formats for these directives are as follows.

**Banked Registers**

```
DATABANK NAME=memName START=addr END=addr [PROTECTED]
```

**Unbanked Registers**

```
SHAREBANK NAME=memName START=addr END=addr [PROTECTED]
```

**Access Registers (PIC18 devices only)**

```
ACCESSBANK NAME=memName START=addr END=addr [PROTECTED]
```

**Linear Data Memory (PIC16F1xxx devices only)**

```
LINEARMEM NAME=linear0 START=addr END=addr PROTECTED
DATABANK NAME=memName START=addr END=addr SHADOWED=linear0:addr
```

where:

<table>
<thead>
<tr>
<th>memName</th>
<th>Any ASCII string used to identify an area in RAM.</th>
</tr>
</thead>
<tbody>
<tr>
<td>addr</td>
<td>A decimal (e.g., .30) or hexadecimal (e.g., 0xFF) number specifying an address.</td>
</tr>
<tr>
<td>[ ]</td>
<td>An optional keyword.</td>
</tr>
<tr>
<td>PROTECTED</td>
<td>A keyword that indicates a region of memory that only can be used when specifically identified in the source code. The linker will not use the protected area.</td>
</tr>
<tr>
<td>SHADOWED</td>
<td>A keyword that maps a data memory range to the specified linear data region linName at an address in that region.</td>
</tr>
</tbody>
</table>
EXAMPLE 11-5:  RAM EXAMPLE - DATABANK AND SHAREBANK

Based on the RAM memory layout shown in PIC16F877A Register File Map, the DATABANK and SHAREBANK entries in the linker script file would appear as shown in the examples below the map.

FIGURE 11-1:  PIC16F877A REGISTER FILE MAP

<table>
<thead>
<tr>
<th>Address</th>
<th>Bank 0</th>
<th>Bank 1</th>
<th>Bank 2</th>
<th>Bank 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>00h</td>
<td>INDF0</td>
<td>INDF0</td>
<td>INDF0</td>
<td>INDF0</td>
</tr>
<tr>
<td>01h</td>
<td>TMR0</td>
<td>OPTION_REG</td>
<td>TMR0</td>
<td>OPTION_REG</td>
</tr>
<tr>
<td>02h</td>
<td>PCL</td>
<td>PCL</td>
<td>PCL</td>
<td>PCL</td>
</tr>
<tr>
<td>03h</td>
<td>STATUS</td>
<td>STATUS</td>
<td>STATUS</td>
<td>STATUS</td>
</tr>
<tr>
<td>04h</td>
<td>FSR</td>
<td>FSR</td>
<td>FSR</td>
<td>FSR</td>
</tr>
<tr>
<td>05h</td>
<td>PORTA</td>
<td>TRISA</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>..</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>..</td>
</tr>
<tr>
<td>0Fh</td>
<td>TMR1H</td>
<td>—</td>
<td>EEARH</td>
<td>—</td>
</tr>
<tr>
<td>10h</td>
<td>T1CON</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>..</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>..</td>
</tr>
<tr>
<td>1Fh</td>
<td>ADCON0</td>
<td>ADCON1</td>
<td>General Purpose RAM (Banked)</td>
<td>General Purpose RAM (Banked)</td>
</tr>
<tr>
<td>20h</td>
<td>General Purpose RAM (Banked)</td>
<td>General Purpose RAM (Banked)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>..</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>..</td>
</tr>
<tr>
<td>70h</td>
<td>General Purpose RAM (Unbanked)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7Fh</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

RAM Memory Declarations for PIC16F877A - Banked Memory

//Special Function Registers in Banks 0-3
DATABANK NAME=sfr0 START=0x0 END=0x1F PROTECTED
DATABANK NAME=sfr1 START=0x80 END=0x9F PROTECTED
DATABANK NAME=sfr2 START=0x100 END=0x10F PROTECTED
DATABANK NAME=sfr3 START=0x180 END=0x18F PROTECTED

//General Purpose RAM in Banks 0-3
DATABANK NAME=gpr0 START=0x20 END=0x6F
DATABANK NAME=gpr1 START=0xA0 END=0xEF
DATABANK NAME=gpr2 START=0x110 END=0x16F
DATABANK NAME=gpr3 START=0x190 END=0x1EF

RAM Memory Declarations for PIC16F877A - Unbanked Memory

//General Purpose RAM - available in all banks
SHAREBANK NAME=gprnobnk START=0x70 END=0x7F
SHAREBANK NAME=gprnobnk START=0xF0 END=0xFF
SHAREBANK NAME=gprnobnk START=0x170 END=0x17F
SHAREBANK NAME=gprnobnk START=0x1F0 END=0x1FF
EXAMPLE 11-6: RAM EXAMPLE - ACCESSBANK

Based on the RAM memory layout shown in PIC18F8680 Register File Map, the ACCESSBANK entries in the linker script file would appear as shown in the examples below the map.

FIGURE 11-2: PIC18F8680 REGISTER FILE MAP

<table>
<thead>
<tr>
<th>Address Range</th>
<th>Bank</th>
<th>Data Memory Map</th>
<th>Access Bank</th>
</tr>
</thead>
<tbody>
<tr>
<td>000h-05Fh</td>
<td>Bank 0</td>
<td>Access RAM</td>
<td>Access RAM Low</td>
</tr>
<tr>
<td>060h-0FFh</td>
<td></td>
<td>GPRs</td>
<td></td>
</tr>
<tr>
<td>100h-1FFh</td>
<td>Bank 1</td>
<td>GPRs</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C00h-CFFh</td>
<td>Bank 12</td>
<td>GPRs</td>
<td></td>
</tr>
<tr>
<td>D00h-DFFh</td>
<td>Bank 13</td>
<td>CAN SFRs</td>
<td></td>
</tr>
<tr>
<td>E00h-EFFh</td>
<td>Bank 14</td>
<td>CAN SFRs</td>
<td></td>
</tr>
<tr>
<td>F00h-F5Fh</td>
<td>Bank 15</td>
<td>CAN SFRs</td>
<td></td>
</tr>
<tr>
<td>F60h-FFFh</td>
<td></td>
<td>SFRs</td>
<td>Access RAM High</td>
</tr>
</tbody>
</table>

RAM Memory Declarations for PIC18F8680 - Access Memory

ACCESSBANK NAME=accessram START=0x0 END=0x5F
ACCESSBANK NAME=accesssfr START=0xF60 END=0xFFF PROTECTED
EXAMPLE 11-7: RAM EXAMPLE - LINEARMEM

Based on the RAM memory layout shown in PIC16F1939 Register File Map, the LINEARMEM entries in the linker script file would appear as shown in the examples below the map.

FIGURE 11-3: PIC16F1939 REGISTER FILE MAP

<table>
<thead>
<tr>
<th>Address Range</th>
<th>General Purpose Registers</th>
<th>Bank</th>
<th>Linear Data Memory Map</th>
</tr>
</thead>
<tbody>
<tr>
<td>20h-6Fh</td>
<td>80 bytes (GPR0)</td>
<td>Bank 0</td>
<td>2000h</td>
</tr>
<tr>
<td>A0h-EFh</td>
<td>80 bytes (GPR1)</td>
<td>Bank 1</td>
<td>2050h</td>
</tr>
<tr>
<td>120h-16Fh</td>
<td>80 bytes (GPR2)</td>
<td>Bank 2</td>
<td>20A0h</td>
</tr>
<tr>
<td>5A0h-5EFh</td>
<td>80 bytes (GPR11)</td>
<td>Bank 11</td>
<td>2370h</td>
</tr>
<tr>
<td>620h-66Fh</td>
<td>48 bytes and Unimplemented (GPR12)</td>
<td>Bank 12</td>
<td></td>
</tr>
<tr>
<td>6A0h-6EFh</td>
<td>Unimplemented (GPR13)</td>
<td>Bank 13</td>
<td></td>
</tr>
<tr>
<td>F20h-F6Fh</td>
<td>Unimplemented (GPR30)</td>
<td>Bank 30</td>
<td>23EFh</td>
</tr>
</tbody>
</table>

RAM Memory Declarations for PIC16F1939 - Linear Memory Region

```
LINEARMEM NAME=linear0 START=0x2000 END=0x23EF PROTECTED

DATABANK NAME=gpr0 START=0x20 END=0x6F SHADOW=linear0:0x2000
DATABANK NAME=gpr1 START=0xA0 END=0xEF SHADOW=linear0:0x2050
DATABANK NAME=gpr2 START=0x120 END=0x16F SHADOW=linear0:0x20A0
DATABANK NAME=gpr3 START=0x1A0 END=0x1EF SHADOW=linear0:0x20F0
DATABANK NAME=gpr4 START=0x220 END=0x26F SHADOW=linear0:0x2140
DATABANK NAME=gpr5 START=0x2A0 END=0x2EF SHADOW=linear0:0x2190
DATABANK NAME=gpr6 START=0x320 END=0x36F SHADOW=linear0:0x21E0
DATABANK NAME=gpr7 START=0x3A0 END=0x3EF SHADOW=linear0:0x2230
DATABANK NAME=gpr8 START=0x420 END=0x46F SHADOW=linear0:0x2280
DATABANK NAME=gpr9 START=0x520 END=0x56F SHADOW=linear0:0x2320
DATABANK NAME=gpr10 START=0x5A0 END=0x5EF SHADOW=linear0:0x2370
```
11.5.2 Defining ROM Memory Regions

The CODEPAGE directive is used for program code, initialized data values, constant data values and external memory. It has the following format:

```
CODEPAGE NAME=memName START=addr END=addr [PROTECTED] [FILL=fillvalue]
```

where:

<table>
<thead>
<tr>
<th>memName</th>
<th>Any ASCII string used to identify a CODEPAGE.</th>
</tr>
</thead>
<tbody>
<tr>
<td>addr</td>
<td>A decimal (e.g., .30) or hexadecimal (e.g., 0xFF) number specifying an address.</td>
</tr>
<tr>
<td>[ ]</td>
<td>An optional keyword.</td>
</tr>
<tr>
<td>FILL</td>
<td>A keyword used to specify a value which fills any unused portion of a memory block. If this value is in decimal notation, it is assumed to be a 16-bit quantity. If it is in hexadecimal notation (e.g., 0x2346), it may be any length divisible by full words (16 bits).</td>
</tr>
<tr>
<td>PROTECTED</td>
<td>A keyword that indicates a region of memory that only can be used by program code that specifically requests it.</td>
</tr>
</tbody>
</table>

**EXAMPLE 11-8: ROM EXAMPLE**

The program memory layout for a PIC16F877A microcontroller is shown below.

<table>
<thead>
<tr>
<th>Memory</th>
<th>Address</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reset Vector</td>
<td>Start: 0000h</td>
</tr>
<tr>
<td>Interrupt Vector</td>
<td>Start: 0004h</td>
</tr>
<tr>
<td>User Memory Space</td>
<td>0005h - 07FFh</td>
</tr>
<tr>
<td>User Memory Space</td>
<td>0800h - 0FFFh</td>
</tr>
<tr>
<td>User Memory Space</td>
<td>1000h - 17FFh</td>
</tr>
<tr>
<td>User Memory Space</td>
<td>1800h - 1FFFh</td>
</tr>
<tr>
<td>ID Locations</td>
<td>2000h - 2003h</td>
</tr>
<tr>
<td>Reserved</td>
<td>2004h - 2005h</td>
</tr>
<tr>
<td>Device ID</td>
<td>2006h</td>
</tr>
<tr>
<td>Configuration Memory Space</td>
<td>2007h</td>
</tr>
<tr>
<td>Reserved</td>
<td>2008h - 20FFh</td>
</tr>
<tr>
<td>EEPROM Data</td>
<td>2100h - 21FFh</td>
</tr>
</tbody>
</table>

Based on this map, the CODEPAGE declarations are:

```
CODEPAGE NAME=page0 START=0x0000 END=0x07FF
CODEPAGE NAME=page1 START=0x0800 END=0x0FFF
CODEPAGE NAME=page2 START=0x1000 END=0x17FF
CODEPAGE NAME=page3 START=0x1800 END=0x1FFF
CODEPAGE NAME=.idlocs START=0x2000 END=0x2003 PROTECTED
CODEPAGE NAME=.config START=0x2007 END=0x2007 PROTECTED
CODEPAGE NAME=eedata START=0x2100 END=0x21FF PROTECTED
```
11.6 LOGICAL SECTION DEFINITION

Logical sections are used to specify which of the defined memory regions should be used for a portion of source code. LINEARMEM is an example of a logical section.

To use logical sections, define the section in the linker script file with the SECTION directive and then reference that name in the source file using that language's built-in mechanism (e.g., #pragma section for MPLAB C18).

The section directive defines a section by specifying its name, and either the block of program memory in ROM or the block of data memory in RAM which contains the section:

```
SECTION NAME=secName { ROM=memName | RAM=memName }
```

where:

- `secName` is an ASCII string used to identify a section.
- `memName` is a previously defined ACCESSBANK, SHAREBANK, DATABANK, or CODEPAGE.

The ROM attribute must always refer to program memory previously defined using a CODEPAGE directive. The RAM attribute must always refer to data memory previously defined with a ACCESSBANK, DATABANK or SHAREBANK directive.

**EXAMPLE 11-9: LOGICAL SECTION DEFINITION**

To specify that a section whose name is `filter_coeffs` be loaded into the region of program memory named `constants`, the following line should be added to the linker script file:

```
SECTION NAME=filter_coeffs ROM=constants
```

**EXAMPLE 11-10: LOGICAL SECTION USAGE**

To place MPASM source code into a section named `filter_coeffs`, use the following line prior to the desired source code:

```
filter_coeffs CODE
```

11.7 STACK DEFINITION

Only MPLAB C18 requires a software stack be set up. The following statement specifies the stack size and an optional DATABANK where the stack is to be allocated:

```
STACK SIZE=allocSize [RAM=memName]
```

where:

- `allocSize` is the size in bytes of the stack and `memName` is the name of a memory previously declared using a ACCESSBANK, DATABANK or SHAREBANK statement.

**EXAMPLE 11-11: STACK EXAMPLE**

To set the stack size to be 0x20 in the RAM area previously defined by `gpr0`, the following line should be added to the linker script file:

```
STACK SIZE=0x20 RAM=gpr0
```
11.8 CONDITIONAL LINKER STATEMENTS

Generic linker scripts contain conditional statements and macros to accommodate several different methods for linking code:

- Debug vs. Release - MPLAB IDE v8 Only (e.g., for the MPLAB REAL ICE in-circuit emulator)
- C code vs. Assembly
- PIC18 Extended Microcontroller mode vs. Traditional mode

Being able to use one linker script instead of several simplifies application development.

MPLINK linker accepts IF/ELSE type conditional statements in the linker scripts, as discussed below. Several macros are used in support of the conditional statements. Also, certain directives are useful with these conditional statements.

11.8.1 IFDEF/ELSE/FI

Two syntaxes are accepted for these conditional statements:

Conditional 1

```
#IFDEF
...
#FI
```

Conditional 2

```
#IFDEF
...
#ELSE
...
#FI
```

11.8.1.1 #IFDEF

Only one macro is allowed after this directive. If the macro is defined before, the if clause will be parsed by the linker. Complex conditions must be constructed using nested if-else clauses.

11.8.1.2 #ELSE

No macro is allowed after this directive. The else clause will be parsed only in case that the if clause is not.

11.8.1.3 #FI

No macro is allowed after this directive. It identifies the end of if or else clause.
11.8.2 Macros

Depending on what you want to do, macros may be set and used with conditional statements to determine how the linker script will be interpreted by the linker.

If you are using MPLAB X IDE or MPLAB IDE v8, all macros listed in Table 11-1 will automatically be set for you. For MPLAB IDE v8, the only exception is Debug vs. Release, which must be selected under the Build Configuration. See MPLAB IDE documentation for more on how to set the Build Configuration.

If you are using the command line, you must set the macros yourself. The macros that are available for you to set are listed below. On the command line, precede the macro with /u. See Section 11.8.4 “Examples of Use” for some examples.

### TABLE 11-1: LINKER SCRIPT MACROS

<table>
<thead>
<tr>
<th>Macro</th>
<th>Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>_CRUNTIME</td>
<td>Link C code or mixed C code and assembly.</td>
</tr>
<tr>
<td>_EXTENDEDMODE</td>
<td>Use PIC18 extended microcontroller mode.</td>
</tr>
<tr>
<td>_DEBUG</td>
<td>Specify debug mode, as opposed to release or production mode.</td>
</tr>
<tr>
<td>_DEBUGCODESTART</td>
<td>Set the start in program memory of the debug executive. I.e., <code>/u_DEBUGCODESTART=address</code></td>
</tr>
<tr>
<td>_DEBUGCODELEN</td>
<td>Set the size of the debug executive. I.e., <code>/u_DEBUGCODELEN=hexvalue</code></td>
</tr>
<tr>
<td>_DEBUGDATASTART</td>
<td>Set the start of data memory reserved registers. I.e., <code>/u_DEBUGDATASTART=address</code></td>
</tr>
<tr>
<td>_DEBUGDATALEN</td>
<td>Set the amount of data memory reserved. I.e., <code>/u_DEBUGDATALEN=hexvalue</code></td>
</tr>
</tbody>
</table>

11.8.3 Supporting Directives

The #DEFINE directive may be used to define a macro or define it and set its value. The ERROR directive can be used within an if-else clause.

11.8.3.1 #DEFINE

This directive is used in the generic linker scripts to calculate the beginning and end of the debug sections in code and data memory.

Through this directive, you can define an macro and associate a numerical value to it. The value can only be calculated using an ‘+’, ‘-’, ‘/’ or ‘*’ operator over two previously defined macros. Complex calculations must be constructed using combination of multiple #DEFINE directives.

The following syntaxes are accepted:

```
#DEFINE newmacro macro1 + macro2
#DEFINE newmacro macro1 - macro2
#DEFINE newmacro macro1 / macro2
#DEFINE newmacro macro1 * macro2
```

newmacro may not be a previously defined macro.

macro1 and macro2 are previously defined macros. The numerical values associated to these macros will be used to calculate a numerical value for newmacro.

11.8.3.2 ERROR

An ERROR directive has been added to MPLINK linker. This directive allows you to stop the linker and emit the message in front of it on the standard output. The syntax of this directive is:

```
ERROR msg
```
11.8.4 Examples of Use

In these examples, the generic linker script for PIC18F6722 is used to demonstrate how different options for building a project can be selected.

1. Building a C project, Extended mode:
   `mplink.exe /p18F6722 /u_CRUNTIME /u_EXTENDEDMODE <other flags>`

2. Building a C project for PIC18F6722 with debug sections for code at 0x1fd80 and for data at 0xef4, Traditional (non-extended) mode:
   `mplink.exe /p18F6722 /u_CRUNTIME /u_DEBUG /u_DEBUGCODESTART=0x1fd80 /u_DEBUGCODELEN=0x280 /u_DEBUGDATATART=0xef4 /u_DEBUGDATALEN=0xc <other flags>`

3. Building a Assembly project, no debug:
   `mplink.exe /p18f6722 <other flags>`
Generic Linker Script - 18f6722_g.lkr

// File: 18f6722_g.lkr
// Generic linker script for the PIC18F6722 processor

#define _CODEEND _DEBUGCODESTART - 1
#define _CEND _DEBUGCODESTART + _DEBUGCODELEN
#define _DATAEND _DEBUGDATASTART - 1
#define _DEND _DEBUGDATASTART + _DEBUGDATALEN

LIBPATH .

#if defined _CRUNTIME
#if defined _EXTENDEDMODE
FILES c018i_e.o
FILES clib_e.lib
FILES p18f6722_e.lib
#else
FILES c018i.o
FILES clib.lib
FILES p18f6722.lib
#endif
#endif

#if defined _DEBUGCODESTART
CODEPAGE NAME=page START=0x0 END=_CODEEND
CODEPAGE NAME=debug START=_DEBUGCODESTART END=_CEND
#else
CODEPAGE NAME=page START=0x0 END=0x1FFFF
#endif

CODEPAGE NAME=idlocs START=0x200000 END=0x200007 PROTECTED
CODEPAGE NAME=config START=0x300000 END=0x30000D PROTECTED
CODEPAGE NAME=devid START=0x3FFFFE END=0x3FFFFF PROTECTED
CODEPAGE NAME=eedata START=0xF00000 END=0xF003FF PROTECTED

#if defined _EXTENDEDMODE
DATABANK NAME=gpre START=0x0 END=0x5F
#else
ACCESSBANK NAME=accessram START=0x0 END=0x5F
#endif

DATABANK NAME=gpr0 START=0x60 END=0xFF
DATABANK NAME=gpr1 START=0x100 END=0x1FF
DATABANK NAME=gpr2 START=0x200 END=0x2FF
DATABANK NAME=gpr3 START=0x300 END=0x3FF
DATABANK NAME=gpr4 START=0x400 END=0x4FF
DATABANK NAME=gpr5 START=0x500 END=0x5FF
DATABANK NAME=gpr6 START=0x600 END=0x6FF
DATABANK NAME=gpr7 START=0x700 END=0x7FF
DATABANK NAME=gpr8 START=0x800 END=0x8FF
DATABANK NAME=gpr9 START=0x900 END=0x9FF
DATABANK NAME=gpr10 START=0xA00 END=0xAFF
DATABANK NAME=gpr11 START=0xB00 END=0xBFF
DATABANK NAME=gpr12 START=0xC00 END=0xCFF
DATABANK NAME=gpr13 START=0xD00 END=0xFFF

#if defined _DEBUGDATASTART
DATABANK NAME=gpr14 START=0xE00 END=_DATAEND
#endif
DATABANK NAME=dbgspr START=_DEBUGDATASTART END=_DEND PROTECTED

#ELSE //no debug
DATABANK NAME=gpr14 START=0xE00 END=0xEFF
#FI

DATABANK NAME=gpr15 START=0xF00 END=0xF5F
ACCESSBANK NAME=accesssfr START=0xF60 END=0xFFF PROTECTED

#else //no runtime

#IFDEF _CRUNTIME
 SECTION NAME=CONFIG ROM=config
 #IFDEF _DEBUGDATASTART
  STACK SIZE=0x100 RAM=gpr13
 #ELSE
  STACK SIZE=0x100 RAM=gpr14
 #FI
 #FI

#FI
Chapter 12. Linker Processing

12.1 INTRODUCTION

Understanding how MPLINK linker processes files and information can be useful to keep in mind when writing and structuring your application code.

Topics covered in this chapter:
- Linker Processing Overview
- Linker Allocation Algorithm
- Relocation Example
- Initialized Data
- Reserved Section Names

12.2 LINKER PROCESSING OVERVIEW

A linker combines multiple input object modules into a single executable output module. The input object modules may contain relocatable or absolute sections of code or data which the linker will allocate into target memory. The target memory architecture is described in a linker script file. This linker script file provides a flexible mechanism for specifying blocks of target memory and for mapping sections to the specified memory blocks. If the linker cannot find a block of target memory in which to allocate a section, an error is generated. The linker combines like-named input sections into a single output section. The linker allocation algorithm is described in Section 12.3 “Linker Allocation Algorithm”.

Once the linker has allocated all sections from all input modules into target memory, it begins the process of symbol relocation. The symbols defined in each input section have addresses dependent upon the beginning of their sections. The linker adjusts the symbol addresses based upon the ultimate location of their allocated sections.

After the linker has relocated the symbols defined in each input section, it resolves external symbols. The linker attempts to match all external symbol references with a corresponding symbol definition. If any external symbol references do not have a corresponding symbol definition, an attempt is made to locate the corresponding symbol definition in the input library files. If the corresponding symbol definition is not found, an error is generated.

If the resolution of external symbols was successful, the linker then proceeds to patch each section's raw data. Each section contains a list of relocation entries which associate locations in a section's raw data with relocatable symbols. The addresses of the relocatable symbols are patched into the raw data. The process of relocating symbols and patching section is described in Section 12.4 “Relocation Example”.

After the linker has processed all relocation entries, it generates the executable output module.
12.3 LINKER ALLOCATION ALGORITHM

The linker allocates memory areas to allow maximum control over the location of code and data, called "sections," in target memory. There are four kinds of sections that the linker handles:

1. Absolute Assigned
2. Absolute Unassigned
3. Relocatable Assigned
4. Relocatable Unassigned

An absolute section is a section with a fixed (absolute) address that cannot be changed by the linker. A relocatable section is a section that will be placed in memory based on the linker allocation algorithm.

An assigned section is a section that has been assigned a target memory block in the linker script file. An unassigned section is a section that has been left unassigned in this file.

The linker performs allocation of absolute (assigned and unassigned) sections first, relocatable assigned sections next, and relocatable unassigned sections last. The linker also handles stack allocation.

12.3.1 Absolute Allocation

Absolute sections may be assigned to target memory blocks in the linker script file. But, since the absolute section's address is fixed, the linker can only verify that if there is an assigned target memory block for an absolute section, the target memory block has enough space and the absolute section does not overlap other sections. If no target memory block is assigned to an absolute section, the linker tries to find the one for it. If one can not be located, an error is generated. Since absolute sections can only be allocated at a fixed address, assigned and unassigned sections are performed in no particular order.

12.3.2 Relocatable Allocation

Once all absolute sections have been allocated, the linker allocates relocatable assigned sections. For relocatable assigned sections, the linker checks the assigned target memory block to verify that there is space available; otherwise an error is generated. The allocation of relocatable assigned sections occurs in the order in which they were specified in the linker script file.

After all relocatable assigned sections have been allocated, the linker allocates relocatable unassigned sections. The linker starts with the largest relocatable unassigned section and works its way down to the smallest relocatable unassigned section. For each allocation, it chooses the target memory block with the smallest available space that can accommodate the section. By starting with the largest section and choosing the smallest accommodating space, the linker increases the chances of being able to allocate all the relocatable unassigned sections.

12.3.3 Stack Allocation

The stack is not a section but gets allocated along with the sections. The linker script file may or may not assign the stack to a specific target memory block. If the stack is assigned a target memory block, it gets allocated just before the relocatable assigned sections are allocated. If the stack is unassigned, then it gets allocated after the relocatable assigned sections and before the other relocatable unassigned sections are allocated.
12.4 RELOCATION EXAMPLE

The following example illustrates how the linker relocates sections. Suppose the following source code fragment occurred in a file:

```c
/* File: ref.c */
char var1;          /* Line 1 */
void setVar1(void)  /* Line 2 */
{
    var1 = 0xFF;      /* Line 3 */
}
```

Suppose this compiles into the following assembly instructions:

```
0x0000 MOVLW 0xFF
0x0001 MOVLB ?? ; Need to patch with var1's bank
0x0002 MOVWF ?? ; Need to patch with var1's offset
```

When the compiler processes source line 1, it creates a symbol table entry for the identifier `var1` which has the following information:

Symbol[index] => name=var1, value=0, section=.data, class=extern

When the compiler processes source line 3, it generates two relocation entries in the code section for the identifier symbol `var1` since its final address is unknown until link time. The relocation entries have the following information:

Reloc[index] => address=0x0001 symbol=var1 type=bank
Reloc[index] => address=0x0002 symbol=var1 type=offset

Once the linker has placed every section into target memory, the final addresses are known. Once all identifier symbols have their final addresses assigned, the linker must patch all references to these symbols using the relocation entries. In the example above, the updated symbol might now be at location 0x125:

Symbol[index] => name=var1, value=0x125, section=.data, class=extern

If the code section above were relocated to begin at address 0x50, the updated relocation entries would now begin at location 0x51:

Reloc[index] => address=0x0051 symbol=var1 type=bank
Reloc[index] => address=0x0052 symbol=var1 type=offset

The linker will step through the relocation entries and patch their corresponding sections. The final assembly equivalent output for the above example would be:

```
0x0050 MOVLW 0xFF
0x0051 MOVLB 0x1   ; Patched with var1's bank
0x0052 MOVWF 0x25  ; Patched with var1's offset
```
12.5 INITIALIZED DATA

MPLINK linker performs special processing for input sections with initialized data. Initialized data sections contain initial values (initializers) for the variables and constants defined within them. Because the variables and constants within an initialized data section reside in RAM, their data must be stored in nonvolatile program memory (ROM). For each initialized data section, the linker creates a section in program memory. The data is moved by initializing code (supplied with MPLAB C18 and MPASM assembler) to the proper RAM location(s) at start-up.

The names of the initializer sections created by the linker are the same as the initialized data sections with a _i appended. For example, if an input object module contains an initialized data section named .idata_main.o the linker will create a section in program memory with the name .idata_main.o_i which contains the data.

In addition to creating initializer sections, the linker creates a section named .cinit in program memory. The .cinit section contains a table with entries for each initialized data section. Each entry is a triple which specifies where in program memory the initializer section begins, where in data memory the initialized data section begins, and how many bytes are in the initialized data section. The boot code accesses this table and copies the data from ROM to RAM.

12.6 RESERVED SECTION NAMES

Both the MPASM assembler and the MPLAB C18 C compiler have reserved names for certain types of sections. Please see the documentation for these tools to ensure that you do not use a reserved name for your own section. The linker will be unable to generate the application if there is a section naming conflict.
Chapter 13. Sample Applications

13.1 INTRODUCTION

You can learn the basics of how to use MPLINK linker from the four sample applications listed below. These sample applications can be used as templates for your own application.

- How to Build the Sample Applications
- Sample Application 1 - Templates and Linker Scripts
  - How to find and use template files
  - When to modify the generic linker script file
- Sample Application 2 - Placing Code and Setting Config Bits
  - How to place program code in different memory regions
  - How to place data tables in ROM memory
  - How to set configuration bits in C
- Sample Application 3 - Using a Boot Loader
  - How to partition memory for a boot loader
  - How to compile code that will be loaded into external RAM and executed
- Sample Application 4 - Configuring External Memory
  - How to create new linker script memory section
  - How to declare external memory through #pragma code directive
  - How to access external memories using C pointers

13.2 HOW TO BUILD THE SAMPLE APPLICATIONS

To build the sample applications, you will need the MPASM assembler, the MPLINK linker and, for some sample applications, the MPLAB C compiler for PIC18 MCUs (formerly MPLAB C18) installed on your PC. The assembler and linker are automatically installed with MPLAB X IDE and MPLAB IDE v8, or may be acquired separately on the Microchip website or the C compiler CD-ROM. A free demo (student) version of the C compiler may be obtained on the Microchip website. The full C compiler must be purchased separately.

By default, the tool executables are located as specified in the tables below.

**TABLE 13-1: ASSEMBLY CODE EXECUTABLES AND PATHS – MPLAB IDE V8**

<table>
<thead>
<tr>
<th>Executables</th>
<th>Default Paths to Executables</th>
</tr>
</thead>
<tbody>
<tr>
<td>mpasmwin.exe</td>
<td>C:\Program Files\Microchip\MPASM Suite</td>
</tr>
<tr>
<td>mplink.exe</td>
<td>C:\Program Files\Microchip\MPASM Suite</td>
</tr>
</tbody>
</table>

**TABLE 13-2: ASSEMBLY CODE EXECUTABLES AND PATHS – MPLAB X IDE**

<table>
<thead>
<tr>
<th>Executables</th>
<th>Default Paths to Executables</th>
</tr>
</thead>
<tbody>
<tr>
<td>mpasmx.exe</td>
<td>C:\Program Files\Microchip\MPLABX\mpasmx</td>
</tr>
<tr>
<td>mplink.exe</td>
<td>C:\Program Files\Microchip\MPLABX\mpasmx</td>
</tr>
</tbody>
</table>
To ensure the IDE sees the installed tools:

- For MPLAB X IDE, go to Tools>Options, Embedded button, Build Tools tab to check the paths.
- For MPLAB IDE v8, go to Project>Set Language Tool Locations, “Microchip MPASM Toolsuite”, “Executables”, and check the tool paths.

To use the examples, see:

- Using MPLAB X IDE
- Using MPLAB IDE v8
- Using the Command Line

13.2.1 Using MPLAB X IDE

MPLAB X IDE provides a GUI method of developing your code.

13.2.1.1 BUILDING APPLICATIONS

To build an application with MPLAB X IDE:

1. Use the Project wizard to create a project (File>New Project).
   a) **Choose Project**: Select “Embedded” for the category and “C/ASM Stand-alone Project” for the project. Click Next> to continue.
   b) **Select Device**: Select the device. Click Next> to continue.
   c) **Select Header**: Select the header for this device if used.
   d) **Select Tool**: Choose a development tool from the list. Tool support for the selected device is shown as a colored circle next to the tool. Mouse over the circle to see the support as text. Click Next> to continue.
   e) **Select Compiler**: For assembly applications, select “MPASMX”. For C code applications or combined C code and assembly applications, select “C18”. Click Next> to continue.
   f) **Select Project Name and Folder**: Enter a project name and then select a location for the project folder. Click Finish to complete the project creation and setup.

2. Once the project is created, add the sample files to your project, e.g., source1.c, source2.asm and (if customized) script.lkr.

3. Right click on the project name in the project tree and then select “Properties” to set up language tool options.
   - For MPLAB C compiler for PIC18 MCUs sample applications, click “MCC18” and enter CompilerInstallationPath\lib under “Include Path”, where CompilerInstallationPath is the location where the C compiler is installed on your system.
   - Select “MPLINK” and then enter a map file name next to “Generate map file”.

---

**TABLE 13-3: C CODE EXECUTABLES AND PATHS\(^{1}\)**

<table>
<thead>
<tr>
<th>Executables</th>
<th>Default Paths to Executables</th>
</tr>
</thead>
<tbody>
<tr>
<td>mcc18.exe</td>
<td>C:\mcc18\bin</td>
</tr>
<tr>
<td>mpasmwin.exe</td>
<td>C:\mcc18\mpasm</td>
</tr>
<tr>
<td>mplink.exe(^{2})</td>
<td>C:\mcc18\bin</td>
</tr>
</tbody>
</table>

**Note 1:** Future C compiler versions may be located at:
C:\Program Files\Microchip\MPLAB C18.

**2:** Use mplink.exe and not _mplink.exe. The executable file _mplink.exe is not a stand-alone program.
4. Right click on the project name in the project tree and select “Build” to build the application. If your project contains a single assembly file with no linker script file, you will be asked if you want to build “absolute” code or “relocatable” code. The sample applications should be built as relocatable code.

5. If the application fails to build, check that the environment variables discussed in the next section were set correctly during tool installation.

6. If the application build successfully, use **Debug>Debug Project** to run and debug your application or **Run>Run Project** to run your application. To program it into a device, click the “Program Target Project” button on the debug toolbar.

### 13.2.2 Using MPLAB IDE v8

MPLAB IDE provides a GUI method of developing your code.

#### 13.2.2.1 BUILDING APPLICATIONS

To build an application with MPLAB IDE:

1. Use the Project Wizard under the Project menu to create a project.
   - Select the device specified in the sample application.
   - For assembly applications, select the “Microchip MPASM Toolsuite” as the active toolsuite. For C code applications or combined C code and assembly applications, select the “Microchip C18 Toolsuite” as the active toolsuite. Make sure the executable paths are correct, as per Table 13-1 or Table 13-3, respectively.
   - Name the project and place it in its own folder.
   - Add the sample files to your project, e.g., `source1.c`, `source2.asm` and (if customized) `script.lkr`.

2. Once the project is created, select **Project>Build Options>Project** to open the Build Options for Project dialog.
   - For MPLAB C compiler for PIC18 MCUs sample applications, click the **Directories** tab and enter `CompilerInstallationPath\lib` under “Library Path”, where `CompilerInstallationPath` is the location where the C compiler is installed on your system.
   - Click the **MPLINK Linker** tab and then click the “Generate map file” checkbox to select it.

3. Select from the Build Configuration list (see below) whether you will be developing your application (Debug) or are ready to program it into a device (Release).

   ![Build Configuration](image)

   Setting this control will set the value for the macro `_DEBUG` found in the linker script file. Other macros in the linker script (e.g., `_CRUNTIME`) are automatically set by MPLAB IDE.

4. Select **Project>Build All** to build the application. If your project contains a single assembly file with no linker script file, you will be asked if you want to build “absolute” code or “relocatable” code. The sample applications should be built as relocatable code.

5. If the application fails to build, check that the environment variables discussed in the next section were set correctly during tool installation.
13.2.2.2 EXAMPLE

As an example, consider Sample Application 3, C code mixed boot loader/application.

To build an application with MPLAB IDE:

1. Use the Project Wizard under the Project menu to create a project.
   - Select PIC18F8722 as the device.
   - Select the “Microchip C18 Toolsuite” as the active toolsuite. Make sure the executable paths are correct, as per Table 13-3.
   - Name the project and place it in its own folder.
   - Add the sample files to your project, i.e., c018i_mod.c, mixed.asm and mixed.lkr.
   - View the Project window (View>Project) to see your project files.

2. Once the project is created, select Project>Build Options>Project to open the Build Options for Project dialog.
   - Click the Directories tab and enter C:\mcc18\lib under “Library Path”.
   - Click the MPLINK Linker tab and then click the “Generate map file” checkbox to select it.

3. Select “Debug” from the Build Configuration list on the Project Manager toolbar.

4. Select Project>Build All to build the application.
### 13.2.3 Using the Command Line

The command line provides a platform independent method to develop your code.

#### 13.2.3.1 BUILDING APPLICATIONS

To build an application on the command line:

1. The listed Environment Variables need to be set as specified. To set these variables, go to the Command prompt and type `SET` to view and set the variables.
   - In Windows OS, go to **Start>Settings>Control Panel>System, Advanced** tab, **Environment Variables** button. View and edit variables here.
   - **PATH** - Make sure the executables can be found, as per Table 13-1 and Table 13-3.
   - **MCC_INCLUDE** - If MPLAB C Compiler for PIC18 MCUs is used, this should point to the \h subdirectory of the C compiler installation directory.

2. For C code compilation, use the following:
   ```
   mcc18 -pdevice source1.c
   ```
   where **device** is the device representation (e.g., 18F8772 for the PIC18F8722 device) and **source1.c** is the C code source file example. For multiple files, leave a space between each file.

3. For MPASM assembly (with MPLAB X IDE), use the following:
   - **Windows OS:** `mpasmx /p device source2.asm`
   - **Linux or Mac OS:** `mpasmx -p device source2.asm`
   where **device** is the device representation and **source2.asm** is the assembly code source file example. For multiple files, leave a space between each file.

4. For MPLINK linking of files to create an application, use the following. The example is for Windows OS and is shown on two lines, but you should type on one.
   ```
   mplink /p device /u_macro source1.o source2.o /l c:\mcc18\lib /m app.map
   ```
   or (for a modified linker script):
   ```
   mplink modified.lkr /p device /u_macro source1.o source2.o /l c:\mcc18\lib /m app.map
   ```
   where:

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>device</strong></td>
<td>The device representation.</td>
</tr>
<tr>
<td><strong>modified.lkr</strong></td>
<td>The modified linker script file.</td>
</tr>
<tr>
<td><strong>_macro</strong></td>
<td>A conditional macro (e.g., _CRUNTIME). For more details, see Section 11.8 “Conditional Linker Statements”.</td>
</tr>
<tr>
<td><strong>source1.o</strong></td>
<td>A C code object file.</td>
</tr>
<tr>
<td><strong>source2.o</strong></td>
<td>An assembly code object file.</td>
</tr>
<tr>
<td><strong>c:\mcc18\lib</strong></td>
<td>The library path, only needed if the MPLAB C compiler for PIC18 MCUs was used, as here to generate source1.o from source1.c.</td>
</tr>
<tr>
<td><strong>app.map</strong></td>
<td>The map file.</td>
</tr>
</tbody>
</table>
13.2.3.2 EXAMPLE

As an example, consider Sample Application 3, C code mixed boot loader/application. To build an application on the command line:

1. The listed Environment Variables need to be set as specified.
   a) PATH - Make sure the executables can be found, as per Table 13-3.
   b) MCC_INCLUDE - Point to the c:\mcc18\h subdirectory.

2. For C code compilation, use the following:
   mcc18 -p18F8722 c018i_mod.c mixed.c

3. For MPLINK linking of files to create an application, use the following. The example is for Windows OS and is shown on two lines, but you should type on one.
   mplink mixed.lkr /pdevice /u_CRUNTIME c018i_mod.o mixed.o
   /l c:\mcc18\lib /m mixed.map

If you want to link for debug mode or PIC18 extended mode, see Section 11.8 “Conditional Linker Statements”.
13.3 SAMPLE APPLICATION 1 - TEMPLATES AND LINKER SCRIPTS

In the MPLAB X IDE or MPLAB IDE v8 installation, assembly source code templates and generic linker script files are provided for most devices supported by the IDE. The source code templates give you a starting point from which to begin coding. The generic linker scripts are used automatically by the linker to simplify application development. Or you may modify a linker script and then manually add it on the linker command line or to the project.

This first general example will discuss templates and linker scripts.

13.3.1 Locating Templates and Linker Script Files

For MPLAB X IDE or MPLAB IDE v8 installed in the default location, source code templates may be found at:

C:\Program Files\Microchip\MPASM Suite\Template

in the following subdirectories:

- **Code** - Contains absolute assembly code examples by device
- **Object** - Contains relocatable assembly code examples by device

The relocatable source code template `18F8722TMPO.ASM` for the PIC18F8722 may be found in the **Object** directory. This template provides oscillator setup, example variable and EEPROM setup, reset and interrupt handling routines, and a section `main` for application code.

For MPLAB X IDE installed in the default location, the generic linker script files may be found at:

C:\Program Files\Microchip\MPASM Suite\LKR

The generic linker script file for the PIC18F8722 would be `18f8722_g.lkr`. This file defines initialization files, program code sections, GPR sections, and access memory sections. These definitions are grouped based on debugger or programmer usage, and regular or extended memory usage.

Program memory sections specified by the template code and linker script are compared below.

**TABLE 13-4: PROGRAM MEMORY MAP - PIC18F8722**

<table>
<thead>
<tr>
<th>Program Memory Address</th>
<th>Linker Script Section (Not debug or extended)</th>
<th>Template Source Code Section</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x0000 0x0007</td>
<td>page - ROM code space</td>
<td>RESET_VECTOR - Reset vector</td>
</tr>
<tr>
<td>0x0008 0x0017</td>
<td></td>
<td>HI_INT_VECTOR - High priority interrupt vector</td>
</tr>
<tr>
<td>0x0018</td>
<td></td>
<td>LOW_INT VECTOR - Low priority interrupt vector</td>
</tr>
<tr>
<td>0x0019 0x1FFFF</td>
<td></td>
<td>High_Int - High priority interrupt handler Low_Int - Low priority interrupt handler Main - Main application code</td>
</tr>
<tr>
<td>0x200000 0x200007</td>
<td>idlocs - ID locations</td>
<td></td>
</tr>
<tr>
<td>0x300000 0x30000D</td>
<td>config - Configuration bits</td>
<td>CONFIG - Configuration settings</td>
</tr>
<tr>
<td>0x3FFFFFF 0x3FFFFFF</td>
<td>devid - Device ID</td>
<td></td>
</tr>
<tr>
<td>0xF00000 0xF003FF</td>
<td>eedata - EEPROM data</td>
<td>DATA_EEPROM - Data EEPROM</td>
</tr>
</tbody>
</table>
13.3.2 Modifying Templates and Linker Script Files

For this sample application, assembly code is added to the template but the generic linker script is not edited.

In general, you will modify templates to create your own application code but you should not need to modify the generic linker script file. Still, there are reasons why you might want to customize a linker script, as shown in the other sample applications.

In addition, a case where you might want to modify the linker script is when you want to use a C code data object that is larger than 256 bytes, such as a large array. This application is discussed in the *MPLAB C Compiler for PIC18 MCUs Getting Started* (DS51295), FAQ-10.

**Modified 18F8722TMPO.ASM**

In the template, add the following udata section:

```asm
; Oscillator Selection:
CONFIG OSC = LP

; Array variables
array UDATA
element1 RES 1
element2 RES 1
element3 RES 1
element4 RES 1
element5 RES 2

; Variable definitions

; Array variables
array UDATA
element1 RES 1
element2 RES 1
element3 RES 1
element4 RES 1
element5 RES 2

; Variable definitions
```

Then, in the main code portion, add the following program code:

```asm
; Start of main program
; The main program code is placed here.

Main:

; *** main code goes here ***

  banksel element1 ; Select element1 bank
  movlw 0x55 ; Move literal
  movwf element1,1 ; to element1
  movff element1,element2 ; Move element1
  rrcf element2,1,1 ; to element2, right shift
  movff element2,WREG ; to element2, move to WREG
  movwf element3 ; Move WREG to element3,
  rrcf element3,1,1 ; right shift and
  movff element3,element4 ; move to element4
  rrcf element4,1,1 ; Right shift element4
  movff element4,element5 ; and move to element5 low byte
  rrcf element4,1,1 ; Right shift element4
  movff element4,element5+1 ; again and move to element5 high byte

Loop
  goto Loop

; End of program

END
```
13.3.3 Building the Application

To build the application, see Section 13.2 “How to Build the Sample Applications”. Then, to continue development with the IDE, you could place the element variables in a Watch(es) window to see their values, remembering to change `element5` to a 16-bit value (Properties dialog, Watch Properties tab).
13.4 SAMPLE APPLICATION 2 - PLACING CODE AND SETTING CONFIG BITS

This example is for the PIC18F8720 in extended microcontroller mode.

The file `eeprom2.asm` places interrupt handling code at 0x20000 (external memory.)
The assembly code directive, `INTHAND CODE`, places the code that follows into the
`INTHAND` section. The modified linker script file (`eprom.lkr`) maps the `INTHAND`
section to the `CODE` region that begins at 0x20000.

The file `eeprom1.c` has a 0x1000 element data table in program memory in the same
code page with the interrupt handlers. The data table is defined in C using the `#pragma
romdata` directive to place the table in a section called `DATTBL`. The modified linker
script file maps the `DATTBL` section to the `CODE` region that begins at 0x20000.

Additionally, configuration bits are set in C using the `#pragma config` directive.
The main function in the C file is placed in the default `CODE` section because there is
no section directive explicitly assigned.

For additional information, you may wish to reference:
• PIC18F8720 Device Data Sheet (DS39609)
• MPLAB C18 C Compiler User’s Guide (DS51288)
• External Memory Interfacing Techniques for the PIC18F8XXX (AN869)

Program memory sections specified by the code and linker script are compared below.
Specific sections highlighted in this sample application (SA2) are noted.

<table>
<thead>
<tr>
<th>TABLE 13-5: PROGRAM MEMORY MAP - PIC18F8720</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SA2</strong></td>
</tr>
<tr>
<td>---------</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>→</td>
</tr>
<tr>
<td></td>
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<td></td>
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<tr>
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<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>
### 13.4.1 C Source Code - eeprom1.c

/* eeprom1.c */

#include <p18f8720.h>

#define DATA_SIZE 0x1000

/* Data Table Setup */

#pragma romdata DATTBL // Put following romdata into section DATTBL
unsigned rom data[DATA_SIZE];
#pragma romdata // Set back to default romdata section

/* Configuration Bits Setup
The #pragma config directive specifies the processor-specific
configuration settings (i.e., configuration bits) to be used by
the application. For more on this directive, see the "MPLAB C18
C Compiler User's Guide" (DS51288). */

#pragma config OSCS = ON, OSC = LP // Enable OSC switching and LP
#pragma config PWRT = ON           // Enable POR
#pragma config BOR = ON, BORV = 42 // Enable BOR at 4.2v
#pragma config WDT = OFF           // Disable WDT
#pragma config MODE = EM           // Use Extended MCU mode

/* Main application code for default CODE section */

void main( void )
{
    while( 1 )
    {
    } // end while
} // end main

### 13.4.2 Assembler Source Code - eeprom2.asm

; eeprom2.asm

    list p=18f8720

    #include p18f8720.inc

INTHAND code

; place interrupt handling code in here

end
13.4.3 Linker Script - eeprom.lkr

The linker script file eeprom.lkr is a modified version of the generic linker script file 18f8720_g.lkr. Modify the generic linker script as follows to create eeprom.lkr.

Add EEPROM codepage information:

```assembly
#IFDEF _DEBUGCODESTART
CODEPAGE NAME=page START=0x0 END=_CODEEND
CODEPAGE NAME=debug START=_DEBUGCODESTART END=_CEND       PROTECTED
#ELSE
CODEPAGE NAME=page START=0x0 END=0x1FFFF
#FI

//EEPROM codepage
CODEPAGE NAME=eeprom START=0x20000 END=0x1FFFFF       PROTECTED
CODEPAGE NAME=idlocs START=0x200000 END=0x200007       PROTECTED
CODEPAGE NAME=config START=0x300000 END=0x30000D       PROTECTED
CODEPAGE NAME=devid START=0x3FFFFE END=0x3FFFFF       PROTECTED
CODEPAGE NAME=eedata START=0xF00000 END=0xF003FF       PROTECTED

Then add section information for the EEPROM sections:

#IFDEF _CRUNTIME
SECTION NAME=CONFIG ROM=config
SECTION NAME=INTHAND ROM=eeprom // Interrupt handlers
SECTION NAME=DATTBL ROM=eeprom // Data tables
#IFDEF _DEBUGDATASTART
STACK SIZE=0x100 RAM=gpr13
#ELSE
STACK SIZE=0x100 RAM=gpr14
#FI
#FI
```

13.4.4 Building the Application

To build the application, see Section 13.2 “How to Build the Sample Applications”. Then, to continue development with MPLAB IDE v8:

**Note:** MPLAB X IDE does not yet support External Memory views.

1. Though the configuration bits in code set the microcontroller mode to external, you must tell the IDE the range of external memory you wish to use. Select **Configure>External Memory**. In the dialog, click “Use External Memory” and enter “0x1FFFFF” as the “Address Range End”. Click **OK**.
2. Select **Project>Build All** to build the application again.

13.4.5 Absolute Method

Instead of adding SECTION lines to the linker script, you could add the absolute address in code, i.e.,

```
INTHAND code 0x20000
```

However, if you need to place additional code in the CODEPAGE eeprom area, you would need to know the disassembly code length of the interrupt handler to determine the absolute address at which to place this additional code. Also, if you edit the interrupt handler code, you would need to remember to change the address of the additional code.

Therefore, it is usually easier not to place code absolutely but to allow the linker script to place code for you.
13.5 SAMPLE APPLICATION 3 - USING A BOOT LOADER

A boot loader is a special program that, when programmed into the target PIC microcontroller, is responsible for downloading and programming relocatable application code into the same target PIC microcontroller. The relocatable application or "user" code is typically transferred to the boot loader through serial communications, such as RS232.

13.5.1 C Compiler Usage

This section discusses how to use the MPLAB C Compiler for PIC18 MCUs (the C compiler) when developing bootloader and related application code.

There are three examples showing how to modify the C compiler linker scripts and how to use the #pragma code directive in the source code for the C compiler boot loader project. To better understand how the code corresponds to locations in device program memory, see 13.5.1.1 “C Compiler Memory Map”.

Example 1 shows how to configure the C compiler linker script and suggests how to use code directives for the C compiler boot loader. See 13.5.1.2 “Example 1: C Compiler Boot Loader”.

Example 2 shows the C compiler linker script configuration and suggested code directives for the C compiler application targeted for a microcontroller that is running the C compiler boot loader. See 13.5.1.3 “Example 2: C Compiler Application”.

Example 3 is a mixed language example using the C compiler application targeted for a microcontroller, such as the PIC18F8720 with a limited boot block size, running an MPASM boot loader. A boot loader written in C code will typically require more program memory than a boot loader written in assembly and therefore requires a microcontroller with a larger boot block region, such as the PIC18F8722. See 13.5.1.4 “Example 3: Mixed Language Boot Loader/Application”.

Boot loader and application code written for the C compiler must use the C compiler linker scripts to command the linker to place the compiled C source code into appropriate program memory sections. Typically, boot loader code is compiled and linked for a destination in the "boot" section of the target microcontroller's program memory. The "application" code is compiled and linked for a destination inside the user section of program memory.

To build the C compiler sample application, refer to Section 13.2 “How to Build the Sample Applications”.

13.5.1.1 C COMPILER MEMORY MAP

The first two C compiler boot loader examples are demonstrated using a PIC18F8722 which offers a configurable boot block size of 2K, 4K or 8K bytes. The remaining program memory is available for the relocatable application code and data tables. For these two examples it is assumed the boot block is configured for 2K bytes and requires modification to the C compiler linker script file in order to accommodate the selected boot block size.

The third example, a mix of an MPASM assembler boot loader and C compiler source code, uses the PIC18F8720. For the corresponding memory map, see Section 13.5.2.1 “Assembler Memory Map”.

For the first two examples, program memory sections specified by the code and linker script are compared below. Specific sections highlighted in these sample application (SA3) examples are noted.
TABLE 13-6: PROGRAM MEMORY MAP - PIC18F8722

<table>
<thead>
<tr>
<th>SA3</th>
<th>Program Memory Address</th>
<th>Linker Script Section (Not debug or extended)</th>
<th>Source Code Section</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0x000000</td>
<td>vectors - Reset, Interrupts</td>
<td>Vectors, IntH, IntL</td>
</tr>
<tr>
<td></td>
<td>0x000029</td>
<td></td>
<td></td>
</tr>
<tr>
<td>→</td>
<td>0x00007FF</td>
<td>boot - Boot Loader</td>
<td>Boot</td>
</tr>
<tr>
<td></td>
<td>0x000800</td>
<td>page - Remapped Vectors and User Code</td>
<td>R_vectors, R_IntH, R_IntL, Boot Loader Updated Application Code</td>
</tr>
<tr>
<td></td>
<td>0x1FFFFF</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

13.5.1.2 EXAMPLE 1: C COMPILER BOOT LOADER

This example shows a section of linker script modified to accommodate the boot loader code.

Boot Loader Linker Script

The partial C compiler linker script file shown below demonstrates the modifications required to the generic linker script when building the C compiler boot loader source code files. The MPLINK linker will use this configuration to link the compiled source code into the boot program memory region starting at 002Ah. The vector locations will be specified in the boot loader source code using the appropriate #pragma code directives.

```c
CODEPAGE NAME=vectors START=0x0 END=0x29
CODEPAGE NAME=boot START=0x2A END=0x7FF

#ifdef _DEBUGCODESTART
  CODEPAGE NAME=page START=0x800 END=CODEEND
  CODEPAGE NAME=debug START=DEBUGCODESTART END=CEND PROTECTED
#else
  CODEPAGE NAME=page START=0x800 END=0x1FFFF
#endif

CODEPAGE NAME=idlocs START=0x200000 END=0x200007 PROTECTED
CODEPAGE NAME=config START=0x300000 END=0x30000D PROTECTED
CODEPAGE NAME=devid START=0x3FFFFE END=0x3FFFFF PROTECTED
CODEPAGE NAME=eedata START=0xF00000 END=0xF003FF
```
Boot Loader Source Code

The C compiler boot loader code can be composed of one or more aggregate relocatable C source files that are compiled and linked together during build time. In this example, the source code file uses the #pragma code directive to instruct the linker to place the interrupt vectors at memory locations 0008h and 0018h. A "main" function must be included, as this is called from the C compiler startup code that is added during link process.

```c
#include <p18cxxx.h>
#define RM_RESET_VECTOR 0x000800 // define relocated vector addresses
#define RM_HIGH_INTERRUPT_VECTOR 0x000808
#define RM_LOW_INTERRUPT_VECTOR 0x000818

/** VECTOR MAPPING ******************************************/
#pragma code _HIGH_INTERRUPT_VECTOR = 0x000008
void _high_ISR (void)
{   
   _asm goto RM_HIGH_INTERRUPT_VECTOR _endasm
}

#pragma code _LOW_INTERRUPT_VECTOR = 0x000018
void _low_ISR (void)
{   
   _asm goto RM_LOW_INTERRUPT_VECTOR _endasm
}
/** BOOT LOADER CODE ******************************************/
#pragma code
void main(void)
{   
   //Check Bootload Mode Entry Condition
   if(PORTBbits.RB4 == 1)      // If not pressed, User Mode
   {   
      _asm goto RM_RESET_VECTOR _endasm
   }   
   //Else continue with bootloader code here ...
}
#pragma code user = RM_RESET_VECTOR   // This address defined as 0x800 above
   // or can be defined in header file
/** END OF BOOT LOADER ******************************************/
```
13.5.1.3  EXAMPLE 2: C COMPILER APPLICATION

This example shows a section of linker script modified to accommodate the application code.

Application Linker Script

The boot loader linker script file may be used when building the C compiler application source code files. The linker will use this configuration to link the compiled source code into the page1 program memory region above the protected boot loader region.

Application Source Code

The C compiler application code can be composed of one or more aggregate relocatable C source files that are compiled and linked together during build time. In the code snippet shown below, the source code file uses the #pragma code directive to instruct the linker to place the relocated reset and interrupt vectors at the appropriate memory locations. A main function must be included, as this is called from the C compiler startup code that is added during the link process. The linker automatically includes this C compiler initialization code provided in file c018i.c and must be accessed by the application code through an "in-line" assembly goto instruction shown below.

```c
#include <p18cxxx.h>

/** VECTOR MAPPING *******************************************************/
extern void _startup (void);  // See c018i.c in your C18 compiler dir

#pragma code _RESET_INTERRUPT_VECTOR = 0x000800
void _reset (void)
{
    _asm goto _startup _endasm
}

#pragma code _HIGH_INTERRUPT_VECTOR = 0x000808
void _high_ISR (void)
{
    ;
}

#pragma code _LOW_INTERRUPT_VECTOR = 0x000818
void _low_ISR (void)
{
    ;
}

/** APPLICATION CODE***************************************************/
#pragma code
void main(void)
{
    while(1)
    {
        ;  // Main application code here
    }
}
/** END OF APPLICATION ***************************************************/
```
13.5.1.4  EXAMPLE 3: MIXED LANGUAGE BOOT LOADER/APPLICATION

This example shows the linker script, startup code, and source code modifications needed to accommodate a mixed language application which employs a boot loader.

Mixed Language Linker Script

The partial C compiler linker script file shown below demonstrates the required modifications when building the mixed assembly boot loader/C code application. The linker will use this configuration to link the compiled source code into the user program memory region above the protected boot loader. In this linker script example, the C compiler start-up file `c018i.o` has been remarked out, preventing the linker from linking this object file to the project. Instead it will use the modified file in the next section.

```c
#IFDEF _CRUNTIME
#IFDEF _EXTENDEDMODE
FILES c018i_e.o
FILES clib_e.lib
FILES p18f8722_e.lib

#ELSE
// FILES c018i.o <-- Note this line to be ignored by linker
FILES clib.lib
FILES p18f8722.lib
#FI
#FI
CODEPAGE   NAME=vectors    START=0x0               END=0x29
CODEPAGE   NAME=boot       START=0x2A              END=0x1FF

#IFDEF _DEBUGCODESTART
CODEPAGE   NAME=page       START=0x200             END=_CODEEND          PROTECTED
CODEPAGE   NAME=debug      START=_DEBUGCODESTART   END=_CEND

#ELSE
CODEPAGE   NAME=page       START=0x200             END=0x1FFFF

#FI

Mixed Language c018i.c Modifications

For a typical C compiler application, the `c018i.c` startup code normally specifies program memory location 0000h as the entry section and is linked into the project by the linker when specified in the MPLAB C18 linker script. Since the C compiler application code in this example has been relocated to program memory address 0200h because of the boot loader, it is necessary to change the code section `ENTRY_SCN` definition in `c018i.c` file as shown below and to add the `c018i.c` source file to the project for recompiling and linking.

```c
#pragma code_entry_scn=0x000200
void
_entry (void)
{
  _asm goto _startup _endasm
}
```
### Mixed Language Source Code

The C compiler application code can be composed of one or more relocatable C source files that are compiled and linked together during build time. In the code snippet shown below, the source code file uses the `#pragma code` directive to instruct the linker to place the relocated reset and interrupt vectors at the appropriate memory locations. A `main` function must be included, as this is called from the C compiler startup code that is added during the link process.

```c
#include <p18cxxx.h>

/** VECTOR MAPPING ******************************************/

#pragma code _HIGH_INTERRUPT_VECTOR = 0x000208
void _high_ISR (void)
{
    ; // ISR goes here
}

#pragma code _LOW_INTERRUPT_VECTOR = 0x000218
void _low_ISR (void)
{
    ; // ISR goes here
}

/** APPLICATION CODE******************************************/
#pragma code
void main(void)
{
    while(1)
    {
        ; // Main application code here
    }
}

/** END OF APPLICATION ******************************************/
```

### 13.5.2 Assembler Usage

This section discusses how to use the MPASM assembler (the assembler) when developing bootloader and related application code.

There are three assembler examples showing suggested linker script modifications and appropriate source code directive usage for a boot loader and application project. To better understand how the code corresponds to locations in device program memory, see Section 13.5.2.1 “Assembler Memory Map”.

The modified linker script file provided in this example is designed to support all three of the following examples. See Section 13.5.2.2 “Assembler Linker Script”.

Example 1 shows an assembler boot loader. See Section 13.5.2.3 “Example 1: Assembler Boot Loader Source Code”.

Example 2 shows a multiple module relocatable assembler application. See Section 13.5.2.4 “Example 2: Assembler Application Source Code”.

Example 3 incorporates both the assembler boot loader and multiple module relocatable assembler application as a single program memory image. See Section 13.5.2.5 “Example 3: Assembler Boot Loader/Application Source Code”.

To build the assembler sample application, refer to Section 13.2 “How to Build the Sample Applications”. 
13.5.2.1 ASSEMBLER MEMORY MAP

The boot loader typically resides in the "boot block" region of the PIC18F8720's program memory, which is the first 512 bytes of memory, from location 0000h to 01FFh. The remaining program memory, starting at location 0200h, is available for relocatable application code and data lookup tables. Other PIC18F microcontrollers offer larger boot block regions and will require slightly different linker script modifications than what is represented in this example. However, the concepts shown here can be migrated to these other PIC microcontrollers.

For this example, program memory sections specified by the code and linker script are compared below. Specific sections highlighted in this sample application (SA3) example are noted.

### TABLE 13-7: PROGRAM MEMORY MAP - PIC18F8720

<table>
<thead>
<tr>
<th>SA3</th>
<th>Program Memory Address</th>
<th>Linker Script Section</th>
<th>Source Code Section</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0x000000 0x000029</td>
<td>vectors - Reset, Interrupts</td>
<td>Vectors, IntH, IntL</td>
</tr>
<tr>
<td>→</td>
<td>0x00002A 0x0001FF</td>
<td>boot_code - Boot Loader</td>
<td>Boot</td>
</tr>
<tr>
<td></td>
<td>0x000200 0x1FFFFF</td>
<td>page - Remapped Vectors, User Code, Data Tables</td>
<td>R_vectors, R_IntH, R_IntL, user_code</td>
</tr>
</tbody>
</table>

13.5.2.2 ASSEMBLER LINKER SCRIPT

To protect the boot block and vector memory regions, the linker script file uses modified CODEPAGE directives to establish these memory regions and uses the PROTECTED modifier to prevent the linker from assigning any relocatable code that is not explicitly assigned to these regions.

The section of modified generic linker script below shows how the linker can assign the relocatable application code to the user code memory region (page) that is not protected. The other program memory regions can only be populated if the CODE directive used in the source files specifies placement of code within these protected memory regions. This linker script file is designed to accommodate all three boot loader design considerations demonstrated in this chapter.

**boot.lkr** - The linker script file for boot loader and application code example projects.

```assembly
CODEPAGE  NAME=vectors  START=0x0  END=0x29  PROTECTED
CODEPAGE  NAME=boot    START=0x2A  END=0x1FF  PROTECTED

#if _DEBUGCODESTART
CODEPAGE  NAME=page    START=0x200  END=_CODEEND
CODEPAGE  NAME=debug   START=_DEBUGCODESTART  END=_CEND  PROTECTED
#else
CODEPAGE  NAME=page    START=0x200  END=0x1FFFF
#endif

CODEPAGE  NAME=idlocs  START=0x200000  END=0x200007  PROTECTED
CODEPAGE  NAME=config  START=0x300000  END=0x30000D  PROTECTED
CODEPAGE  NAME=devid   START=0x3FFFFE  END=0x3FFFFF  PROTECTED
CODEPAGE  NAME=eedata  START=0xF00000  END=0xF003FF
```
13.5.2.3  EXAMPLE 1: ASSEMBLER BOOT LOADER SOURCE CODE

In this example, the boot loader is a single source file that will not be linked with any other source code at build time. The `CODE` directives used in the boot loader source code instructs the linker to place the reset and interrupt vectors at their appropriate program memory locations for the PIC microcontroller and to place the starting location of the boot loader executable code just above this region starting at location 002Ah.

The program memory section names `Vectors`, `IntH` and `IntL` are used with the `CODE` directive to instruct the linker to place the assembled code that follows each directive at the specified program memory location. In this case, the boot loader is not linked with any application code so the relocated reset and interrupt vectors, 0208h, 0218h and 022Ah are assumed and therefore are explicitly coded.

**18Fboot.asm** - This is an example of how the startup portion of a boot loader could be configured when designing and programming only the boot loader code into the target PIC microcontroller.

```assembly
; *****************************************************************************
; 18Fboot.asm
; *****************************************************************************
LIST P=18F8720
#include P18cxxx.inc
Vectors code 0x0000
  VReset: bra Boot_Start
IntH code 0x0008
  VIntH: bra 0x0208       ; Re-map Interrupt vector to app's code space
IntL code 0x0018
  VIntL: bra 0x0218       ; Re-map Interrupt vector to app's code space
Boot code 0x002A        ; Boot loader executable code starts here
  Boot_Start:
    ; Logic to determine if bootloader executes or branch to user's code
    ; ...
    bra 0x022A            ; Branch to user's application code
    ; ...
  ; end of boot loader code section
; *****************************************************************************
END
```
EXAMPLE 2: ASSEMBLER APPLICATION SOURCE CODE

In this example the application code is composed of several relocatable source files that are assembled and linked together during build time. The relocatable reset and interrupt vector locations are defined in main.asm and are assigned to a specific program memory location by the CODE directive.

**main.asm** - This is a sample of the startup portion of a main source code file that contains the relocated reset and interrupts and is the main entry point into the application.

```assembly
;******************************************************************************
; main.asm
;******************************************************************************
LIST P=18F8720
#include P18cxxx.inc

;******************************************************************************

R_vectors code 0x200
RvReset: ; Re-mapped RESET vector
bra main

R_IntH code 0x208 ; Re-mapped HI-priority interrupt vector
RVIntH:
; High priority interrupt vector code here
;...
retfie

R_IntL code 0x218 ; Re-mapped LOW-priority interrupt vector
RVIntL:
; Low priority interrupt vector code here
;...
retfie

user_code code 0x22A
main:
; Entry into application code starts here
; ....
; end of main code section
;******************************************************************************
END
```
13.5.2.5  EXAMPLE 3: ASSEMBLER BOOT LOADER/APPLICATION SOURCE CODE

The final example demonstrates the possibility of combining both the boot loader and application code into a single program memory image that can be programmed into a target microcontroller at the same time. Since the boot loader will be assembled and linked with the application source code files, any references to external labels, defined in the application code, must be resolved by the linker. To accomplish this, the GLOBAL directive used in main.asm and the EXTERN directive used in the boot loader source file allow the linker to resolve the relocated reset and interrupt vector labels defined in main.asm and referenced in the 18Fboot_r.asm. For this example, the same boot.lkr linker script file used in the previous examples is used to link the boot loader and application files together.

**18Fboot_r.asm** - This sample version of the boot loader allows for relocatable vectors that are defined, not in the boot loader, but in the application source code.

```assembly
;*****************************************************************************
; 18Fboot_r.asm
;*****************************************************************************
LIST P=18F8720
#include P18cxxx.inc

; Declare labels used here but defined outside this module
extern RVReset, RVIntH, RVIntL

;*****************************************************************************
Vectors code 0x0000
VReset:  bra Boot_Start

IntH code 0x0008
VIntH:  bra RVIntH       ; Re-map Interrupt vector

IntL code 0x0018
VIntL:  bra RVIntL       ; Re-map Interrupt vector

;*****************************************************************************
Boot code 0x002A       ; Define explicit Bootloader location
Boot_Start:            
;/ Determine if bootloader should execute or branch to user's code 
;/ ....
; bra RVReset           ; Branch to user's application code 
;/ Else Bootloader execution starts here 
;/ ....

;*****************************************************************************
END
```
**main_r.asm** - This is a sample version of a main source code file that uses the `GLOBAL` directive to make the relocatable reset and interrupt vector labels available to the boot loader.

```assembly
;******************************************************************************
; main_r.asm
;******************************************************************************
LIST P=18F8720
#include P18cxxx.inc

; Define labels here but used outside this module
   global   RVReset, RVIntH, RVIntL
;******************************************************************************

R_vectors   code   0x200
RVReset:                      ;Re-mapped RESET vector
   bra   main

R_IntH      code   0x208      ;Re-mapped HI-priority interrupt vector
RVIntH:
;High priority interrupt vector code here
;...
   retfie

R_IntL      code   0x218      ;Re-mapped LOW-priority interrupt vector
RVIntL:
;Low priority interrupt vector code here
;...
   retfie

user_code   code   0x22A
main:
; Entry into application code starts here
;....
; end of main code section
;******************************************************************************
END
```
13.6 SAMPLE APPLICATION 4 - CONFIGURING EXTERNAL MEMORY

Most of the larger pin count PIC microcontrollers have the ability to interface to external 8- or 16-bit data FLASH or SRAM memories through the External Memory Bus (EMB). The PIC18F8722, for example, has 128K bytes of internal program memory (00000h - 1FFFFh). But, when configured for Extended Microcontroller mode, external program memory space from locations 20000h through 1FFFFFh becomes externally addressable through the EMB created from the I/O pins.

The use of a linker script file can be extended to other external memory-mapped devices such as programmable I/O peripherals, real-time clocks or any device that has multiple configuration or control registers that can be accessed through an 8- or 16-bit data bus.

13.6.1 C Compiler Usage

This section discusses how to use the MPLAB C Compiler for PIC18 MCUs (the C compiler) when developing external memory application code.

The C compiler linker script file for the PIC18F8722 is modified to instruct the linker that a new memory region is available by adding a CODEPAGE definition as shown below. The use of the PROTECTED modifier prevents the linker from assigning random relocatable code to this region. The name xsram is arbitrary and can be any desired name. What is important are the START and END addresses, which should match the physical memory address range of the external memory being used.

```
CODEPAGE   NAME=xsram   START=0x020000    END=0x01FFFFF   PROTECTED
```

In addition to the new CODEPAGE, a new logical SECTION is created and assigned to the program memory region specified in the associated CODEPAGE definition.

```
SECTION    NAME=SRAM_BASE  ROM=xsram
```

In the C compiler application’s source code file, the #pragma romdata directive instructs the linker to allocate the SRAM’s starting address to the memory region specified by the SRAM_BASE logical section definition. The physical address is provided by the xsram codepage directive at 20000h. Since the memory region occupied by the SRAM is program memory, not data memory, the rom qualifier is required in the declaration of the char array variable, sram[]. In addition, this memory region is beyond a 16-bit address range (64Kbyte) and therefore requires the use of the far qualifier in order for C pointers to correctly access this region.

```
#pragma romdata SRAM_BASE ;Assigns this romdata space at 0x020000
rom far char sram[];    ;Declare an array at starting address
```

To build the C compiler sample application, refer to Section 13.2 “How to Build the Sample Applications”.

The large memory model must be used in this project.

- At the end of Step 2, click the MPLAB C18 tab and chose the Category of “Memory Model” from the drop-down list. Under “Code Model”, click “Large code mode (>64K)”.
- For the command line, use the -ml option when compiling.

Note: MPLAB X IDE does not yet support External Memory views.
13.6.1.1 C COMPILER MEMORY MAP

The table below shows the memory mapping for the PIC18F8722 when used with the 1Mbyte external SRAM device. Notice that the first 128K bytes of the external memory region is overlapped with the 128K bytes of internal program memory space and therefore cannot be accessed using the external memory bus. Without any additional external memory address decoding, the first 128K bytes of the SRAM are not accessible and therefore the first addressable location of SRAM is 20000h, as used in this example (SA4).

<table>
<thead>
<tr>
<th>SA4</th>
<th>Program Memory Address</th>
<th>SRAM Address</th>
<th>Linker Script Section</th>
<th>Source Code Section</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0x000000</td>
<td>0x000000</td>
<td>page - Reset, Interrupt vectors and On-chip Memory</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0x01FFFF</td>
<td>0x01FFFF</td>
<td></td>
<td></td>
</tr>
<tr>
<td>→</td>
<td>0x020000</td>
<td>0x020000</td>
<td>xsram - External Memory</td>
<td>SRAM_BASE - romdata space</td>
</tr>
<tr>
<td></td>
<td>0x0FFFFF</td>
<td>0x0FFFFF</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0x100000</td>
<td>0x100000</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

13.6.1.2 C COMPILER LINKER SCRIPT

The sections of modified PIC18F8722 C compiler generic linker script file shown below demonstrates suggested modifications for external memory applications.

First the CODEPAGE statement is added.

```c
CODEPAGE NAME=xram START=0x020000 END=0x1FFFFF PROTECTED
CODEPAGE NAME=idlocs START=0x200000 END=0x200007 PROTECTED
CODEPAGE NAME=config START=0x300000 END=0x30000D PROTECTED
CODEPAGE NAME=devid START=0x3FFFFE END=0x3FFFFF PROTECTED
CODEPAGE NAME=eedata START=0xF00000 END=0xF003FF PROTECTED
```

Then the external memory section is added.

```c
#ifdef _CRUNTIME
 SECTION NAME=CONFIG ROM=config
 SECTION NAME=SRAM_BASE ROM=xram
#endif
#ifdef _DEBUGDATASTART
 STACK SIZE=0x100 RAM=gpr13
#else
 STACK SIZE=0x100 RAM=gpr14
#endif
#endif
```
13.6.1.3 C COMPILER SOURCE CODE

This is a simple code example showing the use of #pragma romdata for declaration of external memory and the use of C pointers for accessing this memory region.

If you are using MPLAB IDE v8 to run this example, remember to enable external memory (Configure->External Memory) to see this extra memory in the Program Memory window.

```c
#include <p18F8722.h>

// Microprocessor mode - a memory mode that supports external memory.
#pragma config MODE = MP

#pragma romdata SRAM_BASE // Assigns this romdata space at 0x20000
rom far char sram[];     // Declare an array at starting address

#pragma code
void main(void)
{
  rom far char* dataPtr; // Create a "far" pointer
  dataPtr = sram;        // Assign this pointer to the memory array
  *dataPtr++ = 0xCC;     // Write low byte of 16-bit word to SRAM
  *dataPtr = 0x55;       // Write high byte of 16-bit word to SRAM
}
```
13.6.2 Assembler Usage

This section discusses how to use the MPASM assembler (the assembler) when developing external memory application code.

In an assembler application's source file, using a simple `#define` or `equ` directive provides an easy way to define the SRAM starting address, which can be used to set up the table pointers prior to a table read or table write operation.

```
#define  SRAM_BASE_ADDRS 0x20000  ; Base addr for external memory device
#define  SRAM_END_ADDRS  0x1FFFFF ; End addr (not required)
```

Accessing the external program memory through table reads and table writes requires the table pointer register be set up with the appropriate address as shown by the following example.

```asm
movlw   upper (SRAM_BASE_ADDRS)
movwf   TBLPTRU
movlw   high (SRAM_BASE_ADDRS)
movwf   TBLPTRH
movlw   low (SRAM_BASE_ADDRS)
movwf   TBLPTRL
```

To build the assembler sample application, refer to Section 13.2 “How to Build the Sample Applications”.

13.6.2.1 ASSEMBLER MEMORY MAP

The figure below shows the memory mapping for the PIC18F8722 when used with the 1Mbyte external SRAM device. Notice that the first 128K bytes of the external memory region is overlapped with the 128K bytes of internal program memory space and therefore cannot be accessed using the external memory bus. Without any additional external memory address decoding, the first 128K bytes of the SRAM are not accessible and therefore the first addressable location of SRAM is 20000h, as used in this example (SA4).

<table>
<thead>
<tr>
<th>TABLE 13-9: PROGRAM MEMORY MAP - PIC18F8722 AND 1MB SRAM</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SA4</strong></td>
</tr>
<tr>
<td>---------</td>
</tr>
<tr>
<td>0x00000</td>
</tr>
<tr>
<td>0x00002</td>
</tr>
<tr>
<td>0x020000</td>
</tr>
<tr>
<td>0x10000</td>
</tr>
</tbody>
</table>

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13.6.2.2 ASSEMBLER LINKER SCRIPT

The modified PIC18F8722 assembler linker script file shown below demonstrates suggested modifications for external memory applications.

First the CODEPAGE statements are added.

```
CODEPAGE   NAME=vectors     START=0x0      END=0x29   PROTECTED
#IFDEF _DEBUGCODESTART
  CODEPAGE   NAME=page       START=0x2A     END=_CODEEND
  CODEPAGE   NAME=debug      START=_DEBUGCODESTART END=_CEND        PROTECTED
#ELSE
  CODEPAGE   NAME=page       START=0x2A     END=0x1FFFF
#FI

CODEPAGE   NAME=xrsm   START=0x020000      END=0x1FFFFF       PROTECTED
CODEPAGE   NAME=idlocs  START=0x200000     END=0x200007       PROTECTED
CODEPAGE   NAME=config  START=0x300000     END=0x30000D       PROTECTED
CODEPAGE   NAME=devid   START=0x3FFFFE     END=0x3FFFFF       PROTECTED
CODEPAGE   NAME=eedata  START=0xF00000     END=0xF003FF       PROTECTED
```

Then the vectors, program, and external memory section is added.

```
#IFDEF _CRUNTIME
  SECTION    NAME=CONFIG     ROM=config
  SECTION    NAME=VECTORS    ROM=vectors
  SECTION    NAME=PROG       ROM=page
  SECTION    NAME=SRAM       ROM=xrsm
#IFDEF _DEBUGDATASTART
  STACK SIZE=0x100 RAM=gpr13
#ELSE
  STACK SIZE=0x100 RAM=gpr14
#FI
#FI
```
13.6.2.3 ASSEMBLER SOURCE CODE

This is a simple code example showing the definition of the external memory SRAM address at 20000h and how to write a 16-bit value to two consecutive memory locations using the table pointer register and table write instruction.

If you are using MPLAB IDE v8 to run this example, remember to enable external memory (Configure>External Memory) to see this extra memory in the Program Memory window.

```
#include <p18F8722.inc>

; Microprocessor mode - a memory mode that supports external memory.
CONFIG MODE = MP

#define SRAM_BASE_ADDRS 0x20000    ; Base addr for external memory device
#define SRAM_END_ADDR  0x1FFFFF    ; End addr (not required)

vectors code
   bra   main

prog   code
main:
   ; Example - how to write "0x55CC" to first word location in external SRAM memory
   movlw   upper (SRAM_BASE_ADDRS)
   movwf   TBLPTRU
   movlw   high (SRAM_BASE_ADDRS)
   movwf   TBLPTRH
   movlw   low (SRAM_BASE_ADDRS)
   movwf   TBLPTRL
   movlw   0xCC
   movwf   TABLAT
   tblwt*+            ; Writes "0xCC" to byte location 0x020000;
                      ; Increments table pointer to next location
   movlw   0x55
   movwf   TABLAT
   tblwt*             ; Write "0x55" to byte location 0x020001;

END
```
Chapter 14. Errors, Warnings and Common Problems

14.1 INTRODUCTION

Error messages and warning messages are produced by the MPLINK linker. These messages always appear in the listing file directly above each line in which the error occurred.

Common problems and limitations of the linker tool are also listed here.

Topics covered in this chapter:

• Linker Parse Errors
• Linker Errors
• Linker Warnings
• COFF File Errors
• Other Errors, Warnings and Messages
• Common Problems

14.2 LINKER PARSE ERRORS

MPLINK linker parse errors are listed alphabetically below:

**Could not open 'cmdfile'.**

A linker script file could not be opened. Check that the file exists, is in the current search path, and is readable.

**Illegal <filename> for FILES in 'cmdfile:line'.**

An object or library filename must end with `.o` or `.lib` respectively.

**Illegal <filename> for INCLUDE in 'cmdfile:line'.**

A linker script filename must end with `.lkr`.

**Illegal <libpath> for LIBPATH in 'cmdfile:line'.**

The `libpath` must be a semicolon delimited list of directories. Enclose directory name which have embedded spaces in double quotes.

**Illegal <lkrpath> for LKRPATH in 'cmdfile:line'.**

The `lkrpath` must be a semicolon delimited list of directories. Enclose directory names which have embedded spaces in double quotes.

**Invalid attributes for memory in 'cmdfile:line'.**

A CODEPAGE, DATABANK, or SHAREBANK directive does not specify a NAME, START, or END attribute; or another attribute is specified which is not valid.

**Invalid attributes for SECTION in 'cmdfile:line'.**

A SECTION directive must have a NAME and either a RAM or ROM attribute.
Invalid attributes for STACK in 'cmdfile:line'.
A STACK directive does not specify a SIZE attribute, or another attribute is specified which is not valid.

-k switch requires <pathlist>.
A semicolon delimited path must be specified. Enclose directory names containing embedded spaces with double quotes. For example:
-k ..;c:\mylkr;"c:\program files\microchip\mpasm suite\lkr"

-l switch requires <pathlist>.
A semicolon delimited path must be specified. Enclose directory names containing embedded spaces with double quotes. For example:
-l ..;c:\mylib;"c:\program files\microchip\mpasm suite"

-m switch requires <filename>.
A map filename must be specified. For example: -m main.map.

Multiple inclusion of library file 'filename'.
A library file has been included multiple times either on the command line or with a FILES directive in a linker script file. Remove the multiple references.

Multiple inclusion of linker script file 'cmdfile'.
A linker script file can only be included once. Remove multiple INCLUDE directives to the referenced linker script file.

Multiple inclusion of object file 'filename'.
An object file has been included multiple times either on the command line or with a FILES directive in a linker script file. Remove the multiple references.

-n switch requires <length>.
The number of source lines per listing file page must be specified. A length of zero will suppress pagination of the listing file.

-o switch requires <filename>.
A COFF output filename must be specified. For example: -o main.out

Unknown switch: 'cmdline token'.
An unrecognized command line switch was supplied. Refer to the Usage documentation for the list of supported switches.

Unrecognized input in 'cmdfile:line'.
All statements in a linker script file must begin with a directive keyword or the comment Delimiter //.
14.3 LINKER ERRORS

MPLINK linker errors are listed alphabetically below:

**Absolute code section 'secName' must start at a word-aligned address.**

Program code sections will only be allocated at word-aligned addresses. MPLINK will give this error message if an absolute code section address is specified that is not word-aligned.

**Configuration settings have been specified for address 0x300001 in more than one object module. Found in 'foo.o' previously found in 'bar.o'**

This error is issued when MPLAB C18’s `#pragma config` directive has been used in two separate `.c` files (e.g., `foo.c` and `bar.c`) with settings specified from the same configuration byte. Set configuration bits for a given byte in a single `.c` file.

**Conflicting types for symbol ‘symName’**:  
Symbol `symName` is defined in different locations as different types.

**Could not find definition of symbol 'symName' in file ‘filename’**.  
A symbol `symName` is used without being defined in file `filename`.

**Could not find file 'filename'**.  
An input object or library file was specified which does not exist, or cannot be found in the linker path.

**Could not open map file 'filename' for writing**.  
Verify that if `filename` exists, it is not a read-only file.

**Could not resolve section reference ‘symName’ in file ‘filename’**.  
The symbol `symName` is an external reference. No input module defines this symbol. If the symbol is defined in a library module, ensure that the library module is included on the command line or in the linker script file using the FILES directive.

**Could not resolve symbol 'symName' in file 'filename'**.  
The symbol `symName` is an external reference. No input module defines this symbol. If the symbol is defined in a library module, ensure that the library module is included on the command line or in the linker script file using the FILES directive.

**Device not specified. Use '/p' option to specify a device**

If the device is not specified, this error will be generated. For Windows OS, you specify the device by `/pdevice`. For Linux or Mac OS, you specify the device by `-pdevice`. `device` represents the device name without a “PIC” or “dsPIC” preface, as in 18F8722 instead of PIC18F8722.

**Duplicate definition of memory 'memName'**.  
All CODEPAGE and DATABANK directives must have unique NAME attributes.

**Duplicate definitions of SECTION 'secName'**.  
Each SECTION directive must have unique NAME attributes. Remove duplicate definitions.
File ‘filename’, section ‘secName’, performs a call to symbol ‘symName’ which is not in the lower half of a page.

For 12-bit devices, the program counter (PC), bit 8, is cleared in the CALL instruction or any modify PCL instruction. Therefore, all subroutine calls or computed jumps are limited to the first 256 locations of any program memory page (512 words long.)

Inconsistent length definitions of SHAREBANK 'memName'.

All SHAREBANK definitions which have the same NAME attribute must be of equal length.

Internal Coff output file is corrupt.

The linker cannot write to the COFF file.

Memory 'memName' overlaps memory 'memName'.

All CODEPAGE blocks must specify unique memory ranges which do not overlap. Similarly DATABANK and SHAREBANK blocks may not overlap.

Mixing extended and non-extended mode modules not allowed

The linker cannot link a mixture of extended mode modules and non-extended mode modules. Extended and non-extended memory modes apply to PIC18 devices.

When using MPASM to create object file modules, extended memory mode is enabled/disabled on the command line using the /y or -y option. In the IDE, select File>Project Properties (MPLAB X IDE) or Project>Build Options, MPASM Assembly tab (MPLAB IDE v8), and check/uncheck the option "Extended Mode".

When using MPLAB C18 to create object file modules, extended memory mode is enabled/disabled on the command line using the --extended option. In the IDE, select File>Project Properties (MPLAB X IDE) or Project>Build Options, MPLAB C18 tab (MPLAB IDE v8), and check/uncheck the option "Extended Mode".

When using linker scripts, those with the suffix _e apply to extended mode use.

MPASM's __CONFIG directive (found in 'bar.o') cannot be used with either MPLAB C18’s #pragma config directive or MPASM’s CONFIG directive (found in 'foo.o')

This error message is issued when MPASM assembler's __CONFIG directive is specified in a .asm file (e.g., bar.asm) and MPLAB C18’s #pragma config directive is specified in a .c file (e.g., foo.c). Set configuration bits using either MPASM assembler's __CONFIG directive or MPLAB C18’s #pragma config directive.

Multiple map files declared: 'filename1', 'filename2'.

The -m <mapfile> switch was specified more than once.

Multiple output files declared: 'filename1', 'filename2'.

The -o <outfile> switch was specified more than once.

Multiple STACK definitions.

A STACK directive occurs more than once in the linker script file or included linker script files. Remove the multiple STACK directives.

No input object files specified.

No input object or library file was specified to the linker. Enter files to link.
Errors, Warnings and Common Problems

Overlapping definitions of SHAREBANK 'memName'.

A SHAREBANK directive specifies a range of addresses that overlap a previous definition. Overlaps are not permitted.

{PCL | TOSH | TOSU | TOSL} cannot be used as the destination of a MOVFF or MOVSF instruction.

The MOVFF instruction has unpredictable results when its destination is the PCL, TOSH, TOSU, or TOSL registers. MPLINK will not allow the destination of a MOVFF instruction to be replaced with any of these addresses.

Processor types do not agree across all input files.

Each object module and library file specifies a processor type or a processor family. All input modules processor types or families must match.

Section {absolute|access|overlay|share} types for 'secName' do not match across input files.

A section with the name secName occurs in more than one input file. However, in some files it is marked as either an absolute, access, overlay or shared section, and in some it is not. Change the section's type in the source files and rebuild the object modules.

Section 'secName' can not fit the absolute section. Section 'secName' start=0xHHHH, length=0xHHHH.

A section which has not been assigned to a memory in the linker script file can not be allocated. Use the -m <mapfile> switch to generate an error map file. The error map will show the sections which were allocated prior to the error. More memory must be made available by adding a CODEPAGE, SHAREBANK, or DATABANK directive, or by removing the PROTECTED attribute, or the number of input sections must be reduced.

Section 'romName' can not have a 'RAM' memory attribute specified in the linker script file.

Use only the ROM attribute when defining the section in the linker script file.

Section 'secName' can not fit the section. Section 'secName' length='0xHHHHH'.

A section which has not been assigned to a memory in the linker script file can not be allocated. Use the -m <mapfile> switch to generate an error map file. The error map will show the sections which were allocated prior to the error. More memory must be made available by adding a CODEPAGE, SHAREBANK, or DATABANK directive, or by removing the PROTECTED attribute, or the number of input sections must be reduced.

Section 'secName' contains code and can not have a 'RAM' memory attribute specified in the linker script file.

Use only the ROM attribute when defining the section in the linker script file.

Section 'secName' contains initialized data and can not have a 'ROM' memory attribute specified in the linker script file.

Use only the RAM attribute when defining the section in the linker script file.
Section 'secName' contains initialized rom data and can not have a 'RAM' memory attribute specified in the linker script file.
Use only the ROM attribute when defining the section in the linker script file.

Section 'secName' contains uninitialized data and can not have a 'ROM' memory attribute specified in the linker script file.
Use only the RAM attribute when defining the section in the linker script file.

Section 'secName' has a memory 'memName' which can not fit the absolute section. Section 'secName' start=0xHHHH, length=0xHHHH.
The memory which was assigned to the section in the linker script file either does not have space to fit the section, or the section will overlap another section. Use the -m <mapfile> switch to generate an error map file. The error map will show the sections which were allocated prior to the error.

Section 'secName' has a memory 'memName' which can not fit the section. Section 'secName' length='0xHHHH'.
The memory which was assigned to the section in the linker script file either does not have space to fit the section, or the section will overlap another section. Use the -m <mapfile> switch to generate an error map file. The error map will show the sections which were allocated prior to the error.

Section 'secName' has a memory 'memName' which is not defined in the linker script file.
Add a CODEPAGE, DATABANK, or SHAREBANK directive for the undefined memory to the linker script file.

Section 'secName' type is non-overlay and absolute but occurs in more than one input file.
An absolute section with the name secName may only occur in a single input file. Relocatable sections with the same name may occur in multiple input files. Either remove the multiple absolute sections in the source files or use relocatable sections instead.

Starting addresses for absolute overlay section 'secName' do not match across all input files.
A section with the name secName occurs in more than one input file. However, its absolute overlay starting address varies between files. Change the section's address in the source files and rebuild the object modules.

Symbol 'symName' has multiple definitions.
A symbol may only be defined in a single input module.

Symbol 'symName' is not word-aligned. It cannot be used as the target of a (branch | call or goto) instruction.
The target of a branch, call, or goto instruction was at an odd address, but the instruction encoding cannot reference addresses that are not word-aligned.
symbol 'symName' out of range of relative branch instruction.

A relative branch instruction had symName as its target, but a 2's compliment encoding of the offset to symName wouldn't fit in the limited number of instruction bits used for the target of a branch instruction.

The _CONFIG_DECL macro can only be specified in one module. Found in 'foo.o' previously found in 'bar.o'

This error is issued when MPLAB C18's _CONFIG_DECL macro is specified in two separate .c files (e.g., foo.c and bar.c). Set configuration bits by using the _CONFIG_DECL macro in only one .c file.

The _CONFIG_DECL macro (found in 'foo.o') cannot be used with MPASM's __CONFIG directive (found in 'bar.o')

This error is issued when MPLAB C18's _CONFIG_DECL macro is used in a .c file (e.g., foo.c) and MPASM assembler's __CONFIG directive is used in a .asm file (e.g., bar.asm). Set configuration bits using either the _CONFIG_DECL macro from MPLAB C18 or the __CONFIG directive in MPASM assembler.

The _CONFIG_DECL macro (found in 'foo.o') cannot be used with either MPLAB C18's #pragma config directive or MPASM's CONFIG directive (found in 'bar.o')

This error is issued when MPLAB C18's _CONFIG_DECL macro is used in a .c file (e.g., foo.c) with either MPLAB C18's #pragma config directive in a second .c file (e.g., bar.c) or MPASM assembler's __CONFIG directive in a .asm file (e.g., bar.asm). Set configuration bits by using only one of _CONFIG_DECL, #pragma config, or __CONFIG directive.

TRIS argument is out of range '0xHHHH' not between '0xHHHH' and '0xHHHH'.

Check the device data sheet to determine acceptable hex values for the TRIS register you are using.

Undefined CODEPAGE 'memName' for SECTION 'secName'.

A SECTION directive with a ROM attribute refers to a memory block which has not been defined. Add a CODEPAGE directive to the linker script file for the undefined memory block.

Undefined DATABANK/SHAREBANK 'memName' for SECTION 'secName'.

A SECTION directive with a RAM attribute refers to a memory block that has not been defined. Add a DATABANK or SHAREBANK directive to the linker script file for the undefined memory block.

Undefined DATABANK/SHAREBANK 'memName' for STACK.

No input object files specified. At least one object module must be specified either on the command line or in the linker script file using the FILES directive.

Unknown section type for 'secName'.

The section type for 'secName' needs to be defined.
Unknown section type for 'secName' in file 'filename'.
An input object or library module is not of the proper file type or it may be corrupted.

Unsupported processor type in file 'filename'.
A processor was specified that is not currently supported by the linker. See the Readme file for a list of supported devices.

Unsupported relocation type.
A relocation type was specified that is not currently supported by the linker.

14.4 LINKER WARNINGS

MPLINK linker warnings are listed alphabetically below:

Fill pattern for memory 'memName' doesn't divide evenly into unused section locations. Last value was truncated.
If a fill pattern is specified for a ROM section, but the free space in that section isn't evenly divisible by the fill pattern size, this warning will be issued to warn of incomplete patterns.

'/a' command line option ignored with '/x'
/x or –x prevents the generation of a .hex file. Therefore, specifying the format of hex output file with /a or –a is irrelevant.

'/n' command line option ignored with '/w'
/w or –w prevents the generation of a .lst file. Therefore, specifying the number of lines per listing page with /n or –n is irrelevant.
14.5 COFF FILE ERRORS

All the COFF errors listed below indicate an internal error in the file's contents. Please contact Microchip support if any of these errors are generated.

- Coff file 'filename' could not read file header.
- Coff file 'filename' could not read line numbers.
- Coff file 'filename' could not read optional file header.
- Coff file 'filename' could not read raw data.
- Coff file 'filename' could not read relocation info.
- Coff file 'filename' could not read section header.
- Coff file 'filename' could not read string table.
- Coff file 'filename' could not read string table length.
- Coff file 'filename' could not read symbol table.
- Coff file 'filename' could not write file header.
- Coff file 'filename' could not write lineinfo.
- Coff file 'filename' could not write optional file header.
- Coff file 'filename' could not write raw data.
- Coff file 'filename' could not write reloc.
- Coff file 'filename' could not write section header.
- Coff file 'filename' could not write string.
- Coff file 'filename' could not write string table length.
- Coff file 'filename' could not write symbol.
- Coff file 'filename', cScnHdr.size() != cScnNum.size().
- Coff file 'filename' does not appear to be a valid COFF file.
- Coff file 'filename' has relocation entries but an empty symbol table.
- Coff file 'filename' missing optional file header.
- Coff file 'filename' section["xx"] has an invalid s_offset.
- Coff file 'filename', section 'secName' line["xx"] has an invalid l_fcnndx.
- Coff file 'filename', section 'secName' line["xx"] has an invalid l_srcndx.
- Coff file 'filename', section 'secName' reloc["xx"] has an invalid r_symndx.
- Coff file 'filename' symbol["xx"] has an invalid n_offset.
- Coff file 'filename' symbol["xx"] has an invalid n_scnum.
- Coff file 'filename', symbol["xx"] has an invalid index.
- Could not find section name 'secName' in string table.
- Could not find symbol name 'symName' in string table.
- Could not open Coff file 'filename' for reading.
- Could not open Coff file 'filename' for writing.
- Could not read archive magic string in library file 'filename'.
- Unable to find aux_file name in string table.
- Unable to find section name in string table.
- Unable to find symbol name in string table.
14.6  OTHER ERRORS, WARNINGS AND MESSAGES

If you are using the linker with any of the utilities, i.e., MPLIB librarian or you have not used the linker options /w or /x (Windows OS) or –w or –x (Linux or Mac OS), then you may need to look in the utility troubleshooting sections for your error.

- MPLIB Librarian - Chapter 17. “Errors”
- MP2COD and/or MP2HEX - Chapter 19. “Errors and Warnings”

14.7  COMMON PROBLEMS

Although I set up listing file properties with MPASM assembler directives, none of these properties is appearing in my listing file.

Although MPASM assembler is often used with MPLINK object linker, MPASM assembler directives are not supported in MPLINK linker scripts. See Section 10.3 “Command Line Interface” for control of listing and hex file output.

How do I split up linear memory in the linker script file?

Currently the only name linear memory can be is linear0 and nothing else due a limitation in the linker. This prevents you from splitting the linear memory region because names other than linear0 cannot be used.
Part 3 – MPLIB Object Librarian

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Chapter 16. Librarian Interfaces ........................................................................ 299
Chapter 17. Errors .............................................................................................. 301
Chapter 15. MPLIB Librarian Overview

15.1 INTRODUCTION

An overview of the MPLIB object librarian and its capabilities is presented.

Topics covered in this chapter:

• What is MPLIB Librarian
• How MPLIB Librarian Works
• How MPLIB Librarian Helps You
• Librarian Operation
• Librarian Input/Output Files

15.2 WHAT IS MPLIB LIBRARIAN

MPLIB object librarian (the librarian) combines object modules generated by the MPASM assembler or the MPLAB C18 C compiler into a single library file. This file may then be inputted into the MPLINK object linker.

15.3 HOW MPLIB LIBRARIAN WORKS

A librarian manages the creation and modification of library files. A library file is simply a collection of object modules that are stored in a single file. There are several reasons for creating library files:

• Libraries make linking easier. Since library files can contain many object files, the name of a library file can be used instead of the names of many separate object files when linking.
• Libraries help keep code small. Since a linker only uses the required object files contained in a library, not all object files which are contained in the library necessarily wind up in the linker’s output module.
• Libraries make projects more maintainable. If a library is included in a project, the addition or removal of calls to that library will not require a change to the link process.
• Libraries help to convey the purpose of a group of object modules. Since libraries can group together several related object modules, the purpose of a library file is usually more understandable than the purpose of its individual object modules. For example, the purpose of a file named math.lib is more apparent than the purpose of power.o, ceiling.o, and floor.o.
15.4 HOW MPLIB LIBRARIAN HELPS YOU

The MPLIB librarian can help you in the following ways:

- The librarian makes linking easier because single libraries can be included instead of many smaller files.
- The librarian helps keep code maintainable by grouping related modules together.
- The librarian commands allow libraries to be created and modules to be added, listed, replaced, deleted, or extracted.

15.5 LIBRARIAN OPERATION

The librarian combines multiple input object modules, generated by the MPASM assembler or MPLAB C18 C compilers, into a single output library (.lib) file. Library files are used in conjunction with the MPLINK linker to produce executable code.

**FIGURE 15-1: MPLIB LIBRARIAN OPERATION**

15.6 LIBRARIAN INPUT/OUTPUT FILES

The MPLIB librarian combines multiple object files into one library (.lib) file.

**Input Files**

| Object File (.o) | Relocatable code produced from source files. |

**Output Files**

| Library File (.lib) | A collection of object files grouped together for convenience. |

15.6.1 Object File (.o)

Object files are the relocatable code produced from source files. The MPLIB librarian combines several object files into a single library file.

15.6.2 Library File (.lib)

A library file may be created from object files by the MPLIB librarian or may be an existing standard library.
Chapter 16. Librarian Interfaces

16.1 INTRODUCTION

How to use MPLIB librarian is discussed here. For information on how librarian output can be used with the MPASM assembler and the MPLINK linker, see the documentation for these tools.

Topics covered in this chapter:
• MPLAB X IDE Interface
• MPLAB IDE v8 Interface
• Command Line Options
• Command Line Examples and Tips

16.2 MPLAB X IDE INTERFACE

The MPLIB librarian may be used to create library files to be used in an MPLAB X IDE project.

16.3 MPLAB IDE V8 INTERFACE

The MPLIB librarian may be used with MPLAB IDE to create a library file from project object files instead of an executable (hex) file.

With your project open in MPLAB IDE, select Project>Build Options>Project. In the Build Options dialog, click on the MPASM/C17/C18 Suite tab. Click the radio button next to “Build library target (invoke MPLIB)”. Then click OK. Now when you build your project, you will be building a library file.
16.4 COMMAND LINE OPTIONS

MPLIB librarian is invoked with the following syntax:

Windows OS: mplib [/q] /{ctdrx} LIBRARY [MEMBER...]

Linux or Mac OS: mplib [-q] -{ctdrx} LIBRARY [MEMBER...]

Options

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
<th>Detail</th>
</tr>
</thead>
<tbody>
<tr>
<td>c</td>
<td>Create library</td>
<td>creates a new LIBRARY with the listed MEMBER(s)</td>
</tr>
<tr>
<td>d</td>
<td>Delete member</td>
<td>deletes MEMBER(s) from the LIBRARY; if no MEMBER is specified the LIBRARY is not altered</td>
</tr>
<tr>
<td>q</td>
<td>Quiet mode</td>
<td>no output is displayed</td>
</tr>
<tr>
<td>r</td>
<td>Add/replace member</td>
<td>if MEMBER(s) exist in the LIBRARY, then they are replaced, otherwise MEMBER is appended to the end of the LIBRARY</td>
</tr>
<tr>
<td>t</td>
<td>List members</td>
<td>prints a table showing the names of the members in the LIBRARY</td>
</tr>
<tr>
<td>x</td>
<td>Extract member</td>
<td>if MEMBER(s) exist in the LIBRARY, then they are extracted. If no MEMBER is specified, all members will be extracted</td>
</tr>
</tbody>
</table>

16.5 COMMAND LINE EXAMPLES AND TIPS

Example of Use - Windows OS

Suppose you wanted to create a library named dsp.lib from three object modules named fft.o, fir.o, and iir.o. The following command line would produce the desired results:

mplib /c dsp.lib fft.o fir.o iir.o

To display the names of the object modules contained in a library file named dsp.lib, the following command line would be appropriate:

mplib /t dsp.lib

Tips

MPLIB librarian creates library files that may contain only a single external definition for any symbol. Therefore, if two object modules define the same external symbol, the librarian will generate an error if both object modules are added to the same library file.

To minimize the code and data space which results from linking with a library file, the library's member object modules should be as small as possible. Creating object modules that contain only a single function can significantly reduce code space.
Chapter 17. Errors

17.1 INTRODUCTION

MPLIB librarian detects the following sources of error and reports them. Topics covered in this chapter:

• Librarian Parse Errors
• Library File Errors
• COFF File Errors

17.2 LIBRARIAN PARSE ERRORS

MPLIB librarian parse errors are listed alphabetically below:

Invalid Object Filename
All object filenames must end with ‘.o’.

Invalid Switch
An unsupported switch was specified. For a list of supported switches, refer to command line options.

Library Filename is Required
All commands require a library filename. All library filenames must end with ‘.lib’.
17.3 LIBRARY FILE ERRORS

Library file processing errors are listed alphabetically below:

**Could not build member 'memberName' in library file 'filename'**.
The file is not a valid library file or it is corrupted.

**Could not open library file 'filename' for reading**.
Verify that `filename` exists and can be read.

**Could not open library file 'filename' for writing**.
Verify that if `filename` exists, it is not read-only.

**Could not write archive magic string in library file 'filename'**.
The file may be corrupted.

**Could not write member header for 'memberName' in library file 'filename'**.
The file may be corrupted.

**File 'filename' is not a valid library file**.
Library files must end with `.lib`.

**Library file 'filename' has a missing member object file**.
The file not a valid object file or it may be corrupted.

**'memberName' is not a member of library 'filename'**.
`memberName` can not be extracted or deleted from a library unless it is a member of the library.

**Symbol 'symName' has multiple external definitions**.
A symbol may only be defined once in a library file.

17.4 COFF FILE ERRORS

For a list of COFF File Errors, see MPLINK linker Section 14.5 “COFF File Errors”. 
Part 4 – Utilities

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Chapter 18. Utilities Overview and Usage

18.1 INTRODUCTION

An overview of the 8-bit utilities and their capabilities are presented.

Topics covered in this chapter:

• What are Utilities
• Utilities Operation
• mp2hex.exe Utility
• mp2cod.exe Utility

18.2 WHAT ARE UTILITIES

Utilities are tools available for use with the assembler and/or linker. The MPLIB object librarian is a utility that was discussed in the previous sections.

<table>
<thead>
<tr>
<th>TABLE 18-1: AVAILABLE UTILITIES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Utility</td>
</tr>
<tr>
<td>mplib.exe</td>
</tr>
<tr>
<td>mp2hex.exe</td>
</tr>
<tr>
<td>mp2cod.exe</td>
</tr>
</tbody>
</table>

18.3 UTILITIES OPERATION

The utilities MP2HEX and MP2COD work with the MPLINK object linker to generate executable code (.hex) or a linker listing file (.lst) from the linker COF file. The Hex file is used by simulators, emulators, debuggers and programmers.

FIGURE 18-1: UTILITIES OPERATION
18.4 MP2HEX.EXE UTILITY

Use this utility to take the MPLINK linker output COF file and create a Hex file. A Hex file contains no debug information but may be programmed directly into a device.

The MPLINK linker /x or –x option will result in the linker not using this utility.

18.5 MP2COD.EXE UTILITY

Use this utility to take the MPLINK linker output COF file and create a COD file and a list file. A COD file is a legacy debug file that is no longer used. A list file generated by this utility is specific to the linker (see Section 9.7.6 “Listing File (.lst)”.)

The MPLINK linker /w or –w option will result in the linker not using this utility.
Chapter 19. Errors and Warnings

19.1 INTRODUCTION

Error messages and warning messages are produced by the 8-bit utilities. These messages always appear in the listing file directly above each line in which the error occurred.

- Hex File Errors
- COFF To COD Conversion Errors
- COFF To COD Converter Warnings
- COD File Errors

19.2 HEX FILE ERRORS

Selected hex format does not support byte addresses above 64kb; use INHX32 format!

Your code addresses more than 64 Kbytes of program memory, but your selected hex format cannot support this. Switch to INHX32 format.

Could not open hex file ‘filename’ for writing.

The hex file was never created due to other errors, or an existing hex file is write-protected.

19.3 COFF TO COD CONVERSION ERRORS

Source file ‘filename’ name exceeds file format maximum of 63 characters.

The COD file name, including the path, has a 63-character limit.

Coff file 'filename' must contain at least one 'code' or 'romdata' section.

In order to convert a COFF file to a COD file, the COFF file must have either a code or a romdata section.

Could not open list file 'filename' for writing.

Verify that if filename exists and that it is not a read-only file.

19.4 COFF TO COD CONVERTER WARNINGS

Could not open source file 'filename'. This file will not be present in the list file.

The referenced source file could not be opened. This can happen if an input object/library module was built on a machine with a different directory structure. If source level debugging for the file is desired, rebuild the object or library on the current machine.
19.5 COD FILE ERRORS

All the COD file errors listed below indicate an internal error in the file's contents. Please contact Microchip support if any of these errors are generated.

- Cod file 'filename' does not have a proper debug message table.
- Cod file 'filename' does not have a proper Index.
- Cod file 'filename' does not have a proper line info table.
- Cod file 'filename' does not have a proper local vars table.
- Cod file 'filename' does not have a proper long symbol table.
- Cod file 'filename' does not have a proper memory map table.
- Cod file 'filename' does not have a proper name table.
- Cod file 'filename' does not have a proper symbol table.
- Cod file 'filename' does not have a properly formed first directory.
- Cod file 'filename' does not have a properly formed linked directory.
- Could not open Cod file ‘filename’ for reading.
- Could not open Cod file ‘filename’ for writing.
- Could not write ‘blockname’ block in Cod file ‘filename’.
- Could not write directory in Cod file ‘filename’.
Part 5 – Appendices

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Appendix A. Instruction Sets

A.1 INTRODUCTION

PIC1X MCU instruction sets are used in developing applications with MPASM assembler, MPLINK object linker and MPLIB object librarian.

Instructions listed here are grouped either by instruction width or device number.

<table>
<thead>
<tr>
<th>Instruction Width</th>
<th>Devices Supported</th>
</tr>
</thead>
<tbody>
<tr>
<td>12 Bit</td>
<td>PIC10F2XX, PIC12C5XX, PIC12CE5XX, PIC16X5X, PIC16C505</td>
</tr>
<tr>
<td>14 Bit</td>
<td>PIC12C67X, PIC12CE67X, PIC12F629/675, PIC16X</td>
</tr>
<tr>
<td>16 Bit</td>
<td>PIC18X</td>
</tr>
</tbody>
</table>

Topics covered are:
- Key to 12/14-Bit Instruction Width Instruction Sets
  - 12-Bit Instruction Width Instruction Set
  - 14-Bit Instruction Width Instruction Set
  - 14-Bit Instruction Width Extended Instruction Set
  - 12-Bit/14-Bit Instruction Width Pseudo-Instructions
- Key to PIC18 Device Instruction Set
  - PIC18 Device Instruction Set
  - PIC18 Device Extended Instruction Set

A.2 KEY TO 12/14-BIT INSTRUCTION WIDTH INSTRUCTION SETS

Use this key to determine the meaning of abbreviations in the 12- and 14-bit instruction width instruction sets tables.

<table>
<thead>
<tr>
<th>Field</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>dest</td>
<td>Destination either the WREG register or the specified register file location. See d.</td>
</tr>
<tr>
<td>f</td>
<td>Register file address (5-bit, 7-bit or 8-bit).</td>
</tr>
<tr>
<td>n</td>
<td>FSR or INDF number (0 or 1).</td>
</tr>
<tr>
<td>p</td>
<td>Peripheral register file address (5-bit).</td>
</tr>
<tr>
<td>r</td>
<td>Port for TRIS.</td>
</tr>
<tr>
<td>x</td>
<td>Don’t care (‘0’ or ‘1’). The assembler will generate code with x = 0. It is the recommended form of use for compatibility with all Microchip software tools.</td>
</tr>
<tr>
<td>k</td>
<td>Literal field, constant data or label.</td>
</tr>
<tr>
<td>k</td>
<td>4-bit.</td>
</tr>
<tr>
<td>kk</td>
<td>8-bit.</td>
</tr>
<tr>
<td>kkk</td>
<td>12-bit.</td>
</tr>
<tr>
<td>mm</td>
<td>Pre-post increment-decrement mode selection.</td>
</tr>
</tbody>
</table>
### Bits

<table>
<thead>
<tr>
<th>Field</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>b</td>
<td>Bit address within an 8-bit file register (0 to 7).</td>
</tr>
</tbody>
</table>
| d     | Destination select bit.  
  d = 0: store result in WREG  
  d = 1: store result in file register f (default) |
| i     | Table pointer control.  
  i = 0: do not change.  
  i = 1: increment after instruction execution. |
| s     | Destination select bit.  
  s = 0: store result in file register f and WREG  
  s = 1: store result in file register f (default) |
| t     | Table byte select.  
  t = 0: perform operation on lower byte.  
  t = 1: perform operation on upper byte. |

' ' Bit values, as opposed to Hex value.

### Named Registers

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>BSR</td>
<td>Bank Select Register. Used to select the current RAM bank.</td>
</tr>
<tr>
<td>OPTION</td>
<td>OPTION Register.</td>
</tr>
<tr>
<td>PCL</td>
<td>Program Counter Low Byte.</td>
</tr>
<tr>
<td>PCH</td>
<td>Program Counter High Byte.</td>
</tr>
<tr>
<td>PCLATH</td>
<td>Program Counter High Byte Latch.</td>
</tr>
<tr>
<td>PCLATU</td>
<td>Program Counter Upper Byte Latch.</td>
</tr>
<tr>
<td>PRODH</td>
<td>Product of Multiply High Byte.</td>
</tr>
<tr>
<td>PRODL</td>
<td>Product of Multiply Low Byte.</td>
</tr>
<tr>
<td>TBLATH</td>
<td>Table Latch (TBLAT) High Byte.</td>
</tr>
<tr>
<td>TBLATL</td>
<td>Table Latch (TBLAT) Low Byte.</td>
</tr>
<tr>
<td>TBLPTR</td>
<td>16-bit Table Pointer (TBLPTRH:TBLPTRL). Points to a Program Memory location.</td>
</tr>
<tr>
<td>WREG</td>
<td>Working register (accumulator).</td>
</tr>
</tbody>
</table>

### Named Bits

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>ALU Status bits: Carry, Digit Carry, Zero, Overflow, Negative.</td>
</tr>
<tr>
<td>DC</td>
<td>Time-out bit.</td>
</tr>
<tr>
<td>Z</td>
<td>Power-down bit.</td>
</tr>
<tr>
<td>OV</td>
<td>Global Interrupt Enable bit(s).</td>
</tr>
</tbody>
</table>

### Named Device Features

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>PC</td>
<td>Program Counter.</td>
</tr>
<tr>
<td>TOS</td>
<td>Top-of-Stack.</td>
</tr>
<tr>
<td>WDT</td>
<td>Watchdog Timer.</td>
</tr>
</tbody>
</table>

### Misc. Descriptors

<table>
<thead>
<tr>
<th>Descriptor</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>( )</td>
<td>Contents.</td>
</tr>
<tr>
<td>→ , ↔</td>
<td>Assigned to.</td>
</tr>
<tr>
<td>&lt; &gt;</td>
<td>Register bit field.</td>
</tr>
</tbody>
</table>
A.3 12-BIT INSTRUCTION WIDTH INSTRUCTION SET

Microchip’s baseline 8-bit microcontroller family uses a 12-bit wide instruction set. All instructions execute in a single instruction cycle unless otherwise noted. Any unused opcode is executed as a NOP.

The instruction set is grouped into the following categories: byte-oriented file register operations, bit-oriented file register operations, and core literal and control operations. Instructions. Additionally, instructions that apply to both 12-bit and 14-bit devices are shown in Section A.6 “12-Bit/14-Bit Instruction Width Pseudo-Instructions”.

Instruction opcode is show in hex by making certain assumptions, either listed in the key or as a footnote. For more information on the opcode bit values for each instruction, as well as the number of cycles per instruction, status bits affected and complete instruction details, see the relevant device data sheet.

### TABLE A-1: 12-BIT BYTE-ORIENTED FILE REGISTER OPERATIONS

<table>
<thead>
<tr>
<th>Hex</th>
<th>Mnemonic</th>
<th>Description</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>1Ef*</td>
<td>ADDWF f,d</td>
<td>Add W and f</td>
<td>WREG + f → dest</td>
</tr>
<tr>
<td>16f*</td>
<td>ANDWF f,d</td>
<td>AND W and f</td>
<td>WREG .AND. f → dest</td>
</tr>
<tr>
<td>06f</td>
<td>CLRF f</td>
<td>Clear f</td>
<td>0 → f</td>
</tr>
<tr>
<td>040</td>
<td>CLRW</td>
<td>Clear W</td>
<td>0 → WREG</td>
</tr>
<tr>
<td>26f*</td>
<td>COMF f,d</td>
<td>Complement f</td>
<td>.NOT. f → dest</td>
</tr>
<tr>
<td>0Ef*</td>
<td>DECF f,d</td>
<td>Decrement f</td>
<td>f - 1 → dest</td>
</tr>
<tr>
<td>2Ef*</td>
<td>DECSZ f,d</td>
<td>Decrement f, skip if zero</td>
<td>f - 1 → dest, skip if zero</td>
</tr>
<tr>
<td>2Af*</td>
<td>INCFSZ f,d</td>
<td>Increment f</td>
<td>f + 1 → dest</td>
</tr>
<tr>
<td>3Ef*</td>
<td>IORWF f,d</td>
<td>Inclusive OR W and f</td>
<td>WREG .OR. f → dest</td>
</tr>
<tr>
<td>22f*</td>
<td>MOVF f,d</td>
<td>Move f</td>
<td>f → dest</td>
</tr>
<tr>
<td>02f</td>
<td>MOVWF f</td>
<td>Move W to f</td>
<td>WREG → f</td>
</tr>
<tr>
<td>000</td>
<td>NOP</td>
<td>No operation</td>
<td></td>
</tr>
<tr>
<td>36f*</td>
<td>RLF f,d</td>
<td>Rotate left f</td>
<td>register f</td>
</tr>
<tr>
<td>32f*</td>
<td>RRF f,d</td>
<td>Rotate right f</td>
<td>register f</td>
</tr>
<tr>
<td>0Af*</td>
<td>SUBWF f,d</td>
<td>Subtract W from f</td>
<td>f - WREG → dest</td>
</tr>
<tr>
<td>3Af*</td>
<td>SWAPF f,d</td>
<td>Swap halves f</td>
<td>f(0:3) ↔ f(4:7) → dest</td>
</tr>
<tr>
<td>1Af*</td>
<td>XORWF f,d</td>
<td>Exclusive OR W and f</td>
<td>WREG .XOR. f → dest</td>
</tr>
</tbody>
</table>

* Assuming default bit value for d.

### TABLE A-2: 12-BIT BIT-ORIENTED FILE REGISTER OPERATIONS

<table>
<thead>
<tr>
<th>Hex</th>
<th>Mnemonic</th>
<th>Description</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>4bf</td>
<td>BCF f,b</td>
<td>Bit clear f</td>
<td>0 → f(b)</td>
</tr>
<tr>
<td>5bf</td>
<td>BSF f,b</td>
<td>Bit set f</td>
<td>1 → f(b)</td>
</tr>
<tr>
<td>6bf</td>
<td>BTSC f,b</td>
<td>Bit test, skip if clear</td>
<td>skip if f(b) = 0</td>
</tr>
<tr>
<td>7bf</td>
<td>BTFSS f,b</td>
<td>Bit test, skip if set</td>
<td>skip if f(b) = 1</td>
</tr>
</tbody>
</table>
### TABLE A-3: 12-BIT LITERAL AND CONTROL OPERATIONS

<table>
<thead>
<tr>
<th>Hex</th>
<th>Mnemonic</th>
<th>Description</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ekk</td>
<td>ANDLW kk</td>
<td>AND literal and W kk</td>
<td>kk .AND. WREG → WREG</td>
</tr>
<tr>
<td>9kk</td>
<td>CALL kk</td>
<td>Call subroutine</td>
<td>PC + 1 → TOS, kk → PC</td>
</tr>
<tr>
<td>004</td>
<td>CLRWDI</td>
<td>Clear watchdog timer</td>
<td>0 → WDT (and Prescaler if assigned)</td>
</tr>
<tr>
<td>Akk</td>
<td>GOTO kk</td>
<td>Goto address (k is nine bits)</td>
<td>kk → PC(9 bits)</td>
</tr>
<tr>
<td>Dkk</td>
<td>IORLW kk</td>
<td>Incl. OR literal and W kk</td>
<td>kk .OR. WREG → WREG</td>
</tr>
<tr>
<td>Ckk</td>
<td>MOVLW kk</td>
<td>Move Literal to W kk</td>
<td>kk → WREG</td>
</tr>
<tr>
<td>002</td>
<td>OPTION</td>
<td>Load OPTION Register</td>
<td>WREG → OPTION Register</td>
</tr>
<tr>
<td>8kk</td>
<td>RETLW kk</td>
<td>Return with literal in W</td>
<td>kk → WREG, TOS → PC</td>
</tr>
<tr>
<td>003</td>
<td>SLEEP</td>
<td>Go into Standby Mode</td>
<td>0 → WDT, stop oscillator</td>
</tr>
<tr>
<td>00r</td>
<td>TRIS r</td>
<td>Tristate port r</td>
<td>WREG → I/O control reg r</td>
</tr>
<tr>
<td>Fkk</td>
<td>XORLW kk</td>
<td>Exclusive OR literal and W kk</td>
<td>kk .XOR. WREG → WREG</td>
</tr>
</tbody>
</table>
A.4 14-BIT INSTRUCTION WIDTH INSTRUCTION SET

Microchip’s midrange 8-bit microcontroller family uses a 14-bit wide instruction set. This instruction set consists of 36 instructions, each a single 14-bit wide word. Most instructions operate on a file register, f, and the working register, WREG (accumulator). The result can be directed either to the file register or the WREG register or to both in the case of some instructions. A few instructions operate solely on a file register (BSF, for example).

The instruction set is grouped into the following categories: byte-oriented file register operations, bit-oriented file register operations, and core literal and control operations. Additionally, instructions that apply to both 12-bit and 14-bit devices are shown in Section A.6 “12-Bit/14-Bit Instruction Width Pseudo-Instructions”.

Instruction opcode is shown in hex by making certain assumptions, either listed in the key or as a footnote. For more information on the opcode bit values for each instruction, as well as the number of cycles per instruction, status bits affected and complete instruction details, see the relevant device data sheet.

### TABLE A-4: 14-BIT BYTE-ORIENTED FILE REGISTER OPERATIONS

<table>
<thead>
<tr>
<th>Hex</th>
<th>Mnemonic</th>
<th>Description</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>07df</td>
<td>ADDWF</td>
<td>Add W and f</td>
<td>W + f → d</td>
</tr>
<tr>
<td>05df</td>
<td>ANDWF</td>
<td>AND W and f</td>
<td>W .AND. f → d</td>
</tr>
<tr>
<td>01'1'f</td>
<td>CLRF</td>
<td>Clear f</td>
<td>0 → f</td>
</tr>
<tr>
<td>01xx</td>
<td>CLRWF</td>
<td>Clear W</td>
<td>0 → W</td>
</tr>
<tr>
<td>09df</td>
<td>COMF</td>
<td>Complement f</td>
<td>.NOT. f → d</td>
</tr>
<tr>
<td>03df</td>
<td>DECF</td>
<td>Decrement f</td>
<td>f - 1 → d</td>
</tr>
<tr>
<td>0Bdf</td>
<td>DECFSZ</td>
<td>Decrement f, skip if zero</td>
<td>f - 1 → d, skip if 0</td>
</tr>
<tr>
<td>0Adf</td>
<td>INCF</td>
<td>Increment f</td>
<td>f + 1 → d</td>
</tr>
<tr>
<td>0Fdf</td>
<td>INCFSZ</td>
<td>Increment f, skip if zero</td>
<td>f + 1 → d, skip if 0</td>
</tr>
<tr>
<td>04df</td>
<td>IORWF</td>
<td>Inclusive OR W and f</td>
<td>W .OR. f → d</td>
</tr>
<tr>
<td>08df</td>
<td>MOVF</td>
<td>Move f</td>
<td>f → d</td>
</tr>
<tr>
<td>00'1'f</td>
<td>MOVWF</td>
<td>Move W to f</td>
<td>W → f</td>
</tr>
<tr>
<td>0000</td>
<td>NOP</td>
<td>No operation</td>
<td></td>
</tr>
<tr>
<td>0Ddf</td>
<td>RLF</td>
<td>Rotate left f</td>
<td></td>
</tr>
<tr>
<td>0Cdf</td>
<td>RRφ</td>
<td>Rotate right f</td>
<td></td>
</tr>
<tr>
<td>02df</td>
<td>SUBWF</td>
<td>Subtract W from f</td>
<td>f - W → d</td>
</tr>
<tr>
<td>0Edf</td>
<td>SWAPF</td>
<td>Swap halves f</td>
<td>f(0:3) ↔ f(4:7) → d</td>
</tr>
<tr>
<td>06df</td>
<td>XORWF</td>
<td>Exclusive OR W and f</td>
<td>W .XOR. f → d</td>
</tr>
</tbody>
</table>

### TABLE A-5: 14-BIT BIT-ORIENTED FILE REGISTER OPERATIONS

<table>
<thead>
<tr>
<th>Hex</th>
<th>Mnemonic</th>
<th>Description</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>4bf</td>
<td>BCF</td>
<td>Bit clear f</td>
<td>0 → f(b)</td>
</tr>
<tr>
<td>5bf</td>
<td>BSF</td>
<td>Bit set f</td>
<td>1 → f(b)</td>
</tr>
<tr>
<td>6bf</td>
<td>BTFSC</td>
<td>Bit test, skip if clear</td>
<td>skip if f(b) = 0</td>
</tr>
<tr>
<td>7bf</td>
<td>BTFSS</td>
<td>Bit test, skip if set</td>
<td>skip if f(b) = 1</td>
</tr>
</tbody>
</table>
## TABLE A-6: 14-BIT LITERAL AND CONTROL OPERATIONS

<table>
<thead>
<tr>
<th>Hex</th>
<th>Mnemonic</th>
<th>Description</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>3Ekk</td>
<td>ADDLW kk</td>
<td>Add literal to W</td>
<td>$kk + \text{WREG} \rightarrow \text{WREG}$</td>
</tr>
<tr>
<td>39kk</td>
<td>ANDLW kk</td>
<td>AND literal and W</td>
<td>$\text{kk} \cdot \text{AND} \cdot \text{WREG} \rightarrow \text{WREG}$</td>
</tr>
<tr>
<td>2'0'kkk</td>
<td>CALL kkk</td>
<td>Call subroutine</td>
<td>$\text{PC} + 1 \rightarrow \text{TOS}, \text{kk} \rightarrow \text{PC}$</td>
</tr>
<tr>
<td>0064</td>
<td>CLRWDT</td>
<td>Clear watchdog timer</td>
<td>$0 \rightarrow \text{WDT}$ (and Prescaler if assigned)</td>
</tr>
<tr>
<td>2'1'kkk</td>
<td>GOTO kkk</td>
<td>Goto address (k is nine bits)</td>
<td>$\text{kk} \rightarrow \text{PC}(9 \text{ bits})$</td>
</tr>
<tr>
<td>38kk</td>
<td>IORLW kk</td>
<td>Incl. OR literal and W</td>
<td>$\text{kk} \cdot \text{OR} \cdot \text{WREG} \rightarrow \text{WREG}$</td>
</tr>
<tr>
<td>30kk</td>
<td>MOVLW kk</td>
<td>Move Literal to W</td>
<td>$\text{kk} \rightarrow \text{WREG}$</td>
</tr>
<tr>
<td>0062</td>
<td>OPTION</td>
<td>Load OPTION register</td>
<td>$\text{WREG} \rightarrow \text{OPTION Register}$</td>
</tr>
<tr>
<td>0009</td>
<td>RETFIE</td>
<td>Return from Interrupt</td>
<td>$\text{TOS} \rightarrow \text{PC}, 1 \rightarrow \text{GIE}$</td>
</tr>
<tr>
<td>0008</td>
<td>RETURN</td>
<td>Return from subroutine</td>
<td>$\text{TOS} \rightarrow \text{PC}$</td>
</tr>
<tr>
<td>0063</td>
<td>SLEEP</td>
<td>Go into Standby Mode</td>
<td>$0 \rightarrow \text{WDT}, \text{stop oscillator}$</td>
</tr>
<tr>
<td>3Ckk</td>
<td>SUBLW kk</td>
<td>Subtract W from literal</td>
<td>$\text{kk} - \text{WREG} \rightarrow \text{WREG}$</td>
</tr>
<tr>
<td>006r</td>
<td>TRIS r</td>
<td>Tristate port r</td>
<td>$\text{WREG} \rightarrow \text{I/O control reg r}$</td>
</tr>
<tr>
<td>3Akk</td>
<td>XORLW kk</td>
<td>Exclusive OR literal and W</td>
<td>$\text{kk} \cdot \text{XOR} \cdot \text{WREG} \rightarrow \text{WREG}$</td>
</tr>
</tbody>
</table>
### 14-BIT INSTRUCTION WIDTH EXTENDED INSTRUCTION SET

Some of Microchip’s midrange 8-bit microcontroller family use a 14-bit wide extended instruction set. (Consult your device data sheet to see if you device uses an extended instruction set.) This instruction set consists of 41 instructions, each a single 14-bit wide word. Most instructions operate on a file register, f, and the working register, WREG (accumulator). The result can be directed either to the file register or the WREG register or to both in the case of some instructions. A few instructions operate solely on a file register (BSF, for example).

The instruction set is grouped into the following categories: byte-oriented file register operations, byte-oriented skip operations, bit-oriented file register operations, bit-oriented skip operations, core literal operations, core control operations, core inherent operations and C-compiler optimized operations. Additionally, instructions that apply to both 12-bit and 14-bit devices are shown in Section A.6 “12-Bit/14-Bit Instruction Width Pseudo-Instructions”.

Instruction opcode is show in hex by making certain assumptions, either listed in the key or as a footnote. For more information on the opcode bit values for each instruction, as well as the number of cycles per instruction, status bits affected and complete instruction details, see the relevant device data sheet.

#### TABLE A-7: 14-BIT BYTE-ORIENTED FILE REGISTER OPERATIONS

<table>
<thead>
<tr>
<th>Hex</th>
<th>Mnemonic</th>
<th>Description</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>07df</td>
<td>ADDWF f,d</td>
<td>Add W and f</td>
<td>W + f → d</td>
</tr>
<tr>
<td>3Ddf</td>
<td>ADDWF f,d</td>
<td>Add with Carry W and f</td>
<td>W + f + C → d</td>
</tr>
<tr>
<td>05df</td>
<td>ANDWF f,d</td>
<td>AND W with f</td>
<td>W .AND. f → d</td>
</tr>
<tr>
<td>37df</td>
<td>ASRF* f,d</td>
<td>Arithmetic Right Shift</td>
<td>msb register f</td>
</tr>
<tr>
<td>35df</td>
<td>LSLF* f,d</td>
<td>Logical Left Shift</td>
<td>0 register f</td>
</tr>
<tr>
<td>36df</td>
<td>LSRF* f,d</td>
<td>Logical Right Shift</td>
<td>0 register f</td>
</tr>
<tr>
<td>01'1'f</td>
<td>CLRF f</td>
<td>Clear f</td>
<td>0 → f</td>
</tr>
<tr>
<td>01xx</td>
<td>CLRW</td>
<td>Clear W</td>
<td>0 → W</td>
</tr>
<tr>
<td>09df</td>
<td>COMF f,d</td>
<td>Complement f</td>
<td>.NOT. f → d</td>
</tr>
<tr>
<td>03df</td>
<td>DECF f,d</td>
<td>Decrement f</td>
<td>f - 1 → d</td>
</tr>
<tr>
<td>0Adf</td>
<td>INCF f,d</td>
<td>Increment f</td>
<td>f + 1 → d</td>
</tr>
<tr>
<td>04df</td>
<td>IORWF f,d</td>
<td>Inclusive OR W with f</td>
<td>W .OR. f → d</td>
</tr>
<tr>
<td>08df</td>
<td>MOVWF f,d</td>
<td>Move f</td>
<td>f → d</td>
</tr>
<tr>
<td>00'1'f</td>
<td>MOVWF f</td>
<td>Move W to f</td>
<td>W → f</td>
</tr>
<tr>
<td>0Ddf</td>
<td>RLF f,d</td>
<td>Rotate left f</td>
<td></td>
</tr>
<tr>
<td>0Cdf</td>
<td>RRF f,d</td>
<td>Rotate right f</td>
<td></td>
</tr>
</tbody>
</table>
### TABLE A-7: 14-BIT BYTE-ORIENTED FILE REGISTER OPERATIONS (CONTINUED)

<table>
<thead>
<tr>
<th>Hex</th>
<th>Mnemonic</th>
<th>Description</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>02df</td>
<td>SUBWF</td>
<td>Subtract W from f</td>
<td>f - W → d</td>
</tr>
<tr>
<td>3Bdf</td>
<td>SUBWFB*</td>
<td>Subtract with Borrow W from f</td>
<td>f - W - B → d</td>
</tr>
<tr>
<td>0Edf</td>
<td>SWAPF</td>
<td>Swap halves f</td>
<td>f(0:3) ↔ f(4:7) → d</td>
</tr>
<tr>
<td>06df</td>
<td>XORWF</td>
<td>Exclusive OR W and f</td>
<td>W .XOR. f → d</td>
</tr>
</tbody>
</table>

* Operation in 14-bit extended instruction set but not 14-bit instruction set.

### TABLE A-8: 14-BIT BYTE-ORIENTED SKIP OPERATIONS

<table>
<thead>
<tr>
<th>Hex</th>
<th>Mnemonic</th>
<th>Description</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>0Bdf</td>
<td>DECFSZ</td>
<td>Decrement f, skip if zero</td>
<td>f - 1 → d, skip if 0</td>
</tr>
<tr>
<td>0Fdf</td>
<td>INCFSZ</td>
<td>Increment f, skip if zero</td>
<td>f + 1 → d, skip if 0</td>
</tr>
</tbody>
</table>

### TABLE A-9: 14-BIT BIT-ORIENTED FILE REGISTER OPERATIONS

<table>
<thead>
<tr>
<th>Hex</th>
<th>Mnemonic</th>
<th>Description</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>4bf</td>
<td>BCF</td>
<td>Bit clear f</td>
<td>0 → f(b)</td>
</tr>
<tr>
<td>5bf</td>
<td>BSF</td>
<td>Bit set f</td>
<td>1 → f(b)</td>
</tr>
</tbody>
</table>

### TABLE A-10: 14-BIT BIT-ORIENTED SKIP OPERATIONS

<table>
<thead>
<tr>
<th>Hex</th>
<th>Mnemonic</th>
<th>Description</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>6bf</td>
<td>BTFSC</td>
<td>Bit test, skip if clear</td>
<td>skip if f(b) = 0</td>
</tr>
<tr>
<td>7bf</td>
<td>BTFSS</td>
<td>Bit test, skip if set</td>
<td>skip if f(b) = 1</td>
</tr>
</tbody>
</table>

### TABLE A-11: 14-BIT LITERAL OPERATIONS

<table>
<thead>
<tr>
<th>Hex</th>
<th>Mnemonic</th>
<th>Description</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>3Ekk</td>
<td>ADDLW</td>
<td>Add literal to W</td>
<td>kk + WREG → WREG</td>
</tr>
<tr>
<td>39kk</td>
<td>ANDLW</td>
<td>AND literal and W</td>
<td>kk .AND. WREG → WREG</td>
</tr>
<tr>
<td>38kk</td>
<td>IORLW</td>
<td>Incl. OR literal and W</td>
<td>kk .OR. WREG → WREG</td>
</tr>
<tr>
<td>002k</td>
<td>MOVLB*</td>
<td>Move literal to BSR</td>
<td>k → BSR</td>
</tr>
<tr>
<td>3L'kk</td>
<td>MOVLP*</td>
<td>Move literal to PCLATH</td>
<td>kk → PCLATH</td>
</tr>
<tr>
<td>30kk</td>
<td>MOVLW</td>
<td>Move Literal to W</td>
<td>kk → WREG</td>
</tr>
<tr>
<td>3Ckk</td>
<td>SUBLW</td>
<td>Subtract W from literal</td>
<td>kk - WREG → WREG</td>
</tr>
<tr>
<td>3akk</td>
<td>XORLW</td>
<td>Exclusive OR literal and W</td>
<td>kk .XOR. WREG → WREG</td>
</tr>
</tbody>
</table>

* Operation in 14-bit extended instruction set but not 14-bit instruction set.

### TABLE A-12: 14-BIT CONTROL OPERATIONS

- **Note:**操作在14位扩展指令集中但不在14位指令集中。

<table>
<thead>
<tr>
<th>Hex</th>
<th>Mnemonic</th>
<th>Description</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>32kk</td>
<td>BRA*</td>
<td>Relative branch</td>
<td>PC + kk → PC</td>
</tr>
<tr>
<td>000B</td>
<td>BRW*</td>
<td>Relative branch with W</td>
<td>PC + W → PC</td>
</tr>
<tr>
<td>2'0'kkk</td>
<td>CALL</td>
<td>Call subroutine</td>
<td>PC + 1 → TOS, kk → PC</td>
</tr>
<tr>
<td>000A</td>
<td>CALLW*</td>
<td>Call subroutine with W</td>
<td>PC + 1 → TOS, W → PC</td>
</tr>
<tr>
<td>2'1'kkk</td>
<td>GOTO</td>
<td>Goto address (k is nine bits)</td>
<td>kk → PC(9 bits)</td>
</tr>
<tr>
<td>0009</td>
<td>RETFIE</td>
<td>Return from Interrupt</td>
<td>TOS → PC, 1 → GIE</td>
</tr>
<tr>
<td>34kk</td>
<td>RETLW</td>
<td>Return with literal in W</td>
<td>kk → WREG, TOS → PC</td>
</tr>
<tr>
<td>0008</td>
<td>RETURN</td>
<td>Return from subroutine</td>
<td>TOS → PC</td>
</tr>
</tbody>
</table>

* Operation in 14-bit extended instruction set but not 14-bit instruction set.
### TABLE A-13: 14-BIT INHERENT OPERATIONS

<table>
<thead>
<tr>
<th>Hex</th>
<th>Mnemonic</th>
<th>Description</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>0064</td>
<td>CLRWDT</td>
<td>Clear watchdog timer</td>
<td>0 → WDT (and Prescaler if assigned)</td>
</tr>
<tr>
<td>0000</td>
<td>NOP</td>
<td>No operation</td>
<td></td>
</tr>
<tr>
<td>0062</td>
<td>OPTION</td>
<td>Load OPTION register</td>
<td>WREG → OPTION Register</td>
</tr>
<tr>
<td>0001</td>
<td>RESET*</td>
<td>Software device reset</td>
<td>TOS → PC</td>
</tr>
<tr>
<td>0063</td>
<td>SLEEP</td>
<td>Go into Standby Mode</td>
<td>0 → WDT, stop oscillator</td>
</tr>
<tr>
<td>0060</td>
<td>TRIS</td>
<td>Tristate port r</td>
<td>WREG → I/O control reg r</td>
</tr>
</tbody>
</table>

* Operation in 14-bit extended instruction set but not 14-bit instruction set.

### TABLE A-14: 14-BIT C-COMPILER OPTIMIZED OPERATIONS

<table>
<thead>
<tr>
<th>Hex</th>
<th>Mnemonic</th>
<th>Description</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>31'0'nk</td>
<td>ADDFSR*</td>
<td>Add Literal to FSRn</td>
<td>FSR(n) + k → FSR(n)</td>
</tr>
<tr>
<td>001'0'mn</td>
<td>MOVIW*</td>
<td>Move INDFn to W, with pre/post inc/dec</td>
<td>INDFn → W</td>
</tr>
<tr>
<td>001'0'nm</td>
<td></td>
<td>Move INDFn to W, Indexed Indirect.</td>
<td></td>
</tr>
<tr>
<td>3F'0'nk</td>
<td>MOVWI*</td>
<td>Move W to INDFn, with pre/post inc/dec</td>
<td>W → INDFn</td>
</tr>
<tr>
<td>001'1'mn</td>
<td></td>
<td>Move W to INDFn, Indexed Indirect.</td>
<td></td>
</tr>
<tr>
<td>001'1'nm</td>
<td></td>
<td>Move W to INDFn, Indexed Indirect.</td>
<td></td>
</tr>
<tr>
<td>3F'1'nk</td>
<td></td>
<td>Move W to INDFn, Indexed Indirect.</td>
<td></td>
</tr>
</tbody>
</table>

* Operation in 14-bit extended instruction set but not 14-bit instruction set.
A.6  12-BIT/14-BIT INSTRUCTION WIDTH PSEUDO-INSTRUCTIONS

The following pseudo-instructions are applicable to both the 12-bit and 14-bit instruction word devices. These pseudo-instructions are alternative mnemonics for standard PIC1X instructions or are macros that generate one or more PIC1X instructions. Use of these pseudo-instructions is not recommended for new designs. These are documented mainly for historical purposes.

### TABLE A-15: 12-BIT/14-BIT SPECIAL INSTRUCTION MNEMONICS

<table>
<thead>
<tr>
<th>Mnemonic</th>
<th>Description</th>
<th>Equivalent Operation(s)</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADDCF f,d</td>
<td>Add Carry to File</td>
<td>BTFSC 3,0 f,d</td>
<td>Z</td>
</tr>
<tr>
<td>ADDDCF f,d</td>
<td>Add Digit Carry to File</td>
<td>BTFSC 3,1 f,d</td>
<td>Z</td>
</tr>
<tr>
<td>B k</td>
<td>Branch</td>
<td>GOTO k</td>
<td>-</td>
</tr>
<tr>
<td>BC k</td>
<td>Branch on Carry</td>
<td>BTFSC 3,0 GOTO k</td>
<td>-</td>
</tr>
<tr>
<td>BDC k</td>
<td>Branch on Digit Carry</td>
<td>BTFSC 3,1 GOTO k</td>
<td>-</td>
</tr>
<tr>
<td>BNC k</td>
<td>Branch on No Carry</td>
<td>BTFSS 3,0 GOTO k</td>
<td>-</td>
</tr>
<tr>
<td>BNDC k</td>
<td>Branch on No Digit Carry</td>
<td>BTFSS 3,1 GOTO k</td>
<td>-</td>
</tr>
<tr>
<td>BNZ k</td>
<td>Branch on No Zero</td>
<td>BTFSS 3,2 GOTO k</td>
<td>-</td>
</tr>
<tr>
<td>BZ k</td>
<td>Branch on Zero</td>
<td>BTFSC 3,2 GOTO k</td>
<td>-</td>
</tr>
<tr>
<td>CLRC</td>
<td>Clear Carry</td>
<td>BCF 3,0</td>
<td>-</td>
</tr>
<tr>
<td>CLRDC</td>
<td>Clear Digit Carry</td>
<td>BCF 3,1</td>
<td>-</td>
</tr>
<tr>
<td>CLRZ</td>
<td>Clear Zero</td>
<td>BCF 3,2</td>
<td>-</td>
</tr>
<tr>
<td>LCALL k</td>
<td>Long Call</td>
<td>BCF/BSF 0x0A,3 CALL k</td>
<td>-</td>
</tr>
<tr>
<td>LGOTO k</td>
<td>Long GOTO</td>
<td>BCF/BSF 0x0A,4 GOTO k</td>
<td>-</td>
</tr>
<tr>
<td>MOVFW f</td>
<td>Move File to W</td>
<td>MOVF f,0</td>
<td>Z</td>
</tr>
<tr>
<td>NEGF f,d</td>
<td>Negate File</td>
<td>COMF f,1 INCF f,d</td>
<td>Z</td>
</tr>
<tr>
<td>SETC</td>
<td>Set Carry</td>
<td>BSF 3,0</td>
<td>-</td>
</tr>
<tr>
<td>SETDC</td>
<td>Set Digit Carry</td>
<td>BSF 3,1</td>
<td>-</td>
</tr>
<tr>
<td>SETZ</td>
<td>Set Zero</td>
<td>BSF 3,2</td>
<td>-</td>
</tr>
<tr>
<td>SKPC</td>
<td>Skip on Carry</td>
<td>BTFSS 3,0</td>
<td>-</td>
</tr>
<tr>
<td>SKPDC</td>
<td>Skip on Digit Carry</td>
<td>BTFSS 3,1</td>
<td>-</td>
</tr>
<tr>
<td>SKPNC</td>
<td>Skip on No Carry</td>
<td>BTFSC 3,0</td>
<td>-</td>
</tr>
<tr>
<td>SKPNDCE</td>
<td>Skip on No Digit Carry</td>
<td>BTFSC 3,1</td>
<td>-</td>
</tr>
<tr>
<td>SKPNZ</td>
<td>Skip on Non Zero</td>
<td>BTFSC 3,2</td>
<td>-</td>
</tr>
<tr>
<td>SKPZ</td>
<td>Skip on Zero</td>
<td>BTFSS 3,2</td>
<td>-</td>
</tr>
<tr>
<td>SUBCF f,d</td>
<td>Subtract Carry from File</td>
<td>BTFSC 3,0 DECF f,d</td>
<td>Z</td>
</tr>
</tbody>
</table>
### TABLE A-15: 12-BIT/14-BIT SPECIAL INSTRUCTION MNEMONICS (CONTINUED)

<table>
<thead>
<tr>
<th>Mnemonic</th>
<th>Description</th>
<th>Equivalent Operation(s)</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>SUBDCF f,d</td>
<td>Subtract Digit Carry from File</td>
<td>BTFSC, DEC, MOVF</td>
<td>Z</td>
</tr>
<tr>
<td>TSTF f</td>
<td>Test File</td>
<td>MOVF</td>
<td>Z</td>
</tr>
</tbody>
</table>
### A.7 KEY TO PIC18 DEVICE INSTRUCTION SET

Use this key to determine the meaning of abbreviations in the PIC18 (16-bit instruction width) instruction sets tables.

<table>
<thead>
<tr>
<th>Field</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Register Files</strong></td>
<td></td>
</tr>
<tr>
<td>dest</td>
<td>Destination either the WREG register or the specified register file location. See d.</td>
</tr>
</tbody>
</table>
| f | Register file address.  
| f | 8-bit (0x00 to 0xFF).  
| f | 12-bit (0x000 to 0xFFFF). This is the source address.  
| f | 12-bit (0x000 to 0xFFFF). This is the destination address. |
| r | 0, 1 or 2 for FSR number. |
| x | Don’t care (‘0’ or ‘1’).  
| | The assembler will generate code with x = 0. It is the recommended form of use for compatibility with all Microchip software tools. |
| z | Indirect addressing offset.  
| z | 7-bit offset value for indirect addressing of register files (source).  
| z | 7-bit offset value for indirect addressing of register files (destination). |
| **Literals** |
| k | Literal field, constant data or label.  
| k | 4-bit.  
| kk | 8-bit.  
| kkk | 12-bit. |
| **Offsets, Increments/Decrements** |
| n | The relative address (2’s complement number) for relative branch instructions, or the direct address for Call/Branch and Return instructions. |
| * | The mode of the TBLPTR register for the table read and table write instructions.  
| | Only used with table read (TBLRD) and table write (TBLWT) instructions:  
| | No Change to register  
| | Post-Increment register  
| | Post-Decrement register  
| | Pre-Increment register |
| **Bits** |
| a | RAM access bit  
| a | 0: RAM location in Access RAM (BSR register is ignored)  
| a | 1: RAM bank is specified by BSR register (default) |
| b | Bit address within an 8-bit file register (0 to 7). |
| d | Destination select bit  
| d | 0: store result in WREG  
| d | 1: store result in file register f (default) |
| s | Fast Call/Return mode select bit  
| s | 0: do not update into/from shadow registers (default)  
<p>| s | 1: certain registers loaded into/from shadow registers (Fast mode) |
| ’ ’ | Bit values, as opposed to Hex value. |
| <strong>Named Registers</strong> |
| BSR | Bank Select Register. Used to select the current RAM bank. |
| FSR | File Select Register. |
| PCL | Program Counter Low Byte. |
| PCH | Program Counter High Byte. |
| PCLATH | Program Counter High Byte Latch. |
| PCLATU | Program Counter Upper Byte Latch. |
| PRODH | Product of Multiply High Byte. |</p>
<table>
<thead>
<tr>
<th>Field</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRODL</td>
<td>Product of Multiply Low Byte.</td>
</tr>
<tr>
<td>STATUS</td>
<td>Status Register</td>
</tr>
<tr>
<td>TABLAT</td>
<td>8-bit Table Latch.</td>
</tr>
<tr>
<td>TBLPTR</td>
<td>21-bit Table Pointer (points to a Program Memory location).</td>
</tr>
<tr>
<td>WREG</td>
<td>Working register (accumulator).</td>
</tr>
</tbody>
</table>

**Named Bits**

- C, DC, Z, OV, N: ALU Status bits: Carry, Digit Carry, Zero, Overflow, Negative.
- TO: Time-out bit.
- PD: Power-down bit.
- PEIE: Peripheral Interrupt Enable bit.
- GIE, GIEL/H: Global Interrupt Enable bit(s).

**Named Device Features**

- MCLR: Master clear device reset.
- PC: Program Counter.
- TOS: Top-of-Stack.
- WDT: Watchdog Timer.

**Misc. Descriptors**

- ( ): Contents.
- →: Assigned to.
- < >: Register bit field.
A.8 PIC18 DEVICE INSTRUCTION SET

Microchip’s new high-performance 8-bit microcontroller family uses a 16-bit wide instruction set. This instruction set consists of 76 instructions, each a single 16-bit wide word (2 bytes). Most instructions operate on a file register, f, and the working register, WREG (accumulator). The result can be directed either to the file register or the WREG register or both in the case of some instructions. A few instructions operate solely on a file register (BSF, for example).

The instruction set is grouped into the following categories: byte-oriented file register operations, bit-oriented file register operations, control operations, literal operations and memory operations. Additionally, extended mode instructions are shown in Section A.9 “PIC18 Device Extended Instruction Set”.

Instruction opcode is show in hex by making certain assumptions, either listed in the key or as a footnote. For more information on the opcode bit values for each instruction, as well as the number of cycles per instruction, status bits affected and complete instruction details, see the relevant device data sheet.

### TABLE A-16: PIC18 BYTE-ORIENTED REGISTER OPERATIONS

<table>
<thead>
<tr>
<th>Hex</th>
<th>Mnemonic</th>
<th>Description</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>27f*</td>
<td>ADDWF f,d,a</td>
<td>ADD WREG to f</td>
<td>WREG+f → dest</td>
</tr>
<tr>
<td>23f*</td>
<td>ADDWF f,d,a</td>
<td>ADD WREG and Carry bit to f</td>
<td>WREG+f+C → dest</td>
</tr>
<tr>
<td>17f*</td>
<td>ANDWF f,d,a</td>
<td>AND WREG with f</td>
<td>WREG .AND. f → dest</td>
</tr>
<tr>
<td>6Bf*</td>
<td>CLRf f,a</td>
<td>Clear f</td>
<td>0 → f</td>
</tr>
<tr>
<td>1Ff*</td>
<td>COMF f,d,a</td>
<td>Complement f</td>
<td>.NOT. f → dest</td>
</tr>
<tr>
<td>63f*</td>
<td>CPFSEQ f,a</td>
<td>Compare f with WREG, skip if f=WREG</td>
<td>f-WREG, if f=WREG, PC+4 → PC else PC+2 → PC</td>
</tr>
<tr>
<td>65f*</td>
<td>CPFSGT f,a</td>
<td>Compare f with WREG, skip if f &gt; WREG</td>
<td>f-WREG, if f &gt; WREG, PC+4 → PC else PC+2 → PC</td>
</tr>
<tr>
<td>61f*</td>
<td>CPFSLT f,a</td>
<td>Compare f with WREG, skip if f &lt; WREG</td>
<td>f-WREG, if f &lt; WREG, PC+4 → PC else PC+2 → PC</td>
</tr>
<tr>
<td>07f*</td>
<td>DECF f,d,a</td>
<td>Decrement f</td>
<td>f-1 → dest</td>
</tr>
<tr>
<td>2Ff*</td>
<td>DECFSZ f,d,a</td>
<td>Decrement f, skip if 0</td>
<td>f-1 → dest, if dest=0, PC+4 → PC else PC+2 → PC</td>
</tr>
<tr>
<td>4Ff*</td>
<td>DCFSNZ f,d,a</td>
<td>Decrement f, skip if not 0</td>
<td>f-1 → dest, if dest ≠ 0, PC+4 → PC else PC+2 → PC</td>
</tr>
<tr>
<td>2Bf*</td>
<td>INCf f,d,a</td>
<td>Increment f</td>
<td>f+1 → dest</td>
</tr>
<tr>
<td>3Ff*</td>
<td>INCFSZ f,d,a</td>
<td>Increment f, skip if 0</td>
<td>f+1 → dest, if dest=0, PC+4 → PC else PC+2 → PC</td>
</tr>
<tr>
<td>4Bf*</td>
<td>INFSNZ f,d,a</td>
<td>Increment f, skip if not 0</td>
<td>f+1 → dest, if dest ≠ 0, PC+4 → PC else PC+2 → PC</td>
</tr>
<tr>
<td>13f*</td>
<td>IORWF f,d,a</td>
<td>Inclusive OR WREG with f</td>
<td>WREG .OR. f → dest</td>
</tr>
<tr>
<td>53f*</td>
<td>MOVf f,d,a</td>
<td>Move f</td>
<td>f → dest</td>
</tr>
<tr>
<td>CF'</td>
<td>MOVFF f',f&quot;</td>
<td>Move f’ to fd” (second word)</td>
<td>f’ → f&quot;</td>
</tr>
<tr>
<td>FF&quot;</td>
<td>MOVVF f',f&quot;</td>
<td>Move f’ to fd” (second word)</td>
<td>f’ → f&quot;</td>
</tr>
<tr>
<td>6Ff*</td>
<td>MOVF f,a</td>
<td>Move WREG to f</td>
<td>WREG → f</td>
</tr>
<tr>
<td>03f*</td>
<td>MULWF f,a</td>
<td>Multiply WREG with f</td>
<td>WREG * f → PRODH:PRODL</td>
</tr>
<tr>
<td>6Df*</td>
<td>NEGF f,a</td>
<td>Negate f</td>
<td>-f → f</td>
</tr>
</tbody>
</table>
| 37f* | RLCF f,d,a | Rotate left f through Carry | register f

C

7.....0
### TABLE A-16: PIC18 BYTE-ORIENTED REGISTER OPERATIONS (CONTINUED)

<table>
<thead>
<tr>
<th>Hex</th>
<th>Mnemonic</th>
<th>Description</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>47f*</td>
<td>RLNCF f,d,a</td>
<td>Rotate left f (no carry)</td>
<td>register f&lt;7...0&gt;</td>
</tr>
<tr>
<td>33f*</td>
<td>RRCF f,d,a</td>
<td>Rotate right f through Carry</td>
<td>register f&lt;7...0&gt;, C&lt;7..0&gt;</td>
</tr>
<tr>
<td>43f*</td>
<td>RRNCF f,d,a</td>
<td>Rotate right f (no carry)</td>
<td>register f&lt;7...0&gt;</td>
</tr>
<tr>
<td>69f*</td>
<td>SETF f,a</td>
<td>Set f</td>
<td>0xFF → f</td>
</tr>
<tr>
<td>57f*</td>
<td>SUBFWB f,d,a</td>
<td>Subtract f from WREG with Borrow</td>
<td>WREG–f–C → dest</td>
</tr>
<tr>
<td>5Ff*</td>
<td>SUBWF f,d,a</td>
<td>Subtract WREG from f</td>
<td>f–WREG → dest</td>
</tr>
<tr>
<td>5BF*</td>
<td>SUBWFB f,d,a</td>
<td>Subtract WREG from f with Borrow</td>
<td>f–WREG–C → dest</td>
</tr>
<tr>
<td>3BF*</td>
<td>SWAPF f,d,a</td>
<td>Swap nibbles of f</td>
<td>f&lt;3:0&gt; → dest&lt;7:4&gt;, f&lt;7:4&gt; → dest&lt;3:0&gt;</td>
</tr>
<tr>
<td>67f*</td>
<td>TSTFSZ f,a</td>
<td>Test f, skip if 0</td>
<td>PC+4 → PC, if f=0, else PC+2 → PC</td>
</tr>
<tr>
<td>1BF*</td>
<td>XORWF f,d,a</td>
<td>Exclusive OR WREG with f</td>
<td>WREG .XOR. f → dest</td>
</tr>
</tbody>
</table>

* Assuming default bit values for d and a.
### TABLE A-17: PIC18 BIT-ORIENTED REGISTER OPERATIONS

<table>
<thead>
<tr>
<th>Hex</th>
<th>Mnemonic</th>
<th>Description</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>91f*</td>
<td>BCF</td>
<td>Bit Clear f</td>
<td>0 → f&lt;\text{b}&gt;</td>
</tr>
<tr>
<td>81f*</td>
<td>BSF</td>
<td>Bit Set f</td>
<td>1 → f&lt;\text{b}&gt;</td>
</tr>
<tr>
<td>B1f*</td>
<td>BTFSC</td>
<td>Bit test f, skip if clear</td>
<td>if f&lt;\text{b}&gt;=0, PC+4→PC, else PC+2→PC</td>
</tr>
<tr>
<td>A1f*</td>
<td>BTFSS</td>
<td>Bit test f, skip if set</td>
<td>if f&lt;\text{b}&gt;=1, PC+4→PC, else PC+2→PC</td>
</tr>
<tr>
<td>71f*</td>
<td>BTG</td>
<td>Bit Toggle f</td>
<td>f&lt;\text{b}&gt; → f&lt;\text{b}&gt;</td>
</tr>
</tbody>
</table>

* Assuming b = 0 and default bit value for a.

### TABLE A-18: PIC18 CONTROL OPERATIONS

<table>
<thead>
<tr>
<th>Hex</th>
<th>Mnemonic</th>
<th>Description</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>E2n</td>
<td>BC</td>
<td>Branch if Carry</td>
<td>if C=1, PC+2+2*n→PC, else PC+2→PC</td>
</tr>
<tr>
<td>E6n</td>
<td>BN</td>
<td>Branch if Negative</td>
<td>if N=1, PC+2+2*n→PC, else PC+2→PC</td>
</tr>
<tr>
<td>E3n</td>
<td>BNC</td>
<td>Branch if Not Carry</td>
<td>if C=0, PC+2+2*n→PC, else PC+2→PC</td>
</tr>
<tr>
<td>E7n</td>
<td>BNN</td>
<td>Branch if Not Negative</td>
<td>if N=0, PC+2+2*n→PC, else PC+2→PC</td>
</tr>
<tr>
<td>E5n</td>
<td>NOV</td>
<td>Branch if Not Overflow</td>
<td>if OV=0, PC+2+2*n→PC, else PC+2→PC</td>
</tr>
<tr>
<td>E1n</td>
<td>NZ0</td>
<td>Branch if Not Zero</td>
<td>if Z=0, PC+2+2*n→PC, else PC+2→PC</td>
</tr>
<tr>
<td>E4n</td>
<td>NOV</td>
<td>Branch if Overflow</td>
<td>if OV=1, PC+2+2*n→PC, else PC+2→PC</td>
</tr>
<tr>
<td>D'0'n</td>
<td>BRA</td>
<td>Branch Unconditionally</td>
<td>PC+2+2*n→PC</td>
</tr>
<tr>
<td>E0n</td>
<td>BZ</td>
<td>Branch if Zero</td>
<td>if Z=1, PC+2+2*n→PC, else PC+2→PC</td>
</tr>
<tr>
<td>ECkk*</td>
<td>CALL</td>
<td>Call Subroutine</td>
<td>1st word 2nd word</td>
</tr>
<tr>
<td>Fkkk</td>
<td></td>
<td></td>
<td>PC+4 → TOS, n → PC&lt;20:1&gt;, WREG → WREGs, STATUS → STATUSs, BSR → BSRs</td>
</tr>
<tr>
<td>0004</td>
<td>CLRWDT</td>
<td>Clear Watchdog Timer</td>
<td>0 → WDT, 0 → WDT postscaler, 1 → TO,1 → PD</td>
</tr>
<tr>
<td>0007</td>
<td>DAW</td>
<td>Decimal Adjust WREG</td>
<td>if WREG&lt;3:0&gt; &gt;9 or DC=1, WREG&lt;3:0&gt;→WREG&lt;3:0&gt;, else WREG&lt;3:0&gt;→WREG&lt;3:0&gt;;</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>if WREG&lt;7:4&gt; &gt;9 or C=1, WREG&lt;7:4&gt;→WREG&lt;7:4&gt;, else WREG&lt;7:4&gt;→WREG&lt;7:4&gt;;</td>
</tr>
<tr>
<td>EFkk</td>
<td>GOTO</td>
<td>Go to address</td>
<td>1st word 2nd word</td>
</tr>
<tr>
<td>Fkkk</td>
<td></td>
<td></td>
<td>n → PC&lt;20:1&gt;</td>
</tr>
<tr>
<td>0000</td>
<td>NOP</td>
<td>No Operation</td>
<td>No Operation</td>
</tr>
<tr>
<td>Fxxx</td>
<td>NOP</td>
<td>No Operation</td>
<td>No Operation (2-word instructions)</td>
</tr>
<tr>
<td>0006</td>
<td>POP</td>
<td>Pop top of return stack (TOS)</td>
<td>TOS-1 → TOS</td>
</tr>
<tr>
<td>0005</td>
<td>PUSH</td>
<td>Push top of return stack (TOS)</td>
<td>PC+2→TOS</td>
</tr>
<tr>
<td>D'1'n</td>
<td>RCALL</td>
<td>Relative Call</td>
<td>PC+2 → TOS, PC+2+2*n→PC</td>
</tr>
<tr>
<td>00FF</td>
<td>RESET</td>
<td>Software device reset</td>
<td>Same as MCLR reset</td>
</tr>
<tr>
<td>0010*</td>
<td>RETFIE</td>
<td>Return from interrupt</td>
<td>(and enable interrupts) TOS → PC, 1 → GIE/GIEH or PEIE/GIEL, if s=1, WREGs → WREG, STATUSs → STATUS, BSRs → BSR, PCLATU/PCLATH are unchanged.</td>
</tr>
<tr>
<td>0012*</td>
<td>RETURN</td>
<td>Return from subroutine</td>
<td>TOS → PC, if s=1, WREGs → WREG, STATUSs → STATUS, BSRs → BSR, PCLATU/PCLATH are unchanged.</td>
</tr>
<tr>
<td>0003</td>
<td>SLEEP</td>
<td>Enter SLEEP Mode</td>
<td>0 → WDT, 0 → WDT postscaler, 1 → TO, 0 → PD</td>
</tr>
</tbody>
</table>

* Assuming default bit value for s.
### TABLE A-19: PIC18 LITERAL OPERATIONS

<table>
<thead>
<tr>
<th>Hex</th>
<th>Mnemonic</th>
<th>Description</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>0Fkk</td>
<td>ADDLW k</td>
<td>Add literal to WREG</td>
<td>WREG+k → WREG</td>
</tr>
<tr>
<td>0Bkk</td>
<td>ANDLW k</td>
<td>AND literal with WREG</td>
<td>WREG . AND. k → WREG</td>
</tr>
<tr>
<td>09kk</td>
<td>IORLW k</td>
<td>Inclusive OR literal with WREG</td>
<td>WREG . OR. k → WREG</td>
</tr>
<tr>
<td>EErk</td>
<td>LFSR r,k</td>
<td>Move literal (12 bit) 2nd word to FSRr 1st word</td>
<td>k → FSRr</td>
</tr>
<tr>
<td>F0kk</td>
<td>LFSR k,k</td>
<td></td>
<td></td>
</tr>
<tr>
<td>010k</td>
<td>MOVLD k</td>
<td>Move literal to BSR&lt;3:0&gt;</td>
<td>k → BSR</td>
</tr>
<tr>
<td>0Ekk</td>
<td>MOVLD k</td>
<td>Move literal to WREG</td>
<td>k → WREG</td>
</tr>
<tr>
<td>0Dkk</td>
<td>MULLW k</td>
<td>Multiply literal with WREG</td>
<td>WREG * k → PRODH:PRODL</td>
</tr>
<tr>
<td>0Ckk</td>
<td>RETLW k</td>
<td>Return with literal in WREG</td>
<td>k → WREG</td>
</tr>
<tr>
<td>08kk</td>
<td>SUBLW k</td>
<td>Subtract WREG from literal</td>
<td>k − WREG → WREG</td>
</tr>
<tr>
<td>0Akk</td>
<td>XORLW k</td>
<td>Exclusive OR literal with WREG</td>
<td>WREG . XOR. k → WREG</td>
</tr>
</tbody>
</table>

### TABLE A-20: PIC18 MEMORY OPERATIONS

<table>
<thead>
<tr>
<th>Hex</th>
<th>Mnemonic</th>
<th>Description</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>0008</td>
<td>TBLRD*</td>
<td>Table Read</td>
<td>Prog Mem (TBLPTR) → TABLAT</td>
</tr>
<tr>
<td>0009</td>
<td>TBLRD**</td>
<td>Table Read with post-increment</td>
<td>Prog Mem (TBLPTR) → TABLAT TBLPTR +1 → TBLPTR</td>
</tr>
<tr>
<td>000A</td>
<td>TBLRD*-</td>
<td>Table Read with post-decrement</td>
<td>Prog Mem (TBLPTR) → TABLAT TBLPTR -1 → TBLPTR</td>
</tr>
<tr>
<td>000B</td>
<td>TBLRD+*</td>
<td>Table Read with pre-increment</td>
<td>TBLPTR +1 → TBLPTR Prog Mem (TBLPTR) → TABLAT</td>
</tr>
<tr>
<td>000C</td>
<td>TBLWT*</td>
<td>Table Write</td>
<td>TABLAT → Prog Mem (TBLPTR)</td>
</tr>
<tr>
<td>000D</td>
<td>TBLWT**</td>
<td>Table Write with post-increment</td>
<td>TABLAT → Prog Mem (TBLPTR) TBLPTR +1 → TBLPTR</td>
</tr>
<tr>
<td>000E</td>
<td>TBLWT*-</td>
<td>Table Write with post-decrement</td>
<td>TABLAT → Prog Mem (TBLPTR) TBLPTR -1 → TBLPTR</td>
</tr>
<tr>
<td>000F</td>
<td>TBLWT+*</td>
<td>Table Write with pre-increment</td>
<td>TBLPTR +1 → TBLPTR TABLAT → Prog Mem (TBLPTR)</td>
</tr>
</tbody>
</table>
A.9 PIC18 DEVICE EXTENDED INSTRUCTION SET

Some PIC18 devices have an extended mode of operation for use with the MPLAB C18 compiler. This mode will change the operation of some instructions listed in Section A.8 “PIC18 Device Instruction Set” and add the instructions listed in this section.

In general, you should not need to use the extended instruction set. However, if needed, the extended mode is set using a special device configuration bit. For more on extended mode, see the MPLAB C18 C Compiler User’s Guide (DS51288) and your device data sheet. To set up your IDE project for use with extended mode, see the MPASM online help for Section “MPLAB C18: Setup for PIC18 Extended Instruction Set Use” (MPLAB X IDE) or Section “MPLAB C18: Setup for PIC18 Extended Instruction Set Use” (MPLAB IDE v8).

Instruction opcode is shown in hex by making certain assumptions, either listed in the key or as a footnote. For more information on the opcode bit values for each instruction, as well as the number of cycles per instruction, status bits affected and complete instruction details, see the relevant device data sheet.

<table>
<thead>
<tr>
<th>Hex</th>
<th>Mnemonic</th>
<th>Description</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>E8fk</td>
<td>ADDFSR f,k</td>
<td>Add literal to FSR</td>
<td>FSR(f)+k → FSR(f)</td>
</tr>
<tr>
<td>E8Ck</td>
<td>ADDULNK k</td>
<td>Add literal to FSR2 and return</td>
<td>FSR2+k → FSR2, (TOS) → PC</td>
</tr>
<tr>
<td>0014</td>
<td>CALLW</td>
<td>Call subroutine using WREG</td>
<td>(PC + 2) → TOS, (W) → PCL,</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(PCLATH) → PCH, (PCLATU) → PCU</td>
</tr>
<tr>
<td>EB’0’z</td>
<td>MOVSF z’, f”</td>
<td>Move z’ (source) to 1st word,</td>
<td>((FSR2)+z’) → f’</td>
</tr>
<tr>
<td>Ffff</td>
<td></td>
<td>f” (destination)2nd word</td>
<td></td>
</tr>
<tr>
<td>EB’1’z</td>
<td>MOVSS z’, z”</td>
<td>Move z’ (source) to 1st word,</td>
<td>((FSR2)+z’) → ((FSR2)+z”)</td>
</tr>
<tr>
<td>Fxzz</td>
<td></td>
<td>z” (destination)2nd word</td>
<td></td>
</tr>
<tr>
<td>EAkk</td>
<td>PUSHL k</td>
<td>Store literal at FSR2, decrement FSR2</td>
<td>k → (FSR2), FSR2-1 → FSR2</td>
</tr>
<tr>
<td>E9fk</td>
<td>SUBFSR f,k</td>
<td>Subtract literal from FSR</td>
<td>FSR(f-k) → FSR(f)</td>
</tr>
<tr>
<td>E9Ck</td>
<td>SUBULNK k</td>
<td>Subtract literal from FSR2 and return</td>
<td>FSR2-k → FSR2, (TOS) → PC</td>
</tr>
</tbody>
</table>
Appendix B. Useful Tables

B.1 INTRODUCTION

Some useful tables are included for reference here. The tables are:
- ASCII Character Set
- Hexadecimal to Decimal Conversion

B.2 ASCII CHARACTER SET

This table displays the standard ASCII character set in nibbles.

<table>
<thead>
<tr>
<th>Most Significant Nibble</th>
<th>HEX</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td>NUL</td>
<td>0</td>
<td>NUL</td>
<td>DLE</td>
<td>Space</td>
<td>0</td>
<td>@</td>
<td>P</td>
<td>`</td>
<td>p</td>
</tr>
<tr>
<td>SOH</td>
<td>1</td>
<td>SOH</td>
<td>DC1</td>
<td>!</td>
<td>1</td>
<td>A</td>
<td>Q</td>
<td>a</td>
<td>q</td>
</tr>
<tr>
<td>STX</td>
<td>2</td>
<td>STX</td>
<td>DC2</td>
<td>*</td>
<td>2</td>
<td>B</td>
<td>R</td>
<td>b</td>
<td>r</td>
</tr>
<tr>
<td>ETX</td>
<td>3</td>
<td>ETX</td>
<td>DC3</td>
<td>#</td>
<td>3</td>
<td>C</td>
<td>S</td>
<td>c</td>
<td>s</td>
</tr>
<tr>
<td>EOT</td>
<td>4</td>
<td>EOT</td>
<td>DC4</td>
<td>$</td>
<td>4</td>
<td>D</td>
<td>T</td>
<td>d</td>
<td>t</td>
</tr>
<tr>
<td>ENQ</td>
<td>5</td>
<td>ENQ</td>
<td>NAK</td>
<td>%</td>
<td>5</td>
<td>E</td>
<td>U</td>
<td>e</td>
<td>u</td>
</tr>
<tr>
<td>ACK</td>
<td>6</td>
<td>ACK</td>
<td>SYN</td>
<td>&amp;</td>
<td>6</td>
<td>F</td>
<td>V</td>
<td>f</td>
<td>v</td>
</tr>
<tr>
<td>Bell</td>
<td>7</td>
<td>Bell</td>
<td>ETB</td>
<td>'</td>
<td>7</td>
<td>G</td>
<td>W</td>
<td>g</td>
<td>w</td>
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<td>8</td>
<td>BS</td>
<td>CAN</td>
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<td>X</td>
<td>h</td>
<td>x</td>
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<td>EM</td>
<td>)</td>
<td>9</td>
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<td>Y</td>
<td>i</td>
<td>y</td>
</tr>
<tr>
<td>LF</td>
<td>A</td>
<td>LF</td>
<td>SUB</td>
<td>*</td>
<td>J</td>
<td>Z</td>
<td>j</td>
<td>z</td>
<td></td>
</tr>
<tr>
<td>VT</td>
<td>B</td>
<td>VT</td>
<td>ESC</td>
<td>+</td>
<td>K</td>
<td>{</td>
<td>k</td>
<td>{</td>
<td></td>
</tr>
<tr>
<td>FF</td>
<td>C</td>
<td>FF</td>
<td>FS</td>
<td>,</td>
<td>L</td>
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<td>I</td>
<td>I</td>
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<tr>
<td>CR</td>
<td>D</td>
<td>CR</td>
<td>GS</td>
<td>–</td>
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<tr>
<td>SO</td>
<td>E</td>
<td>SO</td>
<td>RS</td>
<td>&gt;</td>
<td>N</td>
<td>^</td>
<td>n</td>
<td>~</td>
<td></td>
</tr>
<tr>
<td>SI</td>
<td>F</td>
<td>SI</td>
<td>US</td>
<td>/</td>
<td>?</td>
<td>O</td>
<td>_</td>
<td>o</td>
<td>DEL</td>
</tr>
</tbody>
</table>

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### B.3 HEXADECIMAL TO DECIMAL CONVERSION

This table describes how to convert hexadecimal to decimal. For each HEX digit, find the associated decimal value. Add the numbers together.

<table>
<thead>
<tr>
<th>Hexadecimal</th>
<th>Decimal Value</th>
<th>Decimal Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>000</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>4096</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>8192</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>12288</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>16384</td>
<td>4</td>
</tr>
<tr>
<td>5</td>
<td>20480</td>
<td>5</td>
</tr>
<tr>
<td>6</td>
<td>24576</td>
<td>6</td>
</tr>
<tr>
<td>7</td>
<td>28672</td>
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</tr>
<tr>
<td>8</td>
<td>32768</td>
<td>8</td>
</tr>
<tr>
<td>9</td>
<td>36864</td>
<td>9</td>
</tr>
<tr>
<td>A</td>
<td>40960</td>
<td>A</td>
</tr>
<tr>
<td>B</td>
<td>45056</td>
<td>B</td>
</tr>
<tr>
<td>C</td>
<td>49152</td>
<td>C</td>
</tr>
<tr>
<td>D</td>
<td>53248</td>
<td>D</td>
</tr>
<tr>
<td>E</td>
<td>57344</td>
<td>E</td>
</tr>
<tr>
<td>F</td>
<td>61440</td>
<td>F</td>
</tr>
</tbody>
</table>

For example, HEX A38F converts to 41871 as follows:

<table>
<thead>
<tr>
<th>HEX 1000’s Digit</th>
<th>HEX 100’s Digit</th>
<th>HEX 10’s Digit</th>
<th>HEX 1’s Digit</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>40960</td>
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