MPLAB® ICD 3
In-Circuit Debugger User's Guide

For MPLAB X IDE

DS50002081B

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Object of Declaration: MPLAB® ICD 3 In-Circuit Debugger

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Manufacturer:	Microchip Technology Inc. 2355 W. Chandler Blvd. Chandler, Arizona, 85224-6199 USA

This declaration of conformity is issued by the manufacturer.

The development/evaluation tool is designed to be used for research and development in a laboratory environment. This development/evaluation tool is not intended to be a finished appliance, nor is it intended for incorporation into finished appliances that are made commercially available as single functional units to end users. This development/evaluation tool complies with EU EMC Directive 2004/108/EC and as supported by the European Commission's Guide for the EMC Directive 2004/108/EC (8th February 2010).

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This development/evaluation tool, when incorporating wireless and radio-telecom functionality, is in compliance with the essential requirement and other relevant provisions of the R&TTE Directive 1999/5/EC and the FCC rules as stated in the declaration of conformity provided in the module datasheet and the module product page available at www.microchip.com.

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Signed for and on behalf of Microchip Technology Inc. at Chandler, Arizona, USA

Derek Carlson
VP Development Tools

12-Sep-14
Date

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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 "DSXXXXXXXXA", where "XXXXXXXX" 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® X IDE online help. Select the Help menu, and then Topics to open a list of available online help files.

INTRODUCTION

This chapter contains general information that will be useful to know before using the MPLAB ICD 3 In-Circuit Debugger. Items discussed in this chapter include:

- Document Layout
- Conventions Used in this Guide
- Recommended Reading

DOCUMENT LAYOUT

This document describes how to use the MPLAB ICD 3 In-Circuit Debugger as a development tool to emulate and debug firmware on a target board, as well as how to program devices. The document is organized as follows:

Part 1 – Getting Started

- **Chapter 1. About the Debugger** – What the MPLAB ICD 3 In-Circuit Debugger is and how it can help you develop your application.
- **Chapter 2. Operation** – The theory of MPLAB ICD 3 In-Circuit Debugger operation. Explains configuration options.

Part 2 – Features

- **Chapter 3. Debugger Usage** – A description of basic debug features available in MPLAB X IDE when the MPLAB ICD 3 In-Circuit Debugger is chosen as the debug tool. This includes the debug features for breakpoints and stopwatch.

Part 2 – Troubleshooting

- **Chapter 4. Troubleshooting First Steps** – The first things you should try if you are having issues with debugger operation.
- **Chapter 5. Frequently Asked Questions (FAQs)** – A list of frequently asked questions, useful for troubleshooting.
- **Chapter 6. Error Messages** – A list of error messages and suggested resolutions.
- **Chapter 7. Engineering Technical Notes (ETNs)**

Part 3 – Reference

- **Appendix A. Debugger Function Summary** – A summary of debugger functions available in MPLAB X IDE when the MPLAB ICD 3 debugger is chosen as the debug or program tool.
- **Appendix B. Hardware Specification** – The hardware and electrical specifications of the debugger system.
- **Appendix C. Revision History**

CONVENTIONS USED IN THIS GUIDE

This manual uses the following documentation conventions:

DOCUMENTATION CONVENTIONS

<table>
<tr><th>Description</th><th>Represents</th><th>Examples</th></tr>
<tr><td colspan="3">**Arial font:**</td></tr>
<tr><td rowspan="2">Italic characters</td><td>Referenced books</td><td>*MPLAB® IDE User's Guide*</td></tr>
<tr><td>Emphasized text</td><td>...is the *only* compiler...</td></tr>
<tr><td rowspan="3">Initial caps</td><td>A window</td><td>the Output window</td></tr>
<tr><td>A dialog</td><td>the Settings dialog</td></tr>
<tr><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>Save*</td></tr>
<tr><td rowspan="2">Bold characters</td><td>A dialog button</td><td>Click **OK**</td></tr>
<tr><td>A tab</td><td>Click the **Power** tab</td></tr>
<tr><td>N'Rnnnn</td><td>A number in verilog format, where N is the total number of digits, R is the radix and n is a digit.</td><td>4'b0010, 2'hF1</td></tr>
<tr><td>Text in angle brackets < ></td><td>A key on the keyboard</td><td>Press <Enter>, <F1></td></tr>
<tr><td colspan="3">**Courier New font:**</td></tr>
<tr><td rowspan="7">Plain Courier New</td><td>Sample source code</td><td>`#define START`</td></tr>
<tr><td>Filenames</td><td>`autoexec.bat`</td></tr>
<tr><td>File paths</td><td>`c:\mcc18\h`</td></tr>
<tr><td>Keywords</td><td>`_asm, _endasm, static`</td></tr>
<tr><td>Command-line options</td><td>`-Opa+, -Opa-`</td></tr>
<tr><td>Bit values</td><td>`0, 1`</td></tr>
<tr><td>Constants</td><td>`0xFF, 'A'`</td></tr>
<tr><td>Italic Courier New</td><td>A variable argument</td><td>*`file`*`.o`, where *`file`* can be any valid filename</td></tr>
<tr><td>Square brackets [ ]</td><td>Optional arguments</td><td>`mcc18 [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|1}`</td></tr>
<tr><td rowspan="2">Ellipses...</td><td>Replaces repeated text</td><td>`var_name [, var_name...]`</td></tr>
<tr><td>Represents code supplied by user</td><td>`void main (void)`
`{ ...`
`}`</td></tr>
</table>

RECOMMENDED READING

This user's guide describes how to use MPLAB ICD 3 In-Circuit Debugger. Other useful documents are listed below. The following Microchip documents are available and recommended as supplemental reference resources.

Multi-Tool Design Advisory (DS51764)

Please read this first! This document contains important information about operational issues that should be considered when using the MPLAB ICD 3 with your target design.

Release Notes for MPLAB ICD 3 In-Circuit Debugger

For the latest information on using MPLAB ICD 3 In-Circuit Debugger, read the notes under “Release Notes and Support Documentation” on the MPLAB X IDE Start Page. The release notes contain update information and known issues that may not be included in this user’s guide.

MPLAB X - Using MPLAB ICD 3 In-Circuit Debugger Poster (DS52011)

This poster shows you how to hook up the hardware and install the software for the MPLAB ICD 3 In-Circuit Debugger using standard communications and a target board.

MPLAB ICD 3 In-Circuit Debugger User’s Guide (DS51766)

A comprehensive user’s guide for the debugger. Usage, troubleshooting and hardware specifications are included.

MPLAB ICD 3 In-Circuit Debugger Online Help File

A comprehensive help file for the debugger is included with MPLAB X IDE. Usage, troubleshooting and hardware specifications are covered. This help file may be more up-to-date than the printed documentation.

Processor Extension Pak and Header Specification (DS51292)

This booklet describes how to install and use headers. Headers are used to better debug selected devices, without the loss of pins or resources. See also the PEP and Header online help file.

Transition Socket Specification (DS51194)

Consult this document for information on transition sockets available for use with headers.

Part 1 – Getting Started

Chapter 1. About the Debugger

1.1 INTRODUCTION

An overview of the MPLAB® ICD 3 In-Circuit Debugger system is provided.

- MPLAB ICD 3 In-Circuit Debugger Defined
- How the MPLAB ICD 3 In-Circuit Debugger Helps You
- MPLAB ICD 3 In-Circuit Debugger Components

1.2 MPLAB ICD 3 IN-CIRCUIT DEBUGGER DEFINED

The MPLAB ICD 3 In-Circuit Debugger is an in-circuit debugger that is controlled through a PC running MPLAB X IDE software on a Windows® platform. The MPLAB ICD 3 In-Circuit Debugger is an integral part of the development engineer's tool suite. The application usage can vary from software development to hardware integration.

The MPLAB ICD 3 In-Circuit Debugger is a complex debugger system used for hardware and software development of Microchip PIC® microcontrollers (MCUs) and dsPIC® Digital Signal Controllers (DSCs) that are based on In-Circuit Serial Programming™ (ICSP™) and Enhanced In-Circuit Serial Programming 2-wire serial interfaces.

The debugger system will execute code like an actual device because it uses a device with built-in emulation circuitry instead of a special debugger chip. All available features of a given device are accessible interactively, and can be set and modified by the MPLAB X IDE interface.

The MPLAB ICD 3 debugger was developed for debugging embedded processors with rich debug facilities which differ from conventional system processors in the following aspects:

- Processors run at maximum speeds
- Capability to incorporate I/O port data input

In addition to debugger functions, the MPLAB ICD 3 In-Circuit Debugger system also may be used as a device production programmer.

1.3 HOW THE MPLAB ICD 3 IN-CIRCUIT DEBUGGER HELPS YOU

The MPLAB ICD 3 In-Circuit Debugger system allows you to:

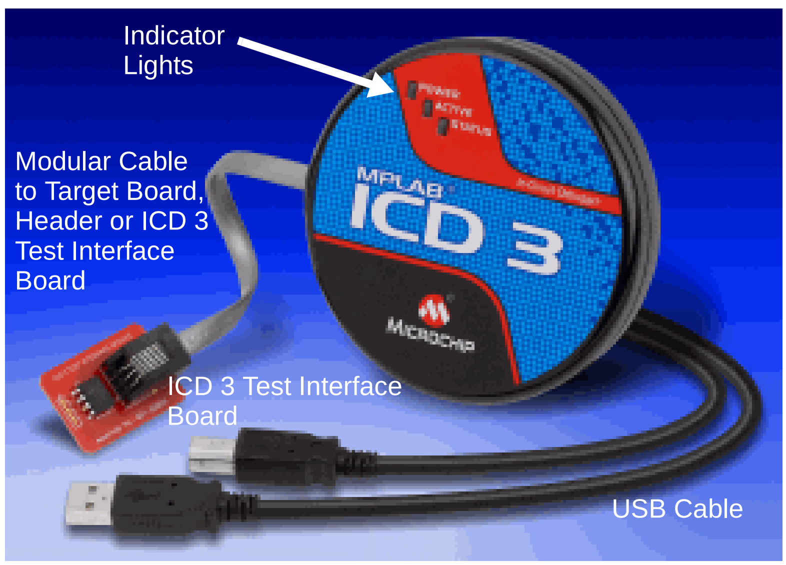
- debug your application on your own hardware in real time
- debug with hardware breakpoints
- debug with software breakpoints
- set breakpoints based on internal events
- monitor internal file registers
- emulate full speed
- program your device

1.4 MPLAB ICD 3 IN-CIRCUIT DEBUGGER COMPONENTS

The components of the MPLAB ICD 3 In-Circuit Debugger system are:

- MPLAB ICD 3 with indicator lights
- USB cable to provide communications between the debugger and a PC and to provide power to the debugger
- Cable to connect the MPLAB ICD 3 to a header module or target board
- ICD 3 Test Interface Board

FIGURE 1-1: BASIC DEBUGGER SYSTEM



Additional hardware that may be ordered separately:

- Transition socket
- ICD headers
- MPLAB processor extension kits

Chapter 2. Operation

2.1 INTRODUCTION

A simplified description of how the MPLAB ICD 3 In-Circuit Debugger system works is provided here. It is intended to provide enough information so that a target board can be designed that is compatible with the debugger for both debugging and programming operations. The basic theory of in-circuit debugging and programming is discussed so that problems, if encountered, are quickly resolved.

- Tools Comparison
- Debugger to Target Communication
- Target Communication Connections
- Debugging
- Requirements for Debugging
- Programming
- Resources Used by the Debugger

2.2 TOOLS COMPARISON

The MPLAB ICD 3 In-Circuit Debugger system differs physically and operationally from other Microchip debug tools as shown below. Specific features may vary by device - see the Development Tools Selector (DTS) on the Microchip website for details.

TABLE 2-1: DEBUG TOOLS COMPARISON

Features	MPLAB ICD 3 In-Circuit Debugger	PICkit 3 Programmer/ Debugger	MPLAB REAL ICE™ In-Circuit Emulator
USB Speed	High and Full	Full Only	High and Full
USB Driver	Microchip	HID	Microchip
USB Powered	Yes	Yes	Yes
Power to Target	Yes	Yes	No
Programmable V_{PP} and V_{DD}	Yes	Yes	Yes
Vdd Drain from Target	<50uA	20mA	<50uA
Overvoltage/Overcurrent Protection	Yes (HW)	Yes (SW)	Yes (HW)
Device emulation	Full speed	Full speed	Full speed
HW Breakpoints	Complex	Simple	Complex
Stopwatch	Yes	Yes	Yes
SW Breakpoints	Yes	No	Yes
Program Image	No	512K bytes	No
Serialized USB	Yes	Yes	Yes
Trace	No	No	Yes
Data Capture	No	No	Yes
Logic Probe Triggers	No	No	Yes
High Speed/LVDS Connection	No	No	Yes
Production Programmer	Yes	No	Yes

2.3 DEBUGGER TO TARGET COMMUNICATION

The debugger system configurations are discussed in the following sections.

> **CAUTION**
>
> **Communication Failure.**
> **Do not connect the hardware before installing the software and USB drivers.**

> **CAUTION**
>
> **Debugger or Target Damage.**
> **Do not change hardware connections while the pod or target is powered.**

2.3.1 Standard ICSP Device Communication

The debugger system can be configured to use standard ICSP communication for both programming and debugging functions. This 6-pin connection is the same one used by the older MPLAB ICD 2 In-Circuit Debugger.

The modular cable can be inserted into either:

- a matching socket at the target, where the target device is on the target board (Figure 2-1), or
- a standard adapter/header board combo (available as a Processor Pak), which is then plugged into the target board (Figure 2-2).

Note:	Older header boards used a 6-pin (RJ-11) modular connector instead of an 8-pin connector, so these headers may be connected directly to the debugger.

For more on standard communication, see **Appendix B. "Hardware Specification"**.

FIGURE 2-1: STANDARD DEBUGGER SYSTEM – DEVICE WITH ON-BOARD ICE CIRCUITRY

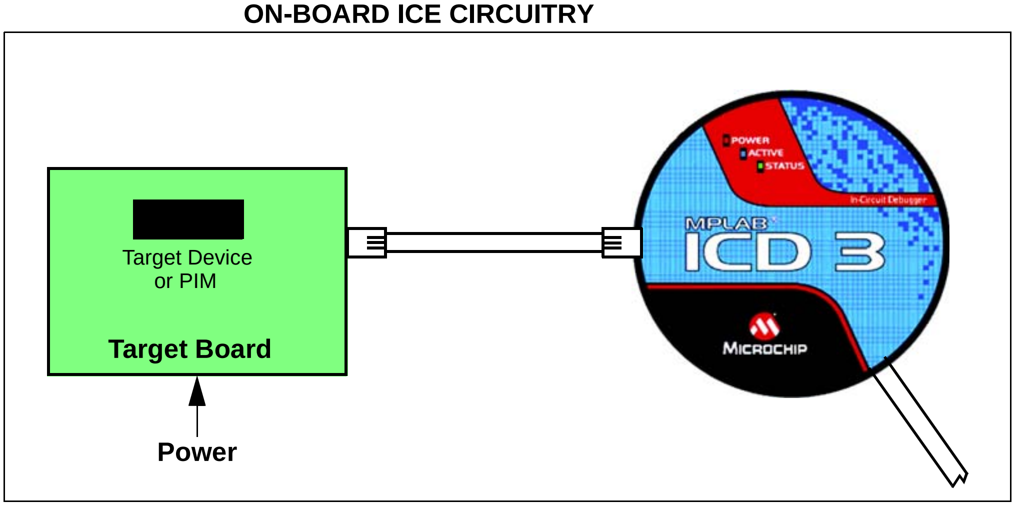
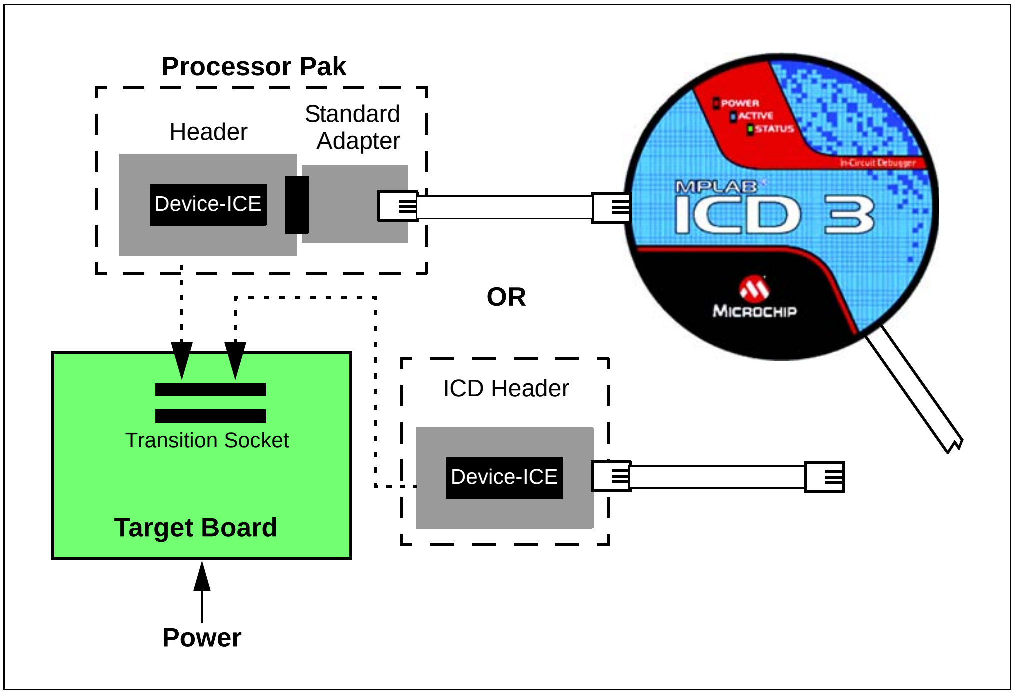


FIGURE 2-2: STANDARD DEBUGGER SYSTEM – ICE DEVICE



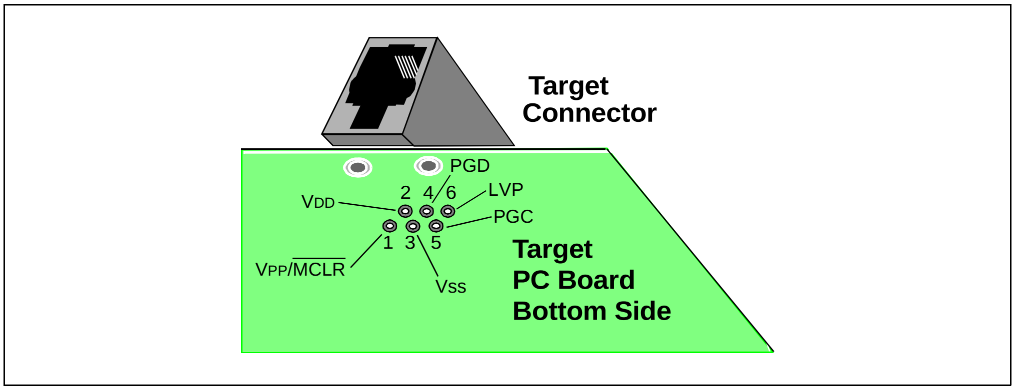
2.4 TARGET COMMUNICATION CONNECTIONS

2.4.1 Standard Communication Target Connection

Using the RJ-11 connector, the MPLAB ICD 3 In-Circuit Debugger is connected to the target device with the modular interface (six conductor) cable. The pin numbering for the connector is shown from the bottom of the target PCB in Figure 2-3.

> **Note:** Cable connections at the debugger and target are mirror images of each other, i.e., pin 1 on one end of the cable is connected to pin 6 on the other end of the cable. See **Section B.5.2.3 "Modular Cable Specification"**.

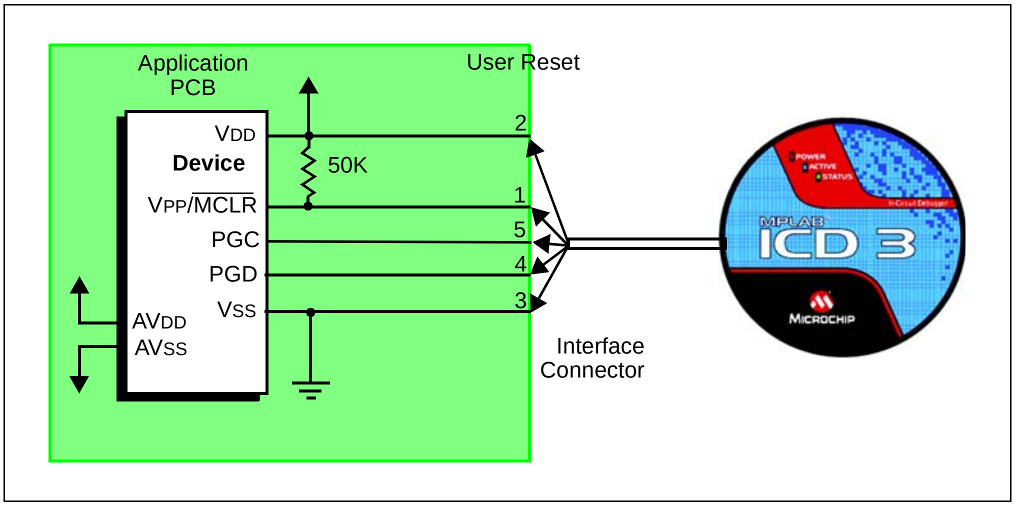
FIGURE 2-3: STANDARD CONNECTION AT TARGET



2.4.2 Target Connection Circuitry

Figure 2-4 shows the interconnections of the MPLAB ICD 3 In-Circuit Debugger to the connector on the target board. The diagram also shows the wiring from the connector to a device on the target PCB. A pull-up resistor (usually around 50 kΩ) connected from the VPP/MCLR line to the VDD is recommended so that the line may be strobed low to reset the device.

FIGURE 2-4: STANDARD CONNECTION TARGET CIRCUITRY



2.4.3 Target Powered

In the following descriptions, only three lines are active and relevant to core debugger operation: pins 1 (VPP/MCLR), 5 (PGC) and 4 (PGD). Pins 2 (VDD) and 3 (VSS) are shown on Figure 2-4 for completeness. MPLAB ICD 3 has two configurations for powering the target device: internal debugger and external target power.

The recommended source of power is external and derived from the target application. In this configuration, target VDD is sensed by the debugger to allow level translation for the target low-voltage operation. If the debugger does not sense voltage on its VDD line (pin 2 of the interface connector), it will not operate.

2.4.4 Debugger Powered

The internal debugger power is limited in two aspects:

- the voltage range is not as wide (3-5V)
- the amount of current it can supply is limited to 100 mA.

This may be of benefit for very small applications that have the device VDD separated from the rest of the application circuit for independent programming. However, it is not recommended for general usage because it imposes more current demands from the USB power system derived from the PC.

Be aware that the target VDD is sensed by the debugger to allow level translation for target low-voltage operation. If the debugger does not sense voltage on its VDD line (pin 2 of the interface connector), it will not allow communication with the target.

Not all devices have the AVDD and AVSS lines, but if they are present on the target device, all must be connected to the appropriate levels in order for the debugger to operate. They cannot be left floating.

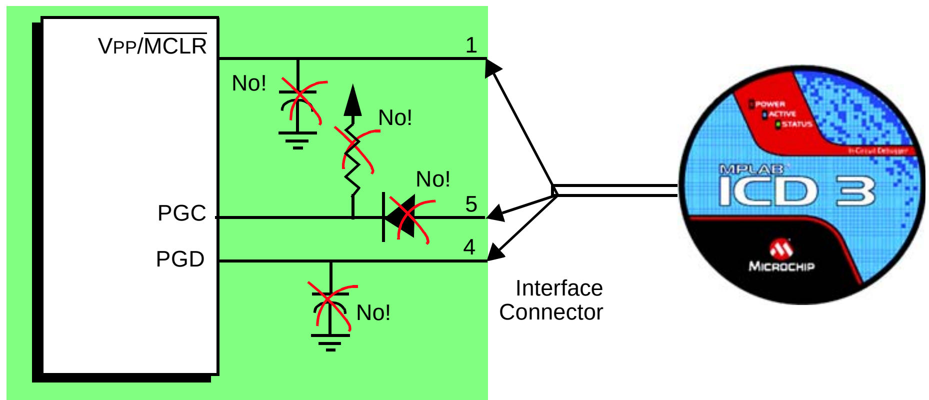
In general, it is recommended that all VDD/AVDD and VSS/AVSS lines be connected to the appropriate levels. Also, devices with a VCAP line (PIC18FXXJ MCUs, for example) should be connected to the appropriate capacitor or level.

> **Note:** The interconnection is very simple. Any problems experienced are often caused by other connections or components on these critical lines that interfere with the operation of the MPLAB ICD 3 In-Circuit Debugger system, as discussed in the following section.

2.4.5 Circuits That Will Prevent the Debugger From Functioning

Figure 2-5 shows the active debugger lines with some components that will prevent the MPLAB ICD 3 In-Circuit Debugger system from functioning.

FIGURE 2-5: IMPROPER CIRCUIT COMPONENTS



In particular, these guidelines must be followed:

- Do not use pull-ups on PGC/PGD – they will disrupt the voltage levels, since these lines have 4.7 kΩ pull-down resistors in the debugger.
- Do not use capacitors on PGC/PGD – they will prevent fast transitions on data and clock lines during programming and debugging communications.
- Do not use capacitors on $\overline{\text{MCLR}}$ – they will prevent fast transitions of VPP. A simple pull-up resistor is generally sufficient.
- Do not use diodes on PGC/PGD – they will prevent bidirectional communication between the debugger and the target device.

2.5 DEBUGGING

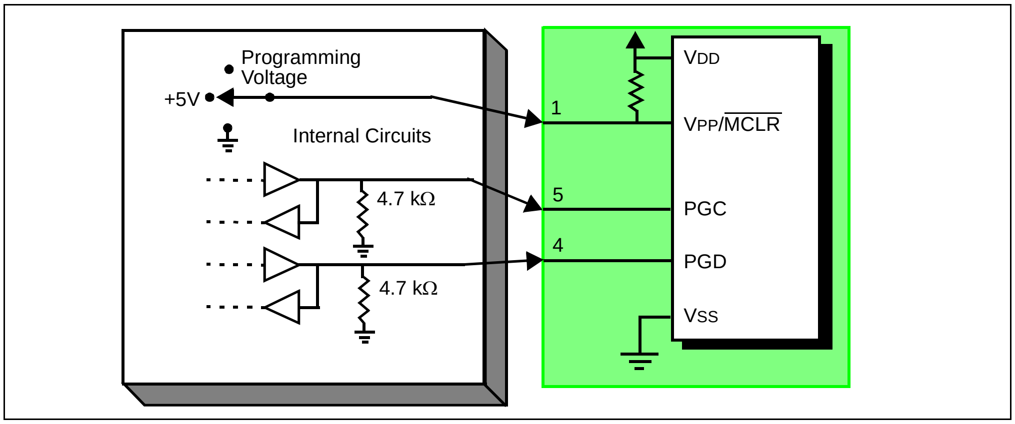
There are two steps to using the MPLAB ICD 3 In-Circuit Debugger system as a debugger. The first requires that an application be programmed into the target device (MPLAB ICD 3 can be used for this). The second uses the internal in-circuit debug hardware of the target Flash device to run and test the application program. These two steps are directly related to the MPLAB X IDE operations:

1. Programming the code into the target and activating special debug functions (see the next section for details).
2. Using the debugger to set breakpoints and run.

If the target device cannot be programmed correctly, the MPLAB ICD 3 In-Circuit Debugger will not be able to debug.

Figure 2-6 shows the basic interconnections required for programming. Note that this is the same as Figure 2-4, but for the sake of clarity, the VDD and VSS lines from the debugger are not shown.

FIGURE 2-6: PROPER CONNECTIONS FOR PROGRAMMING



A simplified diagram of some of the internal interface circuitry of the MPLAB ICD 3 In-Circuit Debugger is shown. For programming, no clock is needed on the target device, but power must be supplied. When programming, the debugger puts programming levels on VPP/MCLR, sends clock pulses on PGC and serial data via PGD. To verify that the part has been programmed correctly, clocks are sent to PGC and data is read back from PGD. This conforms to the ICSP protocol of the device under development. See the device programming specification for details.

2.6 REQUIREMENTS FOR DEBUGGING

To debug (set breakpoints, see registers, etc.) with the MPLAB ICD 3 In-Circuit Debugger system, there are critical elements that must be working correctly:

- The debugger must be connected to a PC. It must be powered by the PC via the USB cable, and it must be communicating with the MPLAB X IDE software via the USB cable. See **Section 3.3 "Common Debug Features"** for details.
- The debugger must be connected as shown in Figure 2-6 to the VPP, PGC and PGD pins of the target device with the modular interface cable (or equivalent). VSS and VDD are also required to be connected between the debugger and target device.
- The target device must have power and a functional, running oscillator. If, for any reason, the target device does not run, the MPLAB ICD 3 In-Circuit Debugger cannot debug.
- The target device must have its Configuration words programmed correctly:
  - The oscillator Configuration bits should correspond to RC, XT, etc., depending on the target design.
  - For some devices, the Watchdog Timer is enabled by default and needs to be disabled.
  - The target device must not have code protection enabled.
  - The target device must not have table read protection enabled.
  - For some devices with more than one PGC/PGD pair, the correct pair needs to be configured. This only refers to debugging, since programming will work over any PGC/PGD pair.
- PGM (LVP) should be disabled.

When the conditions listed above are met, you may proceed to the following:

- Sequence of Operations Leading to Debugging
- Debugging Details

2.6.1 Sequence of Operations Leading to Debugging

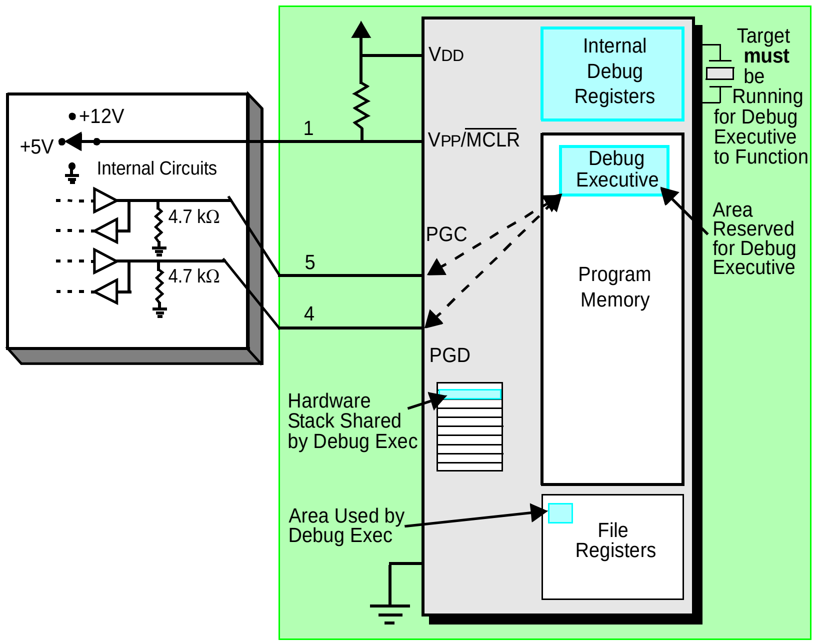
Given that the Requirements for Debugging are met, these actions can be performed when the MPLAB ICD 3 In-Circuit Debugger is set as the current tool from the MPLAB X IDE menu (*Edit>Project Properties*, Advanced, MPLAB Environment):

- When *Debug>Debug Project* is selected, the application code is programmed into the device's memory via the ICSP protocol as described at the beginning of this section.
- A small "debug executive" program is loaded into the high area of program memory of the target device. Since the debug executive must reside in program memory, the application program must not use this reserved space. Some devices have special memory areas dedicated to the debug executive. Check your device data sheet for details.
- Special "in-circuit debug" registers in the target device are enabled by MPLAB X IDE. These allow the debug executive to be activated by the debugger. For more information on the device's reserved resources, see **Section 2.8 "Resources Used by the Debugger"**.
- The target device is run in Debug mode.

2.6.2 Debugging Details

Figure 2-7 illustrates the MPLAB ICD 3 In-Circuit Debugger system when it is ready for debugging.

FIGURE 2-7: MPLAB® ICD 3 IN-CIRCUIT DEBUGGER READY FOR DEBUGGING



Typically, to find out whether an application program will run correctly, a breakpoint is set early in the program code. When a breakpoint is set from the user interface of MPLAB X IDE, the address of the breakpoint is stored in the special internal debug registers of the target device. Commands on PGC and PGD communicate directly to these registers to set the breakpoint address.

Next, the *Debug>Debug Project* function is usually selected in MPLAB X IDE. The debugger tells the debug executive to run. The target starts from the Reset vector and executes until the program counter reaches the breakpoint address that was stored previously in the internal debug registers.

After the instruction at the breakpoint address is executed, the in-circuit debug mechanism of the target device "fires" and transfers the device's program counter to the debug executive (much like an interrupt) and the user's application is effectively halted. The debugger communicates with the debug executive via PGC and PGD, gets the breakpoint status information, and sends it back to MPLAB X IDE. MPLAB X IDE then sends a series of queries to the debugger to get information about the target device, i.e., file register contents and the state of the CPU. These queries are ultimately performed by the debug executive.

The debug executive runs just like an application in program memory. It uses some locations on the stack for its temporary variables. If the device does not run, for whatever reason, such as no oscillator, faulty power supply connection, shorts on the target board, etc., then the debug executive cannot communicate to the MPLAB ICD 3 In-Circuit Debugger, and MPLAB X IDE will issue an error message.

Another way to get a breakpoint is to select *Debug>Pause*. This toggles the PGC and PGD lines so that the in-circuit debug mechanism of the target device switches the Program Counter from the user's code in program memory to the debug executive. Again, the target application program is effectively halted, and MPLAB X IDE uses the debugger communications with the debug executive to interrogate the state of the target device.

2.7 PROGRAMMING

Use the MPLAB ICD 3 as a programmer to program an actual (non -ICE/-ICD) device, i.e., a device not on a header board. Set the MPLAB ICD 3 In-Circuit Debugger as the current tool (*Edit>Project Properties*, Advanced, MPLAB Environment) to perform these actions:

- When *Run>Run Project* is selected, the application code is programmed into the device's memory via the ICSP protocol. No clock is required while programming, and all modes of the processor can be programmed, including code protect, Watchdog Timer enabled, and table read protect.
- A small "program executive" program may be loaded into the high area of program memory for some target devices. This increases programming speeds for devices with large memories.
- Special "in-circuit debug" registers in the target device are disabled by MPLAB X IDE, along with all debug features. This means that a breakpoint cannot be set, and register contents cannot be seen or altered.
- The target device is run in Release mode. As a programmer, the debugger can only toggle the $\overline{\text{MCLR}}$ line to Reset and start the target.

2.8 RESOURCES USED BY THE DEBUGGER

For a complete list of resources used by the debugger for your device, please see the online help file in MPLAB X IDE for the MPLAB ICD 3 In-Circuit Debugger. From the MPLAB X IDE Start Page, click on *Release Notes and Support Documentation*, then clock on the link for the Reserved Resources for MPLAB ICD 3.

Part 2 – Features

Chapter 3. Debugger Usage

3.1 INTRODUCTION

The following topics regarding how to install and use the MPLAB ICD 3 In-Circuit Debugger are discussed.

- Installation and Setup
- Common Debug Features
- Quick Debug/Program Reference
- Debugger Limitations
- Connecting the Target
- Setting Up the Target Board
- Starting and Stopping Debugging
- Viewing Processor Memory and Files
- Breakpoints and Stopwatch

3.2 INSTALLATION AND SETUP

Refer to the Help file "Getting Started with MPLAB X IDE" for details on installing the IDE and setting up the debugger to work with it.

In summary:

1. Install MPLAB X IDE.
2. Connect the MPLAB ICD 3 to the PC and allow the default USB drivers to install. For more information on target connections, see **Chapter 2. "Operation"**.

Note:	The debugger can power a target board only up to 100 mA.

3. Install the language toolsuite/compiler you want to use for development.
4. Launch MPLAB X IDE.
5. Use the New Project wizard (*File>New Project*) to add your "ICD 3" debugger to your project.
6. Use the project Properties dialog (*File>Project Properties*) to set up options.
7. Use the project Properties dialog (*File/Project Properties<Hardware Tool>*) to set up tool options for programming.
8. Run the project (build and run) from *Run>Run Project*.

Items of note are:

1. Each debugger contains a unique identifier which, when first installed, will be recognized by the OS, regardless of which computer USB port is used.
2. MPLAB X IDE operation connects to the hardware tool at runtime (Run or Debug Run). To always be connected to the hardware tool (like MPLAB IDE v8), see *Tools>Options*, **Embedded** button, **Generic Settings** tab, "Keep hardware tool connected" check box.
3. Configuration bits can only be viewed in the Configuration Bits window. To set them in code select *Window>PIC Memory Views*, then, select "Configuration Bits" from the Memory drop list, and select "Read/Write" from the Format drop list to enable access to the settings.

3.3 COMMON DEBUG FEATURES

Refer to the Help file "Getting Started with MPLAB X IDE", Debugging Code section for details on debug features. That section includes:

1. Debug Running the project (build, program and run) from *Debug>Debug Project*.
2. Using breakpoints
3. Stepping through code
4. Using the Watch window
5. Viewing Memory, Variables and the Call Stack
6. Using the Call Graph

3.4 QUICK DEBUG/PROGRAM REFERENCE

The following table is a quick reference for using the MPLAB ICD 3 In-Circuit Debugger as either a debugging or programming tool.

TABLE 3-1: DEBUG VS. PROGRAM OPERATION

Item	Debug	Program
Needed Hardware	A PC and target application (Microchip demo board or your own design).	
	Debugger pod, USB cable, communication driver board(s) and cable(s).	
	Device with on-board debug circuitry or debug header with special -ICE device.	Device (with or without on-board debug circuitry).
MPLAB X IDE selection	Project Properties, ICD 3 as Hardware Tool.	
	Debug>Debug Run	Program Target Project toolbar button.
Program operation	Programs application code into the device. Depending on the selections on the Project Properties dialog, this can be any range of program memory. In addition, a small debug executive is placed in program memory and other debug resources are reserved.	Programs application code into the device. Depending on the selections on the Project Properties dialog, this can be any range of program memory.
Debug features available	All for device – breakpoints, trace, etc.	N/A.
Serial Quick-Time Programming (SQTP)	N/A	Use the MPLAB PM3 to generate the SQTP file. Then, use the ICD3CMD to program the device.
Command-line operation	N/A	Use ICD3CMD, found by default in: C:\Program Files (x86)\Microchip\MPLABX\mplab_ipe.

3.5 DEBUGGER LIMITATIONS

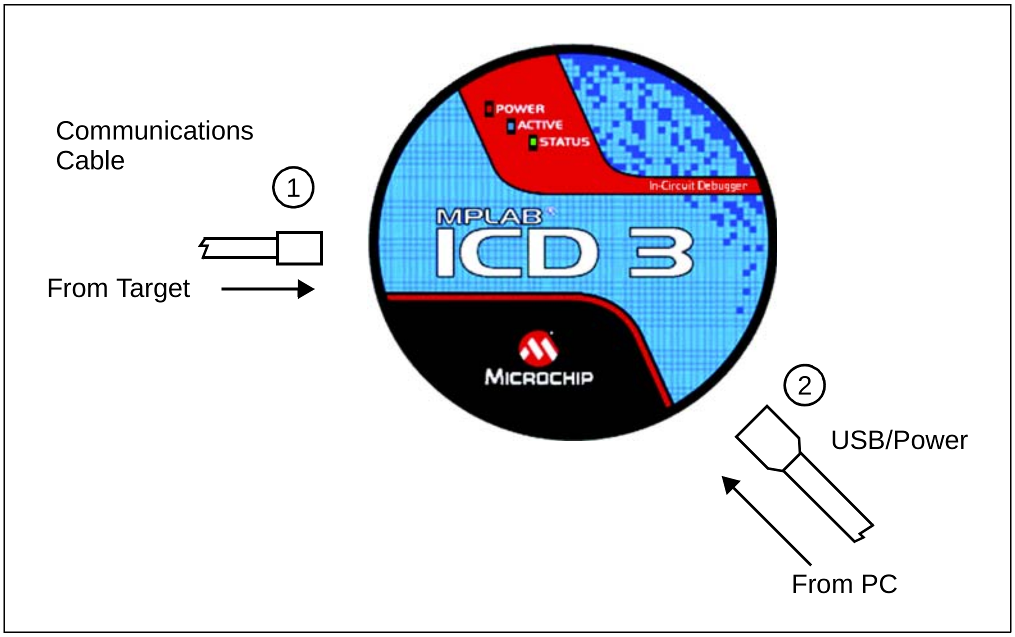
For a complete list of debugger limitations for your device, please see the online help file in MPLAB X IDE for the MPLAB ICD 3 In-Circuit Debugger.

3.6 CONNECTING THE TARGET

A connection is built in to select the type of communication with the target. See **Section 2.3 "Debugger to Target Communication"** for more details and a diagram.

1. Plug in the USB/power cable if not already connected.
2. Attach the communication cable(s) between debugger and target.

FIGURE 3-1: CONNECT COMMUNICATIONS AND USB/POWER CABLES



3.7 SETTING UP THE TARGET BOARD

The target must be set up for the type of target device to be used.

3.7.1 Using Production Devices

For production devices, the debugger may be connected directly to the target board. The device on the target board must have built-in debug circuitry in order to debug with the MPLAB ICD 3 In-Circuit Debugger. Consult the device data sheet to see whether the device has the necessary debug circuitry, i.e., it should have a "Background Debugger Enable" Configuration bit.

The target board must have a connector to accommodate the communications chosen for the debugger. For connection information, see **Section 2.3 "Debugger to Target Communication"**.

3.7.2 Using ICE Devices

For ICE devices, an ICE header board is required. The header board contains the hardware that is required to emulate a specific device or family of devices. For more information on ICE headers, see the "*Processor Extension Pak and Header Specification*" (DS51292).

A transition socket is used with the ICE header to connect the header to the target board. Transition sockets are available in various styles to allow a common header to be connected to one of the supported surface mount package styles. For more information on transition sockets, see the *"Transition Socket Specification"* (DS51194).

Header board layout will be different for headers or processor extension packs. For connection information, see **Section 2.3 "Debugger to Target Communication"**.

3.7.3 Powering the Target

There are a couple of configurations for powering MPLAB ICD 3 and the target. These are configuration essentials:

- When using the USB connection, the MPLAB ICD 3 can be powered from the PC, but it can only provide a limited amount of current, up to 100 mA, (at V_{DD} from 3-5V) to a small target board).
- The desired method is for the target to provide V_{DD}, as it can provide a wider voltage range from 2-5V. The additional benefit is that plug-and-play target detection facility is inherited, i.e., MPLAB X IDE will let you know in the Output window when it has detected the target and has detected the device.

> **Note:** The target voltage is only used for powering up the drivers for the ICSP interface; the target voltage does not power up the MPLAB ICD 3. The MPLAB ICD 3 system power is derived strictly from the USB port.

If you have not already done so, connect the MPLAB ICD 3 to the target using the appropriate cables (see **Section 3.6 "Connecting the Target"**). Then power the target.

3.8 STARTING AND STOPPING DEBUGGING

To debug an application in MPLAB X IDE, you must create a project containing your source code so that the code may be built, programmed into your device, and executed as specified below:

- To run your code, select either *Debug>Debug Project* or **Debug Project** from the Run toolbar.
- To halt your code, select either *Debug>Pause* or **Pause** from the Debug toolbar.
- To run your code again, select either *Debug>Continue* or **Continue** from the Debug toolbar.
- To step through your code, select either *Debug>Step Into* or **Step Into** from the Debug toolbar. Be careful not to step into a Sleep instruction or you will have to perform a processor Reset to resume emulation.
- To step over a line of code, select either *Debug>Step Over* or **Step Over** from the Debug toolbar.
- To end code execution, select either *Debug>Finish Debugger Session* or **Finish Debugger Session** from the Debug toolbar.
- To perform a processor Reset on your code, select either *Debug>Reset* or **Reset** from the Debug toolbar. Additional Resets, such as POR/BOR, MCLR and System, may be available, depending on the device.

3.9 VIEWING PROCESSOR MEMORY AND FILES

MPLAB X IDE provides several windows, for viewing debug and various processor memory information that are selectable from the Window menu. See MPLAB X IDE online help for more information on using these windows.

- *Window>PIC Memory Views* - View data (RAM) and code (ROM) device memory. Select from RAM, Flash, special function registers (SFRs), CPU, and Configuration bits.
- *Window>Debugging* - View debug information. Select from variables, watches, call stack, breakpoints, and stopwatch.

To view your source code, find the source code file you wish to view in the Projects window and double-click to open in a Files window. Code in this window is color-coded according to the processor and build tool that you have selected. To change the style of color-coding, select *Tools>Options*, **Fonts & Colors**, **Syntax** tab.

For more on the Editor, see NetBeans Help, *IDE Basics>Basic File Features*.

3.10 BREAKPOINTS AND STOPWATCH

Use breakpoints to halt code execution at specified lines in your code. Use the stopwatch with breakpoints to time code execution.

- Breakpoint Resources
- Hardware or Software Breakpoint Selection
- Breakpoint and Stopwatch Usage

3.10.1 Breakpoint Resources

For 16-bit devices, breakpoints, data captures and runtime watches use the same resources. Therefore, the available number of breakpoints is actually the available number of combined breakpoints/triggers.

For 32-bit devices, breakpoints use different resources than data captures and runtime watches. Therefore, the available number of breakpoints is independent of the available number of triggers.

The number of hardware and software breakpoints available and/or used is displayed in the Dashboard window (*Window>Dashboard*). See the MPLAB X IDE documentation for more on this feature. Not all devices have software breakpoints.

For limitations on breakpoint operation, including the general number of hardware breakpoints per device and hardware breakpoint skidding amounts, see the online help file in MPLAB X IDE for the MPLAB ICD 3 In-Circuit Debugger limitations.

3.10.2 Hardware or Software Breakpoint Selection

To select hardware or software breakpoints:

1. Select your project in the Projects window. Then, select either *File>Project Properties* or right click and select “Properties”.
2. In the Project Properties dialog, select “ICD3” under “Categories”.
3. Under “Option Categories” select “Debug Options”.
4. Check “Use software breakpoints” to use software breakpoints. Uncheck to use hardware breakpoints.

Note:	Using software breakpoints for debug impacts device endurance. Therefore, it is recommended that devices used in this manner not be used as production parts.

To help you decide which type of breakpoints to use (hardware or software) the following table compares the features of each.

TABLE 3-2: HARDWARE VS. SOFTWARE BREAKPOINTS

Feature	Hardware Breakpoints	Software Breakpoints
Number of breakpoints	Limited	Unlimited
Breakpoints written to*	Internal debug registers	Flash Program Memory
Breakpoints applied to**	Program Memory/Data Memory	Program Memory only
Time to set breakpoints	Minimal	Dependent on oscillator speed, time to program Flash Memory and page size
Breakpoint skidding	Most devices. See the online help, Limitations section, for details.	No

* Where information about the breakpoint is written in the device.
** What kind of device feature applies to the breakpoint. This is where the breakpoint is set.

3.10.3 Breakpoint and Stopwatch Usage

Breakpoints halt execution of code. To determine the time between the breakpoints, use the stopwatch.

Please refer to the MPLAB X IDE online help for how to set up and use breakpoints and the stopwatch.

Part 3 – Troubleshooting

Chapter 4. Troubleshooting First Steps

4.1 INTRODUCTION

If you are having problems with MPLAB ICD 3 In-Circuit Debugger operation, start here.

- The Five Questions to Answer First
- Top Reasons Why You Can't Debug
- Other Things to Consider

4.2 THE FIVE QUESTIONS TO ANSWER FIRST

1. What device are you working with?
   Often an upgrade to a newer version of MPLAB X IDE is required to support newer devices. A yellow light = untested support.
2. Are you using a Microchip demo board or one of your own design?
   Have you followed the guidelines for resistors/capacitors for communications connections? See **Chapter 2. "Operation"**.
3. Have you powered the target?
   The debugger cannot power the target if greater than 100 mA.
4. Are you using a USB hub in your set up? Is it powered?
   If you continue to have problems, try using the debugger without the hub (plugged directly into the PC.)
5. Are you using the standard communication cable (RJ-11) shipped with the debugger?
   If you have made a longer cable, it could cause communications errors.

4.3 TOP REASONS WHY YOU CAN'T DEBUG

1. The oscillator is not working.
   Check your Configuration bits setting for the oscillator. If you are using an external oscillator, try using an internal oscillator. If you are using an internal PLL, make sure your PLL settings are correct.
2. The target board is not powered.
   Check the power cable connection.
3. The V_{DD} voltage is outside the specifications for this device.
   See the device programming specification for details.
4. The debugger has become physically disconnected from the PC and/or the target board.
   Check the connections of the communications cables.
5. The device is code-protected. Check your Configuration bits setting for code protection.
6. Debugger to PC communications have been interrupted.
   Reconnect to the debugger in MPLAB X IDE.

7. The production device you are trying to debug does not have debugging capabilities. Use a debug header instead. (See the "*Processor Extension Pak and Debug Header Specification*" in "Recommended Reading").
8. The target application has somehow become corrupted or contains errors. For example, the regular linker script was used in the project instead of the debugger version of the linker script (e.g., 18F8722.lkr was used instead of 18F8722i.lkr). Try rebuilding and reprogramming the target application. Then initiate a Power-On-Reset of the target.
9. You do not have the correct PGC/PGD pin pairs programmed in your Configuration bits (for devices with multiple PGC/PGD pin pairs).
10. Other configuration settings are interfering with debugging. Any configuration setting that would prevent the target from executing code will also prevent the debugger from putting the code into Debug mode.
11. Brown-Out Detect voltage is greater than the operating voltage V_{DD}. This means the device is in Reset and cannot be debugged.
12. The communications connection guidelines in **Chapter 2. "Operation"** were not followed.
13. The debugger cannot always perform the action requested. For example, the debugger cannot set a breakpoint if the target application is currently running.

4.4 OTHER THINGS TO CONSIDER

1. It is possible the error was a one-time glitch. Try the operation again.
2. There may be a problem programming in general. As a test, switch to Run mode and program the target with the simplest application possible (e.g., a program to blink an LED.) If the program will not run, then you know that something is wrong with the target setup.
3. It is possible that the target device has been damaged in some way (e.g., over current). Development environments are notoriously hostile to components. Consider trying another target device.
4. Microchip Technology Inc. offers demonstration boards to support most of its microcontrollers. Consider using one of these boards, which are known to work, to verify correct MPLAB ICD 3 In-Circuit Debugger functionality. Or, use the Loop-Back Test board to verify the debugger itself (**Section B.6 "ICD 3 Test Interface Board"**).
5. Review debugger operation to ensure proper application setup. For more information, see **Chapter 2. "Operation"**.
6. If the problem persists, contact Microchip Support.

Chapter 5. Frequently Asked Questions (FAQs)

5.1 INTRODUCTION

Look here for answers to frequently asked questions about the MPLAB ICD 3 In-Circuit Debugger system.

- How Does It Work?
- What's Wrong?

5.2 HOW DOES IT WORK?

- **What's in the silicon that allows it to communicate with the MPLAB ICD 3 In-Circuit Debugger?**

  MPLAB ICD 3 In-Circuit Debugger can communicate with Flash silicon via the ICSP interface. It uses the debug executive located in test memory.

- **How is the throughput of the processor affected by having to run the debug executive?**

  The debug executive doesn't run while in Run mode, so there is no throughput reduction when running your code, i.e., the debugger doesn't 'steal' any cycles from the target device.

- **How does the MPLAB ICD 3 In-Circuit Debugger compare with other in-circuit emulators/debuggers?**

  Please refer to **Section 2.2 "Tools Comparison"**.

- **How does MPLAB X IDE interface with the MPLAB ICD 3 In-Circuit Debugger to allow more features than older debuggers?**

  MPLAB ICD 3 In-Circuit Debugger communicates using the debug executive located in the test area. The debug exec is streamlined for more efficient communication. The debugger contains an FPGA, large SRAM Buffers (1Mx8) and a High Speed USB interface. Program memory image is downloaded and is contained in the SRAM to allow faster programming. The FPGA in the debugger serves as an accelerator for interfacing with the device in-circuit debugger modules.

- **On traditional debuggers, the data must come out on the bus in order to perform a complex trigger on that data. Is this also required on the MPLAB ICD 3 In-Circuit Debugger? For example, could I halt, based on a flag going high?**

  Traditional debuggers use a special debugger chip (-ME) for monitoring. There is no -ME with the MPLAB ICD 3 In-Circuit Debugger, so there are no busses to monitor externally. With the MPLAB ICD 3 In-Circuit Debugger, rather than using external breakpoints, the built-in breakpoint circuitry of the debug engine is used – the busses and breakpoint logic are monitored inside the part.

- **Does the MPLAB ICD 3 In-Circuit Debugger have complex breakpoints?**

  Yes. You can break based on a value in a data memory location. You can also do sequenced breakpoints, where several events are happening before it breaks. However, you can only do two sequences. You can also do the AND condition and do PASS counts.

- **Are any of the driver boards optoisolated or electrically isolated?**
  They are DC optoisolated, but not AC optoisolated. You cannot apply a floating or high voltage (120V) to the current system.
- **What limitations are there with the standard cable?**
  The standard ICSP RJ-11 cable does not allow for clock speeds greater than about 15 Mbps. dsPIC33F DSCs running at full speed are greater than the 15 Mbps. limit.
- **Will this slow down the running of the program?**
  There is no cycle stealing with the MPLAB ICD 3 In-Circuit Debugger. The output of data is performed by the state machine in the silicon.
- **Is it possible to debug a dsPIC DSC running at any speed?**
  The MPLAB ICD 3 is capable of debugging at any device speed as specified in the device's data sheet.
- **What is the function of pin 6, the LVP pin?**
  Pin 6 is reserved for the LVP (Low-Voltage Programming) connection.

5.3 What's Wrong?

- **Performing a Verify fails after programming the device. Is this a programming issue?**

  If 'Run' (*Run>Run Project)* is selected, the device will automatically run immediately after programming. Therefore, if your code changes the flash memory, verification could fail. To prevent the code from running after programming, please select 'Hold in Reset'.

- **My PC went into power-down/hibernate mode, and now my debugger won't work. What happened?**

  When using the debugger for prolonged periods of time, and especially as a debugger, be sure to disable the Hibernate mode in the Power Options Dialog window of your PC's operating system. Go to the Hibernate tab and clear or uncheck the "Enable hibernation" check box. This will ensure that all communication is maintained across all the USB subsystem components.

- **I set my peripheral to NOT freeze on halt, but it is suddenly freezing. What's going on?**

  For dsPIC30F/33F and PIC24F/H devices, a reserved bit in the peripheral control register (usually either bit 14 or 5) is used as a Freeze bit by the debugger. If you have performed a write to the entire register, you may have overwritten this bit. (The bit is user-accessible in Debug mode.)

  To avoid this problem, write only to the bits you wish to change for your application (`BTS`, `BTC`) instead of to the entire register (`MOV`).

- **When using a 16-bit device, an unexpected Reset occurred. How do I determine what caused it?**

  Some things to consider:

  - To determine a Reset source, check the RCON register.

  - Handle traps/interrupts in an Interrupt Service Routine (ISR). You should include `trap.c` style code, i.e.,

```
void __attribute__((__interrupt__)) _OscillatorFail(void);
          :
void __attribute__((__interrupt__)) _AltOscillatorFail(void);
          :
void __attribute__((__interrupt__)) _OscillatorFail(void)
   {
        INTCON1bits.OSCFAIL = 0;        //Clear the trap flag
        while (1);
   }
          :
   void __attribute__((__interrupt__)) _AltOscillatorFail(void)
   {
        INTCON1bits.OSCFAIL = 0;
        while (1);
   }
          :
```

  - Use ASSERTs. For example: `ASSERT (IPL==7)`

Chapter 6. Error Messages

6.1 INTRODUCTION

The MPLAB ICD 3 In-Circuit Debugger produces various error messages; some are specific, some are informational, and others can be resolved with general corrective actions. In general, read any instructions under your error message. If those fail to fix the problem or if there are no instructions, refer to the following sections.

- Specific Error Messages
- General Corrective Actions
- Information Messages

6.2 SPECIFIC ERROR MESSAGES

6.2.1 Debugger-to-Target Communication Errors

Failed to send database

If you receive this error:

1. Try downloading again. It may be a one-time error.
2. Try manually downloading the highest-number `.jam` file.

If these actions fail to fix the problem, see **Section 6.3.2 "Debugger-to-Target Communication Error Actions"**.

6.2.2 Corrupted/Outdated Installation Errors

Failed to download firmware

If the Hex file exists:

- Reconnect and try again.
- If this does not work, the file may be corrupted. Reinstall MPLAB X IDE.

If the Hex file does not exist:

- Reinstall MPLAB IDE X.

Unable to download debug executive

If you receive this error while attempting to debug:

1. Deselect the debugger as the debug tool.
2. Close your project, and then close MPLAB IDE X.
3. Restart MPLAB IDE X, and re-open your project.
4. Reselect the debugger as the debug tool, and try to program the target device again.

Unable to download program executive

If you receive this error while attempting to program:

1. Deselect the debugger as the programmer.
2. Close your project, and then close MPLAB IDE X.
3. Restart MPLAB IDE X, and re-open your project.

4. Reselect the debugger as the programmer, and try to program the target device again.

If these actions fail to fix the problem, see **Section 6.3.4 "Corrupted Installation Actions"**.

6.2.3 Debug Failure Errors

The target device is not ready for debugging. Please check your configuration bit settings and program the device before proceeding.

You will receive this message if you try to Run before programming your device. If you receive this message after trying to Run, or immediately after programming your device:

The device is code protected.

The device on which you are attempting to operate (read, program, blank check or verify) is code protected, i.e., the code cannot be read or modified. Check your Configuration bits setting for code protection.

Disable code protection, set or clear the appropriate Configuration bits in code or in the Configuration Bits window according to the device data sheet. Then erase and reprogram the entire device.

If these actions fail to fix the problem, see **Section 6.3.2 "Debugger-to-Target Communication Error Actions"** and **Section 6.3.6 "Debug Failure Actions"**.

6.2.4 Miscellaneous Errors

ICD 3 is busy. Please wait for the current operation to finish.

If you receive this error when attempting to deselect the debugger as a debugger or programmer:

1. Wait - give the debugger time to finish any application tasks. Then try to deselect the debugger again.
2. Select Halt to stop any running applications. Then try to deselect the debugger again.
3. Unplug the debugger from the PC. Then try to deselect the debugger again.
4. Shut down MPLAB IDE X.

6.3 GENERAL CORRECTIVE ACTIONS

These general corrective actions may solve your problem:

- Read/Write Error Actions
- Debugger-to-Target Communication Error Actions
- Debugger-to-PC Communication Error Actions
- Corrupted Installation Actions
- USB Port Communication Error Actions
- Debug Failure Actions
- Internal Error Actions

6.3.1 Read/Write Error Actions

If you receive a read or write error:

1. Did you hit Abort? This may produce read/write errors.
2. Try the action again. It may be a one-time error.
3. Ensure that the target is powered and at the correct voltage levels for the device. See the device data sheet for required device voltage levels.
4. Ensure that the debugger-to-target connection is correct (PGC and PGD are connected.)
5. For write failures, ensure that “Erase all before Program” is checked on the Program Memory tab of the Settings dialog.
6. Ensure that the cables used are of the correct length.

6.3.2 Debugger-to-Target Communication Error Actions

The MPLAB ICD 3 In-Circuit Debugger and the target device are out of sync with each other.

1. Select **Reset** and then try the action again.
2. Ensure that the cable(s) used are of the correct length.

6.3.3 Debugger-to-PC Communication Error Actions

The MPLAB ICD 3 In-Circuit Debugger and MPLAB IDE X are out of sync with each other.

1. Unplug and then plug in the debugger.
1. Reconnect to the debugger.
2. Try the operation again. It is possible the error was a one-time glitch.
3. The version of MPLAB IDE X installed may be incorrect for the version of firmware loaded on the MPLAB ICD 3 In-Circuit Debugger. Follow the steps outlined in **Section 6.3.4 “Corrupted Installation Actions”**.
4. There may be an issue with the PC USB port. See **Section 6.3.5 “USB Port Communication Error Actions”**.

6.3.4 Corrupted Installation Actions

The problem is most likely caused by a incomplete or corrupted installation of MPLAB IDE X.

1. Uninstall all versions of MPLAB IDE X from the PC.
2. Reinstall the desired MPLAB IDE X version.
3. If the problem persists contact Microchip Support.

6.3.5 USB Port Communication Error Actions

The problem is most likely caused by a faulty or non-existent communications port.

1. Reconnect to the MPLAB ICD 3 In-Circuit Debugger.
2. Make sure the debugger is physically connected to the PC on the appropriate USB port.
3. Make sure the appropriate USB port has been selected in the debugger Settings.
4. Make sure the USB port is not in use by another device.
5. If using a USB hub, make sure it is powered.
6. Make sure the USB drivers are loaded.

6.3.6 Debug Failure Actions

The MPLAB ICD 3 In-Circuit Debugger was unable to perform a debugging operation. There are numerous reasons why this might occur. See **Chapter 4. "Troubleshooting First Steps"**.

6.3.7 Internal Error Actions

Internal errors are unexpected and should not happen. They are primarily used for internal Microchip development.

The most likely cause is a corrupted installation (**Section 6.3.4 "Corrupted Installation Actions"**).

Another likely cause is exhausted system resources.

1. Try rebooting your system to free up memory.
2. Make sure you have a reasonable amount of free space on your hard drive (and that it is not overly fragmented.)

If the problem persists contact Microchip Support.

6.4 INFORMATION MESSAGES

MPLAB ICD 3 In-Circuit Debugger informational messages are listed below:

ICD3Info0001: ICD3 is functioning properly. If you are still having problems with your target circuit please check the Target Board Considerations section of the online help.

See **Section B.7 "Target Board Considerations"**.

Chapter 7. Engineering Technical Notes (ETNs)

The following ETNs are related to the MPLAB ICD 3 In-Circuit Debugger. Please see the product web page for details.

- **ETN-29:** Applies to Assembly #10-00421-RC or below.

Part 4 – Reference

Appendix A. Debugger Function Summary

A.1 INTRODUCTION

A summary of the MPLAB ICD 3 In-Circuit Debugger functions is listed here.

- Debugger Selection and Switching
- Debugger Options Selection

A.2 DEBUGGER SELECTION AND SWITCHING

Use the Project Properties dialog to select or switch debuggers for a project. To switch you must have more than one MPLAB ICD 3 connected to your computer. MPLAB X IDE will differentiate between the two by displaying two different serial numbers.

To select or change the debugger used for a project:

1. Open the Project Properties dialog by doing one of the following:
    a) Click on the project name in the Project window and select *File>Project Properties*.
    b) Right click on the project name in the Project window and select "Properties".
2. Under "Categories", click on "[[default]]"
3. Under "Hardware Tools", find "ICD 3" and click on a serial number (SN) to select a debugger for use in the project.

A.3 DEBUGGER OPTIONS SELECTION

Set up debugger options on the debugger property pages of the Project Properties dialog.

1. Open the Project Properties dialog by doing one of the following:
    a) Click on the project name in the Project window and select *File>Project Properties*.
    b) Right click on the project name in the Project window and select "Properties".
2. Under "Categories", click on "ICD 3"
3. Select property pages from "Options categories". Click on an option to see its description in the text box below. Click to the right of an option to change it.

Available option categories are:

- Memories to Program
- Firmware
- Program Options
- Debug Options
- Freeze Peripherals
- Clock
- Power

A.3.1 Memories to Program

Select the memories to be programmed into the target.

TABLE A-1: MEMORIES TO PROGRAM OPTION CATEGORY

Auto select memories and ranges	**Allow ICD 3 to Select Memories** - The debugger uses your selected device and default settings to determine what to program. **Manually select memories and ranges** - You select the type and range of memory to program (see below.)
Memory	Check to program *Memory*, where *Memory* is the type of memory. Types include: EEPROM, ID, Boot Flash, Auxiliary.
Program Memory	Check to program the target program memory range specified below.
Program Memory Start (hex) Program Memory End (hex)	The starting and ending hex address range in program memory for programming, reading, or verification. If you receive a programming error due to an incorrect end address, correct the end address and program again. **Note:** The address range does not apply to the Erase function. The Erase function will erase all data on the device.
Preserve Program Memory	Check to not program the target program memory range specified below.
Preserve Program Memory Start (hex) Preserve Program Memory End (hex)	The starting and ending hex address range in target program memory to preserve when programming, reading, or verifying. This memory is read from the target and overlayed with existing MPLAB X IDE memory.
Preserve *Memory*	Check to not erase *Memory* when programming, where *Memory* is the type of memory. Types include: EEPROM, ID, Boot Flash, Auxiliary.

A.3.2 Firmware

Select and load debugger firmware.

TABLE A-2: FIRMWARE OPTION CATEGORY

Use Latest Firmware	Check to use the latest firmware. Uncheck to select the firmware version below.
Firmware File	Click in the right-hand text box to search for a firmware file (.jam) to associate with the debugger.

A.3.3 Program Options

Choose to erase all memory before programming or to merge code.

TABLE A-3: PROGRAM OPTIONS OPTION CATEGORY

Erase All Before Program	Check to erase all memory before programming begins. Unless programming new or already erased devices, it is important to have this box checked. If not checked, the device is not erased and program code will be merged with the code already in the device.
Enable Low-Voltage Programming	*For Programmer Settings only, PIC12F/16F1xxx devices:* For the LVP configuration bit set to "Low-voltage programming enabled", you may program in either high-voltage (default) or low-voltage (enabled here.) For the LVP configuration bit set to "High-voltage on MCLR/Vpp must be used for programming", you may only program in high-voltage.

A.3.4 Debug Options

Use software breakpoints, if available for the project device.

TABLE A-4: DEBUG OPTIONS OPTION CATEGORY

Use Software Breakpoints	Check to use software breakpoints. Uncheck to use hardware breakpoints. See discussion below to determine which type is best for your application.

TABLE A-5: SOFTWARE VS HARDWARE BREAKPOINTS

Features	Software Breakpoints	Hardware Breakpoints
Number of breakpoints	unlimited	limited
Breakpoints are written to	program memory	debug registers
Time to set breakpoints	oscillator speed dependent – can take minutes	minimal
Skidding	no	yes
Note: Using software breakpoints for debugging impacts device endurance. Therefore, it is recommended that devices used in this manner not be used as production parts.		

A.3.5 Freeze Peripherals

Select peripherals to freeze or not freeze on program halt.

TABLE A-6: FREEZE PERIPHERALS OPTION CATEGORY

Freeze Peripherals	Freeze all peripherals on halt. This options applies to PIC12/16/18 MCUs.
Peripheral	Freeze this peripheral on halt. This options applies to 16- and 32-bit MCUs.

PIC12/16/18 MCU Devices

To freeze/unfreeze all device peripherals on halt, check/uncheck the “Freeze on Halt” checkbox. If this does not halt your desired peripheral, be aware that some peripherals have no freeze on halt capability and cannot be controlled by the debugger.

dsPIC30F/33F, PIC24F/H and PIC32MX Devices

For peripherals in the list “Peripherals to Freeze on Halt”, check to freeze that peripheral on a halt. Uncheck the peripheral to let it run while the program is halted. If you do not see a peripheral on the list, check “All Other Peripherals”. If this does not halt your desired peripheral, be aware that some peripherals have no freeze on halt capability and cannot be controlled by the debugger.

To select all peripherals, including “All Other Peripherals”, click **Check All**. To deselect all peripherals, including “All Other Peripherals”, click **Uncheck All**.

A.3.6 Clock

Set the option to use the fast internal RC clock for selected device.

TABLE A-7: CLOCK OPTION CATEGORY

Use FRC in debug mode (dsPIC33F and PIC24F/H devices only)	When debugging, use the device fast internal RC (FRC) for clocking instead of the oscillator specified for the application. This is useful when the application clock is slow. Checking this checkbox will let the application run at the slow speed but debug at the faster FRC speed. Reprogram after changing this setting. **Note:** Peripherals that are not frozen will operate at the FRC speed while debugging.

A.3.7 Power

Select power options.

TABLE A-8: POWER OPTION CATEGORY

Power target circuit from ICD 3	If you enable (check) this option, the Power On/Off button will be enabled on the toolbar. It will initially be in the Power On state. Every time it is clicked it will toggle to the opposite state. If it is on it will toggle to off, and if it is off it will toggle to on. If the power target circuit setting is disabled (unchecked) the Power On/Off button will go back to the disabled state. Whatever state it is in when the project was last saved will be the state that it is in when the project is reopened.
Voltage Level	If the checkbox above is checked, select the target Vdd (3.0V-3.5V) that the debugger will provide.

Appendix B. Hardware Specification

B.1 INTRODUCTION

The hardware and electrical specifications of the MPLAB ICD 3 In-Circuit Debugger system are detailed.

B.2 HIGHLIGHTS

This chapter discusses:

- USB Port/Power
- MPLAB ICD 3 In-Circuit Debugger
- Standard Communication Hardware
- ICD 3 Test Interface Board
- Target Board Considerations

B.3 USB PORT/POWER

The MPLAB ICD 3 In-Circuit Debugger is connected to the host PC via a Universal Serial Bus (USB) port, version 2.0 compliant. The USB connector is located on the side of the pod.

The system is capable of reloading the firmware via the USB interface.

System power is derived from the USB interface. The debugger is classified as a high-power system per the USB specification, and requires 300 mA of power from the USB to function in all operational modes (debugger/programmer).

Note:	The MPLAB ICD 3 In-Circuit Debugger is powered through its USB connection. The target board is powered from its own supply. Alternatively, the MPLAB ICD 3 can power it only if the target consumes less than 100 mA.

Cable Length – The PC-to-debugger cable length for proper operation is shipped in the debugger kit.

Powered Hubs – If you are going to use a USB hub, make sure it is self-powered. Also, USB ports on PC keyboards do not have enough power for the debugger to operate.

PC Hibernate/Power-Down Modes – Disable the hibernate or other power saver modes on your PC to ensure proper USB communications with the debugger.

B.4 MPLAB ICD 3 IN-CIRCUIT DEBUGGER

The debugger consists of a main board enclosed in the casing with a USB connector and an RJ-11 connector. On the debugger enclosure are indicator lights (LEDs).

B.4.1 Main Board

This component has the interface processor (dsPIC DSC), the USB 2.0 interface capable of USB speeds of 480 Mbps, a Field Programmable Gate Array (FPGA) for general system control and increased communication throughput, an SRAM for holding the program code image for programming into the emulation device on-board Flash and LED indicators.

B.4.2 Indicator Lights (LEDs)

The indicator lights have the following significance.

LED	Color	Description
Power	Green	Lit when powered.
Active	Blue	Lit when power is first applied or when target is connected.
Status	Green	Lit when the debugger is operating normally – standby.
	Red	Lit when an operation has failed.
	Orange	Lit when the debugger is busy.

B.5 STANDARD COMMUNICATION HARDWARE

For standard debugger communication with a target (**Section 2.3 “Debugger to Target Communication”**), use an adapter with the RJ-11 connector.

To use this type of communication with a header board, you may need a device-specific Processor Pak, which includes an 8-pin connector header board containing the desired ICE/ICD device and a standard adapter board.

> **Note:** Older header boards used a 6-pin (RJ-11) connector instead of an 8-pin connector, so these headers may be connected directly to the debugger.

For more on available header boards, see the “*Processor Extension Pak and Header Specification”* (DS51292).

B.5.1 Standard Communication

The standard communication is the main interface to the target processor. It contains the connections to the high voltage (VPP), VDD sense lines, and clock and data connections required for programming and connecting with the target devices.

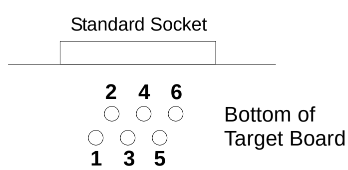
The VPP high-voltage lines can produce a variable voltage that can swing from 0 to 14 volts to satisfy the voltage requirements for the specific emulation processor.

The VDD sense connection draws very little current from the target processor. The actual power comes from the MPLAB ICD 3 In-Circuit Debugger system as the VDD sense line is used as a reference only to track the target voltage. The VDD connection is isolated with an optical switch.

The clock and data connections are interfaces with the following characteristics:

- Clock and data signals are in high-impedance mode (even when no power is applied to the MPLAB ICD 3 In-Circuit Debugger system)
- Clock and data signals are protected from high voltages caused by faulty targets systems, or improper connections
- Clock and data signals are protected from high current caused from electrical shorts in faulty target systems

FIGURE B-1: 6-PIN STANDARD PINOUT



Pin	Name	Function
1	VPP	Power
2	VDD_TGT	Power on target
3	GND	Ground
4	PGD (ICSPDAT)	Standard Com Data
5	PGC (ICSPCLK)	Standard Com Clock
6	PGM (LVP)	Low-Voltage Programming

TABLE B-1: ELECTRICAL LOGIC TABLE(1)

Logic Inputs	Vih = Vdd x 0.7V (min.)			
	Vil = Vdd x 0.3V (max.)			
Logic Outputs	Vdd = 5V	Vdd = 3V	Vdd = 2.3V	Vdd = 1.65V
	Voh = 3.8V min.	Voh = 2.4V min.	Voh = 1.9V min.	Voh = 1.2V min.
	Vol = 0.55V max.	Vol = 0.55V max.	Vol = 0.3V max.	Vol = 0.45V max.

Note 1: Loading PGC/PGD - 4.7K ohm load to ground.

B.5.2 Modular Cable and Connector

For standard communications, a modular cable connects the debugger and the target application. The specifications for this cable and its connectors are listed below.

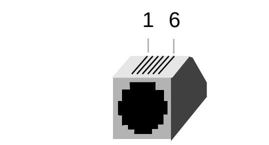
B.5.2.1 MODULAR CONNECTOR SPECIFICATION

- Manufacturer, Part Number – AMP Incorporated, 555165-1
- Distributor, Part Number – Digi-Key, A9031ND

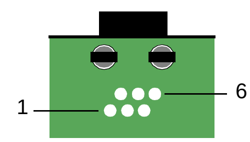
The following table shows how the modular connector pins on an application correspond to the microcontroller pins. This configuration provides full ICD functionality.

FIGURE B-2: MODULAR CONNECTOR PINOUT OF TARGET BOARD

Modular Connector Pin	Microcontroller Pin
6	PGM (LVP)
5	RB6
4	RB7
3	Ground
2	V_{DD} Target
1	V_{PP}



Front View of Modular Connector on Target Board



Bottom View of Modular Connector Pinout on Target Board

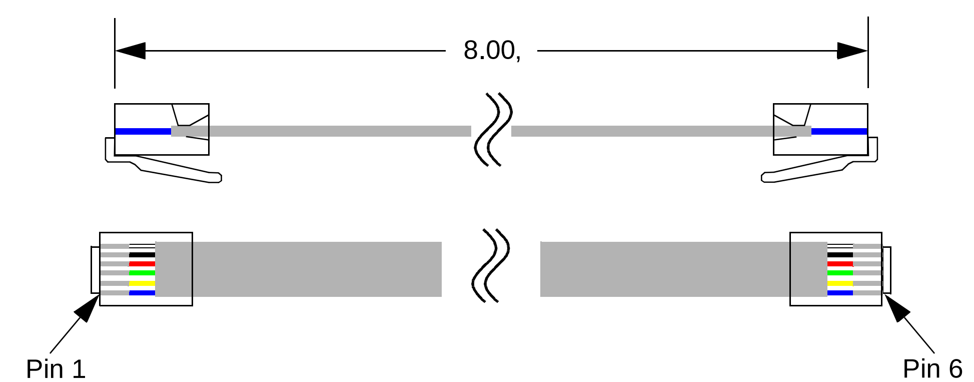
B.5.2.2 MODULAR PLUG SPECIFICATION

- Manufacturer, Part Number – AMP Incorporated, 5-554710-3
- Distributor, Part Number – Digi-Key, A9117ND

B.5.2.3 MODULAR CABLE SPECIFICATION

Manufacturer, Part Number – Microchip Technology, 07-00024

FIGURE B-3: MODULAR CABLE

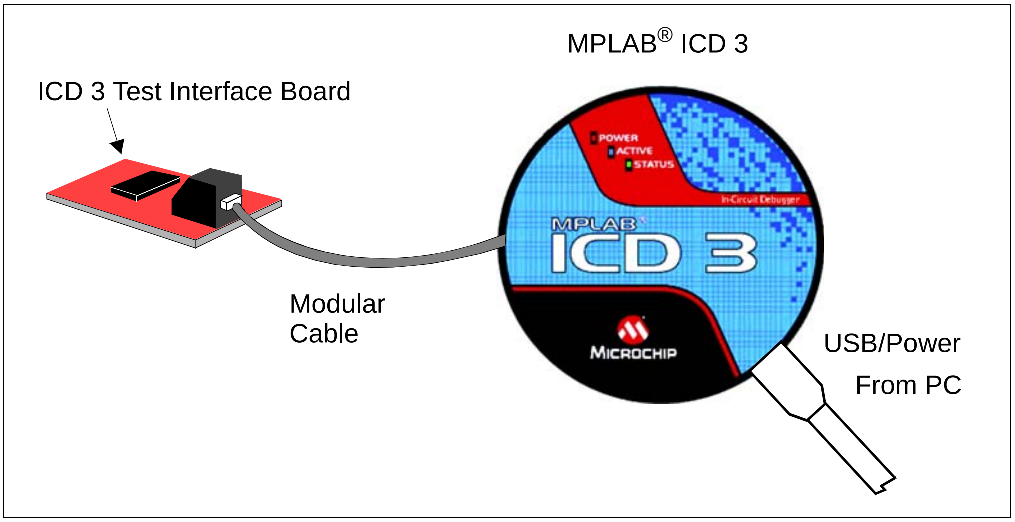


B.6 ICD 3 TEST INTERFACE BOARD

This board can be used to verify that the debugger is functioning properly. To use this board:

1. Disconnect the debugger from the target and the PC.
2. Connect the ICD 3 test interface board to the debugger using the modular cable.

FIGURE B-4: MPLAB ICD 3 CONNECTION TO TEST INTERFACE BOARD



3. Reconnect the debugger to the PC.
4. Launch MPLAB X IDE. **Ensure that all existing projects are closed.**
5. Select <u>*Debug>Run Debugger/Programmer Self Test*</u>, then, select the specific "ICD 3" you want to test and click **OK**.
6. Ensure the ICD 3 Test Interface Board and cable are connected. Click **Yes** to continue.
7. View the self test results in the debugger's Output window. If the test runs successfully, you'll see the following:

```
Test interface PGC clock line write succeeded.
Test interface PGD data line write succeeded.
Test interface PGC clock line read succeeded.
Test interface PGD data line read succeeded.
Test interface LVP control line test succeeded.
Test interface MCLR level test succeeded.
ICD3 is functioning properly. If you are still having problems with
your target circuit please check the Target Board Considerations
section of the online help.
```

8. After the debugger passes the self test, disconnect the ICD 3 Test Interface board from the debugger.

If any test failed, please enter a ticket on http://support.microchip.com/. Copy and paste the content of the output window into the problem description.

B.7 TARGET BOARD CONSIDERATIONS

The target board should be powered according to the requirements of the selected device (2.0V-5.5V) and the application.

The debugger does sense target power. There is a 10KΩ load on Vdd_TGT.

Depending on the type of debugger-to-target communications used, there will be some considerations for target board circuitry:

- **Section 2.4.2 "Target Connection Circuitry"**
- **Section 2.4.5 "Circuits That Will Prevent the Debugger From Functioning"**

Appendix C. Revision History

Revision A (May 2012)

Initial release of this document.

Revision B (September 2014)

- Reorganized Debugger Usage section.
- Updated Recommended Reading section.
- Modified Troubleshooting First Steps, FAQs, and Error Messages chapters.
- Added Engineering Technical Notes chapter.

Support

Please refer to the items discussed here for support issues.

- Warranty Registration
- The Microchip Web Site
- myMicrochip Personalized Notification Service
- Customer Support

A.1 WARRANTY REGISTRATION

If your development tool package includes a Warranty Registration Card, please complete the card and mail it in promptly. Sending in your Warranty Registration Card entitles you to receive new product updates. Interim software releases are available at the Microchip web site.

A.2 THE MICROCHIP WEB SITE

Microchip provides online support via our web site at http://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

A.3 myMICROCHIP PERSONALIZED NOTIFICATION SERVICE

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

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.

A.4 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. See our web site for a complete, up-to-date listing of sales offices.

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

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

Glossary

A

Absolute Section

A GCC compiler section with a fixed (absolute) address that cannot be changed by the linker.

Absolute Variable/Function

A variable or function placed at an absolute address using the OCG compiler's `@ address` syntax.

Access Memory

PIC18 Only – Special registers on PIC18 devices that allow access regardless of the setting of the Bank Select Register (BSR).

Access Entry Points

Access entry points provide a way to transfer control across segments to a function which may not be defined at link time. They support the separate linking of boot and secure application segments.

Address

Value that identifies a location in memory.

Alphabetic Character

Alphabetic characters are those characters that are letters of the Roman alphabet (a, b, …, z, A, B, …, Z).

Alphanumeric

Alphanumeric characters are comprised of alphabetic characters and decimal digits (0,1, …, 9).

ANDed Breakpoints

Set up an ANDed condition for breaking, i.e., breakpoint 1 AND breakpoint 2 must occur at the same time before a program halt. This can only be accomplished if a data breakpoint and a program memory breakpoint occur at the same time.

Anonymous Structure

16-bit C Compiler **–** An unnamed structure.

PIC18 C Compiler **–** An unnamed structure that is a member of a C union. The members of an anonymous structure may be accessed as if they were members of the enclosing union. For example, in the following code, `hi` and `lo` are members of an anonymous structure inside the union `caster`.

```
union castaway
 int intval;
 struct {
  char lo; //accessible as caster.lo
  char hi; //accessible as caster.hi
 };
} caster;
```

ANSI

American National Standards Institute is an organization responsible for formulating and approving standards in the United States.

Application

A set of software and hardware that may be controlled by a PIC® microcontroller.

Archive/Archiver

An archive/library is a collection of relocatable object modules. It is created by assembling multiple source files to object files, and then using the archiver/librarian to combine the object files into one archive/library file. An archive/library can be linked with object modules and other archives/libraries to create executable code.

ASCII

American Standard Code for Information Interchange is a character set encoding that uses 7 binary digits to represent each character. It includes upper and lower case letters, digits, symbols and control characters.

Assembly/Assembler

Assembly is a programming language that describes binary machine code in a symbolic form. An assembler is a language tool that translates assembly language source code into machine code.

Assigned Section

A GCC compiler section which has been assigned to a target memory block in the linker command file.

Asynchronously

Multiple events that do not occur at the same time. This is generally used to refer to interrupts that may occur at any time during processor execution.

Asynchronous Stimulus

Data generated to simulate external inputs to a simulator device.

Attribute

GCC Characteristics of variables or functions in a C program which are used to describe machine-specific properties.

Attribute, Section

GCC Characteristics of sections, such as “executable”, “readonly”, or “data” that can be specified as flags in the assembler `.section` directive.

B

Binary

The base two numbering system that uses the digits 0-1. The rightmost digit counts ones, the next counts multiples of 2, then $2^2 = 4$, etc.

Bookmarks

Use bookmarks to easily locate specific lines in a file.

Select Toggle Bookmarks on the Editor toolbar to add/remove bookmarks. Click other icons on this toolbar to move to the next or previous bookmark.

Breakpoint

Hardware Breakpoint: An event whose execution will cause a halt.

Software Breakpoint: An address where execution of the firmware will halt. Usually achieved by a special break instruction.

Build

Compile and link all the source files for an application.

C

C\C++

C is a general-purpose programming language which features economy of expression, modern control flow and data structures, and a rich set of operators. C++ is the object-oriented version of C.

Calibration Memory

A special function register or registers used to hold values for calibration of a PIC microcontroller on-board RC oscillator or other device peripherals.

Central Processing Unit

The part of a device that is responsible for fetching the correct instruction for execution, decoding that instruction, and then executing that instruction. When necessary, it works in conjunction with the arithmetic logic unit (ALU) to complete the execution of the instruction. It controls the program memory address bus, the data memory address bus, and accesses to the stack.

Clean

Clean removes all intermediary project files, such as object, hex and debug files, for the active project. These files are recreated from other files when a project is built.

COFF

Common Object File Format. An object file of this format contains machine code, debugging and other information.

Command Line Interface

A means of communication between a program and its user based solely on textual input and output.

Compiled Stack

A region of memory managed by the compiler in which variables are statically allocated space. It replaces a software or hardware stack when such mechanisms cannot be efficiently implemented on the target device.

Compiler

A program that translates a source file written in a high-level language into machine code.

Conditional Assembly

Assembly language code that is included or omitted based on the assembly-time value of a specified expression.

Conditional Compilation

The act of compiling a program fragment only if a certain constant expression, specified by a preprocessor directive, is true.

Configuration Bits

Special-purpose bits programmed to set PIC MCU and dsPIC DSC modes of operation. A Configuration bit may or may not be preprogrammed.

Control Directives

Directives in assembly language code that cause code to be included or omitted based on the assembly-time value of a specified expression.

CPU

See Central Processing Unit.

Cross Reference File

A file that references a table of symbols and a list of files that references the symbol. If the symbol is defined, the first file listed is the location of the definition. The remaining files contain references to the symbol.

D

Data Directives

Data directives are those that control the assembler's allocation of program or data memory and provide a way to refer to data items symbolically; that is, by meaningful names.

Data Memory

On Microchip MCU and DSC devices, data memory (RAM) is comprised of General Purpose Registers (GPRs) and Special Function Registers (SFRs). Some devices also have EEPROM data memory.

Data Monitor and Control Interface (DMCI)

The Data Monitor and Control Interface, or DMCI, is a tool in MPLAB X IDE. The interface provides dynamic input control of application variables in projects. Application-generated data can be viewed graphically using any of 4 dynamically-assignable graph windows.

Debug/Debugger

See ICE/ICD.

Debugging Information

Compiler and assembler options that, when selected, provide varying degrees of information used to debug application code. See compiler or assembler documentation for details on selecting debug options.

Deprecated Features

Features that are still supported for legacy reasons, but will eventually be phased out and no longer used.

Device Programmer

A tool used to program electrically programmable semiconductor devices such as microcontrollers.

Digital Signal Controller

A digital signal controller (DSC) is a microcontroller device with digital signal processing capability, i.e., Microchip dsPIC DSC devices.

Digital Signal Processing\Digital Signal Processor

Digital signal processing (DSP) is the computer manipulation of digital signals, commonly analog signals (sound or image) which have been converted to digital form (sampled). A digital signal processor is a microprocessor that is designed for use in digital signal processing.

Directives

Statements in source code that provide control of the language tool's operation.

Download

Download is the process of sending data from a host to another device, such as an emulator, programmer or target board.

DWARF

Debug With Arbitrary Record Format. DWARF is a debug information format for ELF files.

E

EEPROM

Electrically Erasable Programmable Read Only Memory. A special type of PROM that can be erased electrically. Data is written or erased one byte at a time. EEPROM retains its contents even when power is turned off.

ELF

Executable and Linking Format. An object file of this format contains machine code. Debugging and other information is specified in with DWARF. ELF/DWARF provide better debugging of optimized code than COFF.

Emulation/Emulator

See ICE/ICD.

Endianness

The ordering of bytes in a multi-byte object.

Environment

MPLAB PM3 **–** A folder containing files on how to program a device. This folder can be transferred to a SD/MMC card.

Epilogue

A portion of compiler-generated code that is responsible for deallocating stack space, restoring registers and performing any other machine-specific requirement specified in the runtime model. This code executes after any user code for a given function, immediately prior to the function return.

EPROM

Erasable Programmable Read Only Memory. A programmable read-only memory that can be erased usually by exposure to ultraviolet radiation.

Error/Error File

An error reports a problem that makes it impossible to continue processing your program. When possible, an error identifies the source file name and line number where the problem is apparent. An error file contains error messages and diagnostics generated by a language tool.

Event

A description of a bus cycle which may include address, data, pass count, external input, cycle type (fetch, R/W), and time stamp. Events are used to describe triggers, breakpoints and interrupts.

Executable Code

Software that is ready to be loaded for execution.

Export

Send data out of the MPLAB IDE/MPLAB X IDE in a standardized format.

Expressions

Combinations of constants and/or symbols separated by arithmetic or logical operators.

Extended Microcontroller Mode

In extended microcontroller mode, on-chip program memory as well as external memory is available. Execution automatically switches to external if the program memory address is greater than the internal memory space of the PIC18 device.

Extended Mode (PIC18 MCUs)

In Extended mode, the compiler will utilize the extended instructions (i.e., `ADDFSR`, `ADDULNK`, `CALLW`, `MOVSF`, `MOVSS`, `PUSHL`, `SUBFSR` and `SUBULNK`) and the indexed with literal offset addressing.

External Label

A label that has external linkage.

External Linkage

A function or variable has external linkage if it can be referenced from outside the module in which it is defined.

External Symbol

A symbol for an identifier which has external linkage. This may be a reference or a definition.

External Symbol Resolution

A process performed by the linker in which external symbol definitions from all input modules are collected in an attempt to resolve all external symbol references. Any external symbol references which do not have a corresponding definition cause a linker error to be reported.

External Input Line

An external input signal logic probe line (TRIGIN) for setting an event based upon external signals.

External RAM

Off-chip Read/Write memory.

F

Fatal Error

An error that will halt compilation immediately. No further messages will be produced.

File Registers

On-chip data memory, including General Purpose Registers (GPRs) and Special Function Registers (SFRs).

Filter

Determine by selection what data is included/excluded in a trace display or data file.

Fixup

The process of replacing object file symbolic references with absolute addresses after relocation by the linker.

Flash

A type of EEPROM where data is written or erased in blocks instead of bytes.

FNOP

Forced No Operation. A forced NOP cycle is the second cycle of a two-cycle instruction. Since the PIC microcontroller architecture is pipelined, it prefetches the next instruction in the physical address space while it is executing the current instruction. However, if the current instruction changes the program counter, this prefetched instruction is explicitly ignored, causing a forced NOP cycle.

Frame Pointer

A pointer that references the location on the stack that separates the stack-based arguments from the stack-based local variables. Provides a convenient base from which to access local variables and other values for the current function.

Free-Standing

An implementation that accepts any strictly conforming program that does not use complex types and in which the use of the features specified in the library clause (ANSI '89 standard clause 7) is confined to the contents of the standard headers `<float.h>`, `<iso646.h>`, `<limits.h>`, `<stdarg.h>`, `<stdbool.h>`, `<stddef.h>` and `<stdint.h>`.

G

GPR

General Purpose Register. The portion of device data memory (RAM) available for general use.

H

Halt

A stop of program execution. Executing Halt is the same as stopping at a breakpoint.

Heap

An area of memory used for dynamic memory allocation where blocks of memory are allocated and freed in an arbitrary order determined at runtime.

Hex Code\Hex File

Hex code is executable instructions stored in a hexadecimal format code. Hex code is contained in a hex file.

Hexadecimal

The base 16 numbering system that uses the digits 0-9 plus the letters A-F (or a-f). The digits A-F represent hexadecimal digits with values of (decimal) 10 to 15. The rightmost digit counts ones, the next counts multiples of 16, then 16^2 = 256, etc.

High Level Language

A language for writing programs that is further removed from the processor than assembly.

I

ICE/ICD

In-Circuit Emulator/In-Circuit Debugger: A hardware tool that debugs and programs a target device. An emulator has more features than an debugger, such as trace.

In-Circuit Emulation/In-Circuit Debug: The act of emulating or debugging with an in-circuit emulator or debugger.

-ICE/-ICD: A device (MCU or DSC) with on-board in-circuit emulation or debug circuitry. This device is always mounted on a header board and used to debug with an in-circuit emulator or debugger.

ICSP

In-Circuit Serial Programming. A method of programming Microchip embedded devices using serial communication and a minimum number of device pins.

IDE

Integrated Development Environment, as in MPLAB IDE/MPLAB X IDE.

Identifier

A function or variable name.

IEEE

Institute of Electrical and Electronics Engineers.

Import

Bring data into the MPLAB IDE/MPLAB X IDE from an outside source, such as from a hex file.

Initialized Data

Data which is defined with an initial value. In C,

```
int myVar=5;
```

defines a variable which will reside in an initialized data section.

Instruction Set

The collection of machine language instructions that a particular processor understands.

Instructions

A sequence of bits that tells a central processing unit to perform a particular operation and can contain data to be used in the operation.

Internal Linkage

A function or variable has internal linkage if it can not be accessed from outside the module in which it is defined.

International Organization for Standardization

An organization that sets standards in many businesses and technologies, including computing and communications. Also known as ISO.

Interrupt

A signal to the CPU that suspends the execution of a running application and transfers control to an Interrupt Service Routine (ISR) so that the event may be processed. Upon completion of the ISR, normal execution of the application resumes.

Interrupt Handler

A routine that processes special code when an interrupt occurs.

Interrupt Service Request (IRQ)

An event which causes the processor to temporarily suspend normal instruction execution and to start executing an interrupt handler routine. Some processors have several interrupt request events allowing different priority interrupts.

Interrupt Service Routine (ISR)

Language tools – A function that handles an interrupt.

MPLAB IDE/MPLAB X IDE – User-generated code that is entered when an interrupt occurs. The location of the code in program memory will usually depend on the type of interrupt that has occurred.

Interrupt Vector

Address of an interrupt service routine or interrupt handler.

L

L-value

An expression that refers to an object that can be examined and/or modified. An l-value expression is used on the left-hand side of an assignment.

Latency

The time between an event and its response.

Library/Librarian

See Archive/Archiver.

Linker

A language tool that combines object files and libraries to create executable code, resolving references from one module to another.

Linker Script Files

Linker script files are the command files of a linker. They define linker options and describe available memory on the target platform.

Listing Directives

Listing directives are those directives that control the assembler listing file format. They allow the specification of titles, pagination and other listing control.

Listing File

A listing file is an ASCII text file that shows the machine code generated for each C source statement, assembly instruction, assembler directive, or macro encountered in a source file.

Little Endian

A data ordering scheme for multibyte data whereby the least significant byte is stored at the lower addresses.

Local Label

A local label is one that is defined inside a macro with the LOCAL directive. These labels are particular to a given instance of a macro's instantiation. In other words, the symbols and labels that are declared as local are no longer accessible after the ENDM macro is encountered.

Logic Probes

Up to 14 logic probes can be connected to some Microchip emulators. The logic probes provide external trace inputs, trigger output signal, +5V, and a common ground.

Loop-Back Test Board

Used to test the functionality of the MPLAB REAL ICE in-circuit emulator.

LVDS

Low-Voltage Differential Signaling. A low noise, low-power, low amplitude method for high-speed (gigabits per second) data transmission over copper wire.

With standard I/O signaling, data storage is contingent upon the actual voltage level. Voltage level can be affected by wire length (longer wires increase resistance, which lowers voltage). But with LVDS, data storage is distinguished only by positive and negative voltage values, not the voltage level. Therefore, data can travel over greater lengths of wire while maintaining a clear and consistent data stream.

Source: http://www.webopedia.com/TERM/L/LVDS.html

M

Machine Code

The representation of a computer program that is actually read and interpreted by the processor. A program in binary machine code consists of a sequence of machine instructions (possibly interspersed with data). The collection of all possible instructions for a particular processor is known as its "instruction set".

Machine Language

A set of instructions for a specific central processing unit, designed to be usable by a processor without being translated.

Macro

Macro instruction. An instruction that represents a sequence of instructions in abbreviated form.

Macro Directives

Directives that control the execution and data allocation within macro body definitions.

Makefile

Export to a file the instructions to Make the project. Use this file to Make your project outside of MPLAB IDE/MPLAB X IDE, i.e., with a `make`.

Make Project

A command that rebuilds an application, recompiling only those source files that have changed since the last complete compilation.

MCU

Microcontroller Unit. An abbreviation for microcontroller. Also uC.

Memory Model

For C compilers, a representation of the memory available to the application. For the PIC18 C compiler, a description that specifies the size of pointers that point to program memory.

Message

Text displayed to alert you to potential problems in language tool operation. A message will not stop operation.

Microcontroller

A highly integrated chip that contains a CPU, RAM, program memory, I/O ports and timers.

Microcontroller Mode

One of the possible program memory configurations of PIC18 microcontrollers. In microcontroller mode, only internal execution is allowed. Thus, only the on-chip program memory is available in microcontroller mode.

Microprocessor Mode

One of the possible program memory configurations of PIC18 microcontrollers. In microprocessor mode, the on-chip program memory is not used. The entire program memory is mapped externally.

Mnemonics

Text instructions that can be translated directly into machine code. Also referred to as opcodes.

Module

The preprocessed output of a source file after preprocessor directives have been executed. Also known as a translation unit.

MPASM™ Assembler

Microchip Technology’s relocatable macro assembler for PIC microcontroller devices, KeeLoq® devices and Microchip memory devices.

MPLAB *Language Tool* for *Device*

Microchip’s C compilers, assemblers and linkers for specified devices. Select the type of language tool based on the device you will be using for your application, e.g., if you will be creating C code on a PIC18 MCU, select the MPLAB C Compiler for PIC18 MCUs.

MPLAB ICD

Microchip in-circuit debugger that works with MPLAB IDE/MPLAB X IDE. *See* ICE/ICD.

MPLAB IDE/MPLAB X IDE

Microchip's Integrated Development Environment. MPLAB IDE/MPLAB X IDE comes with an editor, project manager and simulator.

MPLAB PM3

A device programmer from Microchip. Programs PIC18 microcontrollers and dsPIC digital signal controllers. Can be used with MPLAB IDE/MPLAB X IDE or stand-alone. Replaces PRO MATE II.

MPLAB REAL ICE™ In-Circuit Emulator

Microchip's next-generation in-circuit emulator that works with MPLAB IDE/MPLAB X IDE. *See* ICE/ICD.

MPLAB SIM

Microchip's simulator that works with MPLAB IDE/MPLAB X IDE in support of PIC MCU and dsPIC DSC devices.

MPLIB™ Object Librarian

Microchip's librarian that can work with MPLAB IDE/MPLAB X IDE. MPLIB librarian is an object librarian for use with COFF object modules created using either MPASM assembler (mpasm or mpasmwin v2.0) or MPLAB C18 C Compiler.

MPLINK™ Object Linker

MPLINK linker is an object linker for the Microchip MPASM assembler and the Microchip C18 C compiler. MPLINK linker also may be used with the Microchip MPLIB librarian. MPLINK linker is designed to be used with MPLAB IDE/MPLAB X IDE, though it does not have to be.

MRU

Most Recently Used. Refers to files and windows available to be selected from MPLAB IDE/MPLAB X IDE main pull down menus.

N

Native Data Size

For Native trace, the size of the variable used in a Watches window must be of the same size as the selected device's data memory: bytes for PIC18 devices and words for 16-bit devices.

Nesting Depth

The maximum level to which macros can include other macros.

Node

MPLAB IDE/MPLAB X IDE project component.

Non-Extended Mode (PIC18 MCUs)

In Non-Extended mode, the compiler will not utilize the extended instructions nor the indexed with literal offset addressing.

Non Real Time

Refers to the processor at a breakpoint or executing single-step instructions or MPLAB IDE/MPLAB X IDE being run in simulator mode.

Non-Volatile Storage

A storage device whose contents are preserved when its power is off.

NOP

No Operation. An instruction that has no effect when executed except to advance the program counter.

O

Object Code/Object File

Object code is the machine code generated by an assembler or compiler. An object file is a file containing machine code and possibly debug information. It may be immediately executable or it may be relocatable, requiring linking with other object files, e.g., libraries, to produce a complete executable program.

Object File Directives

Directives that are used only when creating an object file.

Octal

The base 8 number system that only uses the digits 0-7. The rightmost digit counts ones, the next digit counts multiples of 8, then $8^2 = 64$, etc.

Off-Chip Memory

Off-chip memory refers to the memory selection option for the PIC18 device where memory may reside on the target board, or where all program memory may be supplied by the emulator. The **Memory** tab accessed from *Options>Development Mode* provides the Off-Chip Memory selection dialog box.

Opcodes

Operational Codes. *See* Mnemonics.

Operators

Symbols, like the plus sign '+' and the minus sign '-', that are used when forming well-defined expressions. Each operator has an assigned precedence that is used to determine order of evaluation.

OTP

One-Time-Programmable. EPROM devices that are not in windowed packages. Since EPROM needs ultraviolet light to erase its memory, only windowed devices are erasable.

P

Pass Counter

A counter that decrements each time an event (such as the execution of an instruction at a particular address) occurs. When the pass count value reaches zero, the event is satisfied. You can assign the Pass Counter to break and trace logic, and to any sequential event in the complex trigger dialog.

PC

Personal Computer or Program Counter.

PC Host

Any PC running a supported Windows operating system.

Persistent Data

Data that is never cleared or initialized. Its intended use is so that an application can preserve data across a device Reset.

Phantom Byte

An unimplemented byte in the dsPIC architecture that is used when treating the 24-bit instruction word as if it were a 32-bit instruction word. Phantom bytes appear in dsPIC hex files.

PIC MCUs

PIC microcontrollers (MCUs) refers to all Microchip microcontroller families.

PICkit 2 and 3

Microchip's developmental device programmers with debug capability through Debug Express. See the Readme files for each tool to see which devices are supported.

Plug-ins

The MPLAB IDE/MPLAB X IDE has both built-in components and plug-in modules to configure the system for a variety of software and hardware tools. Several plug-in tools may be found under the Tools menu.

Pod

The enclosure for an in-circuit emulator or debugger. Other names are "Puck", if the enclosure is round, and "Probe", not be confused with logic probes.

Power-on-Reset Emulation

A software randomization process that writes random values in data RAM areas to simulate uninitialized values in RAM upon initial power application.

Pragma

A directive that has meaning to a specific compiler. Often a pragma is used to convey implementation-defined information to the compiler.

Precedence

Rules that define the order of evaluation in expressions.

Production Programmer

A production programmer is a programming tool that has resources designed in to program devices rapidly. It has the capability to program at various voltage levels and completely adheres to the programming specification. Programming a device as fast as possible is of prime importance in a production environment where time is of the essence as the application circuit moves through the assembly line.

Profile

For MPLAB SIM simulator, a summary listing of executed stimulus by register.

Program Counter

The location that contains the address of the instruction that is currently executing.

Program Counter Unit

16-bit assembler – A conceptual representation of the layout of program memory. The program counter increments by two for each instruction word. In an executable section, two program counter units are equivalent to three bytes. In a read-only section, two program counter units are equivalent to two bytes.

Program Memory

MPLAB IDE/MPLAB X IDE – The memory area in a device where instructions are stored. Also, the memory in the emulator or simulator containing the downloaded target application firmware.

16-bit assembler/compiler – The memory area in a device where instructions are stored.

Project

A project contains the files needed to build an application (source code, linker script files, etc.) along with their associations to various build tools and build options.

Prologue

A portion of compiler-generated code that is responsible for allocating stack space, preserving registers and performing any other machine-specific requirement specified in the runtime model. This code executes before any user code for a given function.

Prototype System

A term referring to a user's target application, or target board.

Psect

The OCG equivalent of a GCC section, short for program section. A block of code or data which is treated as a whole by the linker.

PWM Signals

Pulse-Width Modulation Signals. Certain PIC MCU devices have a PWM peripheral.

Q

Qualifier

An address or an address range used by the Pass Counter or as an event before another operation in a complex trigger.

R

Radix

The number base, hex, or decimal, used in specifying an address.

RAM

Random Access Memory (Data Memory). Memory in which information can be accessed in any order.

Raw Data

The binary representation of code or data associated with a section.

Read Only Memory

Memory hardware that allows fast access to permanently stored data but prevents addition to or modification of the data.

Real Time

When an in-circuit emulator or debugger is released from the halt state, the processor runs in Real Time mode and behaves exactly as the normal chip would behave. In Real Time mode, the real time trace buffer of an emulator is enabled and constantly captures all selected cycles, and all break logic is enabled. In an in-circuit emulator or debugger, the processor executes in real time until a valid breakpoint causes a halt, or until the user halts the execution.

In the simulator, real time simply means execution of the microcontroller instructions as fast as they can be simulated by the host CPU.

Recursive Calls

A function that calls itself, either directly or indirectly.

Recursion

The concept that a function or macro, having been defined, can call itself. Great care should be taken when writing recursive macros; it is easy to get caught in an infinite loop where there will be no exit from the recursion.

Reentrant

A function that may have multiple, simultaneously active instances. This may happen due to either direct or indirect recursion or through execution during interrupt processing.

Relaxation

The process of converting an instruction to an identical, but smaller instruction. This is useful for saving on code size. MPLAB XC16 currently knows how to `relax` a `CALL` instruction into an `RCALL` instruction. This is done when the symbol that is being called is within +/- 32k instruction words from the current instruction.

Relocatable

An object whose address has not been assigned to a fixed location in memory.

Relocatable Section

16-bit assembler – A section whose address is not fixed (absolute). The linker assigns addresses to relocatable sections through a process called relocation.

Relocation

A process performed by the linker in which absolute addresses are assigned to relocatable sections and all symbols in the relocatable sections are updated to their new addresses.

ROM

Read-Only Memory (Program Memory). Memory that cannot be modified.

Run

The command that releases the emulator from halt, allowing it to run the application code and change or respond to I/O in real time.

Run-time Model

Describes the use of target architecture resources.

Runtime Watch

A Watch window where the variables change in as the application is run. See individual tool documentation to determine how to set up a runtime watch. Not all tools support runtime watches.

S

Scenario

For MPLAB SIM simulator, a particular setup for stimulus control.

Section

The GCC equivalent of an OCG psect. A block of code or data which is treated as a whole by the linker.

Section Attribute

A GCC characteristic ascribed to a section (e.g., an `access` section).

Sequenced Breakpoints

Breakpoints that occur in a sequence. Sequence execution of breakpoints is bottom-up; the last breakpoint in the sequence occurs first.

Serialized Quick Turn Programming

Serialization allows you to program a serial number into each microcontroller device that the Device Programmer programs. This number can be used as an entry code, password or ID number.

Shell

The MPASM assembler shell is a prompted input interface to the macro assembler. There are two MPASM assembler shells: one for the DOS version and one for the Windows operating system version.

Simulator

A software program that models the operation of devices.

Single Step

This command steps though code, one instruction at a time. After each instruction, MPLAB IDE/MPLAB X IDE updates register windows, watch variables, and status displays so you can analyze and debug instruction execution. You can also single step C compiler source code, but instead of executing single instructions, MPLAB IDE/MPLAB X IDE will execute all assembly level instructions generated by the line of the high level C statement.

Skew

The information associated with the execution of an instruction appears on the processor bus at different times. For example, the executed opcodes appears on the bus as a fetch during the execution of the previous instruction, the source data address and value and the destination data address appear when the opcodes is actually executed, and the destination data value appears when the next instruction is executed. The trace buffer captures the information that is on the bus at one instance. Therefore, one trace buffer entry will contain execution information for three instructions. The number of captured cycles from one piece of information to another for a single instruction execution is referred to as the skew.

Skid

When a hardware breakpoint is used to halt the processor, one or more additional instructions may be executed before the processor halts. The number of extra instructions executed after the intended breakpoint is referred to as the skid.

Source Code

The form in which a computer program is written by the programmer. Source code is written in a formal programming language which can be translated into machine code or executed by an interpreter.

Source File

An ASCII text file containing source code.

Special Function Registers (SFRs)

The portion of data memory (RAM) dedicated to registers that control I/O processor functions, I/O status, timers or other modes or peripherals.

SQTP

See Serialized Quick Turn Programming.

Stack, Hardware

Locations in PIC microcontroller where the return address is stored when a function call is made.

Stack, Software

Memory used by an application for storing return addresses, function parameters, and local variables. This memory is dynamically allocated at runtime by instructions in the program. It allows for reentrant function calls.

Stack, Compiled

A region of memory managed and allocated by the compiler in which variables are statically assigned space. It replaces a software stack when such mechanisms cannot be efficiently implemented on the target device. It precludes reentrancy.

MPLAB Starter Kit for *Device*

Microchip's starter kits contains everything needed to begin exploring the specified device. View a working application and then debug and program you own changes.

Static RAM or SRAM

Static Random Access Memory. Program memory you can read/write on the target board that does not need refreshing frequently.

Status Bar

The Status Bar is located on the bottom of the MPLAB IDE/MPLAB X IDE window and indicates such current information as cursor position, development mode and device, and active tool bar.

Step Into

This command is the same as Single Step. Step Into (as opposed to Step Over) follows a CALL instruction into a subroutine.

Step Over

Step Over allows you to debug code without stepping into subroutines. When stepping over a `CALL` instruction, the next breakpoint will be set at the instruction after the `CALL`. If for some reason the subroutine gets into an endless loop or does not return properly, the next breakpoint will never be reached. The Step Over command is the same as Single Step except for its handling of `CALL` instructions.

Step Out

Step Out allows you to step out of a subroutine which you are currently stepping through. This command executes the rest of the code in the subroutine and then stops execution at the return address to the subroutine.

Stimulus

Input to the simulator, i.e., data generated to exercise the response of simulation to external signals. Often the data is put into the form of a list of actions in a text file. Stimulus may be asynchronous, synchronous (pin), clocked and register.

Stopwatch

A counter for measuring execution cycles.

Storage Class

Determines the lifetime of the memory associated with the identified object.

Storage Qualifier

Indicates special properties of the objects being declared (e.g., `const`).

Symbol

A symbol is a general purpose mechanism for describing the various pieces which comprise a program. These pieces include function names, variable names, section names, file names, struct/enum/union tag names, etc. Symbols in MPLAB IDE/MPLAB X IDE refer mainly to variable names, function names and assembly labels. The value of a symbol after linking is its value in memory.

Symbol, Absolute

Represents an immediate value such as a definition through the assembly `.equ` directive.

System Window Control

The system window control is located in the upper left corner of windows and some dialogs. Clicking on this control usually pops up a menu that has the items "Minimize," "Maximize," and "Close."

T

Target

Refers to user hardware.

Target Application

Software residing on the target board.

Target Board

The circuitry and programmable device that makes up the target application.

Target Processor

The microcontroller device on the target application board.

Template

Lines of text that you build for inserting into your files at a later time. The MPLAB Editor stores templates in template files.

Tool Bar

A row or column of icons that you can click on to execute MPLAB IDE/MPLAB X IDE functions.

Trace

An emulator or simulator function that logs program execution. The emulator logs program execution into its trace buffer which is uploaded to the MPLAB IDE/MPLAB X IDE trace window.

Trace Memory

Trace memory contained within the emulator. Trace memory is sometimes called the trace buffer.

Trace Macro

A macro that will provide trace information from emulator data. Since this is a software trace, the macro must be added to code, the code must be recompiled or reassembled, and the target device must be programmed with this code before trace will work.

Trigger Output

Trigger output refers to an emulator output signal that can be generated at any address or address range, and is independent of the trace and breakpoint settings. Any number of trigger output points can be set.

Trigraphs

Three-character sequences, all starting with ??, that are defined by ISO C as replacements for single characters.

U

Unassigned Section

A section which has not been assigned to a specific target memory block in the linker command file. The linker must find a target memory block in which to allocate an unassigned section.

Uninitialized Data

Data which is defined without an initial value. In C,

```
int myVar;
```

defines a variable which will reside in an uninitialized data section.

Upload

The Upload function transfers data from a tool, such as an emulator or programmer, to the host PC or from the target board to the emulator.

USB

Universal Serial Bus. An external peripheral interface standard for communication between a computer and external peripherals over a cable using bi-serial transmission. USB 1.0/1.1 supports data transfer rates of 12 Mbps. Also referred to as high-speed USB, USB 2.0 supports data rates up to 480 Mbps.

V

Vector

The memory locations that an application will jump to when either a Reset or interrupt occurs.

Volatile

A variable qualifier which prevents the compiler applying optimizations that affect how the variable is accessed in memory.

W

Warning

MPLAB IDE/MPLAB X IDE – An alert that is provided to warn you of a situation that would cause physical damage to a device, software file, or equipment.

16-bit assembler/compiler – Warnings report conditions that may indicate a problem, but do not halt processing.

Watch Variable

A variable that you may monitor during a debugging session in a Watches window.

Watch Window

Watch windows contain a list of watch variables that are updated at each breakpoint.

Watchdog Timer (WDT)

A timer on a PIC microcontroller that resets the processor after a selectable length of time. The WDT is enabled or disabled and set up using Configuration bits.

Workbook

For MPLAB SIM stimulator, a setup for generation of SCL stimulus.

NOTES:

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ASIA/PACIFIC

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