



Chipsmall Limited consists of a professional team with an average of over 10 year of expertise in the distribution of electronic components. Based in Hongkong, we have already established firm and mutual-benefit business relationships with customers from,Europe,America and south Asia,supplying obsolete and hard-to-find components to meet their specific needs.

With the principle of “Quality Parts,Customers Priority,Honest Operation,and Considerate Service”,our business mainly focus on the distribution of electronic components. Line cards we deal with include Microchip,ALPS,ROHM,Xilinx,Pulse,ON,Everlight and Freescale. Main products comprise IC,Modules,Potentiometer,IC Socket,Relay,Connector.Our parts cover such applications as commercial,industrial, and automotives areas.

We are looking forward to setting up business relationship with you and hope to provide you with the best service and solution. Let us make a better world for our industry!



## Contact us

Tel: +86-755-8981 8866 Fax: +86-755-8427 6832

Email & Skype: info@chipsmall.com Web: www.chipsmall.com

Address: A1208, Overseas Decoration Building, #122 Zhenhua RD., Futian, Shenzhen, China





**PICDEM™ Lab  
Development Board  
User's Guide**

---

---

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

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

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

---

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

**Trademarks**

The Microchip name and logo, the Microchip logo, Accuron, dsPIC, KEELOQ, KEELOQ logo, MPLAB, PIC, PICmicro, PICSTART, rPIC, SmartShunt and UNI/O are registered trademarks of Microchip Technology Incorporated in the U.S.A. and other countries.


FilterLab, Linear Active Thermistor, MXDEV, MXLAB, SEEVAL, SmartSensor and The Embedded Control Solutions Company are registered trademarks of Microchip Technology Incorporated in the U.S.A.

Analog-for-the-Digital Age, Application Maestro, CodeGuard, dsPICDEM, dsPICDEM.net, dsPICworks, dsSPEAK, ECAN, ECONOMONITOR, FanSense, In-Circuit Serial Programming, ICSP, ICEPIC, Mindi, MiWi, MPASM, MPLAB Certified logo, MPLIB, MPLINK, mTouch, PICkit, PICDEM, PICDEM.net, PICTail, PIC<sup>32</sup> logo, PowerCal, PowerInfo, PowerMate, PowerTool, REAL ICE, rLAB, Select Mode, Total Endurance, WiperLock and ZENA are trademarks of Microchip Technology Incorporated in the U.S.A. and other countries.

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

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

© 2009, Microchip Technology Incorporated, Printed in the U.S.A., All Rights Reserved.

 Printed on recycled paper.

**QUALITY MANAGEMENT SYSTEM**  
**CERTIFIED BY DNV**  
**== ISO/TS 16949:2002 ==**

*Microchip received ISO/TS-16949:2002 certification for its worldwide headquarters, design and wafer fabrication facilities in Chandler and Tempe, Arizona; Gresham, Oregon and design centers in California and India. The Company's quality system processes and procedures are for its PIC® MCUs and dsPIC® DSCs, KEELOQ® code hopping devices, Serial EEPROMs, microperipherals, nonvolatile memory and analog products. In addition, Microchip's quality system for the design and manufacture of development systems is ISO 9001:2000 certified.*



# PICDEM™ LAB DEVELOPMENT BOARD USER'S GUIDE

---

---

## Table of Contents

---

---

### Chapter 1. Overview

1.1 Introduction .....	5
1.2 Highlights .....	5
1.3 PICDEM™ Lab Development Kit Contents .....	5
1.4 PICDEM™ Lab Development Board Construction and Layout .....	6
1.5 Target Power .....	7
1.6 Connecting the PICkit™ 2 Programmer/Debugger .....	8
1.7 Solderless Prototyping Area Strip Configuration .....	9

### Chapter 2. Getting Started

2.1 Introduction .....	11
2.2 Prerequisites .....	11
2.3 The Software Control Loop .....	11
2.4 MPLAB® IDE Download Instructions .....	12
2.5 Installing the Included Lab Files .....	16

### Chapter 3. General Purpose Input/Output Labs

3.1 Introduction .....	17
3.2 General Purpose Input/Output Labs .....	17
3.3 GPIO Output Labs .....	18
3.3.1 Reference Documentation .....	18
3.3.2 Equipment Required for GPIO Output Labs .....	18
3.3.3 PICDEM Lab Development Board Setup for GPIO Output Labs .....	18
3.3.4 Lab 1: Light LEDs .....	19
3.3.5 Lab 2: Flash LEDs (Delay Loop) .....	25
3.3.6 Lab 3: Simple Delays Using Timer0 .....	29
3.3.7 Lab 4: Rotate LEDs .....	34
3.4 GPIO Input Labs .....	38
3.4.1 Reference Documentation .....	38
3.4.2 Equipment Required for GPIO Input Labs .....	38
3.4.3 PICDEM Lab Development Board Setup for GPIO Input Labs .....	38
3.4.4 Lab 5: Adding a Push Button .....	39
3.4.5 Lab 6: Push Button Interrupt .....	48
3.4.6 Lab 7: Push Button Interrupt-on-Change .....	53
3.4.7 Lab 8: Using Weak Pull-Ups .....	58

# PICDEM™ Lab Development Board User's Guide

---

## Chapter 4. Comparator Peripheral Labs

4.1 Introduction .....	61
4.2 Comparator Labs .....	61
4.2.1 Reference Documentation .....	61
4.2.2 Comparator Labs .....	61
4.2.3 Equipment Required .....	61
4.2.4 Lab 1: Simple Compare .....	62
4.2.5 Lab 2: Using the Comparator Voltage Reference .....	64
4.2.6 Lab 3: Higher Resolution Sensor Readings Using a Single Comparator ...	68

## Chapter 5. Analog-to-Digital Converter Peripheral Labs

5.1 Introduction .....	75
5.2 ADC Labs .....	75
5.2.1 Reference Documentation .....	75
5.2.2 Equipment Required .....	75
5.2.3 Lab 1: Simple ADC .....	76
5.2.4 Lab 2: Audible Temperature Sensor .....	85

## Appendix A. Schematic

A.1 PICDEM Lab Development Kit Schematic .....	91
--	----



# PICDEM™ LAB DEVELOPMENT BOARD USER'S GUIDE

## 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](http://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 “DSXXXXA”, where “XXXX” is the document number and “A” is the revision level of the document.

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

## INTRODUCTION

This chapter contains general information that will be useful to know before using the PICDEM™ Lab Development Board. Items discussed in this chapter include:

- Document Layout
- Conventions Used in this Guide
- Recommended Reading
- The Microchip Web Site
- Customer Support
- Document Revision History

## DOCUMENT LAYOUT

This document describes how to use the PICDEM™ Lab Development Board as a development tool to emulate and debug firmware on a target board. The manual layout is as follows:

- **Chapter 1. “Overview”**
- **Chapter 2. “Getting Started”**
- **Chapter 3. “General Purpose Input/Output Labs”**
- **Chapter 4. “Comparator Peripheral Labs”**
- **Chapter 5. “Analog-to-Digital Converter Peripheral Labs”**
- **Appendix A. “Schematic”**

# PICDEM™ Lab Development Board User's Guide

## CONVENTIONS USED IN THIS GUIDE

This manual uses the following documentation conventions:

### DOCUMENTATION CONVENTIONS

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

## RECOMMENDED READING

This user's guide describes how to use the PICDEM™ Lab Development Kit. Other useful documents are listed below. The following Microchip documents are available and recommended as supplemental reference resources.

### Readme Files

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

## THE MICROCHIP WEB SITE

Microchip provides online support via our web site at [www.microchip.com](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



# PICDEM™ Lab Development Board User's Guide

---

## CUSTOMER SUPPORT

Users of Microchip products can receive assistance through several channels:

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

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

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

## DOCUMENT REVISION HISTORY

### Revision A (February 2009)

- Initial Release of this Document.

---

---

## Chapter 1. Overview

---

---

### 1.1 INTRODUCTION

The PICDEM Lab Development Board supports Microchip's 8, 14, 18 and 20-pin 8-bit MCUs including accommodation for PIC10F products in the 8-pin PDIP package. Dual-row expansion headers on either side of each socket provide connectivity to all pins on the connected PIC® MCU. A solderless prototyping area allows the user to explore a relatively large number of application examples without making permanent modifications to the board. Components permanently mounted to the board are interfaced using expansion headers to the user's application via jumper wires. A variable supply voltage allows user's to supply voltages between 1.2V to 5V to each of the PIC MCU connection sockets.

### 1.2 HIGHLIGHTS

This chapter discusses:

- PICDEM™ Lab Development Kit Contents
- PICDEM™ Lab Development Board Construction and Layout
- Target Power
- Connecting the PICkit™ 2 Programmer/Debugger
- Solderless Prototyping Area Strip Configuration

### 1.3 PICDEM™ LAB DEVELOPMENT KIT CONTENTS

The PICDEM™ Development Kit contains the following items:

1. The PICDEM™ Lab Development Board
2. Lab component kit including:
  - (1) PIC16F616 DIP
  - (1) PIC12F615 DIP
  - (4) 10kΩ Resistors
  - (4) 1kΩ Resistors
  - (8) 470Ω Resistors
  - (4) 220Ω Resistors
  - (4) 100Ω Resistors
  - (1) 10kΩ NTC Thermistor
  - (4) Green LEDs
  - (4) Red LEDs
  - (4) 1N4148 Diodes
  - (2) 0.1μF Capacitors
  - (2) 1μF Capacitors
  - (2) 10μF Capacitors
  - (4) Push buttons
  - (10) 5" Jumper Wires
  - (10) 3" Jumper Wires

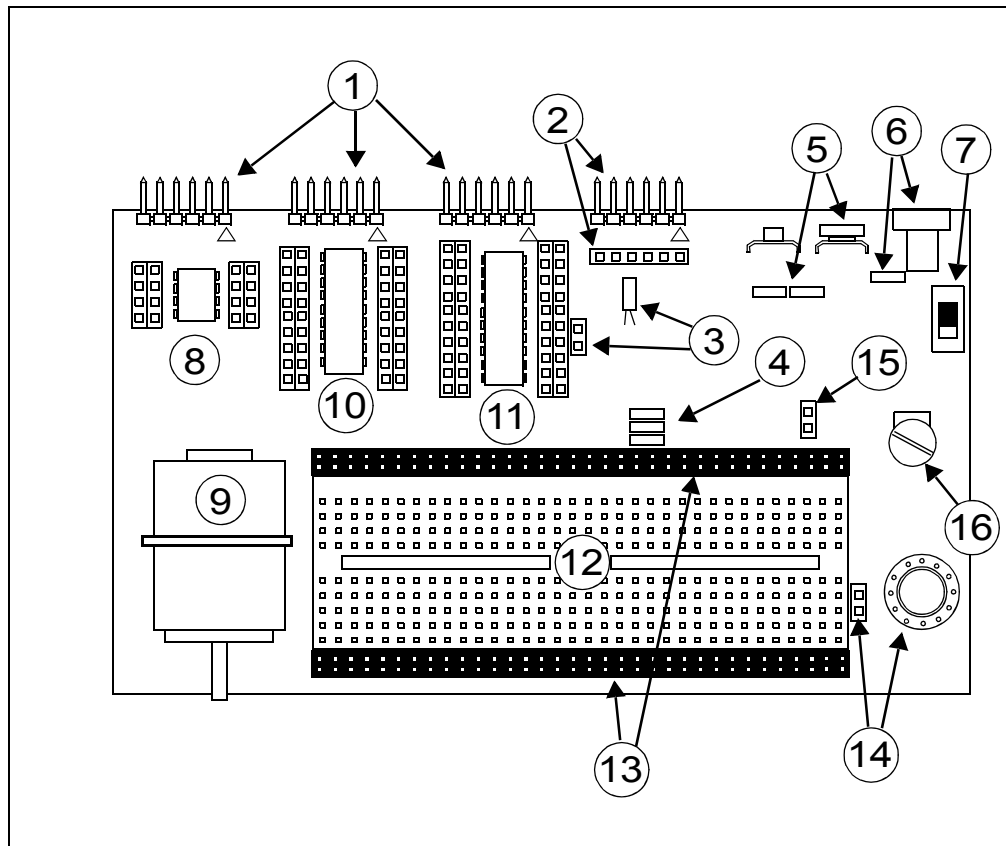
# PICDEM™ Lab Development Board User's Guide

- (10) 1" Jumper Wires
  - (4) IRFD9020 P-CH MOSFETs
  - (4) IRFD010 N-CH MOSFETs
  - (2) 100kΩ Potentiometers
3. PICkit™ 2 Programmer/Debugger with USB Cable
  4. CD-ROM including:
    - "PICDEM™ Lab Development Board User's Guide and Labs" (DS41369)
    - "PIC16F631/677/685/687/689/690 Data Sheet" (DS41262)
    - "Introduction to MPLAB® IDE and HI-TECH C® PRO for the PIC10/12/16 MCU Family Lite Mode Compiler Tutorial" (DS41322)
    - Timer: Timer0 Tutorial (Part 1) (DS51682)
    - Timer: Timer0 Tutorial (Part 2) (DS51702)

## 1.4 PICDEM™ LAB DEVELOPMENT BOARD CONSTRUCTION AND LAYOUT

The Low Pin Count USB Development Board and populated components are shown in Figure 1-1.

FIGURE 1-1: PICDEM™ LAB DEVELOPMENT BOARD



1. **PICkit™ 2 Programmer/Debugger Connection Headers (J13, J12 and J6)**
  - a) J13 dedicated to PIC® microcontroller socket U5
  - b) J12 dedicated to PIC® microcontroller socket U3
  - c) J6 dedicated to PIC® microcontroller socket U2
2. **PICkit™ Serial Analyzer Connection Header (J11) and Receptacle (J15)**

To use the PICkit™ Serial Analyzer, connect to appropriate PIC MCU expansion header using jumper wires from receptacle.

3. **32 kHz Crystal Oscillator (Y1) and Connection Header (J7)**
4. **V<sub>DD</sub> Connect/Disconnect Jumpers (J3, J4, J5)**
  - a) J3 jumper connects/disconnects V<sub>DD1</sub> supply to PIC16F690 MCU in socket U2
  - b) J4 jumper connects/disconnects V<sub>DD2</sub> supply to PIC16F819 MCU in socket U3
  - c) J5 jumper connects/disconnects V<sub>DD3</sub> supply to PIC10F206 MCU in socket U5
5. **Battery Clip Connection (BT1) for 9V Battery and Jumpers (J14)**

J14 jumpers connect/disconnect battery terminals for use in future lab on battery chargers.
6. **9 Vdc Supply Connector (J1) and Connect/Disconnect Jumper (J2)**
7. **Power ON Switch (SW1)**
8. **8-Pin PDIP PIC10F MCU Socket (U5) and Bilateral Dual-Row Expansion Headers (J10 and J18)**

Dual-row expansion headers provide connectivity to each pin on the PIC10F206 MCU populating socket U5.
9. **5V Brushed DC Motor**
10. **18-Pin PDIP PIC MCU Socket (U3) and Bilateral Dual-Row Expansion Headers (J17 and J16)**

Dual-row expansion headers provide connectivity to each pin on the PIC16F819 MCU populating socket U3.
11. **8, 14, 20-Pin PDIP PIC MCU Socket (U2) and Bilateral Dual-Row Expansion Headers (J8 and J9)**

Dual-row expansion headers provide connectivity to each pin on the PIC16F690 MCU populating socket U2.
12. **Solderless Prototyping Area**
13. **Bilateral Dual-Row Supply Headers (J22 and J23)**

Provide both V<sub>DD</sub> and V<sub>SS</sub> connectivity bilaterally to the solderless prototyping area.
14. **0.2 Watt, 8-Ohm Speaker (LS1) with Connection Header (J19)**

J19 connector used to connect speaker LS1 to user application using jumper wires.
15. **Battery Positive (CP+) and Negative (CP-) Connection Header (J26)**

Provides connectivity of positive and negative battery terminals to the user application using jumper wires.
16. **Variable V<sub>DD</sub> Potentiometer (R1)**

Potentiometer used to vary PIC MCU supply voltage from approximately 1.3V to approximately 5V.

## 1.5 TARGET POWER

The PICDEM™ Lab Development Board can be powered in one of three ways:

1. Using a 9-12 VDC power supply connected to connector J1 (Microchip part #AC162039 recommended)  
Ensure that connect/disconnect jumper J2 is in place.

2. Using a 9V battery connected to connector BT1  
Ensure that connect/disconnect jumpers J14 are in place.
3. A PICkit™ 2 Programmer/Debugger connected to any one of the three PICkit™ Programmer/Debugger connectors J13, J12 and J6 (recommended for low-power applications only).

**Note:** When using the PICkit™ 2 Programmer/Debugger as the power source, the variable VDD potentiometer (R1) will not vary the supply voltage.

When using methods 1 or 2, each PIC® microcontroller has an associated connect/disconnect jumper that, when in place, enables the positive supply voltage to the respective VDD pins. The VDD jumpers connect to the following PIC® microcontroller sockets:

1. VDD1 (J3) connects/disconnects supply voltage to the PIC® microcontroller populating U2.
2. VDD2 (J4) connects/disconnects supply voltage to the PIC® microcontroller populating U3.
3. VDD3 (J5) connects/disconnects supply voltage to the PIC® microcontroller populating U5.

Using methods 1 or 2 enables the use of the variable VDD potentiometer (R1) to control supply voltages from approximately 1.3 to 5V. Rotating the potentiometer clockwise will raise the supply voltage while rotating the potentiometer counterclockwise will decrease the supply voltage.

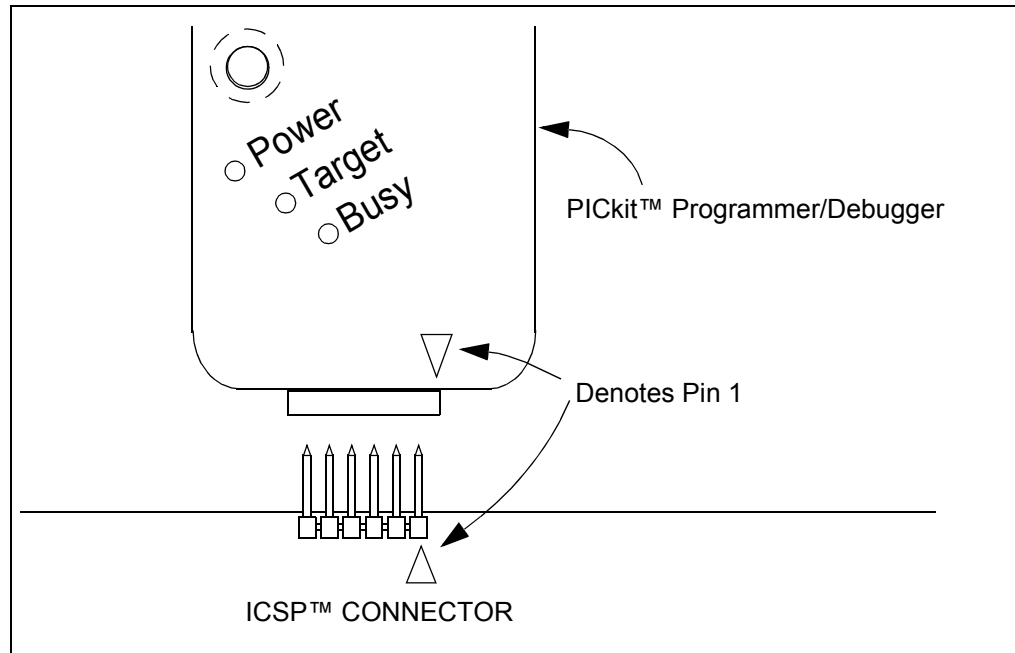
## 1.6 CONNECTING THE PICKIT™ 2 PROGRAMMER/DEBUGGER

The three PIC® microcontrollers populating sockets U5, U3 and U2 have their own PICkit™ Programmer/Debugger (ICSP™) connectors so that each can be programmed or debugged individually. The ICSP™ connect to the following PIC® microcontroller sockets:

1. ICSP1 (J6) connects to the PIC® microcontroller populating U2.
2. ICSP2 (J12) connects to the PIC® microcontroller populating U3.
3. ICSP3 (J13) connects to the PIC® microcontroller populating U5.

The PICkit™ Programmer/Debugger connects to the ICSP™ connector as shown in Figure 1-2.

**FIGURE 1-2: CONNECTING THE PICKIT™ PROGRAMMER/DEBUGGER TO AN ICSP™ CONNECTOR**

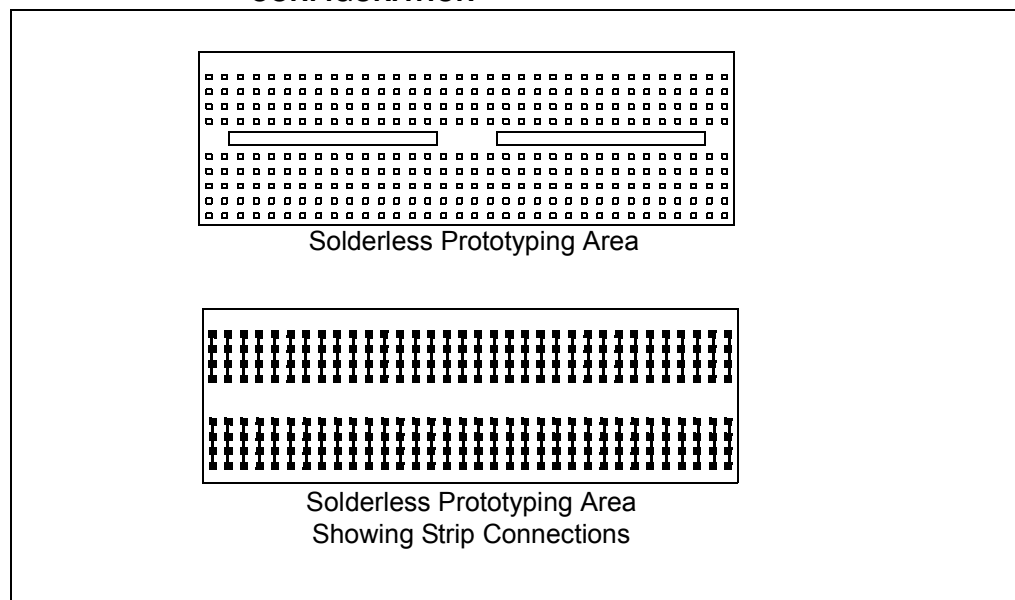


The PICkit™ 2 Programmer/Debugger is then connected to an available USB port on the PC using the included USB cable.

## 1.7 SOLDERLESS PROTOTYPING AREA STRIP CONFIGURATION

The solderless prototyping area contains a variety of strips under the perforated plastic block. These strips “short” vertical rows of holes together as shown in Figure 1-3.

**FIGURE 1-3: SOLDERLESS PROTOTYPING AREA STRIP CONFIGURATION**



# PICDEM™ Lab Development Board User's Guide

---

NOTES:

---

---

## Chapter 2. Getting Started

---

---

### 2.1 INTRODUCTION

This chapter is intended to prepare the reader to complete the labs in the remaining chapters of this user's guide.

### 2.2 PREREQUISITES

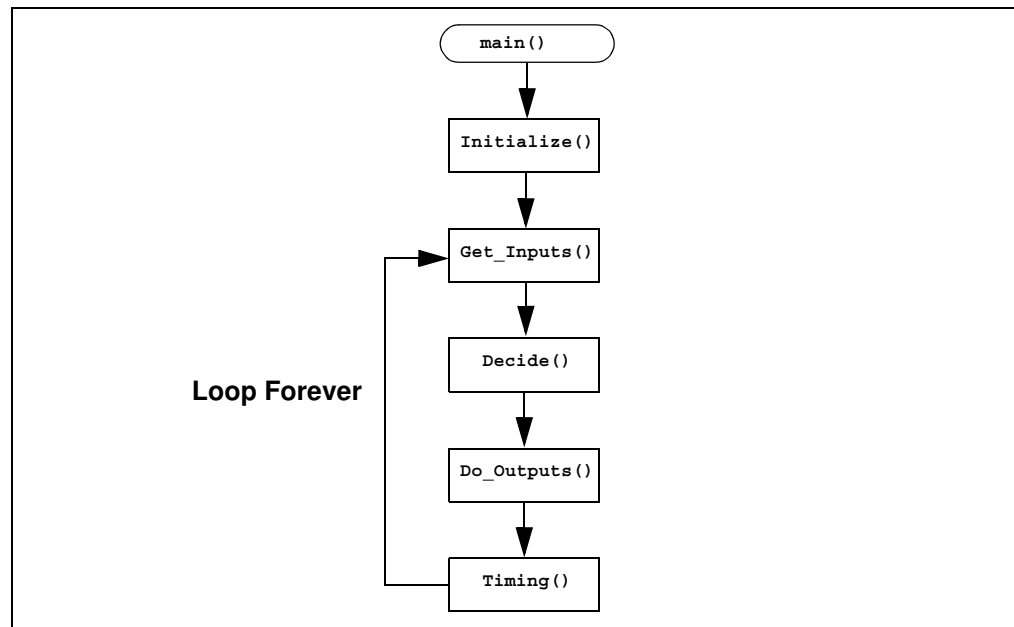
The labs contained within this lab manual assumes the user:

1. Has a basic understanding of the C programming language.
2. Understands basic circuit analysis.
3. Has completed or understands the concepts contained within the introductory tutorial: "Introduction to MPLAB® IDE and HI-TECH C® PRO for the PIC10/12/16 MCU Family Lite Mode Compiler Tutorial" (DS41322B) provided on the accompanying CD-ROM.

### 2.3 THE SOFTWARE CONTROL LOOP

The labs used in this user's guide implement a software control loop in various configurations but always in the same sequence as shown in Example 2-1.

**FIGURE 2-1: MAIN () SOFTWARE CONTROL LOOP FLOWCHART FOR USED IN LABS**



Each block of the software control loop represents a function that organizes tasks into logical, organized groupings that are called from the **main function** (`main ()`). Notice the `Initialize()` is called only once while the remaining functions are executed repeatedly. This method organizes the embedded firmware application into a logic sequence of events:



1. `Initialize()`:
  - Initializes the microcontroller, the peripherals used in the application and any global variables used by multiple functions.
2. `Get_Inputs()`:
  - Obtains any input information either on-chip (from internal registers, etc...) or off-chip (pin voltage levels).
3. `Decide()`:
  - Makes decisions based on the input information gathered in the previous function to manipulate global variables.
4. `Do_Outputs()`:
  - Based on the decisions made in the previous function, this function outputs data onto the pins of the microcontroller or to registers within the device.
5. `Timing()`:
  - This function determines how fast the software control loop executes.

Example 2-1 shows a typical `main()` calling the various functions that make up the software control loop.

## EXAMPLE 2-1: TYPICAL SOFTWARE CONTROL LOOP `MAIN()` USED IN LABS

```
void main(void)
{
    Initialize(); //Initialize the relevant registers

    while(1)
    {

        Decide();//Make any decisions
        Do_Outputs(); //Perform any outputs
        Timing();//Sets execution rate of the
        //Software Control Loop
    }
}
```

An infinity loop will be used by all labs in this user's guide created using a `while` loop that repeatedly call the functions within the curly braces as long as there is power to the microcontroller.

Global variables are used wherever needed in lieu of passing variables between functions.

## 2.4 MPLAB® IDE DOWNLOAD INSTRUCTIONS

The following steps outline how to download the latest version of the MPLAB IDE and HI-TECH C® PRO for the PIC10/12/16 MCU Families compiler. It is strongly recommended that all open programs and applications are closed to expedite the installation process.

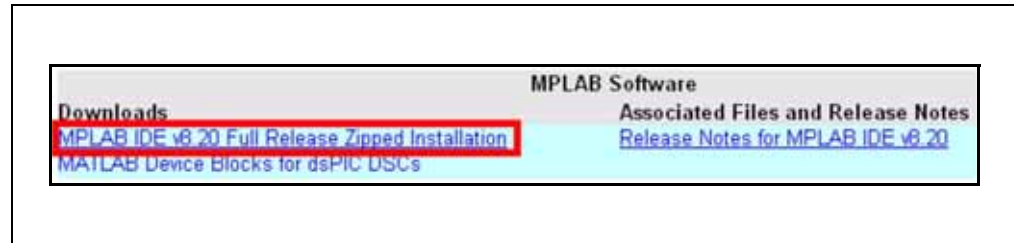
1. Using a PC that is connected to the internet, navigate to the MPLAB® IDE download page at the following url:

[www.microchip.com/mplab](http://www.microchip.com/mplab)

This page outlines the MPLAB IDE and also features downloadable plug-ins, User's Guides and other useful information.

2. Scroll down to the **Downloads** section of the page and select the latest full release zip file for **MPLAB IDE vx.xx**. (See Figure 2-2.)

**FIGURE 2-2: MPLAB ZIP FILE**



3. When prompted open the .zip file and extract all contents to a new folder named something meaningful such as "MPLAB" created in a directory such as Desktop or another location easily accessible.
4. Once all files are extracted, navigate to the folder created and double click on the Install\_MPLAB\_vxxx.exe file to start the installation process.
5. The MPLAB® Tools x.xx Installation window should now be open. Click *Next>* to proceed with the installation.
6. In the next window, read through the MPLAB IDE License Agreement and ensure that the **I accept the terms of the license agreement** radio button is selected. Click *Next>* to continue with the installation.
7. In the Setup Type window select the setup type (complete is recommended for new users) and click *Next>* to continue.
8. In the Choose Destination Location it is recommended to use the default direct C:\Program Files\Microchip\. Click *Next>* to continue.
9. Accept the Application Maestro License agreement in the next window and click *Next>* to continue.
10. Click *Next>* in the Start Copying Files window to start the installation (this may take several minutes to complete).
11. During the installation process, the user will be prompted to install the free HI-TECH C® PRO for the PIC10/12/16 MCU Compiler. It is recommended that the user install the compiler at this point. Select Yes to launch the installer. In the installer window, click **Next** to continue. (See Figure 2-3.)

**FIGURE 2-3: HI TECH INSTALLER WINDOW**



12. In the next window, accept the terms of the license agreement and click **Next** to continue. (See Figure 2-4.)

**FIGURE 2-4: HI TECH LICENSE AGREEMENT**



13. In the next window, select any components in addition to the HI-TECH C® Pro for the PIC10/12/16 MCU Family Compiler to install (additional components are not required to complete the labs in this user's guide) and click **Next** to continue. (See Figure 2-5.)

**FIGURE 2-5: HI TECH COMPONENTS**



14. In the next window, choose the language of preference, select the **Add to environment path** radio button and click **Next** to continue. (See Figure 2-6.)

**FIGURE 2-6: HI TECH LANGUAGE PREFERENCES**



The installation process will now begin.

15. Once the installation is complete, a confirmation window will open. Select or de-select the **Read quick start guide now?** radio button and click **Finish** to proceed. (See Figure 2-7.)

FIGURE 2-7: HI TECH INSTALL CONFIRMATION



16. The MPLAB® Tools Install Shield Wizard Complete window should soon open and prompt the user to restart the computer before using the software. To begin using the tools, select the **Yes, I want to restart my computer** radio button and click **Finish** to end the installation process and restart the computer.

Following restart, the user will be given the option to view a variety of documentation. To view a document, simply highlight and click **View Selected File**.

The MPLAB® IDE and HI-TECH C® PRO for the PIC10/12/16 MCU Family Lite Mode Compiler are now both installed and ready to use. The user is now ready to complete the labs included in this user's guide.

**Note:** A comprehensive introduction to the "*HI-TECH C® PRO for the PIC10/12/16 MCU Family Lite Mode Compiler Tutorial*" (DS41322) is provided on the accompanying CD-ROM.

## 2.5 INSTALLING THE INCLUDED LAB FILES

The PICDEM™ Lab Development Kit CD-ROM includes a .zip file called `PICDEM_Lab.zip`. This file provides a location for the user to save any projects created while completing the labs in this user's guide and contains solutions for each lab in a folder labeled `solution`. To install this folder, simply extract the contents of the .zip file to the `C:\` directory.

**Note:** Lab folders must be installed to the `C:\` to be used by the MPLAB IDE.

---

---

## Chapter 3. General Purpose Input/Output Labs

---

---

### 3.1 INTRODUCTION

The following labs cover some of the fundamental features of the General Purpose Input/Output (GPIO) peripherals available on the PIC16F690. As the name implies, these peripherals are used for general purpose applications that can monitor and control other off-chip devices. Some PIC® microcontrollers have multiple GPIO peripherals on-chip including the PIC16F690 used in the following labs. Therefore, the PORTx naming convention is used. Available ports on the PIC16F690 are:

- PORTA
- PORTB
- PORTC

Reading through the data sheet highlights some of the unique characteristics associated with each port and the reader is encouraged to explore these in greater detail once comfortable with the labs in this user's guide. The labs will focus on two of the port peripherals: PORTC and PORTA. Labs will be naturally divided into two sections since these are General Purpose Input/Output peripherals:

- Output Labs
- Input Labs

Output labs will introduce the reader to concepts necessary to configuring these peripherals for output to off-chip devices using applicable registers by lighting 8 LEDs connected to the PORTC pins

The Input labs will then add a push button interfacing to one of the PORTA pins to highlight concepts necessary for configuring these peripherals to receive information from off-chip devices. Finally, interrupts will be used to optimize the application for different purposes.

### 3.2 GENERAL PURPOSE INPUT/OUTPUT LABS

- **Output Labs:**
  - Lab 1: Light LEDs
  - Lab 2: Flash LEDs (Delay Loop)
  - Lab 3: Simple Delays Using Timer0
  - Lab 4: Rotate LEDs
- **Input Labs:**
  - Lab 5: Adding a Push Button
  - Lab 6: Push Button Interrupt
  - Lab 7: Push Button Interrupt-on-Change
  - Lab 8: Using Weak Pull-ups

## 3.3 GPIO OUTPUT LABS

### 3.3.1 Reference Documentation

All documentation is available on the PICDEM™ Lab Development Kit accompanying CD-ROM.

- PIC16F690 Data Sheet (DS41262)
  - Section 2.2.2.2: Option Register
  - Section 2.2.2.3: Interrupt Control Register INTCON
  - Section 4: I/O Ports
  - Section 5: Timer0 Module
- Timers: Timer0 Tutorial (Part 1) (DS51628)
- Timers: Timer0 Tutorial (Part 2) (DS51702)
- "Introduction to MPLAB® IDE and HI-TECH C® PRO for the PIC10/12/16 MCU Family Lite Mode Compiler Tutorial" (DS41322)

### 3.3.2 Equipment Required for GPIO Output Labs

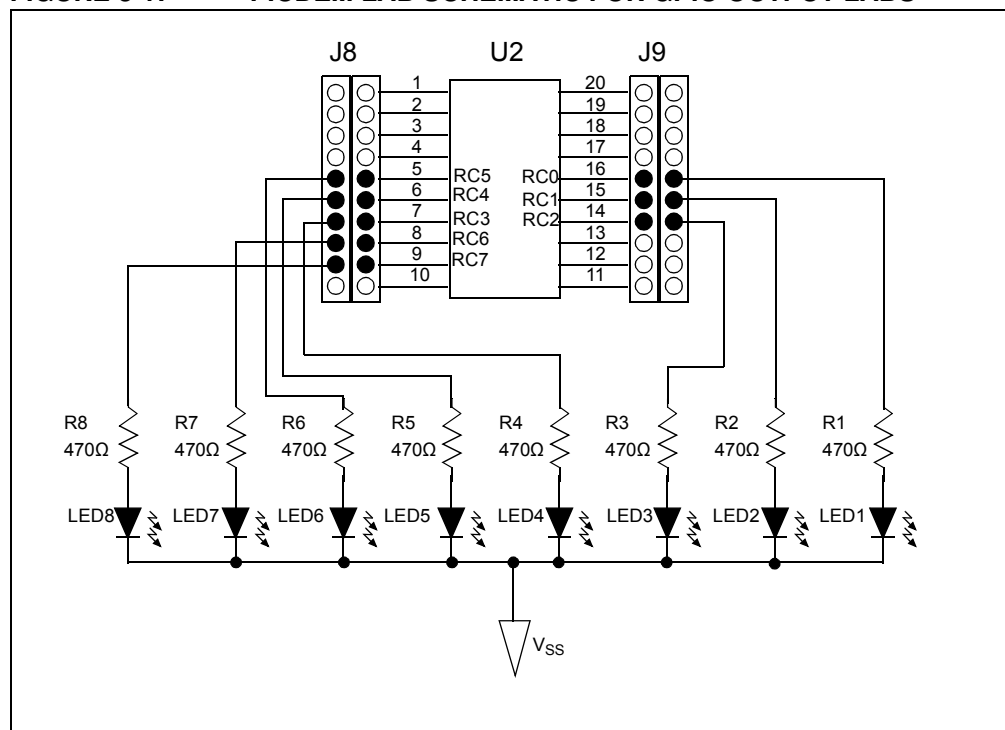
To complete the labs in this section, the following components are required:

1. 8 – Light Emitting Diodes
2. 8 – 470Ω resistors
3. PIC16F690 populating socket U2
4. Assorted jumper wires

### 3.3.3 PICDEM Lab Development Board Setup for GPIO Output Labs

The GPIO output labs will require that the PICDEM Lab Development Board be configured as shown in Figure 3-1 using the components listed in the previous section.

FIGURE 3-1: PICDEM LAB SCHEMATIC FOR GPIO OUTPUT LABS



# General Purpose Input/Output Labs

Special care should be observed when connecting the LED jumper wires to the expansion headers surrounding the PIC16F690, as the PORTC pins are not in sequential order. The 470 $\Omega$  resistors are used to limit the current across the LEDs to manufacturer specifications. Furthermore, the PIC16F690 Data Sheet electrical specifications (see Section 17.0) specify that each port pin should not source/sink more than 25 mA. The maximum output current sourced/sunk by all port pins combined should not exceed 200 mA. The 470 $\Omega$  resistors keep all source current well within these specifications.

## 3.3.4 Lab 1: Light LEDs

### 3.3.4.1 NEW REGISTERS USED IN THIS LAB

To configure the peripherals used in this lab, the following registers are used:

1. PORTC Register: PORTC (Register 4-11 in Section 4 of the PIC16F690 Data Sheet).
  - 8-bit bidirectional port.
2. PORTC Tri-State Register: TRISC (Register 4-12 in Section 4 of the PIC16F690 Data Sheet).
  - Configures corresponding bits in PORTC as either input or output.
3. Analog Select Register High and Analog Select Register Low: ANSELH and ANSEL (Registers 4-4 and 4-3 in Section 4 of the PIC16F690 Data Sheet).
  - Configure associated pins for analog or digital input signals.

### 3.3.4.2 OVERVIEW

This first lab demonstrates how to output data from the PORTC peripheral on the PIC16F690 to its associated pins. LEDs connected to PORTC pins will light when the associated pin is driven high (approx.  $V_{DD}$ ) or turn the LED OFF when driven low (approx.  $V_{SS}$ ). The port peripherals will all default to input on start-up and will therefore need to be configured as output using the TRISC register. Also, PORTC pins RC0, RC1, RC2, RC3, RC6 and RC7 are configurable for both analog and digital signals. On start-up, any analog/digital functional pin is defaulted to analog. Therefore, this application will require that these pins be configured as digital by configuring the associated bits in the ANSEL and ANSELH analog select registers.

**FIGURE 3-2: MAIN () SOFTWARE CONTROL LOOP FLOWCHART FOR LAB 1**

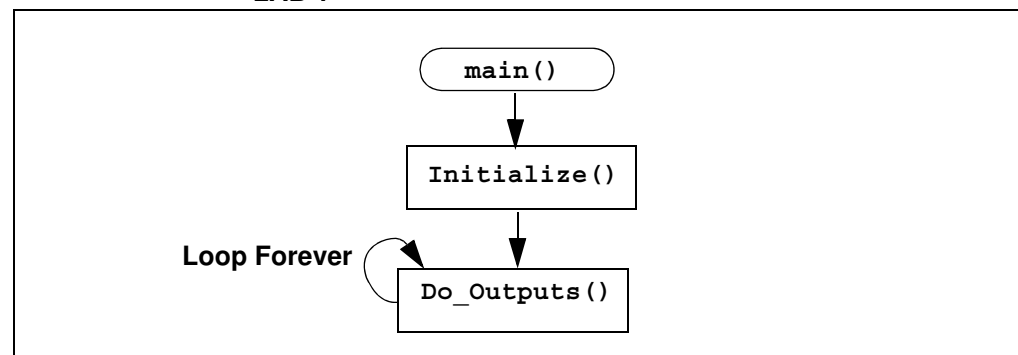




Figure 3-2 shows the software control loop that will be implemented in this lab. At device power-up, the first functional block called from the `main()` is `Initialize()`. This function will initialize the PORTC peripheral as follows:

- Clear the PORTC register data
- Configure the ANSEL and ANSELH bits so that all associated PORTC pins are digital
- Configure the associated PORTC pins as all output using the TRISC register

**Note:** The PORT register should always be initialized to a known value before configuring the associated TRIS bit. This avoids unexpected voltage levels on the associated pins since at start-up port bit values are unknown.

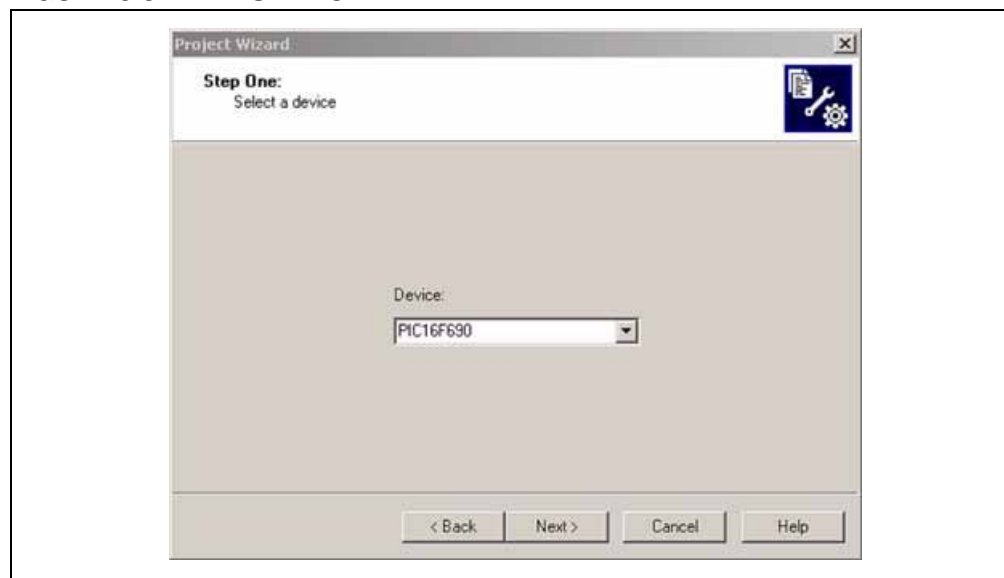
The next function called from `main()` is `Do_Outputs()`. This function will assign values to the PORTC register that will drive the associated pins high or low to light the LEDs connected.

### 3.3.4.3 PROCEDURE

The following steps will demonstrate how to create a new project in MPLAB® IDE. A more in-depth tutorial is provided in the document “*Introduction to MPLAB® IDE and HI-TECH C® PRO for the PIC10/12/16 MCU Family Lite Mode Compiler Tutorial*” (DS41322) included on the accompanying CD-ROM.

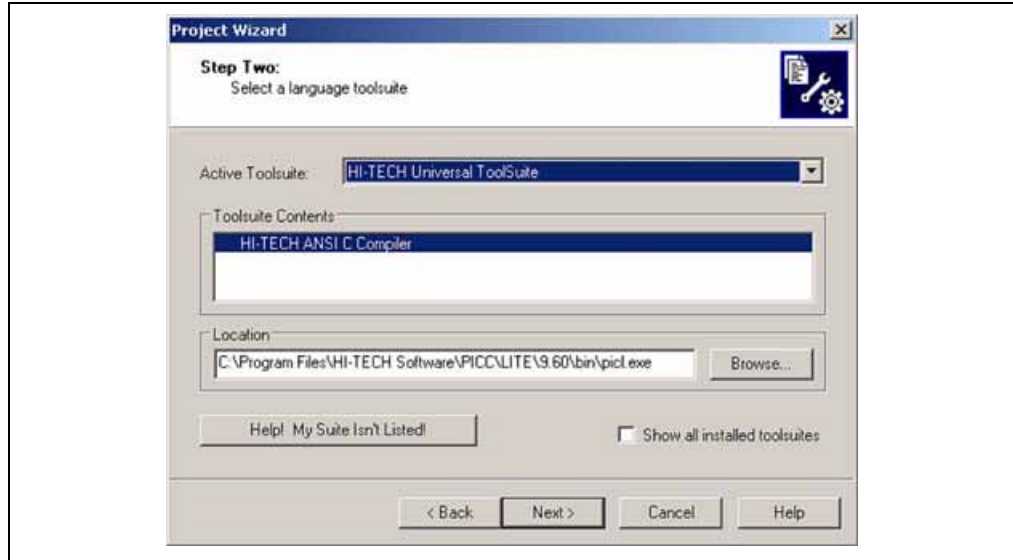
1. Open MPLAB IDE by selecting Start>Microchip>MPLAB IDE vX.XX>MPLAB IDE.
2. In the MPLAB IDE toolbar, select Project>Project Wizard...
3. The Welcome dialog box should now be open. Select Next> to proceed.
4. In the Step One: window, select the PIC16F690 from the Device: drop-down menu and select Next> to continue. (See Figure 3-3.)

**FIGURE 3-3: STEP ONE**



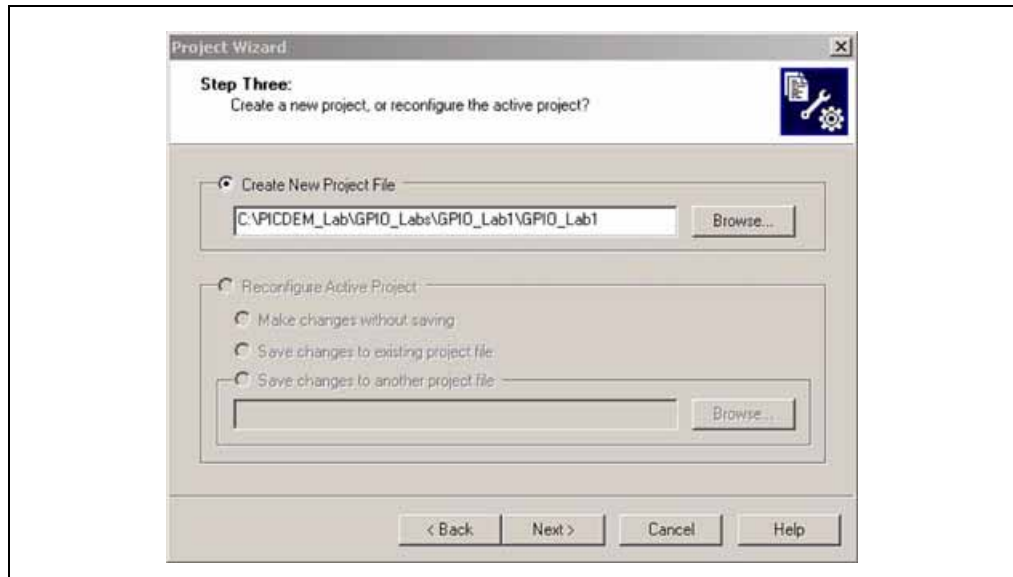
5. In the Step Two: window, select the HI TECH Universal ToolSuite from the Active ToolSuite drop down menu. The window should now resemble Figure 3-4.

FIGURE 3-4: STEP TWO



6. In the Step Three: window, use the **Browse** button and navigate to a new folder on the C: \ drive to store this project. Alternately, the reader may wish to use the C: \PICDEM\_Lab\GPIO\_Labs\GPIO\_Lab1 folder created earlier. (See Figure 3-5.)

FIGURE 3-5: STEP THREE



7. In the Step Four: files are added to the project. A `Lab_Template.c` file has been provided in the `C:\PICDEM_Lab\Lab_Template.c` directory that can be used as the basis for all labs in this manual. To use the `Lab_Template.c` file, select it from the right menu and click the **Add>>** button. Click on the large letter 'A' that appears next to the added file in the right window until it becomes a 'C'. This indicates that a copy of the `Lab_Template.c` will be included in the project directory. Otherwise, changes made to the file during the course of the lab will alter the original file.

Finally, rename the `Lab_Template.c` file in the right window to `GPIO_Lab1.c` by clicking on it three times to enable editing the name. The Step Four: window should now resemble Figure 3-6. Click Next> to continue.