Low Pin Count USB Development Kit

User's Guide

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LOW PIN COUNT USB DEVELOPMENT KIT USER'S GUIDE

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Preface

NOTICE TO CUSTOMERS

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

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

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

INTRODUCTION

This chapter contains general information that will be useful to know before using the Low Pin Count USB Development Kit. 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 Low Pin Count USB Development Kit 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 Project Labs"**
- **Appendix A. "Schematics"**

CONVENTIONS USED IN THIS GUIDE

This manual uses the following documentation conventions:

DOCUMENTATION CONVENTIONS

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

RECOMMENDED READING

This user's guide describes how to use the Low Pin Count USB 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.

Design Center

Microchip has a USB design center which can be found on **www.microchip.com/usb**.

The following Microchip Application Notes are available and recommended as supplemental reference resources.

THE MICROCHIP WEB SITE

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

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

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 (September 2008)

- Initial Release of this Document.

Revision B (February 2009)

- Corrected document errors

Chapter 1. Overview

1.1 INTRODUCTION

The Low Pin Count USB Development Kit provides an easy, low cost way to evaluate the functionality of Microchip's PIC18F14K50 and PIC18F13K50 20-pin USB micro-controllers. The all-inclusive kit contains the hardware, software, and code examples necessary to bring your next USB design from concept to first prototype. Created with the USB novice in mind, the kit includes **"Getting Started with Microchip's Low Pin Count USB Solutions"**, a self-directed course and lab material designed to ease the learning curve associated with adding USB connectivity to embedded systems.

1.2 HIGHLIGHTS

This chapter discusses:

- Low Pin Count USB Development kit contents
- Low Pin Count USB Development Board construction and layout

1.3 LOW PIN COUNT USB DEVELOPMENT KIT CONTENTS

The Low Pin Count USB Development Kit contains the following:

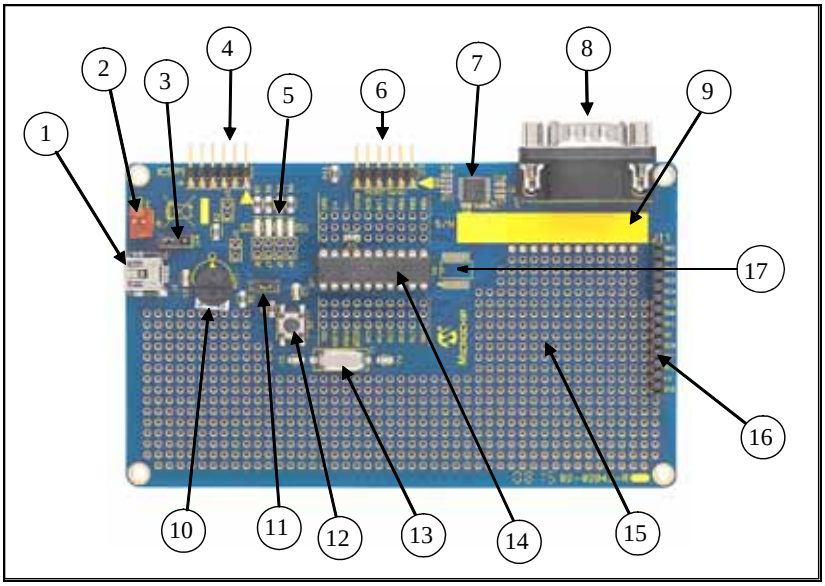
- (1) fully populated Low Pin Count USB Development Board
- (1) unpopulated spare development board
- (1) PIC18F14K50 ICD populated expansion header
- (1) CD containing the user guide, course materials and product documentation.
- (1) PICkit™ 2 Debugger/Programmer with cable.

FIGURE 1-1: LOW PIN COUNT USB DEVELOPMENT KIT

1.4 LOW PIN COUNT USB DEVELOPMENT BOARD CONSTRUCTION AND LAYOUT

The Low Pin Count USB Development Board and populated components are shown in Figure 1-2.

FIGURE 1-2: LOW PIN COUNT USB DEVELOPMENT BOARD



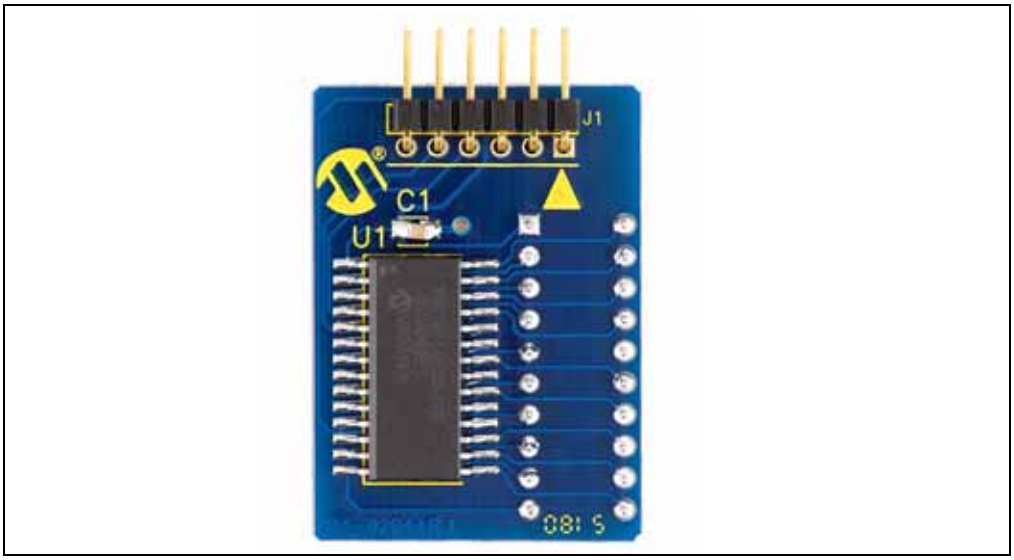
1. USB mini-B connector
2. J9 regulated 5V connection header
3. J14 connects either V_{BUS} (Provided by USB) or J9 regulated 5V to PIC18F14K50 V_{DD} supply
4. PICkit™ 2 Debugger/Programmer connection header
5. LEDs connected to PORTC (RC0, RC1, RC2, RC3)
6. PICkit™ Serial Analyzer connection header
7. **MAX3232** RS-232 line driver/receiver
8. RS-232 connector
9. Area provided for user PID/VID information
10. Potentiometer
11. J12 connects/disconnects V_{USB} on PIC18F14K50
12. Push button
13. 12 MHz crystal
14. PIC18F14K50 MCU
15. Prototyping area
16. PICtail™ daughter board expansion header
17. SSOP Expansion

Note: J2-J5, J7, J8 are shunted on the bottom side of the board and thus the functions default connected even though no jumper is installed. Cut the jumper to disable the circuitry attached to each pin.

1.5 PIC18F14K50 ICD DEBUG HEADER

The Low Pin Count USB Development Kit includes a debug header populated with a PIC18F14K50 ICD MCU to enable for use with the PICkit™ 2 debugger/programmer.

FIGURE 1-3: PIC18F14K50 POPULATED MPLAB ICD 2 DEBUG HEADER



To use the debug header, simply remove the PIC18F14K50 mounted in the MCU socket (U2) on the Low Pin Count USB Development Board. Using a pin header (not included), connect the debug header into the MCU socket and connect the PICkit™ 2 programmer/debugger to the provided connection header.

1.6 "GETTING STARTED WITH MICROCHIP'S LOW PIN COUNT USB SOLUTIONS" SELF-DIRECTED COURSE

The Low Pin Count USB Development Kit includes the self-directed course **"Getting Started with Microchip's Low Pin Count USB Solutions"**. This course provides an introductory overview to the USB 2.0 protocol and implementation on the PIC18F14K50 MCU. Microchip's USB Device Firmware Framework is introduced as a resource providing a library of firmware code for USB operation that handles "low-level" tasks and a number of reference projects. The user is guided through a number of "hands-on" labs to reinforce covered concepts.

NOTES:

Chapter 2. Getting Started Project Labs

2.1 INTRODUCTION

This section of the user's guide will walk the user through a number of project labs that will ease the development of original USB design applications. Labs are formatted so that the user is guided through each project's source code to uncomment or copy and paste sections of code. This format was chosen to force the developer to explore significant sections of the Framework and familiarize themselves with the overall structure of the source files presented.

Lab files can be located in the folder `C:\LPCUSBDK_Labs\Labx_files`. Each lab folder will contain both the source files for the labs and a folder containing the solutions with working code.

Four labs are presented:

1. Project Lab 1 (Enumeration): This lab introduces the user to developing unique descriptors in their own applications that will be used by the Host (PC) to enumerate and ultimately configure the PIC18F14K50.
2. Project Lab 2 (HID Mouse): This lab expands on concepts learned in Project Lab 1 using the descriptors defined. The user will walk through the development of application specific functions within the *mouse.c* firmware file. The end application will behave like a Human Interface Device Class (HID) mouse by moving the pointer on the PC screen.
3. Project Lab 3 (HID Keyboard): In this lab the user is required to alter the descriptors to implement a HID keyboard-based application. The potentiometer on the Low Pin Count USB Development Board is rotated to change the HID specification unicode value transmitted through the USB to the PC that will print characters based on an ADC conversion.
4. Project Lab 4 (CDC Serial Emulator): Finally, the user will implement a communication protocol converter using the Communication Device Class (CDC) driver.

2.2 PREREQUISITES

These labs assume that the user:

1. Has completed the self-directed course **"Getting Started with Microchip's Low Pin Count USB Solutions"** provided on the accompanying CD.
2. Is familiar with the MPLAB IDE and C18 compiler.
3. Has some programming experience using the C language.
4. Is familiar with Microchip's PIC18F family of microcontrollers.

2.3 RESOURCES REQUIRED TO COMPLETE PROJECT LABS

In order to complete the Project Labs, the user should have:

1. The most current version of the MPLAB IDE and C18 compiler installed on their PC. The MPLAB IDE can be found at: http://www.microchip.com/stellent/idcplg?IdcService=SS_GET_PAGE&nodeId=1406&dDocName=en019469&part=SW007002

2. The C18 compiler can be found at:http://www.microchip.com/stellent/idcplg?IdcService=SS_GET_PAGE&nodeId=1406&dDocName=en010014
3. The most current version of the PICkit 2 programmer software.
4. Downloaded and installed the Microchip Full-Speed USB Firmware Framework. Available free at: http://www.microchip.com/stellent/idcplg?IdcService=SS_GET_PAGE&nodeId=2651&param=en534494
5. A copy of the "*Microchip USB Device Firmware Framework User's Guide"* (DS51679)
6. A copy of the PIC18F13K50/14K50 data sheet (DS41350)
7. A copy of the USB Revision 2.0 Specification available for download from: http://www.usb.org/developers/docs/
   This will prove useful as reference throughout the labs.
8. A copy of the Universal Serial Bus (USB) HID Usage Tables available for download at:
   http://www.usb.org/developers/devclass_docs/Hut1_12.pdf
9. Downloaded the USB HID Descriptor Tool available free at:
   http://www.usb.org/developers/hidpage/dt2_4.zip
10. A copy of the Universal Serial Bus Class Definitions for Communications Devices document available for download at:

    http://www.usb.org/developers/devclass_docs
11. Unzipped the LPCUSBDK_Labs.zip file to the C: directory.

2.4 PROJECT LAB 1 (ENUMERATION)

Note: In this and all subsequent project labs, the USB cable must be disconnected from the USB mini-B connector on the Low Pin Count USB Development Board when programming with the PICkit 2 programmer.

2.4.1 Purpose

The purpose of this lab is intended to introduce the user to creating a project in the MPLAB IDE using Microchip's Full-Speed USB Firmware Framework. Though many application examples in the Framework can be used to create original code, building the Framework from scratch is a great way to get familiar to the overall functionality of this multitasking tool.

The user will create a project, ensure that the IDE is configured accordingly, and alter the *usb_descriptor.c* file to enable the enumeration of the PIC18F14K50 as a HID mouse device.

2.4.2 Procedure

2.4.2.1 BUILDING THE FRAMEWORK

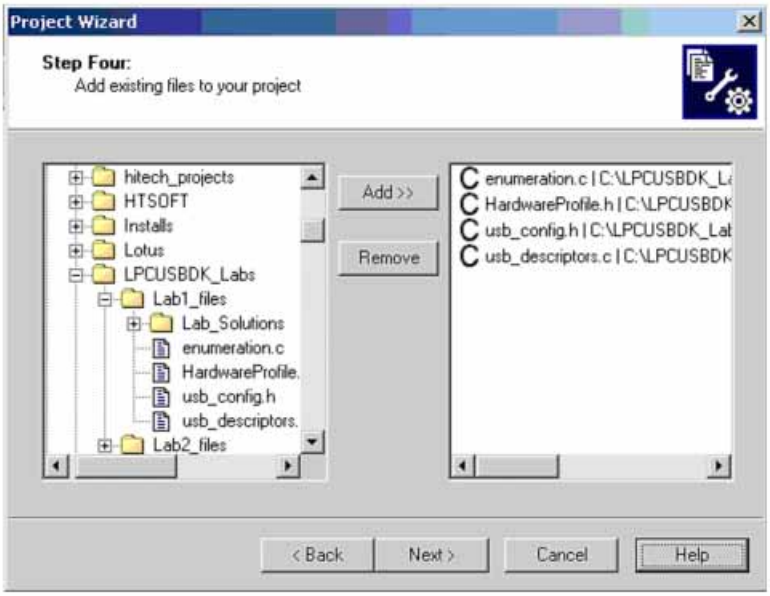
1. Open the MPLAB IDE by selecting *Start>Programs>Microchip>MPLAB IDE vx.xx>MPLAB IDE*
2. Once in the MPLAB IDE, start the Project Wizard by selecting *Project>Project Wizard*
3. Select the **PIC18F14K50** as the device, select the **MPLAB C18 C Compiler** as the language toolsuite, and create a new project folder in the following directory:
   `C:\Microchip Solutions\Project Lab 1\Project Lab 1`

4. In the Add Existing Files to Your Project window, navigate to `C:\LPCUSBDK_Labs\Lab1_files` and copy the following files:
   a) `enumeration.c`
   b) `usb_descriptors.c`
   c) `HardwareProfile.h`
   d) `usb_config.h`

Note:	These files are the user files that will need to be changed to implement any application.

To copy a file, click on the large letter A in front of the file path in the right pane of the window until a large letter C appears. This mode makes a copy of this file into the new project directory leaving the original file intact. (see Figure 2-1)

FIGURE 2-1:



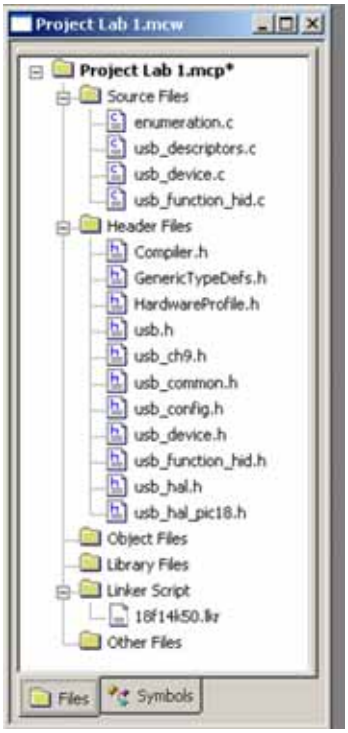
This next section will add the files that will build the Framework that takes care of the low level USB functions. This does not need to be done for every application. The included example projects could be easily converted to suit the needs of a custom application. However, in the interest of providing an intuitive introduction to the Framework, this lab builds this application from scratch.

Note:	These files are used by all the applications in the Framework. Therefore, changing these files will affect all applications. If any of these files are inadvertently altered, it is recommended that the Framework be reinstalled.

5. Next, navigate to `C:\Microchip Solutions\Microchip\Include` and copy over the following files:
   a) `Compiler.h`
   b) `GenericTypeDefs.h`

6. Navigate to `C:\Microchip Solutions\Microchip\Include\Usb` and copy the following files:
   a) `usb.h`
   b) `usb_ch9.h`
   c) `usb_common.h`
   d) `usb_device.h`
   e) `usb_function_hid.h` (file defines components specific to the HID class)
   f) `usb_hal.h`
   g) `usb_hal_pic18.h` (file defines components specific to the PIC18 architecture)
7. Next, navigate to `C:\Microchip Solutions\Microchip\Usb` and copy the following file:
   a) `usb_device.c`
8. Next, navigate to `C:\Microchip Solutions\Microchip\Usb\HID Device Driver` to copy the HID specific source file:
   a) `usb_function_hid.c`
9. Finally, navigate to `C:\MCC18\lkr` and copy the `18f14k50.lkr` linker file.
10. Click *Next>Finish* to exit the project wizard. The Project window should now resemble Figure 2-2.

FIGURE 2-2: PROJECT WINDOW FOR LAB 1



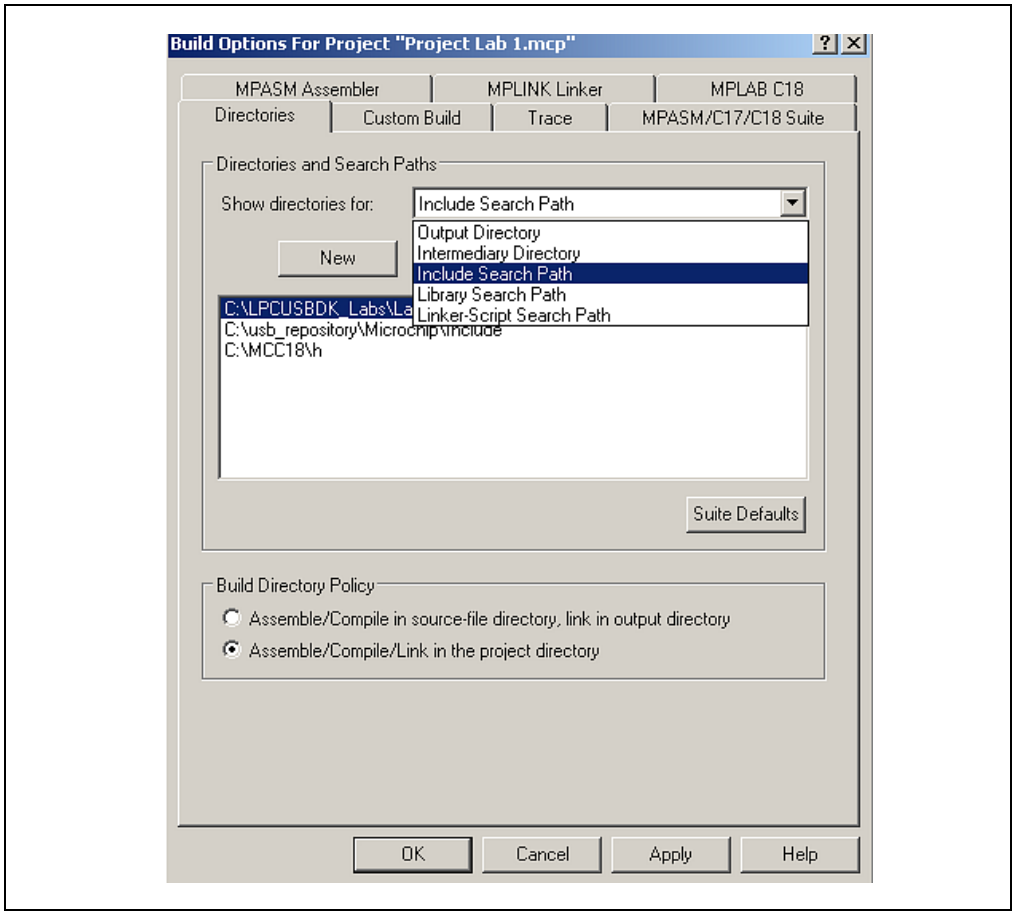
If the project window isn't open in the MPLAB IDE workspace, select *View> Project*.

Next the MPLAB IDE will need to be configured for the Framework by directing the C18 compiler to the associated file locations.

11. In the MPLAB IDE, select *Project>Build Options…>Project*. The Build Options dialog will appear (Figure 2-3).

12. Click on the **Directories** tab and select **Output Directory** and click **New** to add a new path. Click on the ... button, navigate to `C:\LPCUSBDK_Labs\Lab1_files` and create a new folder called **output**. Highlight the folder and click **OK**. This will now be the folder where the output files are placed.
13. Within the **"**Show directories for**"** drop-down menu, select the "Include Search Path**"** directory. Ensure that the `C:\MCC18\h` directory path is listed. Select **New** and navigate to `C:\Microchip Solutions\Microchip\Include` and click **OK** to add to the directory. Repeat these steps to add the application folder `C:\LPCUSBDK_Labs\Lab1_files`.
14. In the "show directories for:" drop-down menu, select Library Search Path**.** Ensure that the `C:\MCC18\lib` is listed. Next, select the Linker-Script Path and ensure that the path points to `C:\MCC18\lkr` directory.

FIGURE 2-3: CONFIGURING FOR MICROCHIP USB FIRMWARE FRAMEWORK



15. Click **Apply,** followed by **OK** to apply these settings and close the Build Options window.

At this point, Framework has been built.

DEFINING PROJECT DESCRIPTORS

Double click the `enumeration.c` source file in the project window to open. Scroll down to the `ProcessIO()`. Note it is empty. Therefore, this application will do nothing. The intention of this lab is to introduce the user to properly configure the firmware so that the PIC18F14K50 will enumerate as a HID mouse once connected to the Host PC. Therefore, the `usb_descriptors.c` file will need to be altered accordingly. As a

reference, the USB Revision 2.0 specification should be opened to **Section 9-5 "Descriptors"**. This section details the various components required in each type of descriptor (device, configuration, interface etc.). This `usb_descriptor.c` file should be an exact replica of the source file of the same name found in the Framework folder

`C:\Microchip Solutions\USB Device - HID - Mouse\HID - Mouse – Firmware\usb_descriptor.c`

This file can be used as a reference during debugging.

16. In the MPLAB IDE Project window, select and open the `usb_descriptors.c` source file.

    Note `#include "./USB/usb_function_hid.h"` at the top of the file. If a different class of device is being defined for a given application, the appropriate class header file will need to be included here.

17. Scroll down to the device descriptor section and copy and paste the code in Example 2-1 between the curly brackets in the section labeled:

    //ADD DEVICE DESCRIPTOR CODE HERE

> **Note:** The user may wish to clean up the look of the code by spacing comment sections accordingly. Tabs were ignored to ensure completeness for this document.

EXAMPLE 2-1: DEVICE DESCRIPTOR FOR LAB 1

```
0x12,                   // Size of this descriptor in bytes
USB_DESCRIPTOR_DEVICE,  // DEVICE descriptor type
0x0110,                 // USB Spec Release Number in BCD format
0x00,                   // Class Code
0x00,                   // Subclass code
0x00,                   // Protocol code
USB_EP0_BUFF_SIZE,      // Max packet size for EP0, see
                        // usbcfg.h
MY_VID,                 // Vendor ID
MY_PID,                 // Product ID
0x0003,                 // Device release number in BCD format
0x01,                   // Manufacturer string index
0x02,                   // Product string index
0x00,                   // Device serial number string index
0x01                    // Number of possible configurations
```

18. Scroll down to the configuration, class specific and interface descriptor section. Copy and paste the code in Example 2-2 between the brackets between the curly brackets in the section labeled:

    //ADD CONFIGURATION, CLASS SPECIFIC AND
    //INTERFACE DESCRIPTOR CODE HERE

EXAMPLE 2-2: CONFIGURATION, CLASS SPECIFIC AND INTERFACE

```
0x09,//sizeof(USB_CFG_DSC),    // Size of this descriptor in bytes
USB_DESCRIPTOR_CONFIGURATION,  // CONFIGURATION descriptor type
DESC_CONFIG_WORD(0x0022),      // Total length of data for this cfg
1,                             // Number of interfaces in this cfg
1,                             // Index value of this configuration
0,                             // Configuration string index
_DEFAULT|_SELF,                // Attributes, see usbd.h
50,                            // Max power consumption (2X mA)

/* Interface Descriptor */
0x09,//sizeof(USB_INTF_DSC),   // Size of this descriptor
                               // in bytes
USB_DESCRIPTOR_INTERFACE,      // INTERFACE descriptor type
0,                             // Interface Number
0,                             // Alternate Setting Number
1,                             // Number of endpoints in this intf
HID_INTF,                      // Class code
BOOT_INTF_SUBCLASS,            // Subclass code
HID_PROTOCOL_MOUSE,            // Protocol code
0,                             // Interface string index

/* HID Class-Specific Descriptor */
0x09,//sizeof(USB_HID_DSC)+3,  // Size of this descriptor in bytes
DSC_HID,                       // HID descriptor type
DESC_CONFIG_WORD(0x0111),      // HID Spec Release Number in BCD
                               // format(1.11)
0x00,                          // Country Code (0x00 for Not
                               // supported)
HID_NUM_OF_DSC,                // Number of class descriptors, see
                               // usbcfg.h
DSC_RPT,                       // Report descriptor type
DESC_CONFIG_WORD(50),          // sizeof(hid_rpt01),
                               // Size of the report descriptor
/* Endpoint Descriptor */
0x07,/*sizeof(USB_EP_DSC)*/
USB_DESCRIPTOR_ENDPOINT,       // Endpoint Descriptor
HID_EP | _EP_IN,               // EndpointAddress
_INT,                          // Attributes
DESC_CONFIG_WORD(3),           // size
0x01                           // Interval
```

The user is encouraged to take some time and compare the code in the preceding code examples against the descriptor definitions in the USB Revision 2.0 specification **Section 9-5 “Descriptors”**. Comments have been included to make the code intuitive and easier to reference with the USB specification. Definition sources can be located by highlighting the definition name and selecting *Edit>Find* in Files in the MPLAB IDE. This will locate all instances of the definition within the project and list them in the Output window.

19. Scroll down to the string descriptor section. String descriptors can be used to describe a device for the user. At enumeration, the string descriptor will appear at the lower right hand section of the screen notifying the user of the intended purpose of the device. Copy and paste the code between the curly brackets for both the manufacturer string descriptor and product string descriptor in Example 2-3 and Example 2-4 in the sections labeled:

    //ADD MANUFACTURER STRING DESCRIPTOR CODE HERE

    and

    //ADD PRODUCT STRING DESCRIPTOR CODE HERE

EXAMPLE 2-3: MANUFACTURER STRING DESCRIPTOR FOR LAB 1

```
'M','i','c','r','o','c','h','i','p',
' ','T','e','c','h','n','o','l','o','g','y',
' ','I','n','c','.'
```

EXAMPLE 2-4: PRODUCT STRING DESCRIPTOR FOR LAB 1

```
'M','o','u','s','e',
' ','E','n','u','m','e','r','a','t','i','o','n ',
' ','D','e','m','o'
```

Finally, the last descriptor to be added is the report descriptor.

Early in the development of the HID class specification, subclasses were intended to be used to identify different HID device categories. However, it became clear that due to the diverse variety of devices that could be implemented in this class, a more robust definition method was required. Therefore, this class does not use subclasses to define most protocols. Instead, a mechanism called the report descriptor identifies data protocol and the types of data provided for a device. It is here that such things as the number of buttons on a mouse, the unicode key value ranges for a keyboard, and other such characteristics are defined.

The USB organization has provided a number of documents and tools specifically designed to implement the report descriptor that can be accessed at:

http://www.usb.org/developers/hidpage/

The user is encouraged to download the HID Usage Tables that define a report descriptor for a given device. Also, the USB organization has further developed a HID Descriptor Tool that will assist the developer in designing their own report descriptors. The tool also includes predefined descriptors for commonly used HID devices such as a mouse and keyboard. This document and tool can be found at the links listed in **Section 2.3 "Resources Required to Complete Project Labs"**.

20. Scroll down to the report descriptor section and copy and paste the code in Example 2-5 between the curly brackets in the section labeled:

    //ADD REPORT DESCRIPTOR CODE HERE

EXAMPLE 2-5: REPORT DESCRIPTOR FOR LAB 1

```
0x05, 0x01, /*  Usage Page (Generic Desktop)*/
0x09, 0x02, /*  Usage (Mouse)*/
0xA1, 0x01, /*  Collection (Application)*/
0x09, 0x01, /*  Usage (Pointer)*/
0xA1, 0x00, /*  Collection (Physical)*/
0x05, 0x09, /*  Usage Page (Buttons) */
0x19, 0x01, /*  Usage Minimum (01)*/
0x29, 0x03, /*  Usage Maximum (03)*/
0x15, 0x00, /*  Logical Minimum (0)*/
0x25, 0x01, /*  Logical Maximum (0)*/
0x95, 0x03, /*  Report Count (3)*/
0x75, 0x01, /*  Report Size (1)*/
0x81, 0x02, /*  Input (Data, Variable, Absolute)*/
0x95, 0x01, /*  Report Count (1)*/
0x75, 0x05, /*  Report Size (5)*/
0x81, 0x01, /*  Input (Constant)    ;5 bit padding  */
0x05, 0x01, /*  Usage Page (Generic Desktop)*/
0x09, 0x30, /*  Usage (X)*/
0x09, 0x31, /*  Usage (Y)*/
0x15, 0x81, /*  Logical Minimum (-127)*/
0x25, 0x7F, /*  Logical Maximum (127)*/
0x75, 0x08, /*  Report Size (8)*/
0x95, 0x02, /*  Report Count (2)*/
0x81, 0x06, /*  Input (Data, Variable, Relative)*/
0xC0, 0xC0
```

The descriptor definitions are now complete.

21. Compile the project. There should be no errors.

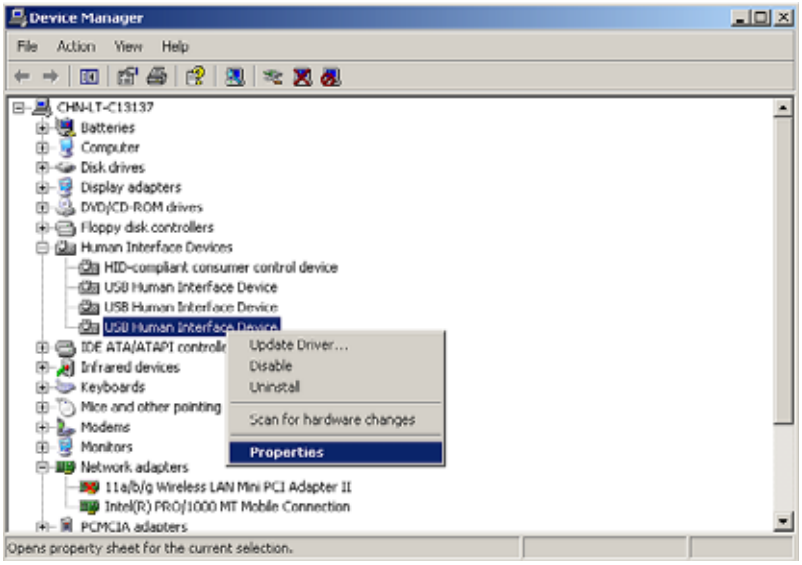
Testing The Application

22. Configure the Low Pin Count USB Development Board so that the J14 jumper is on the two right-most pins. This application will use power supplied by V_{BUS} off of the USB cable.
23. Disconnect the J12 jumper.
24. Connect the PICkit 2 programmer to the PC USB port and then to the J6 connector on the Low Pin Count USB Development Board.
25. Open the PICkit 2 programmer environment by selecting *Start>Programs>Microchip PICkit 2 vx.xx*.
26. The PICkit 2 programmer software should recognize that the PICkit 2 is connected and identify the PIC18F14K50 device.
27. Within the PICkit 2 programmer software, navigate to the `C:\LPCUSBDK_Labs\Lab1_files\output` folder and download the `Project Lab 1.hex` file to the PIC18F14K50.
28. Disconnect the PICkit 2 programmer from J6 and plug the USB cable into the mini B connector, J1.

    Once connected, the enumeration process should begin. The Host PC should recognize the connection of a new device and display a notification at the right corner of the screen indicating the “Mouse Enumeration Demo” text placed in the product string earlier in this lab.

29. Next, the device driver will be checked on the Host PC.
    Navigate to Device Manager on the Host PC by selecting Start>Settings>Control Panel>System to open the System Properties window. Select the **Hardware** tab and click the **Device Manager** button.
30. In the Device Manager window, expand the Human Interface Devices. Right click on each driver and select **Properties** until the "Mouse Enumeration Demo" driver is located. See Figure 2-4.

EXAMPLE 2-6: DEVICE MANAGER WINDOW AND HID DRIVERS INSTALLED



The user is encouraged to familiarize themselves with the HID Usage Tables and HID Descriptor Tool. Changing various aspects of the descriptors and then repeating the enumeration lab steps will help build on these concepts.

2.5 PROJECT LAB 2 (HID MOUSE)

2.5.1 Purpose

This lab implements the Low Pin Count USB Demo Board in a HID mouse application that moves the mouse pointer on the Host PC in a circle.

Note:	The source code developed here is an exact replica of the USB Device - HID – Mouse application found in the Framework.

```
C:\Microchip Solutions\USB Device - HID - Mouse\HID - Mouse – Firmware
```

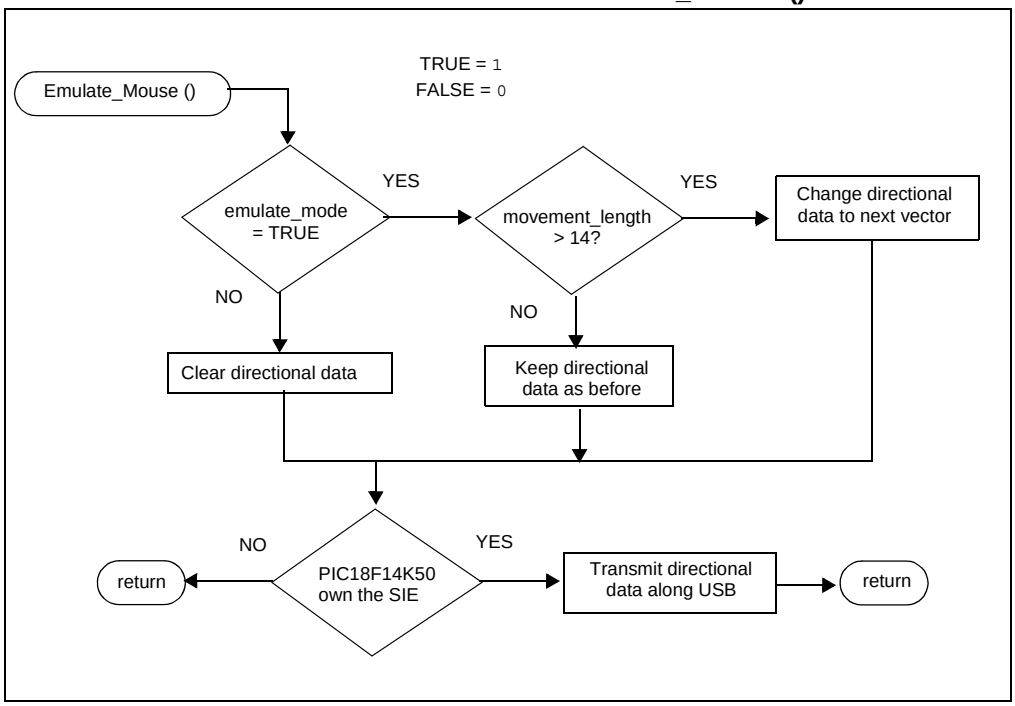
The user is encouraged to use these files as a reference when needed.

2.5.2 Overview of the HID Mouse Firmware

As with most of the Framework applications, the user defined source code is called from the `ProcessIO()` function in the `<application>.c` file. The user defined firmware will manipulate the Host PC mouse pointer to move in a single direction for 14 times through the main loop. After 14 times, the mouse pointer changes direction ultimately moving in a complete circle. A bit flag is initialized named `emulate_mode` that will toggle HIGH/LOW whenever the push button on the Low Pin Count USB Development Board is pressed. The status of this flag will start or stop pointer movement on the screen by not calling the user defined function, `emulate_mouse()`, which handles the mouse movement routines.

The flowchart for the user defined function is shown in Figure 2-4.

FIGURE 2-4: FLOWCHART FOR THE EMULATE_MOUSE()



In the flowchart of Figure 2-4, it can be seen that if the `emulate_mode` flag is '`0`', the directional data transmitted along the USB is cleared. Note that data is transmitted from the PIC18F14K50 whether or not the flag is set. Data is transmitted only when the SIE is capable of transmitting it. This check is implemented in code by using the `if(HIDTxHandleBusy(lastTransmission) == 0)` conditional statement. The `lastTransmission` is loaded at the time of transmission and processed by the `HIDTxHandleBusy` macro in the conditional '`if`' statement.

If the `emulate_mode` flag is set, the function enters into the mouse pointer movement algorithm. This is accomplished by keeping track of a counter variable, `movement_length`. When this variable exceeds 14, a buffer array is loaded with new directional data as supplied by the `dir_table` array defined at the top of the `mouse.c` file. Each element of the array is accessed by incrementing the vector variable counter. The buffer array is then loaded into a `hid_report_in[]` buffer array that is used by the `HIDTxPacket` macro to transmit the data along the USB to the Host PC.

2.5.3 Procedure

This lab expands on the descriptor code developed in Lab 1.

1. Create a new project "Project Lab 2", and build the framework as per procedure steps 1-15 in the previous lab, only this time use the source files found in `C:\LPCUSBDK_Labs\Lab2_files`
2. Ensure that the Project Build Options are configured as was done in Lab 1 steps 11 through 15.
3. In the Project window open the `mouse.c` source file.
4. Scroll down to find the variable definitions and uncomment the variables and arrays that will be used by the user defined function under the section of the source file:

   ```
   /**VARIABLES*****************************/
   ```

   a) `BYTE old_sw2,old_sw3;`
   b) `BOOL emulate_mode;`
   c) `BYTE movement_length;`
   d) `BYTE vector = 0;`
   e) `char buffer[3];`
   f) `USB_HANDLE lastTransmission;`
   g) `ROM signed char dir_table[]={-4,-4,-4, 0, 4, 4, 4, 0};`

5. Scroll down to the private prototype section and uncomment the user function prototype
   `void Emulate_Mouse(void);`
6. Scroll down to the `UserInit()`. It is here that all components pertinent to the application at hand are initialized. Note the variables and function calls that are initialized. Locate the `// emulate_mode = TRUE`; and uncomment the flag initialization.
7. Scroll down to the `ProcessIO()` function. Note the push button check that toggles the `emulate_mode` flag. Uncomment the code:
   `//emulate_mode = !emulate_mode;`
8. Finally, scroll down to the `Emulate_Mouse` function and insert the code in Example 2-7 between the curly brackets in the section marked:

   //ADD EMULATE MOUSE CODE HERE

EXAMPLE 2-7: USER DEFINED FUNCTIONAL CODE FOR EMULATE_MOUSE()

```
if (emulate_mode == TRUE)
    {
      //go 14 times in the same direction before changing
      if (movement_length > 14)
      {
        buffer[0] = 0;
        buffer[1] = dir_table[vector & 0x07];
        //X-Vector
        buffer[2] = dir_table [(vector+2) & 0x07];
        //Y-Vector
        // go to the next direction in the table
       vector++;
        //reset the counter for when to change again
       movement_length = 0;
      }//end if (movement_length > 14)
    }
else
    {
        //don't move the mouse
        buffer[0] = buffer[1] = buffer[2] = 0;
    }
    if(HIDTxHandleBusy(lastTransmission) == 0)
    {
        //copy over the data to the HID buffer
        hid_report_in[0] = buffer[0];
        hid_report_in[1] = buffer[1];
        hid_report_in[2] = buffer[2];
       //Send the 3 byte packet over USB to the host.
       lastTransmission = HIDTxPacket(HID_EP, (BYTE*)hid_report_in,
        0x03);

        //increment the counter to change the data sent
        movement_length++;
    }
```

Note that the HID mouse transmits in 3-byte packets. The format of this packet is as follows:

- This byte is typically used to identify mouse buttons. Since this application does not require any mouse clicks, this byte is always zero.
- The second and third bytes represent horizontal (X) and Vertical (Y) displacements.

Compile the project. There should be no errors.

Testing the Application

Note: The device created in the Device Manager from the previous lab will need to be removed so that the new device, created in this lab, can enumerate properly. In the Device Manager window, right-click on the device and select **Uninstall.**

9. Ensure that the Low Pin Count USB Development Board is configured as in Lab 1.
10. Connect the PICkit 2 Programmer and open the PICkit 2 programming software.
11. Navigate to the *.hex* file located in the `C:\LPCUSBDK_Labs\Lab2_files` for this lab and download to the PIC18F14K50.

12. Disconnect the PICkit 2 and connect the Low Pin Count USB Demo Board to the Host PC port.
13. The device should enumerate and the LEDs on the board flash in accordance with the `BlinkUSBStatus()` discussed in the self-directed course.
14. Pressing the push button should start and subsequently stop the mouse pointer moving in a circle on the Host PC screen.

The user is encouraged to experiment with this application by altering the length of time that the mouse pointer moves until a directional change or altering the values in the `ROM signed char dir_table[]={-4,-4,-4, 0, 4, 4, 4, 0};`

2.6 PROJECT LAB 3 (HID KEYBOARD)

CAUTION

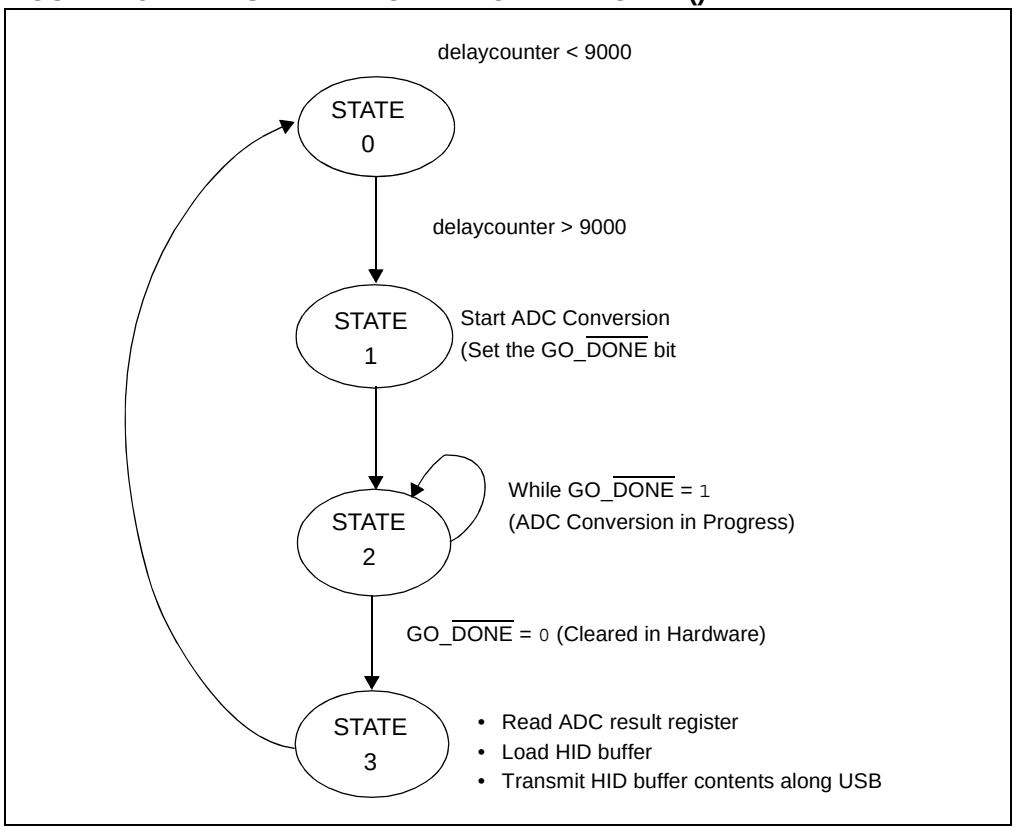
A word of caution, this HID device has the potential to be harmful if a key combination is used that initiates a Windows® shortcut. Great care should be taken to ensure that the transmitting buffer contains only keycodes that the user is confident will not produce any harmful key combinations.

In this lab, the PIC18F14K50 is implemented as a HID keyboard device. The ADC peripheral is configured to perform conversions on the voltage level present on the port pin connected to the potentiometer on the Low Pin Count USB Development Board. The value in the ADC result register is then used to create a numeric value between 4 and 29 that will display an alphabetic character between 'a' and 'z' on the Host PC screen (refer to HID Usage Tables document **Section 10 "Keyboard/Keypad Page"** (`0x07`)). As the potentiometer is rotated, the character outputted to the screen will change accordingly. The user should note that this application could be applied to a data logger application with the potentiometer on the Low Pin Count USB Development Board simulating a mixed signal interface to monitor an off-chip application. The data generated and transmitted via the USB could be connected and interpreted by a Graphical User Interface on the Host PC to monitor real-time application behavior or used to store essential data for later analysis.

2.6.1 Overview of the HID Keyboard Firmware

The `keyboard()` is the user-defined function that is called from `ProcessIO()` to parse the data received from the ADC module, transmit the numeric value along the USB and display the appropriate character on the screen. This function is implemented as a state machine. The state diagram for this function is shown in Figure 2-5.

FIGURE 2-5: STATE DIAGRAM FOR KEYBOARD()



Referring to the state diagram, the individual states perform these general tasks:

1. STATE 0: this is a delay state used to ensure that the hold capacitor on the ADC peripheral has sufficient time to charge before a conversion is initiated.

2. STATE 1: this state begins the conversion process by setting the GO_$\overline{\text{DONE}}$ bit in the ADCON0 control register.

3. STATE 2: checks for a completed conversion (GO_$\overline{\text{DONE}}$ = `0`) before allowing the state machine to move to the next state.

4. STATE 3: this final state reads the ADC result register, converts the result to a value between 4 (‘a’) and 29 (‘z’), loads a HID buffer and transmits the resulting data along the USB to the Host PC for output to an opened *.txt* document.

The main point the user should take away from this lab is this: since the USB Framework is a multitasking environment, no blocking code should be used. Therefore, as shown in this lab, state machines will become the norm in many applications. The `keyboard()` state machine is called each time through the main loop. If the condition that changes the current state to the next state is not met, the state machine simply returns from the function without changing states. The next time through the main loop, the condition is once again checked. If the state condition has been met, the state is changed to the next sequential state. The state variable is declared as a type `static` as this will allow the current value in the state variable to remain after a return from the `keyboard()`.

2.6.2 Procedure

This application will require a few changes to the *usb_descriptor.c* file to configure the PIC18F14K50 as a HID keyboard. Note: the changes made to the report descriptor were done using the HID Descriptor Tool downloaded from http://www.usb.org/developers/hidpage/. The user is encouraged to spend some time reviewing the contents of this page and the resources available for developing HID applications.

1. Create a new project "Project Lab 3" as was done in the previous labs. The source files for Lab 3 can be found in:
   `C:\LPCUSBDK_Labs\Lab3_files`
2. Ensure that the Project Build Options are configured as was done in Lab 1 steps 11 through 15.
3. Open the `usb_descriptor.c` file and scroll down to the interface descriptor. Uncomment the Protocol Code definition `//HID_PROTOCOL_KEYBOARD,`
4. Scroll down to the HID class specific descriptor and uncomment the size of the HID report macro `//DESC_CONFIG_WORD(63),`
   The report descriptor has changed from the previous lab and will contain 63 components that the Host PC will need to identify this device's keyboard attributes.
5. Scroll down to the report descriptor and add the code in Example 2-8 in the section labeled:

   //ADD REPORT DESCRIPTOR HERE

EXAMPLE 2-8: REPORT DESCRIPTOR FOR KEYBOARD()

```
0x05, 0x01,   //   USAGE_PAGE (Generic Desktop)
0x09, 0x06,   //   USAGE (Keyboard)
0xa1, 0x01,   //   COLLECTION (Application)
0x05, 0x07,   //   USAGE_PAGE (Keyboard)
0x19, 0xe0,   //   USAGE_MINIMUM (Keyboard LeftControl)
0x29, 0xe7,   //   USAGE_MAXIMUM (Keyboard Right GUI)
0x15, 0x00,   //   LOGICAL_MINIMUM (0)
0x25, 0x01,   //   LOGICAL_MAXIMUM (1)
0x75, 0x01,   //   REPORT_SIZE (1)
0x95, 0x08,   //   REPORT_COUNT (8)
0x81, 0x02,   //   INPUT (Data,Var,Abs)
0x95, 0x01,   //   REPORT_COUNT (1)
0x75, 0x08,   //   REPORT_SIZE (8)
0x81, 0x03,   //   INPUT (Cnst,Var,Abs)
0x95, 0x05,   //   REPORT_COUNT (5)
0x75, 0x01,   //   REPORT_SIZE (1)
0x05, 0x08,   //   USAGE_PAGE (LEDs)
0x19, 0x01,   //   USAGE_MINIMUM (Num Lock)
0x29, 0x05,   //   USAGE_MAXIMUM (Kana)
0x91, 0x02,   //   OUTPUT (Data,Var,Abs)
0x95, 0x01,   //   REPORT_COUNT (1)
0x75, 0x03,   //   REPORT_SIZE (3)
0x91, 0x03,   //   OUTPUT (Cnst,Var,Abs)
0x95, 0x06,   //   REPORT_COUNT (6)
0x75, 0x08,   //   REPORT_SIZE (8)
0x15, 0x00,   //   LOGICAL_MINIMUM (0)
0x25, 0x65,   //   LOGICAL_MAXIMUM (101)
0x05, 0x07,   //   USAGE_PAGE (Keyboard)
0x19, 0x00,   //   USAGE_MINIMUM (Reserved (no event indicated))
0x29, 0x65,   //   USAGE_MAXIMUM (Keyboard Application)
0x81, 0x00,   //   INPUT (Data,Ary,Abs)
0xc0
```

Next, the *keyboard.c* source file will be configured.

6. In the Project window, open the *keyboard.c* source file and scroll down to the `UserInit()`. Uncomment the port and ADC initialization code. The user is urged to review the PIC18F14K50 data sheet as to the significance of these initializations for the appropriate peripheral.

   ```
   // ADCON0=0x29;
   // ADCON1 = 0X00;
   // ADCON2=0x3F;
   ```

   Scroll down to the `keyboard()` and copy and paste the code in Example 2-9 between the curly braces in the switch at:

   //ADD STATE MACHINE CODE HERE

EXAMPLE 2-9: KEYBOARD() STATE MACHINE CODE

```
//delay to allow the hold capacitor on the ADC to charge
case 0:       if(++delaycounter>9000)
              {
                     delaycounter = 0;
                     state = 1;
              }
              break;

case 1:       ADCON0bits.GO_DONE = 1; //Start an ADC conversion
              state = 2;
              break;


case 2:        if(ADCON0bits.GO_DONE == 0) //Check if conversion is
                                           //completed
              {
                     state = 3;
              }
              break;


case 3:       HIDoutput = ADRESH>>3;//shift the result in ADRESH
                                    //left by three

              if(HIDoutput<=4) HIDoutput = 4;
              if(HIDoutput>=29) HIDoutput = 29;

              //Can the SIE transmit?
              if((HIDTxHandleBusy(lastTransmission) == 0))

              {
                     //Load the HID buffer
                     hid_report_in[0] = 0;
                     hid_report_in[1] = 0;
                     hid_report_in[2] = HIDoutput;
                     hid_report_in[3] = 0;
                     hid_report_in[4] = 0;
                     hid_report_in[5] = 0;
                     hid_report_in[6] = 0;
                     hid_report_in[7] = 0;

              //Send the 8 byte packet over USB to the host.
               lastTransmission = HIDTxPacket(HID_EP,
              (BYTE*)hid_report_in, 0x08);
              state = 0;
              }
              break;
```

Note that the HID keyboard transmits in 8-byte packets along the USB. The format of this packet is as follows:

- The first byte is used for a modifier such as a shift or ctrl character. (i.e., a simultaneous shift and character press on the typical keyboard.)
- The second byte is reserved.
- The remaining bytes are used to carry numeric values that contain the desired keyboard characters pressed.

Compile the project. There should be no errors.

Testing the Application

7. Connect the PICkit 2 Programmer and open the PICkit 2 programming software
8. Navigate to the *.hex* file for this lab and download to the PIC18F14K50.
9. Disconnect the PICkit 2. Open a new notepad, word document or other text editor program and click inside the document to place the cursor.
10. Connect the Low Pin Count USB Demo Board to the Host PC port. The device should enumerate as “Keyboard Demo”.
11. Within the selected text editor, a series of character entries should appear.
12. Turn the potentiometer on the Low Pin Count USB Demo Board to change the character on the screen.

The user is encouraged to experiment with this application by referring to the Keyboard Usage Page and changing the keyboard packet transmitted in the state machine.

2.7 PROJECT LAB 4 (CDC – SERIAL EMULATOR)

In this lab, the PIC18F14K50 is used as a serial emulator taking an RS-232 data transmission using the Enhanced Universal Asynchronous Synchronous Receiver Transmitter (EUSART) peripheral and converting it to the USB protocol within firmware. Many embedded applications continue to use the RS-232 interface to communicate with external systems. However, as USB becomes more prevalent, RS-232 ports are disappearing from newer PC's. A simple solution is to emulate RS-232 over the USB. In this example, a virtual COM port is created that will allow the USB connection to appear as an RS-232 COM connection. Furthermore, this example makes use of Windows drivers that already exist eliminating the need to alter existing software such as the Hyper Terminal application.

The RS-232 connector on the Low Pin Count USB Development Board is configured so that the PIC18F14K50 can be used as a Data Terminal Equipment (DTE) device to interface with Data Communications Equipment (DCE) devices such as alarm systems, modems etc. To accommodate this lab and eliminate the need for the user to create their own DCE interface circuitry, a Null-Modem Gender Changer has been provided in the kit to crosslink the transmit and receive lines so that the Low Pin Count USB Development Board can be converted from a DTE device to a DCE device. In this way, the main concepts of serial emulation can be delivered using only two Hyperlink Terminals on a single PC with one RS-232 serial COM port and one USB connection.

NOTICE

Kits shipped with the RS-232 pin corrector (p/n 04-02087R1) do not require the Null Modem Gender Changer but will instead require a female/female gender changer that does not crosslink the transmit and receive lines. The pin corrector is not used in this lab as the RS-232 connector on this version of the Low Pin Count USB Development Board is configured as a DCE device. Applications using the Low Pin Count USB Development Board as a DTE device will require the use of the pin corrector.

Microchip's Full-Speed USB Firmware Framework provides information files (*.inf*) for all of its CDC application examples that automate Windows driver alterations freeing the user from doing this manually. Once the PIC18F14K50 has been programmed and then connected to the PC USB port, Windows "New Hardware Found Wizard" will prompt the user for additional driver information. At this point, the user need only direct Windows to the directory containing the appropriate *.inf* file.

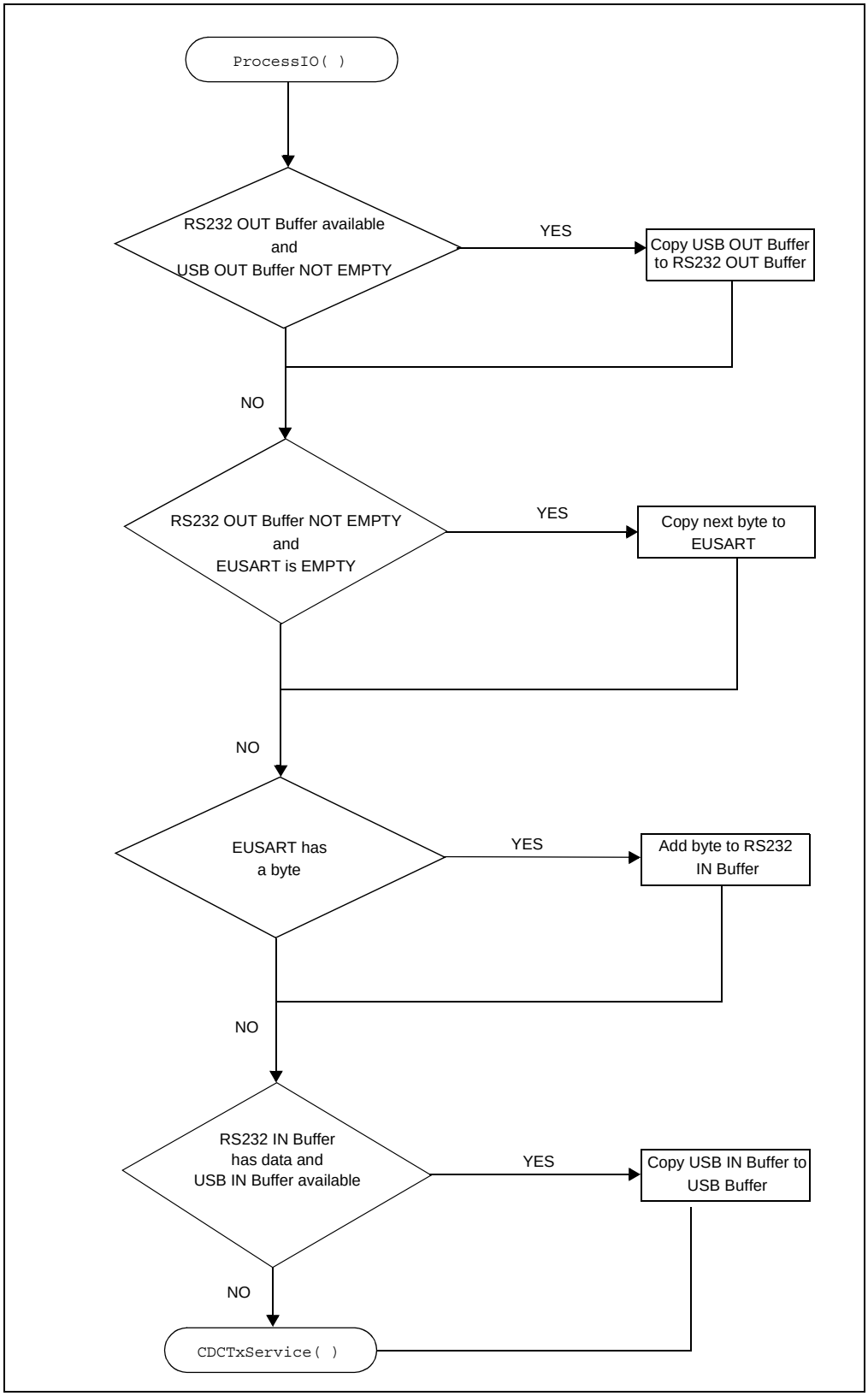
Note: The only information that is required by the user in the *.inf* is the Vendor Identification (VID) and Product Identification (PID) numbers specific to their original design.

Microchip's Full-Speed USB Firmware Framework provides all the source code necessary to perform low-level RS-232 functions, thereby abstracting this from the user.

2.7.1 Overview of the CDC – Serial Emulator Firmware

The CDC Serial Emulator firmware flow is shown in Figure 2-6.

FIGURE 2-6: FLOWCHART FOR CDC SERIAL EMULATOR CODE



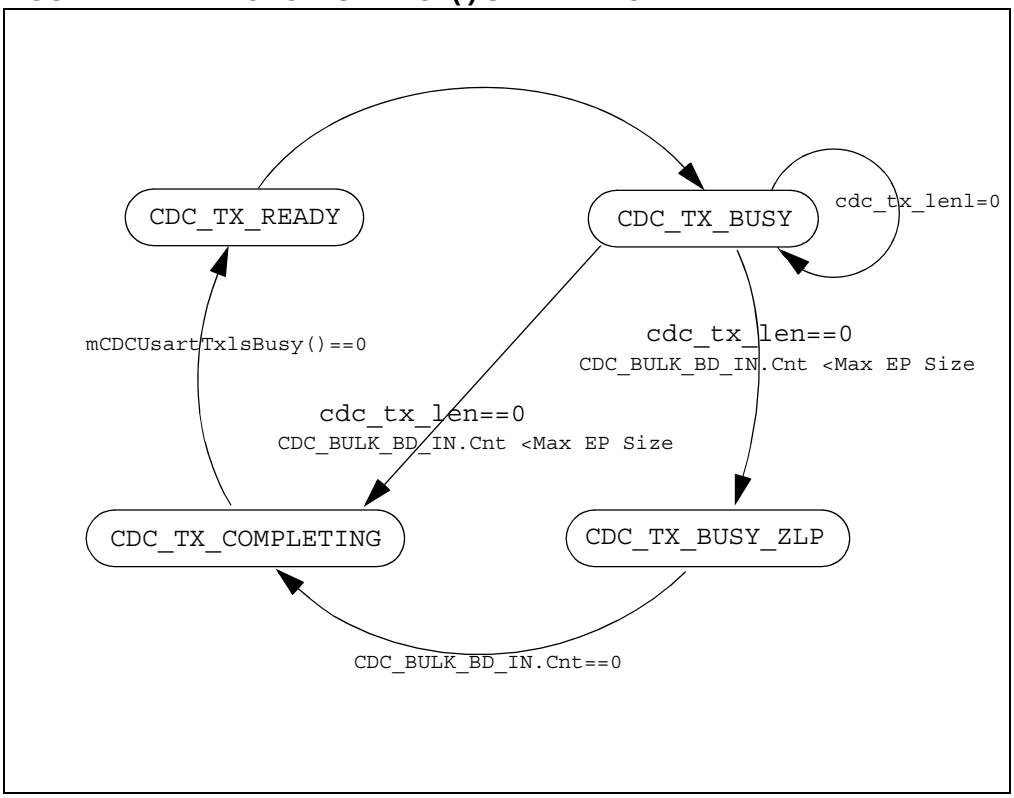
Referring to the flowchart in Figure 2-6, the firmware located in the `ProcessIO()` first checks if the previous RS-232 transmission has been sent via the USB using the `RS232_Out_Data_Rdy` flag. If this flag is cleared (indicating previous transmission has been sent), firmware then checks if any new data has been sent from the RS-232 connection and is ready to be transmitted via the USB using the `getsUSBUSART()`. This function copies data into a buffer and returns the number of bytes the buffer contains. The function ensures that only the expected numbers of bytes, in this case 64, are actually copied into this buffer. Also, if there is no data available, the function returns a zero value indicating no data is available. In this way the function does not wait for data and is therefore, non-blocking, keeping in mind that all firmware must conform to this multitasking environment.

Following the RS-232 data check, the firmware then checks if the EUSART transmit register, TXREG, is empty. This is accomplished using the `mTxRdyUSART()` macro, which checks the TRMT bit in the TXSTA (Transmit Status Control) register in the EUSART peripheral. If the TRMT bit is cleared, the TXREG is Full, and Empty if the TRMT bit is set. Note that this bit is automatically set following a successful transmission from the TXREG. If set, the data collected into the buffer by the `getsUSBUSART()` is then transferred into the TXREG one byte at a time each time through the main loop. Again, such macros take care of the low-level RS-232 communication in a non-blocking fashion so the user doesn't have to. If the TXREG isn't empty, then the previous data has not been transmitted via the USB and should not be overwritten.

The firmware next checks to see if the CDC class device is ready to transmit data. This is accomplished by using the `mUSBUSARTIsTxrfReady()` flag. The user must ensure that this flag is set to '`1`' before calling the `putUSBUSART()` function. As a safety precaution, this function checks the state one more time to make sure it does not override any pending transactions. This function writes data to the USB.

`The CDCTxSevice()` services the transfer of data to the host. This function keeps track of a state machine and breaks up long strings of data into multiple USB data packets. It is called once each time through the main program loop. The state machine for the `CDCTxService()` is shown in Figure 2-7 and the source code can be found in the `usb_function_cdc.c` source file. The reader is encouraged to reference this firmware and compare it against the state diagram at their leisure.

FIGURE 2-7: CDCTXSERVICE( ) STATE DIAGRAM



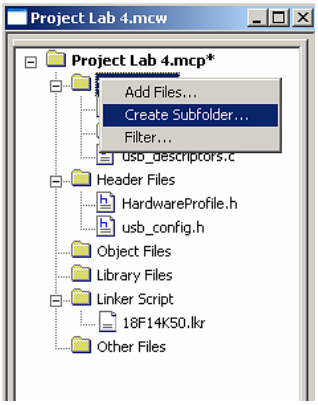
2.7.2 Procedure

This application requires significant changes to the *usb_descriptor.c* file to configure the PIC18F14K50 as a CDC device. Note the absence of the report descriptor. The user is encouraged to spend some time reviewing the *usb_descriptor.c* file and compare it against the information found in the Universal Serial Bus Class Definitions for Communications Devices document referenced at the beginning of this chapter. Note that this lab applies the same firmware found in the CDC – Serial Emulator application example in Microchip's Full-Speed USB Firmware Framework application examples and can be used as a reference for this lab.

1. Create a new project for lab 4, using the Project Wizard, called "Project Lab 4" as was done in the previous labs. The only files added, at this point, will be the `usb_descriptor.c` and `main.c` source files, as well as a new unique descriptor for Lab 4 `rm18f14k50.lkr` can be found in:
   `C:\LPCUSBDK_Labs\Lab4_files`

   Step through to close the Project Wizard. This time, the project will be set up to resemble the application examples in the Framework using sub-folders to distinguish and organize the different source files in the Project window. All remaining source/header files will be added from the Project window.
2. Right click on the **Source Files** folder in the Project window and select **Create Subfolder**...

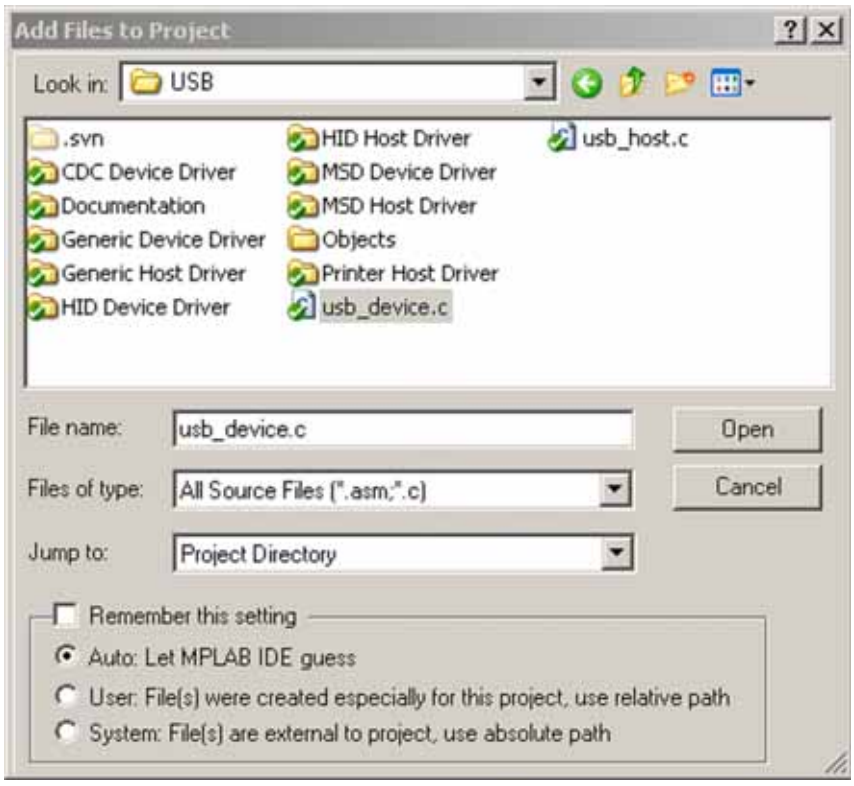
FIGURE 2-8: CREATING A SUB-FOLDER IN THE PROJECT WINDOW



Name the new folder "USB Stack" and click **OK**.

3. Right click on this new USB Stack folder and select **Add Files**. In the Add Files to Project window, navigate to `C:\Microchip Solutions\Microchip\Usb` and select the `usb_device.c` source file. Ensure that "System: File(s) are External to Project, Use Absolute Path" is selected then click **Open**.

FIGURE 2-9: ADDING THE *USB_DEVICE.C* FILE TO THE USB STACK FOLDER



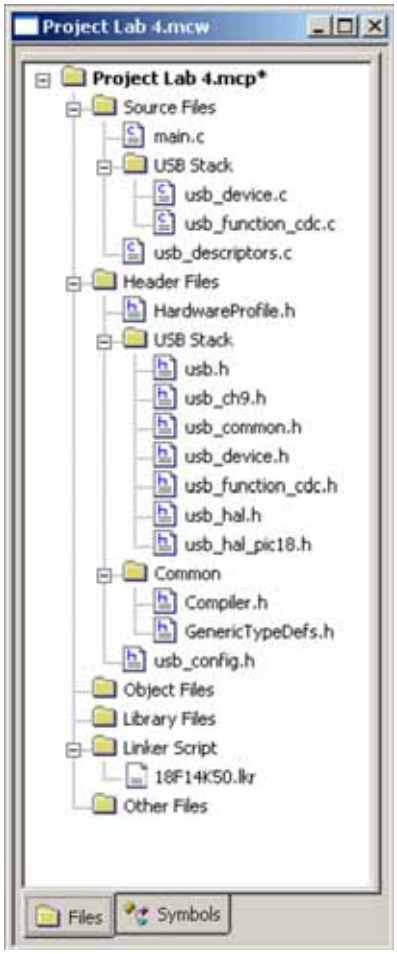
This should add the *usb_device.c* to the "USB Stack" folder in the Project window.

Repeat this step to add the `usb_function_cdc.c` file from the `C:\Microchip Solutions\Microchip\USB\CDC Device Driver` directory to the same "USB Stack" folder.

4. In the Project window create two new sub-folders under the Header Files folder called "Common" and "USB Stack" as per step 2 of this lab.
5. Right click on the "USB Stack" folder and add the following files from the `C:\Microchip Solutions\Microchip\Include\Usb` directory as was done in step 3 of this lab:
   - `usb.h`
   - `usb_ch9.h`
   - `usb_common.h`
   - `usb_device.h`
   - `usb_function_cdc.h`
   - `usb_hal.h`
   - `usb_hal_pic18.h`
6. Right click on the "Common" folder and add the following files from the `C:\Microchip Solutions\Microchip\Include` directory as was done in step 3 of this lab:
   - `Compiler.h`
   - `GenericTypeDefs.h`
7. Ensure that the Project Build Options are configured as was done in Lab 1 steps 11 through 15.
8. Compile the project. There should be no errors.

The Project window should now resemble Figure 2-10.

FIGURE 2-10: PROJECT WINDOW FOR LAB 4



9. Next, the EUSART peripheral will need to be initialized to enable asynchronous communication with a baud rate of 19200. To do this, open the *main.c* file and scroll down to the `InitializeUSART()`. This function is called by the `UserInit()`. Note that in this function, code has been formatted to allow configuration dependant on the specific device and compiler used. Copy and paste the contents of Example 2-10 into the section of the `Initialize-USART()` function labeled:

   //ADD C18 PIC18F14K50 EUSART INITIALIZATION CODE HERE

EXAMPLE 2-10: INITIALIZEUSART() CODE

```
#if defined(__18CXX)
      unsigned char c;
    #if defined(__18F14K50)
      ANSELHbits.ANS11 = 0;      // Make RB5 digital so USART can
                                 //use pin for Rx
    #endif
    UART_TRISRx=1;               // RX
    UART_TRISTx=0;               // TX
    TXSTA = 0x24;                // TX enable BRGH=1
    RCSTA = 0x90;                // Single Character RX
    SPBRG = 0x70;
    SPBRGH = 0x02;               // 0x0271 for 48MHz -> 19200 baud
    BAUDCON = 0x08;              // BRG16 = 1
    c = RCREG;                   // read
#endif
```

The reader is encouraged to review the data sheet for the PIC18F14K50 EUSART section for more information on the specifics of the configuration code.

Next, the application specific code will be added that will implement the flowchart shown in Figure 2-6.

10. Scroll down to the `ProcessIO()` and copy and paste the contents of Example 2-11 into the section labeled:

    /***

    ADD CODE TO CHECK IF RS232 HAS

    BEEN SENT ALONG USB

    AND THE CODE TO CHECK IF

    ANY NEW RS232 TRANSMISSION

    HAS BEEN RECEIVED AND STORED

    ***/

As per the flowchart in Figure 2-6, this code will ensure that the buffer containing the data transmitted from the RS-232 has been sent to the USB firmware. If so, the code then checks for any new RS-232 data that has been stored in the buffer.

EXAMPLE 2-11: RS-232 BUFFER CHECK

```
// only check for new USB buffer if the old RS232 buffer is
// empty.
// Additional USB packets will be NAK'd
// until the buffer is free.

if (RS232_Out_Data_Rdy == 0)
       {
              LastRS232Out = getsUSBUSART(RS232_Out_Data,64);
              if(LastRS232Out > 0)
              {
                     RS232_Out_Data_Rdy = 1;  // signal
                                              //buffer full
                     RS232cp = 0;// Reset the current position
              }
       }
```

11. Next, the code that will check and then load the EUSART Transmit shift register (TXREG) with the contents of the RS-232 buffer will be entered. Copy and paste the contents of Example 2-12 into the section labeled:

    /***

    ADD THE CODE THAT WILL CHECK

    IF THE EUSART TXREG IS EMPTY.

    IF SO, BEGIN SENDING DATA

    FROM RS232 TRANSMISSION INTO

    THE TXREG ONE BYTE AT A TIME

    ***/

EXAMPLE 2-12: TXREG CHECK AND LOAD CODE

```
       if(RS232_Out_Data_Rdy && mTxRdyUSART())
       {
              putcUSART(RS232_Out_Data[RS232cp]);
              ++RS232cp;
              if (RS232cp == LastRS232Out)
                     RS232_Out_Data_Rdy = 0;
}
```

12. Finally, the code to check if the CDC class device is ready to send data into the USB transmit buffer will be entered. Copy and paste the contents of code in Example 2-13 into the section labeled:

    /***

    ADD THE CODE THAT WILL CHECK

    IF THE CDC CLASS DEVICE IS

    READY TO LOAD THE USB BUFFER

    ***/

EXAMPLE 2-13: CHECK CDC CLASS DEVICE CODE

```
if((mUSBUSARTIsTxTrfReady()) && (NextUSBOut > 0))
{
  putUSBUSART(&USB_Out_Buffer[0], NextUSBOut);
  NextUSBOut = 0;
}
```

13. At this point, all the necessary code to run the CDC – Serial Emulator application is complete. Compile the project. There should be no errors.

Installing Application Drivers

14. Connect the PICkit 2 Programmer and open the PICkit 2 programming software.
15. Navigate to the *.hex* file for this lab and download to the PIC18F14K50.
16. Disconnect the PICkit 2.
17. Connect the Low Pin Count USB Demo Board to the Host PC port. Windows should recognize the PIC18F14K50 as “CDC RS-232 Emulation Demo”.

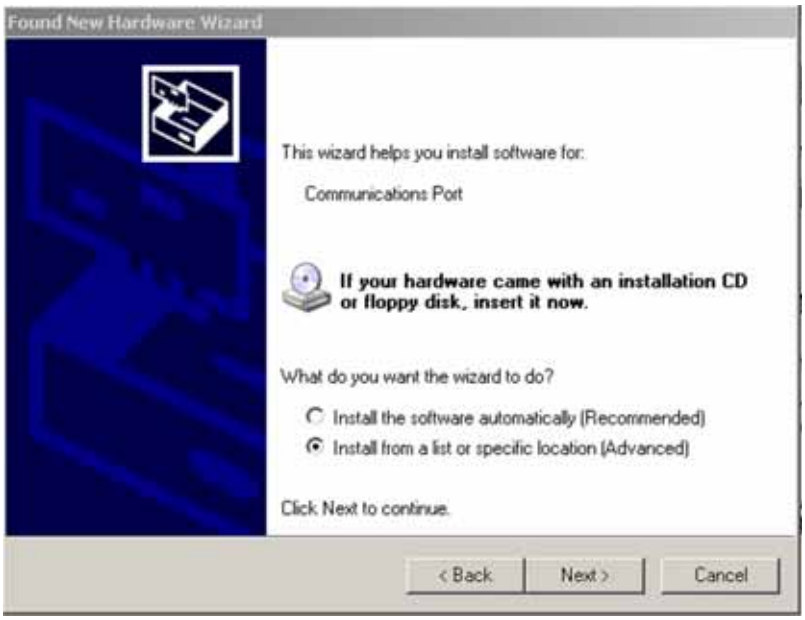
Windows will now prompt the user for driver information.

18. In the “Welcome to the Found New Hardware Wizard” window, select “No, not this time” and then **Next** (see Figure 2-11).

FIGURE 2-11: FOUND NEW HARDWARE WIZARD WINDOW

19. The wizard will then prompt the user for a location from which to load the software for the communication port. Select "Install from a list or specific location (Advanced)" and click **Next** (see Figure 2-12).

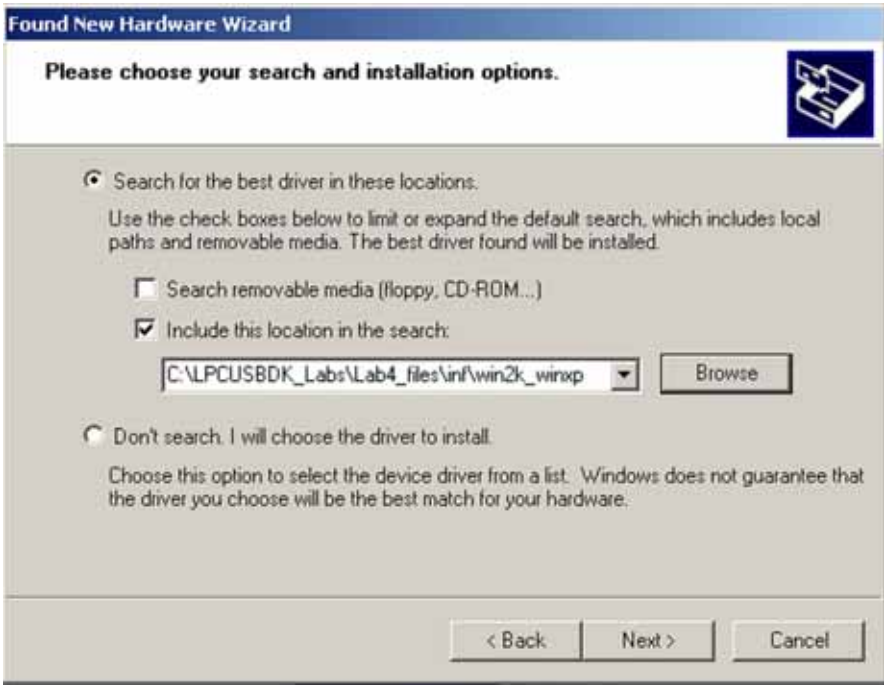
FIGURE 2-12: SELECTING SOFTWARE LOCATION FOR COMMUNICATIONS PORT



The wizard now prompts the user for the location of the *.inf* file that Windows will use to automatically configure the binary driver files (*.sys* files) to create the virtual COM port connection for the USB. Ensure that both "Search for the best driver in these locations" and "Include this location in the search" are both selected. Select **Browse** and navigate to the lab 4 source files in the `C:\LPCUSBDK_Labs\Lab4_files\inf\win2k_winxp` directory (see Figure 2-13).

Highlight the `win2k_winxp` file and click **OK**.

FIGURE 2-13: DIRECTING WINDOWS TO THE *.INF* FILE FOR THE CDC – SERIAL EMULATOR APPLICATION



Click **Next**.

The window should now begin loading the software. If any warnings are issued, select **Continue Anyway.**

20. The wizard should indicate that the software for the Communications port was successfully installed. Select **Finish.** (See Figure 2-14.)

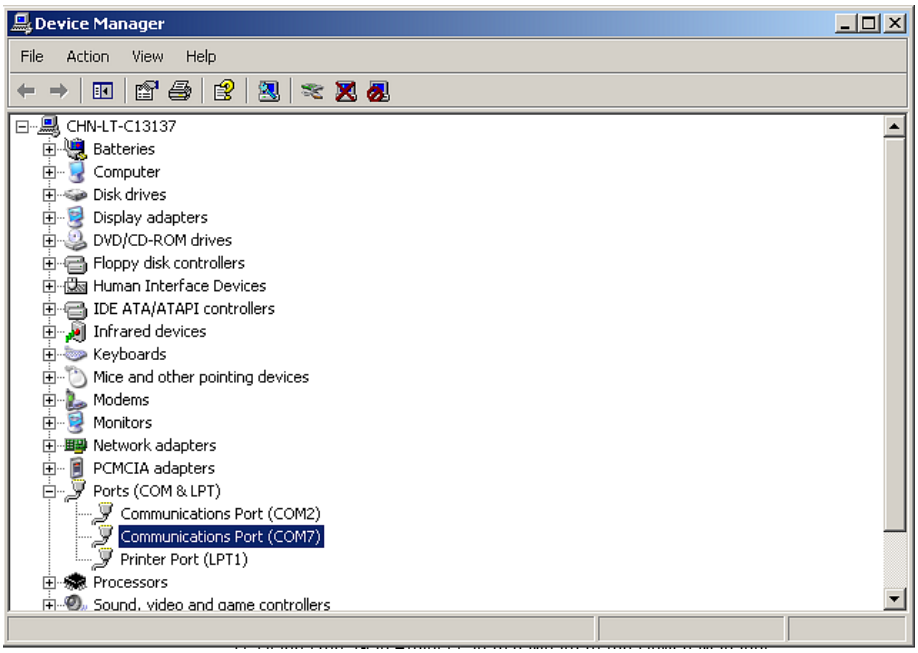
FIGURE 2-14: SUCCESSFUL SOFTWARE INSTALLATION WINDOW

Next, the virtual COM port will be checked in the Device Manager to identify the COM port number.

Establish Communication

21. Using step 29 in Project Lab 1 to navigate to the Device Manager, expand the ports (COM and LPT). The new virtual COM port (usually COM 5 and above on most PCs) created by the *.inf* file should be found in the Ports (COM & LPT) drop-down list in the Device Manager window. If there is difficulty locating the virtual COM port, right click on each driver and select **Properties** until the CDC RS-232 Emulation Demo is located. Note the COM port number for both the virtual COM port and the COM port used for an RS-232 connection (Serial Port Connection on the Host PC). Figure 2-15 shows a list of COM ports available. The reader's list may differ.

FIGURE 2-15: EXAMPLE LIST OF AVAILABLE COM PORTS IN THE DEVICE MANAGER



This COM port number will be used in the Hyper Terminal program to establish connectivity to both the USB and RS-232 connections between the Low Pin Count USB Development Board and Host PC.

22. Open a Hyper Terminal window by selecting within Windows,

    Start>Programs>Accessories>Communications>HyperTerminal.

The Hyper Terminal Program should now prompt the user for a "Connection Description".

23. Name this first connection "USB Connection" and click **OK**. (See Figure 2-16.)

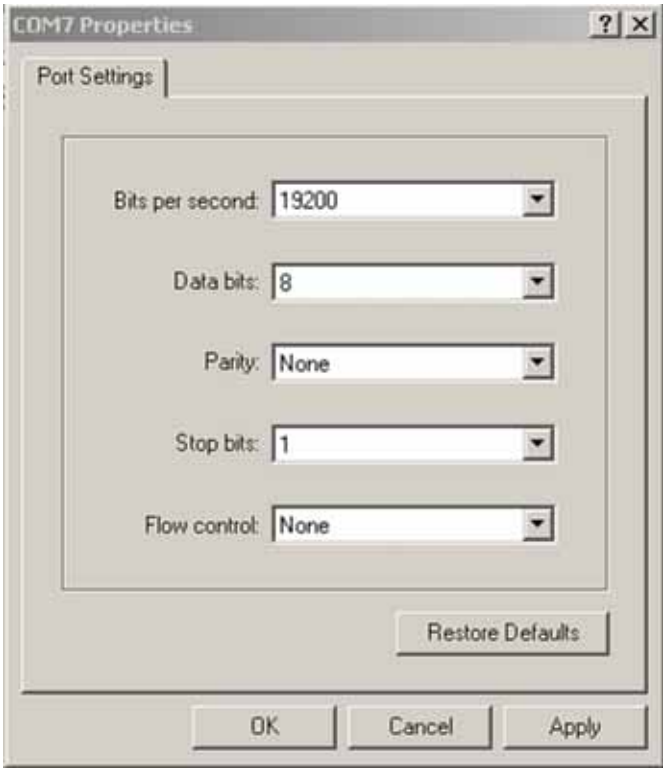
FIGURE 2-16: HYPER TERMINAL CONNECTION DESCRIPTION

24. In the “Connect To“ window, select the virtual COM port that was noted in step 21 in the “Connect Using” drop-down menu and select **OK**. In Figure 2-17, the virtual COM port is on COM7. Note that this may differ on the user’s PC.

FIGURE 2-17: HYPER TERMINAL CONNECT TO WINDOW

25. In the COM Properties window, configure the connection as shown in Figure 2-18 with a baud rate of 19200 and click **Apply** then **OK**.

FIGURE 2-18: HYPER TERMINAL COM PROPERTIES WINDOW



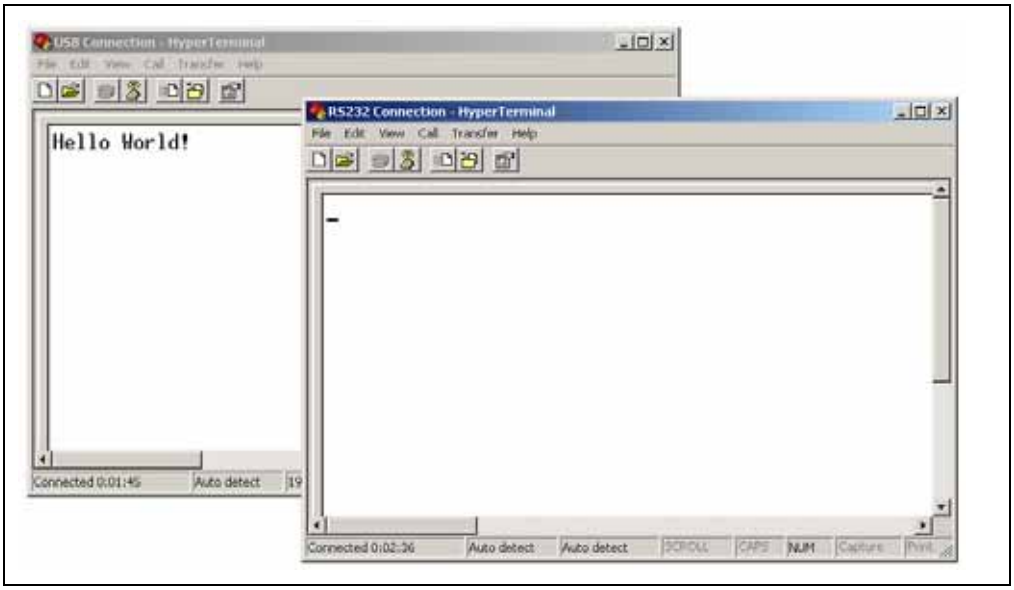
This now establishes a connection between the Low Pin Count USB Development Board USB connector and the Host PC COM port.

26. Next, connect the RS-232 serial cable to the connector on the Low Pin Count USB Development Board and to a serial port connector on the Host PC using a "Gender Changer" adapter.
27. Repeat steps 22 to 25 to establish an RS-232 connection using the related port noted in step 21 for the Serial Port Connector on the Host PC. Name this connection "RS232 Connection" and ensure that the COM properties resemble Figure 2-18.

Testing the Application

28. Once connected, click inside the RS232 Connection COM window and type a message. Note that unless configured to echo locally, the originating message COM window will not print the message. The message should be printed in the "USB Connection" COM window as shown in Figure 2-19.

FIGURE 2-19: CONFIRMING RS-232 TO USB COMMUNICATION



This will confirm communication from the Host PC via an RS-232 connection into the PIC18F14K50, which in turn transmits data received back to the Host PC. In other words, an RS-232 to USB conversion.

NOTES:

Appendix A. Schematics

A.1 INTRODUCTION

This appendix contains the Low Pin Count USB Development Kit hardware diagrams.

FIGURE A-1: LOW PIN COUNT USB DEVELOPMENT BOARD BILL OF MATERALS

QTY	DESCRIPTION
1	IC, PIC18F14K50, 20P DIP
1	IC SMT, MAX3232CPWR ,DRVR/RCVR MLTCH RS232 16TSSO (U3)
5	CAP SMT, 0.1uF 0603 CER 16V 10% X7R (C6 - C10)
2	CAP SMT, 0.1uF 0805 CER 50V 10% X7R (C1, C3)
1	CAP SMT, 0.47uF 0805 CER 16V 10% X7R (C2)
2	CAP SMT, 22pF 0805 CER 100V 5% C0G (C4, C5)
4	RES SMT, 330-OHM 1/16W 1% 0603 (R8 - R11)
2	RES SMT, 1.0K-OHM 1/10W 1% 0805 (R1, R3)
1	RES SMT, 10K-OHM 1/10W 1% 0805 (R2)
1	RES SMT, 150K-OHM 1/10W 1% 0805 (R12)
4	RES SMT, 470-OHM 1/10W 1% 0805 (R4 - R7)
1	RES POT, 10K-OHM 1/2W THUMBWH CERM ST (POT 1)
4	LED, 565NM GREEN CLEAR 0805 T/R (D1 - D4)
1	OSC SMT, 12.000MHz CRYSTAL 18PF FUND SMD (HC49) (Y1)
1	SWITCH SMT, PUSH BUTTON SPST MOM 6MM 160GF/230GF (S1)
1	CONN SMT, RECPT, USB MINI-B 5POS RA (J1)
1	CONN, D-SUB, 9P PLUG RT ANGLE W/ JACK SCREWS (J15)
1	CONN, RECPT, 1x14 PIN 0.100" STR (J11)
2	CONN, HDR, 1x6 BREAKAWAY, 0.100" PITCH, 0.025 SQ, RA, (0.230/0.090) (J6, J13)
1	CONN, HDR, 1x2, 0.100" PITCH, 0.025 SQ POST, TIN (0.135"/0.380"), POL (J9)
1	CONN, HDR, 1x3 BREAKAWAY, 0.100" PITCH, 0.025 SQ POST, GD (0.100"/0.230") (J14)
1	SOCKET, 20P DIP 0.300W COLLET OPEN FRAME (@XU1)
1	-SPARE- LOCATION (U2, J2 - J5, J7, J8)

A.2 SCHEMATICS

FIGURE A-2: PICkit™ 2 USB DEVELOPMENT SCHEMATIC

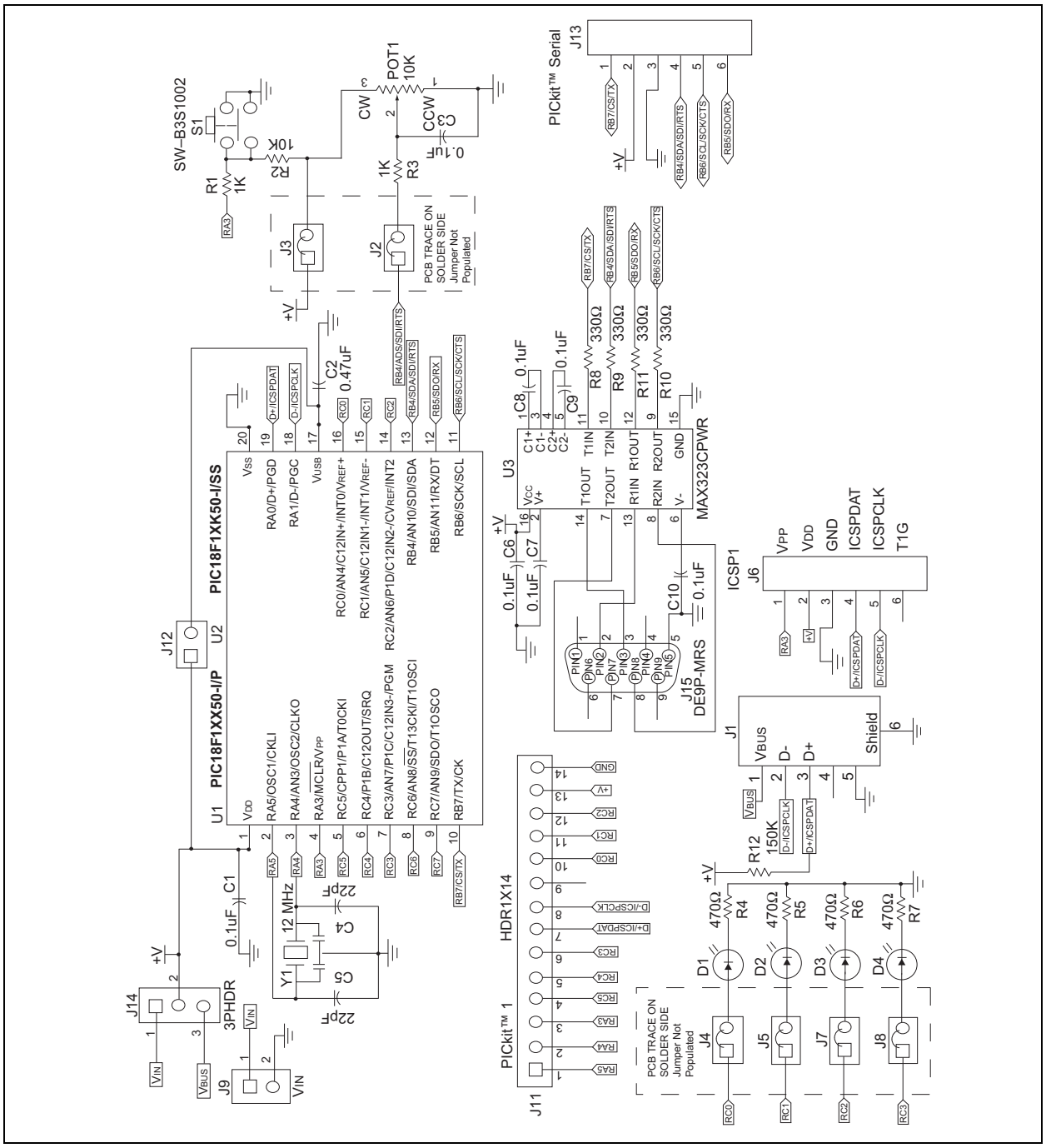
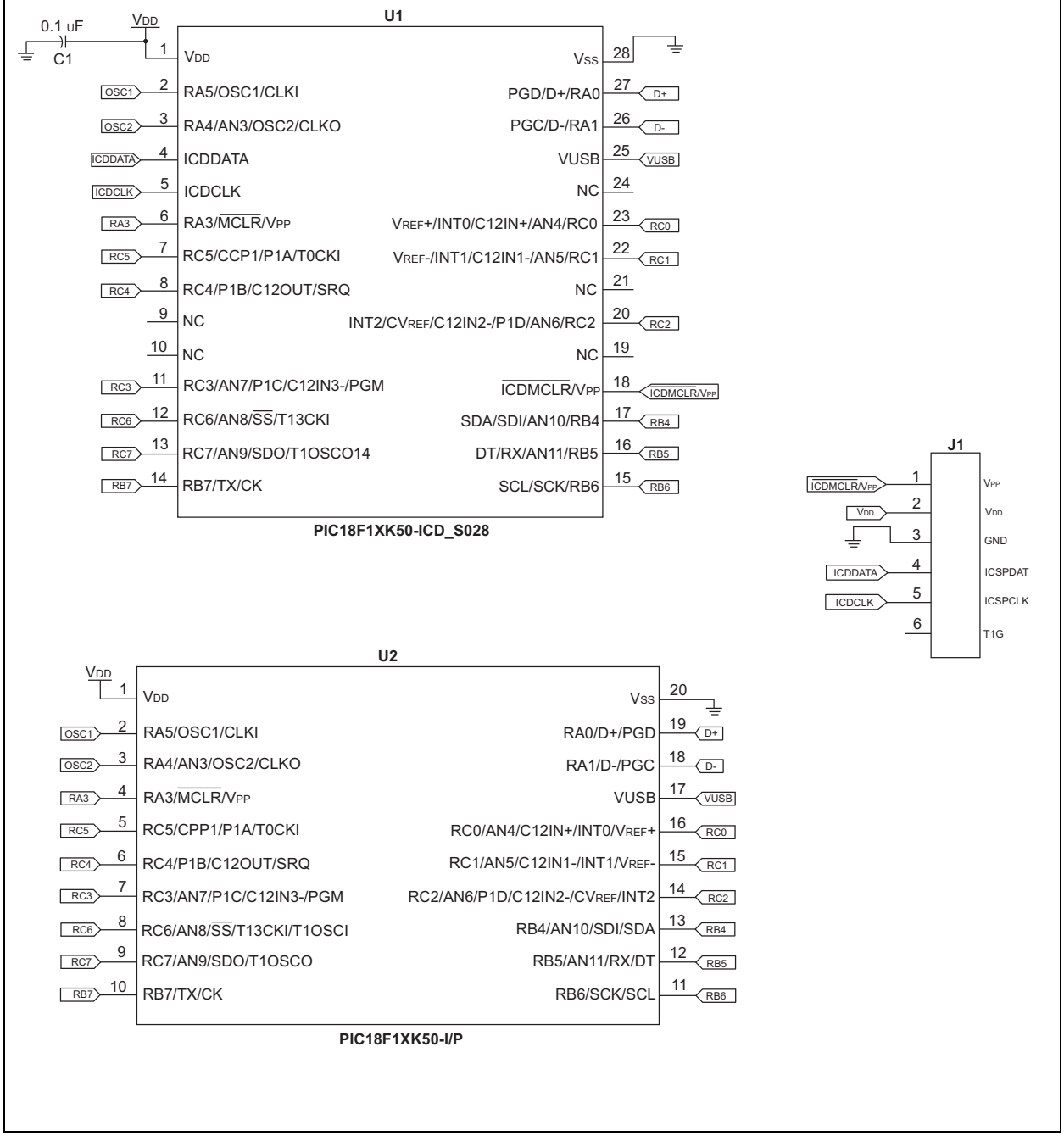


FIGURE A-3: PICkit™ 2 DEBUG HEADER



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