PICkit™ 1 FLASH Starter Kit User's Guide

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Table of Contents

NOTES:

Preface

INTRODUCTION

This chapter contains general information about this user's guide and customer support that will be useful prior to using the PICkit™ 1 FLASH Starter Kit.

HIGHLIGHTS

Items discussed in this chapter are:

- About this Guide
- Warranty Registration
- Recommended Reading
- Troubleshooting
- Microchip On-Line Support
- Customer Change Notification Service
- Customer Support

ABOUT THIS GUIDE

This document describes how to use the PICkit 1 FLASH Starter Kit. The manual layout is as follows:

- **Chapter 1: Using the PICkit 1 FLASH Starter Kit** – An overview of the PICkit 1 FLASH Starter Kit and instructions on how to use it.
- **Chapter 2: Tutorial Projects** – Tutorials that describe the different concepts in controlling the PIC microcontroller.
- **Chapter 3: Loading Projects in MPLAB IDE** – A quick overview on how to load a project in MPLAB IDE.
- **Chapter 4: PICkit 1 FLASH Starter Kit Hardware** – Instructions on Programming the PICkit 1 FLASH Starter Kit Hardware.
- **Chapter 5: Troubleshooting** – Provides resolutions for solving common problems with the PICkit 1 FLASH Starter Kit.
- **Appendix A: Hardware Schematics** – Illustrates the PICkit 1 hardware schematic diagrams.
- **Glossary** – A glossary of terms used in this guide.
- **Index** – Cross-reference listing of terms, features and sections of this document.
- **Worldwide Sales and Service** – A listing of Microchip sales and service locations and telephone numbers worldwide.

Conventions Used in This Guide

This manual uses the following documentation conventions:

Table: Documentation Conventions

Description	Represents	Examples
Code (Courier font):		
Plain characters	Sample code Filenames and paths	`#define START` `c:\autoexec.bat`
Angle brackets: < >	Variables	`<label>, <exp>`
Square brackets [ ]	Optional arguments	`MPASMWIN [main.asm]`
Curly brackets and pipe character: { | }	Choice of mutually exclusive arguments; An OR selection	`errorlevel {0|1}`
Lower case characters in quotes	Type of data	`"filename"`
Ellipses...	Used to imply (but not show) additional text that is not relevant to the example	`list ["list_option...,` `"list_option"]`
0xnnn	A hexadecimal number where n is a hexadecimal digit	`0xFFFF, 0x007A`
Italic characters	A variable argument; it can be either a type of data (in lower case characters) or a specific example (in upper case characters).	`char isascii (char,` *`ch`*`);`
Interface (Arial font):		
Underlined, italic text with right arrow	A menu selection from the menu bar	<u>*File > Save*</u>
Bold characters	A window or dialog button to click	**OK**, **Cancel**
Characters in angle brackets < >	A key on the keyboard	<Tab>, <Ctrl-C>
Documents (Arial font):		
Italic characters	Referenced books	*MPLAB IDE User’s Guide*

Documentation Updates

All documentation becomes dated, and this user’s guide is no exception. Since the PICkit 1 FLASH Starter Kit *User’s Guide* and other Microchip tools are constantly evolving to meet customer needs, some PICkit 1 FLASH Starter Kit actual dialogs and/or tool descriptions may differ from those in this document. Please refer to our web site to obtain the latest documentation available.

Documentation Numbering Conventions

Documents are numbered with a “DS” number. The 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	=	The document number.
A	=	The revision level of the document.

WARRANTY REGISTRATION

Please complete the enclosed Warranty Registration Card and mail it promptly. Sending in your Warranty Registration Card entitles you to receive new product updates. Interim software releases are available at the Microchip web site.

RECOMMENDED READING

This user's guide describes how to use the PICkit 1 FLASH Starter Kit. Other useful documents are listed below:

PIC12F629/675 Data Sheet (DS41190)

Consult this document for information regarding the PIC12F629/675 8-pin FLASH based 8-bit CMOS Microcontroller device specifications.

PIC16F630/676 Data Sheet (DS40039)

Consult this document for information regarding the PIC16F630/676 14-pin FLASH based 8-bit CMOS Microcontroller device specifications.

MPLAB IDE User's Guide (DS51025)

Consult this document for more information pertaining to the installation and features of the MPLAB Integrated Development Environment (IDE) Software.

To obtain these documents, contact the nearest Microchip sales location (see back page). These documents are also available on the Microchip web site at: www.microchip.com.

Microsoft® Windows® Manuals

This manual assumes that users are familiar with the Microsoft Windows operating system. Many excellent references exist for this software program, and should be consulted for general operation of Windows.

TROUBLESHOOTING

See Chapter 5 for information on common problems.

MICROCHIP ON-LINE SUPPORT

Microchip provides on-line support on the Microchip web site at:

http://www.microchip.com

A file transfer site is also available by using an FTP service connecting to:

ftp://ftp.microchip.com

The web site and file transfer site provide a variety of services. Users may download files for the latest development tools, data sheets, application notes, user' guides, articles and sample programs. A variety of Microchip specific business information is also available, including listings of Microchip sales offices and distributors. Other information available on the web site includes:

- Latest Microchip press releases
- Technical support section with FAQs
- Design tips
- Device errata
- Job postings
- Microchip consultant program member listing
- Links to other useful web sites related to Microchip products
- Conferences for products, development systems, technical information and more
- Listing of seminars and events

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The Development Systems product group categories are:

- Compilers
- Emulators
- In-Circuit Debuggers
- MPLAB IDE
- Programmers

Here is a description of these categories:

Compilers – The latest information on Microchip C compilers and other language tools. These include the MPLAB C17, MPLAB C18 and MPLAB C30 C Compilers; MPASM and MPLAB ASM30 assemblers; MPLINK and MPLAB LINK30 linkers; and MPLIB and MPLAB LIB30 librarians.

Emulators – The latest information on Microchip in-circuit emulators. This includes the MPLAB ICE 2000 and MPLAB ICE 4000.

In-Circuit Debuggers – The latest information on Microchip in-circuit debuggers. These include the MPLAB ICD and MPLAB ICD 2.

MPLAB – The latest information on Microchip MPLAB IDE, the Windows Integrated Development Environment for development systems tools. This list is focused on the MPLAB IDE, MPLAB SIM simulator, MPLAB IDE Project Manager and general editing and debugging features.

Programmers – The latest information on Microchip device programmers. These include the PRO MATE® II device programmer and PICSTART® Plus development programmer.

CUSTOMER SUPPORT

Users of Microchip products can receive assistance through several channels:

- Distributors
- Local Sales Office
- Field Application Engineers (FAEs)
- Corporate Applications Engineers (CAEs)
- Systems Information and Upgrade Hot Line

Customers should call their distributor or field application engineer (FAE) for support. Local sales offices are also available to help customers. See the last page of this document for a listing of sales offices and locations.

Corporate applications engineers (CAEs) may be contacted at (480) 792-7627.

Systems Information and Upgrade Line

The Systems Information and Upgrade Information Line provides system users with a listing of the latest versions of all of Microchip's development systems software products. Plus, this line provides information on how customers can receive the most current upgrade kits. The Information Line Numbers are:

1-800-755-2345 for U.S. and most of Canada.
1-480-792-7302 for the rest of the world.

Chapter 1. Using the PICkit™ 1 FLASH Starter Kit

1.1 INTRODUCTION

The PICkit 1 FLASH Starter Kit serves as a development and evaluation tool for the 8/14-pin FLASH PIC® microcontroller devices.

1.2 HIGHLIGHTS

This chapter discusses:

- The PICkit 1 FLASH Starter Kit Contents
- Running the PICkit 1 FLASH Starter Kit Default Demonstration
- Pre-loaded HEX files
- Using the PICkit 1 FLASH Starter Kit Programming Software

1.3 PICkit 1 FLASH STARTER KIT CONTENTS

The PICkit 1 FLASH Starter Kit contains the following items:

1. The PICkit 1 FLASH Starter Kit Printed Circuit Board (PCB)
2. USB cable
3. PICkit 1 FLASH Starter Kit CD-ROM
4. MPLAB® IDE CD-ROM
5. Microchip Tips n' Tricks booklet
6. PICkit 1 FLASH Starter Kit USB Installation for Windows® 98 Second Edition

Use the Quick Start Guide to install the PICkit 1 FLASH Starter Kit and MPLAB IDE software.

1.4 RUNNING THE PICkit 1 FLASH STARTER KIT DEFAULT DEMONSTRATION

Connect the PICkit 1 FLASH Starter Kit board to the PC's USB port using the USB cable. The pre-loaded demonstration program is displayed on the board.

The demo program will blink the eight red lights in succession. Press the button (labeled SW1) on the board and the sequence of the lights will change. If the variable resistor (labeled RP1) is turned, the light sequence will blink at a different rate.

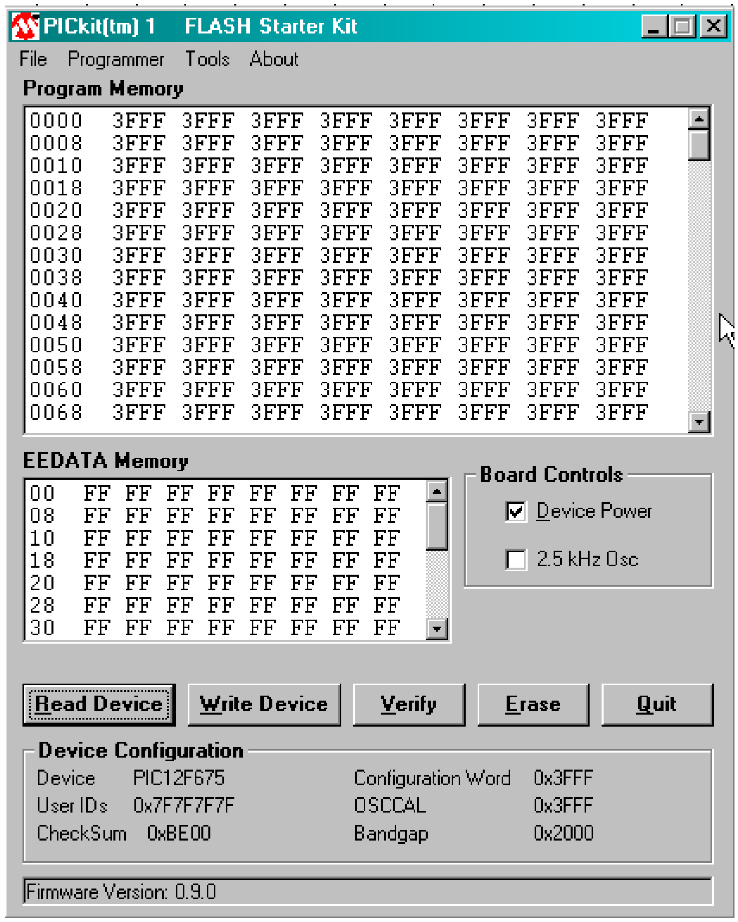
1.5 HEX FILES

The PICkit 1 FLASH Starter Kit CD-ROM includes tutorial HEX files and source code to use in conjunction with the program tutorials in Chapter 2. The HEX files are a binary form of instructions executed on the PIC microcontroller. They are generated when the source files are built in MPLAB IDE.

1.6 USING THE PICkit 1 FLASH STARTER KIT PROGRAMMING INTERFACE

Execute the software by selecting *Start > Programs > PICkit(tm) 1 FLASH Starter Kit*. The programming interface appears, as shown in Figure 1-1.

FIGURE 1-1: PICkit 1 FLASH STARTER KIT PROGRAMMING INTERFACE



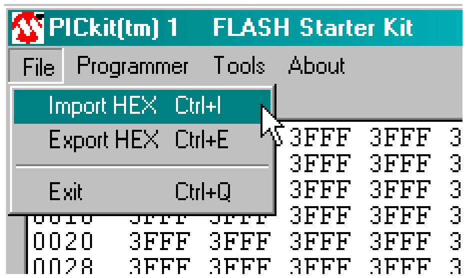
Notice that the Device Power check box is selected. This is a default function indicating the device power is turned on.

Note:	To turn the device power off, deselect the check box.

1.6.1 Download Project from MPLAB

To download a compiled program to the PICkit 1 FLASH Starter Kit, select *File > Import HEX*, as shown in Figure 1-2. Browse for the HEX file and click **Open**.

FIGURE 1-2: IMPORT HEX FILE

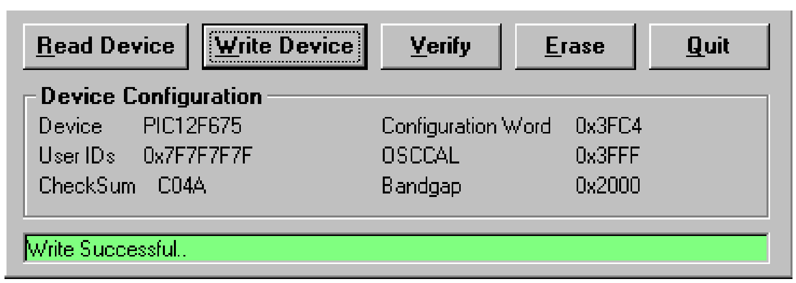


The code is displayed in the Program Memory and EEDATA Memory windows. (For more information on Program and EEDATA memory, see Tutorial 5, Chapter 2.7 and Tutorial 6, Chapter 2.8.)

After the HEX file is imported, write the program to the device by clicking the **Write Device** button. The existing program will be erased and replaced with the new one. The status of the program write is displayed in the status bar located at the bottom of the interface window.

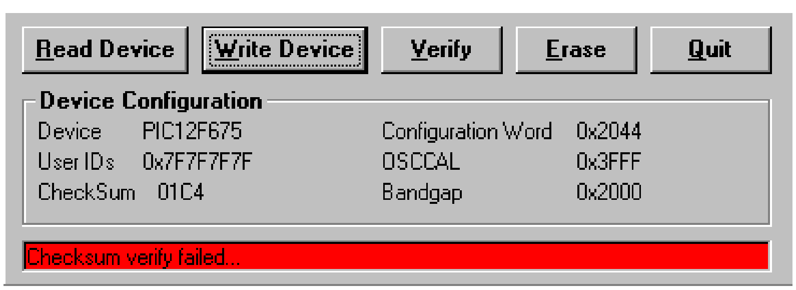
If the write is successful, the status bar turns green and displays “write successful”, as shown in Figure 1-3.

FIGURE 1-3: WRITE SUCCESSFUL STATUS BAR



If the write fails, the status bar turns red and displays “checksum verify failed”, as shown in Figure 1-4. This error indicates the data was corrupted during the programming sequence. If this error is displayed, write the program to the device again. If this error continues, see Chapter 5 for troubleshooting.

FIGURE 1-4: WRITE ERROR STATUS BAR



1.6.2 Automatic File Reload

Prior to each write, the time stamp is compared to the version on the disk. If the version on the disk is newer, it is reloaded. This occurs only when a HEX file has been read from the disk.

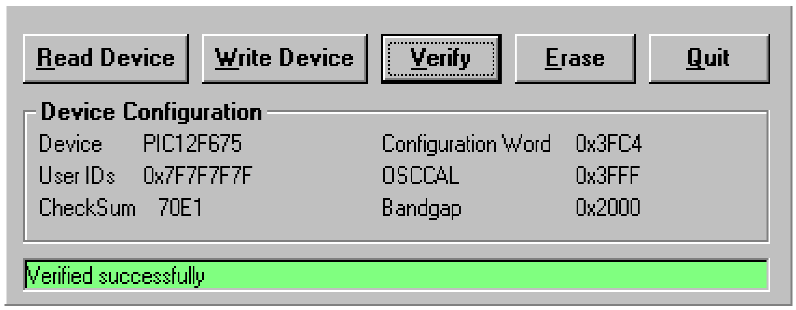
In the normal mode of operation, the HEX file is updated with every build in MPLAB IDE. This ensures that the latest version built by MPLAB IDE will be written to the device.

1.6.3 Verify Program Code

This function verifies the program written to the device against a HEX file. It compares all areas of memory including Program, EEDATA and Configuration.

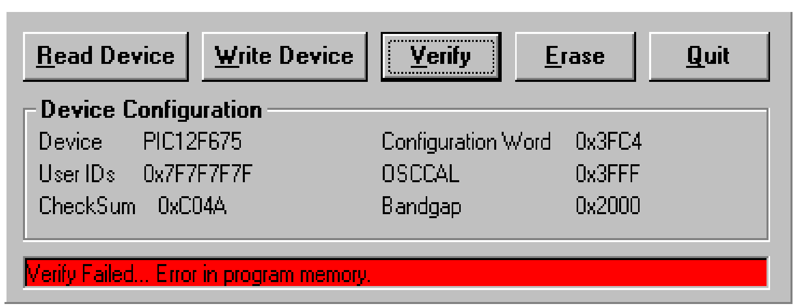
To verify the code, import the HEX file and click **Verify**. If the code is the same, the status bar turns green and displays "Verified successfully", as shown in Figure 1-5.

FIGURE 1-5: CODE VERIFY STATUS BAR



If a discrepancy is found, the status bar turns red and displays the error "Verify Failed... Error in program memory.", as shown in Figure 1-6.

FIGURE 1-6: CODE ERROR STATUS BAR



1.6.4 Read Device

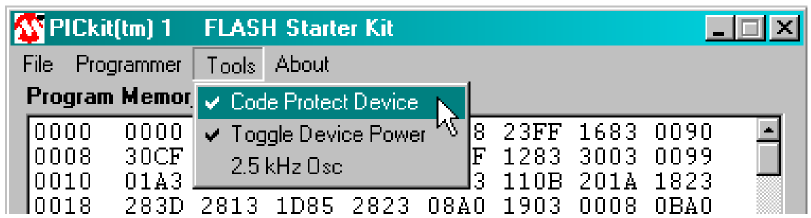
To view the code written to the device, click **Read Device**. The code is displayed in the Program and EEDATA Memory windows for your review.

1.6.5 Code Protect

This function enables the code protection features of the device. To protect the code, complete the following steps:

1. Import the HEX file.
2. Select *Tools > Code Protect Device*, as shown in Figure 1-7.
3. Click **Write Device**.

FIGURE 1-7: CODE PROTECT



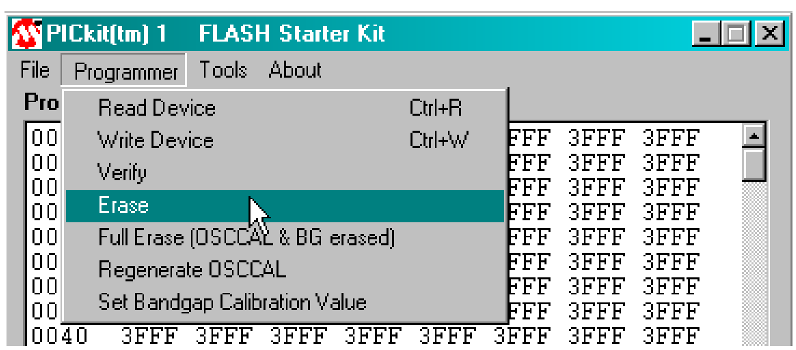
> **Note:** If the device is read after it has been code protected, the Program and EEDATA Memory windows will display all zeros.

1.6.6 Erase

The Erase function erases code from the device. However, this function is not normally needed since the Write Device function performs an erase prior to writing code to the device.

To erase the device using the Erase function, click the **Erase** button, or select *Programmer > Erase* from the toolbar menu, as shown in Figure 1-8.

FIGURE 1-8: DEVICE ERASE



1.6.6.1 FULL ERASE

Unlike the Erase function, the Full Erase allows the user to erase not only the device, but the OSCCAL and Bandgap Calibration as well. Performing a full erase is not recommended or needed in the normal course of events. Only use this function if the OSCCAL or Bandgap data has been corrupted.

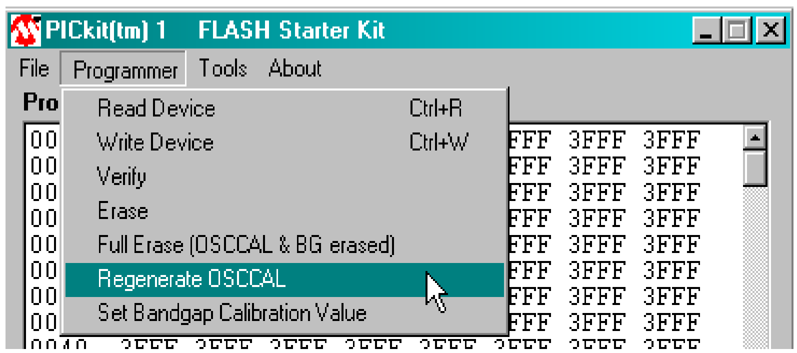
To perform a full erase, select _Programmer > Full Erase (OSCCAL & BG erased)_ from the toolbar menu, as shown in Figure 1-8.

Once the full erase is complete, regenerate the OSCCAL and reset the Bandgap Calibration Value bits.

> **Note:** The Regenerate OSCCAL function runs a program on the device to recalculate the oscillator calibration value. See Tutorial 7, Chapter 2.9, for more details.

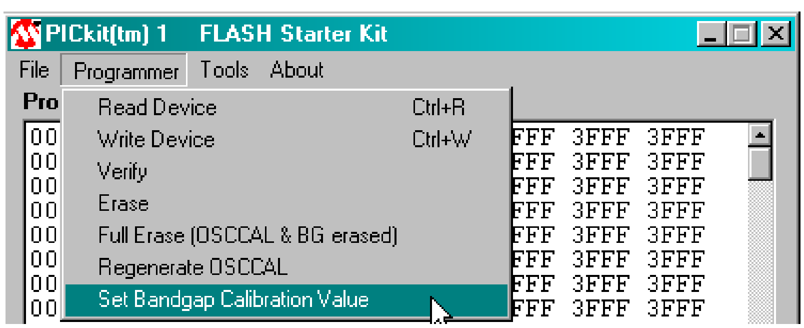
To regenerate the OSCCAL, select _Programmer > Regenerate OSCCAL_ from the toolbar menu, as shown in Figure 1-9.

FIGURE 1-9: REGENERATE OSCCAL



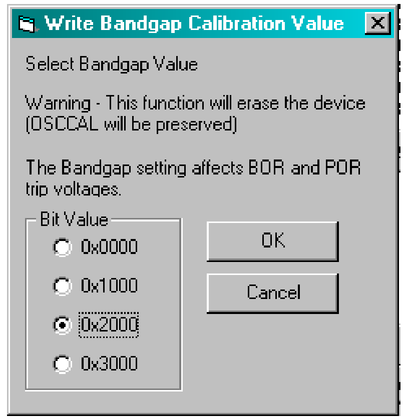
To set the Bandgap Calibration Value, select _Programmer > Set Bandgap Calibration Value_ from the toolbar menu, as shown in Figure 1-10.

FIGURE 1-10: REGENERATE BANDGAP CALIBRATION VALUE



The Write Bandgap Calibration Value window will appear as shown in Figure 1-11. Select a bit value from the list and click **OK**.

FIGURE 1-11: SELECT BANDGAP BIT VALUE



The Bandgap bit value will appear in the Device Configuration box, as shown in Figure 1-12.

FIGURE 1-12: DEVICE CONFIGURATION

For more information on the OSCCAL and Bandgap Calibration, see the PIC12F629/675 (DS41190) and PIC16F630/676 (DS40039) Data Sheets located on the CD or the Microchip web site (www.microchip.com).

1.6.7 2.5 kHz OSC

The 2.5 kHz OSC is a square wave signal that, when selected, is input to pin 3 of the Evaluation Socket. See Figure A-1 in the Appendix.

This function is used by Tutorial 7, Section 2.9, and for OSCCAL regeneration.

FIGURE 1-13: BOARD CONTROLS

NOTES:

Chapter 2. Tutorial Projects

2.1 INTRODUCTION

The tutorials in this chapter describe the different concepts in controlling the PIC® microcontroller. Each tutorial includes instructions for running a program demo that illustrates each of the concepts listed below in Section 2.2. It is necessary to follow the tutorials in the listed sequential order, for each tutorial builds upon the previous one. (The HEX files and source code for the tutorials can be found on the CD.)

2.2 HIGHLIGHTS

The following tutorials are discussed in this chapter:

Tutorial 1 – Switch Debouncing

Tutorial 2 – State Machines

Tutorial 3 – Interrupts

Tutorial 4 – Analog-to-Digital Converters and Comparators

Tutorial 5 – Data Tables in Program Memory

Tutorial 6 – Using EEPROM Memory

Tutorial 7 – Frequency Counting with Timer1 Gate

2.3 TUTORIAL 1 – SWITCH DEBOUNCING

Mechanical switches play an important and extensive role in practically every computer, microprocessor and microcontroller application. Mechanical switches are inexpensive, simple and reliable. In addition, switches can be very noisy. The apparent noise is caused by the closing and opening action that seldom results in a clean electrical transition. The connection makes and breaks several, perhaps even hundreds, of times before the final switch state settles.

The problem is known as switch bounce. Some of the intermittent activity is due to the switch contacts actually bouncing off each other. Imagine slapping two billiard balls together. The hard non-resilient material doesn't absorb the kinetic energy of motion. Instead, the energy dissipates over time and friction in the bouncing action against the forces push the billiard balls together. Hard metal switch contacts react in much the same way. Also, switch contacts are not perfectly smooth. As the contacts move against each other, the imperfections and impurities on the surfaces cause the electrical connection to be interrupted. The result is switch bounce.

The consequences of uncorrected switch bounce can range from being just annoying to catastrophic. For example, imagine advancing the TV channel, but instead of getting the next channel, the selection skips one or two. This is a situation a designer should strive to avoid.

Switch bounce has been a problem even before the earliest computers. The classic solution involved filtering, such as through a resistor-capacitor circuit, or through re-settable shift registers (see Figure 2-1 and Figure 2-2). These methods are still effective but they involve additional cost in material, installation and board real estate. Why suffer the additional expense when software is free and program memory is abundant.

FIGURE 2-1: FILTERING DEBOUNCE SOLUTION

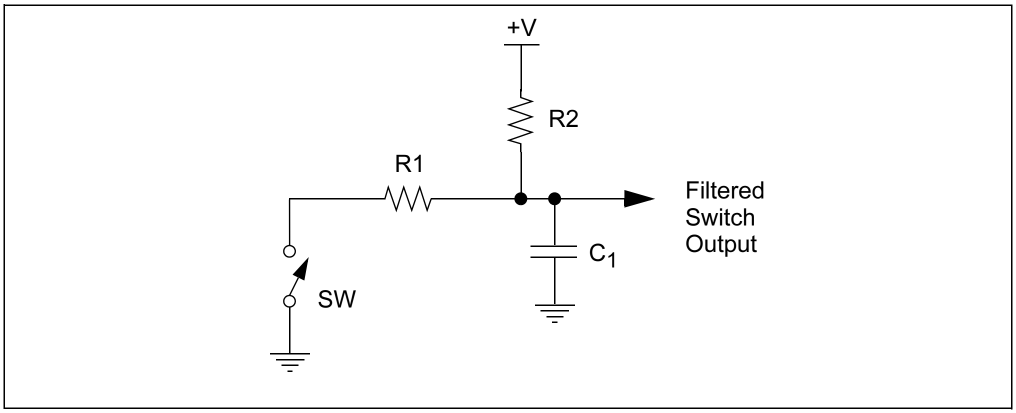
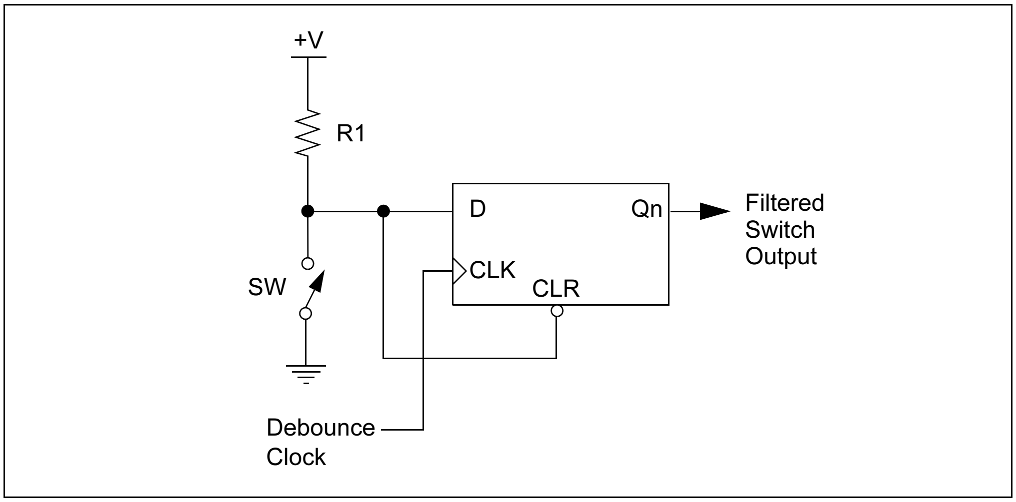


FIGURE 2-2: SHIFT REGISTER DEBOUNCE SOLUTION



2.3.1 Design

Switch bounce is intermittent contact and release of the switch contacts. Two parameters characterize switch bounce: bounce period and bounce duration.

Bounce period is the random length of time the contacts remain open, or closed, while the bounce is occurring. Bounce periods can vary anywhere from a few nanoseconds to a few milliseconds.

Bounce duration is the time from the leading edge of the first bounce period to the trailing edge of the last bounce period. The difficulty is bounce duration is indeterminate.

Bounce abatement design starts by making assumptions based on empirical data. The first assumption is bounce period will be absolutely less than 10 milliseconds. Experience dictates this is a good assumption, however, bench and field-testing are still essential to ensure the switch selected for the application does not have a longer bounce period. The second assumption is the total bounce duration is indeterminate. A good design should work regardless of how long the switch bounces provided that it eventually does stop bouncing.

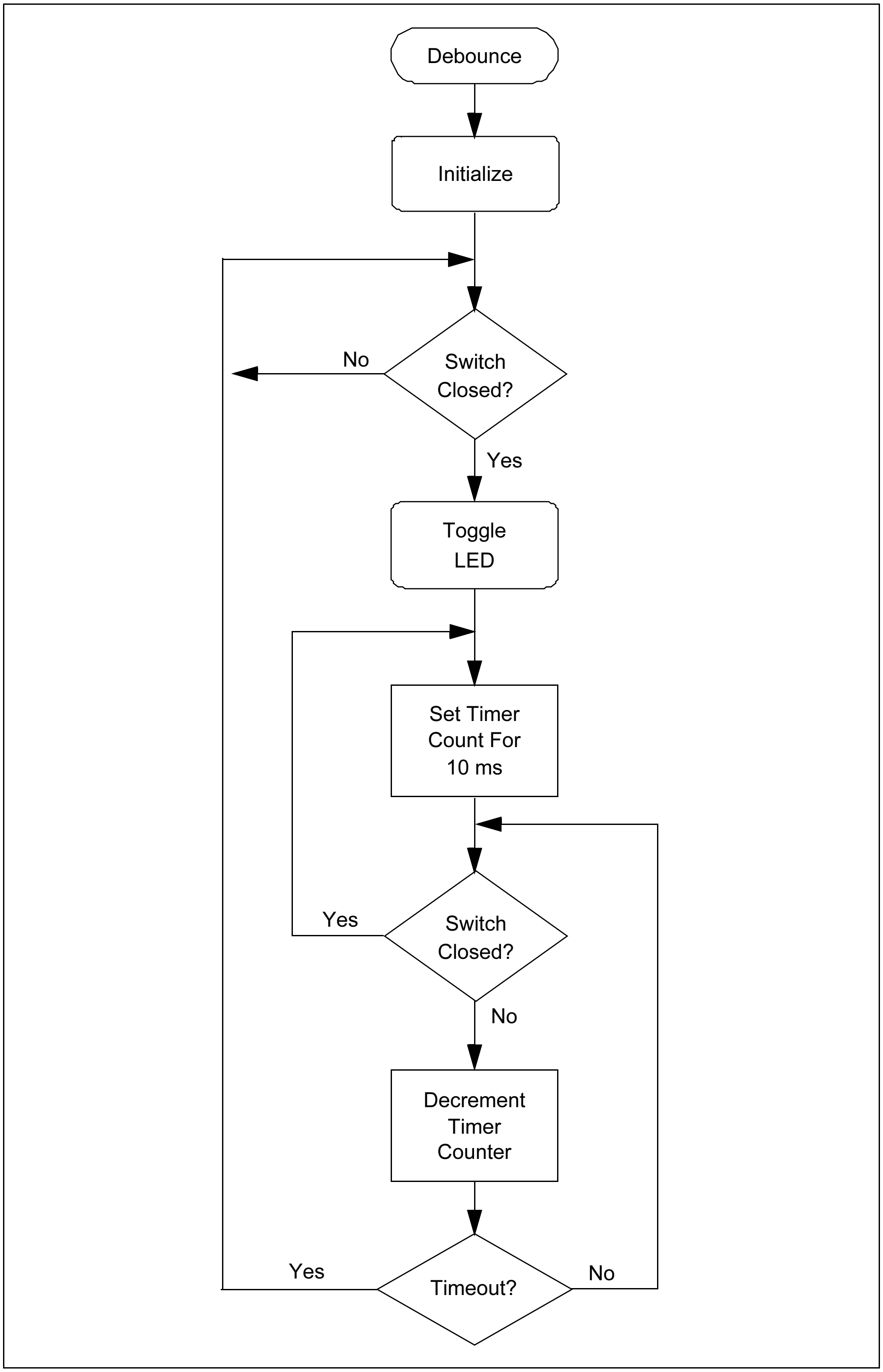
2.3.1.1 BRUTE FORCE DEBOUNCE

Consider a simple push button application. In this case, some event should occur when a button is pushed. Ideally the invoked event will occur immediately, and only once for each button push. The system should be also ready to respond to a repeat button push as soon as possible after the button is released. This presents an apparent dilemma. How is the difference between switch bounce and repeated button pushes determined?

Recall the assumption that the bounce period is less than 10 milliseconds. If the switch input level is stable for longer than 10 milliseconds, then bouncing has stopped and the input level represents the pushed or released switch state. The Brute Force method only cares about a button-push event because this is what invokes the action. It recognizes the switch release state as the stable state and everything else is considered unstable. When the switch becomes unstable, the action is invoked permitting nothing to happen until the switch returns to the released stable state.

The flowchart in Figure 2-3 outlines the software actions necessary to implement the Brute Force debounce method. Notice that the debounce loop is looking for a stable released state for 10 milliseconds before returning to the top of the main loop. Any instability, including a stable button pushed state, resets the debounce 10 millisecond timer.

FIGURE 2-3: BRUTE FORCE SWITCH DEBOUNCE



2.3.1.2 SWITCH FILTER DEBOUNCE

There are situations when both stable switch states must be recognized. It is undesirable for immediate action to occur if the switch intermittently leaves either the pushed or released state. A door open or closed sensor switch is a good example of this. If the door is closed and gets bumped, then the door-open action, such as an alarm, should not occur because the door is still closed.

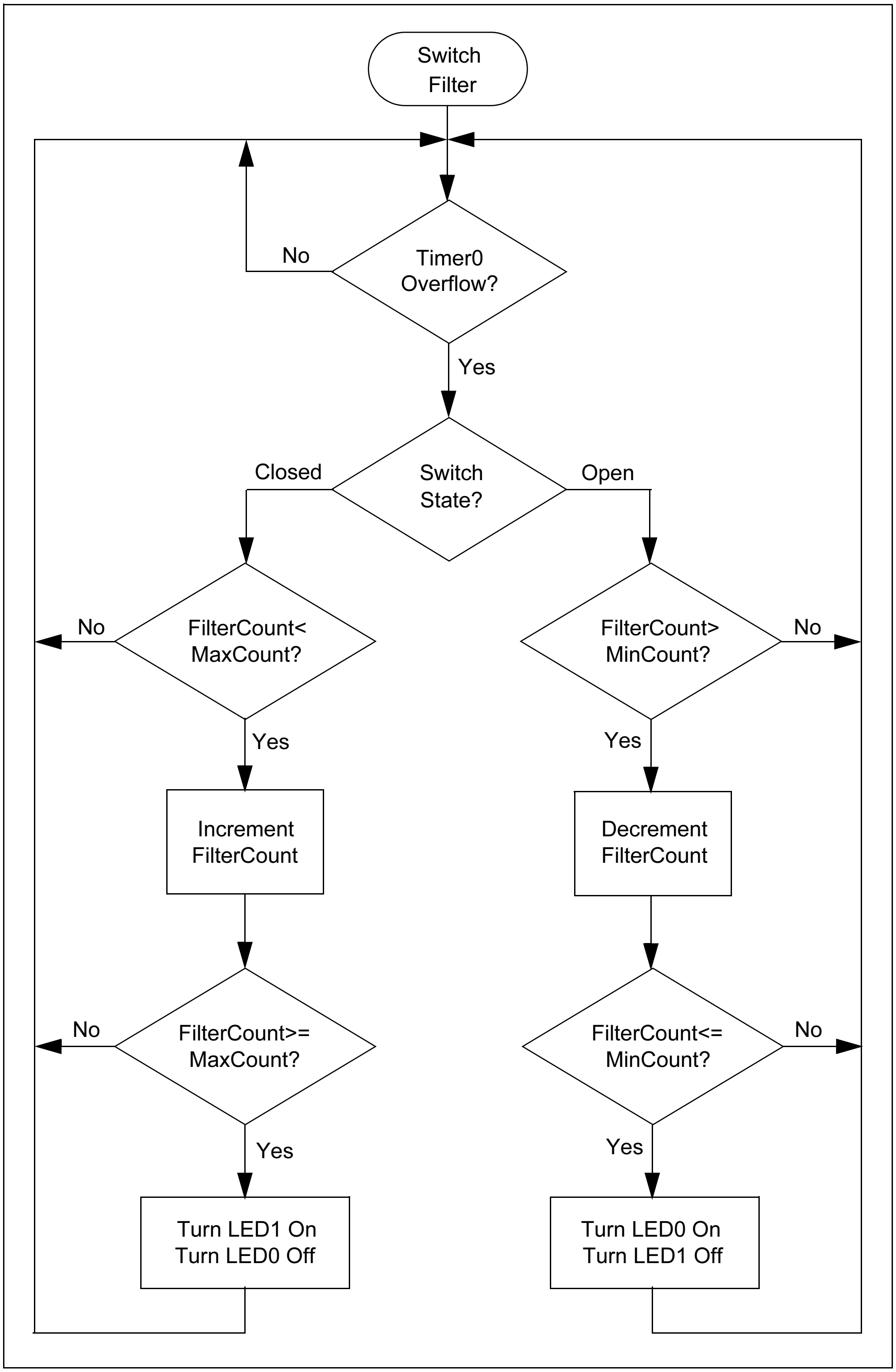
The Switch Filter debounce method delays the response to a changed switch state. Delay time can even be extended to several times the bounce period. Switch Filter debounce incorporates a saturating up/down counter. (A saturating counter is one that stops counting when the maximum, or minimum, number is reached.) The counter counts up when the switch is closed, and counts down when the switch is open. The appropriate action is invoked when the counter reaches either the full up or down count.

Hysteresis is built into the count length. Switch release or contact action is invoked only upon the first occurrence of counter saturation. The counter must saturate at the opposite state before the previous state can be re-invoked. During switch bounce, the counter intermittently counts up and down. The counter will progress up when the average closed to open period favors contact, and down when the average period favors release. The faster the switch settles in the closed or open state, the faster the counter will reach the corresponding saturated condition.

Switch Filtering assumes, when the switch is mostly closed or open, the bouncing will favor the closed or open levels respectively. It is possible for the counter to saturate before the switch has stopped bouncing. It is unlikely that the counter will change saturation state unless the count is too short, or the switch is headed in that direction.

Figure 2-4 outlines the software actions necessary to implement the Switch Filtering debounce method.

FIGURE 2-4: TIME AVERAGED SWITCH FILTER DEBOUNCE



2.3.2 Applications

Reliable, robust software requires debouncing of all mechanical switches. This includes push buttons of all types, limit switches of all types and even X*Y matrix keyboards. Matrix keyboards offer a new challenge to debouncing. Keyboards are not a single line input level but a pattern on several inputs. One pattern represents all keys released, or the stable state. All other patterns represent keys pressed, or the unstable states. Reliable keyboards can be designed by debouncing to only the stable state, but allowing new actions to occur immediately upon a change from one unstable state to another. The solution is left to the interested student.

2.3.3 Running the Demos

There are three switch debounce demos: Debounce, SwchFltr and DbncFltr. The file name suffix denotes the source code language for each demo. The suffix ".asm" denotes assembly language. The suffix ".c" denotes C language. Use the Intel 32-bit HEX file output as the input file to the PICkit 1 FLASH Starter Kit demo board. Intel HEX files are denoted by the ".hex" file suffix.

2.3.3.1 DEBOUNCE DEMO

Debounce is the Brute Force debounce demo. Each button push in this demo causes LED D0 to toggle on or off.

Perform the following steps to run the Debounce demo:

1. Connect the USB cable to the USB PC port and to the PICkit 1 FLASH Starter Kit demo board.
2. Execute the PICkit 1 FLASH Starter Kit programming software.
3. From the toolbar menu, select *File -> Import Hex*. Browse to locate the HEX file named "Debounce.hex". Select this file and click the **Open** button.

> **Note:** The Program Memory window displays the program code.

4. Click the **Write Device** button. The status of the program write is displayed in the status bar located at the bottom of the interface window.
5. To run the demo, push the **SW1** switch on the board and observe that LED D0 toggles as expected.

2.3.3.2 SWCHFLTR DEMO

SwchFltr is an abbreviation for the Switch Filter debounce demo. In this demo, LED D1 lights up when SW1 is pushed. When SW1 is released, LED D0 lights up.

Repeat steps 1 through 5 above and load the SwchFltr.hex file to run this demo.

2.3.3.3 DBNCFLTR DEMO

DbncFltr is an abbreviation for Debounce Filter. This demo is a combination of the Debounce and Switch Filter demos. DbncFltr also demonstrates timed expansion of switch functions. This demo initializes in the Switch Filter mode. Holding the button down for more than 1 second, while in the Switch Filter mode, causes the demo to change to the Brute Force method. LED D0 will light as an indication of the change. Holding the button down for more than 1 second, while in the Brute Force mode, causes the demo to change to the Switch Filter method. LED D1 will light as an indication of the change.

Repeat steps 1 through 5 above and load the DbncFltr.hex file to run this demo.

2.4 TUTORIAL 2 – INTRODUCTION TO STATE MACHINES

State Machines are an integral part of software programming. State machines make code more efficient, easier to debug and help organize the program flow. State machines are not limited to just firmware, they can be used to streamline any system. However, this document limits the scope of state machines to microcontroller firmware.

2.4.1 Design

2.4.1.1 WHAT IS A STATE MACHINE

A Finite State Machine (FSM) is based on the idea of there being finite number of states for a given system. For instance, when an application turns an LED on and off, two states exist; one state is when the LED is on and the other is when it is off. The example firmware that this document refers to turns on eight LEDs sequentially. Only one LED is on at a time, therefore eight states exist. Each state consists of one LED being turned on while all the rest are off.

State machines require a State Variable (SV). The SV is essentially a pointer that keeps track of the state that the microcontroller is in, and directs the program flow to the corresponding software module. The SV can be modified in the software modules (or states) themselves or by an outside function. The example firmware uses an outside function which detects a button press to advance through the states.

2.4.1.2 BENEFITS OF STATE MACHINES

The introduction briefly mentioned some advantages of state machines. These advantages are worth studying in greater detail because they are what make programming with state machines so rewarding and beneficial to firmware developers.

The first advantage is using state machines inherently promotes good firmware design techniques. When beginning to implement an application, think about what states are necessary to make the application work. List all the pieces, or states, of an application and then explore how they tie to one another. This will help prevent developing bugs in the code. This line of thinking also leads to the development of a very useful engineering tool – the flow chart. The following paragraph covers state machine development in greater detail.

State machines have one characteristic that cause them to be very beneficial. They always return to one spot (or jump station) in the code at which the program flow is channeled, by the state variable, to the corresponding software module. This provides several advantages. First, this characteristic makes calling repetitive tasks on a regular basis quite simple. Clearing the watchdog timer, checking for I/O button presses or communicating with a host that requires periodic communication are examples of repetitive tasks. The alternative to using state machines is to use looping code. In order for looping code to handle repetitive tasks, the functions that handle these tasks must be distributed throughout the code in each of the loops. This is not only highly inefficient but also confusing to understand. Figure 2-5 shows a block diagram of what the example code would look like if a state machine where not used. Compared to Figure 2-6, which shows a block diagram of state machine based code, it is clear that using a state machine cuts down on code space and the likelihood of missing a repetitive task call.

FIGURE 2-5: STATE MACHINE NOT USED

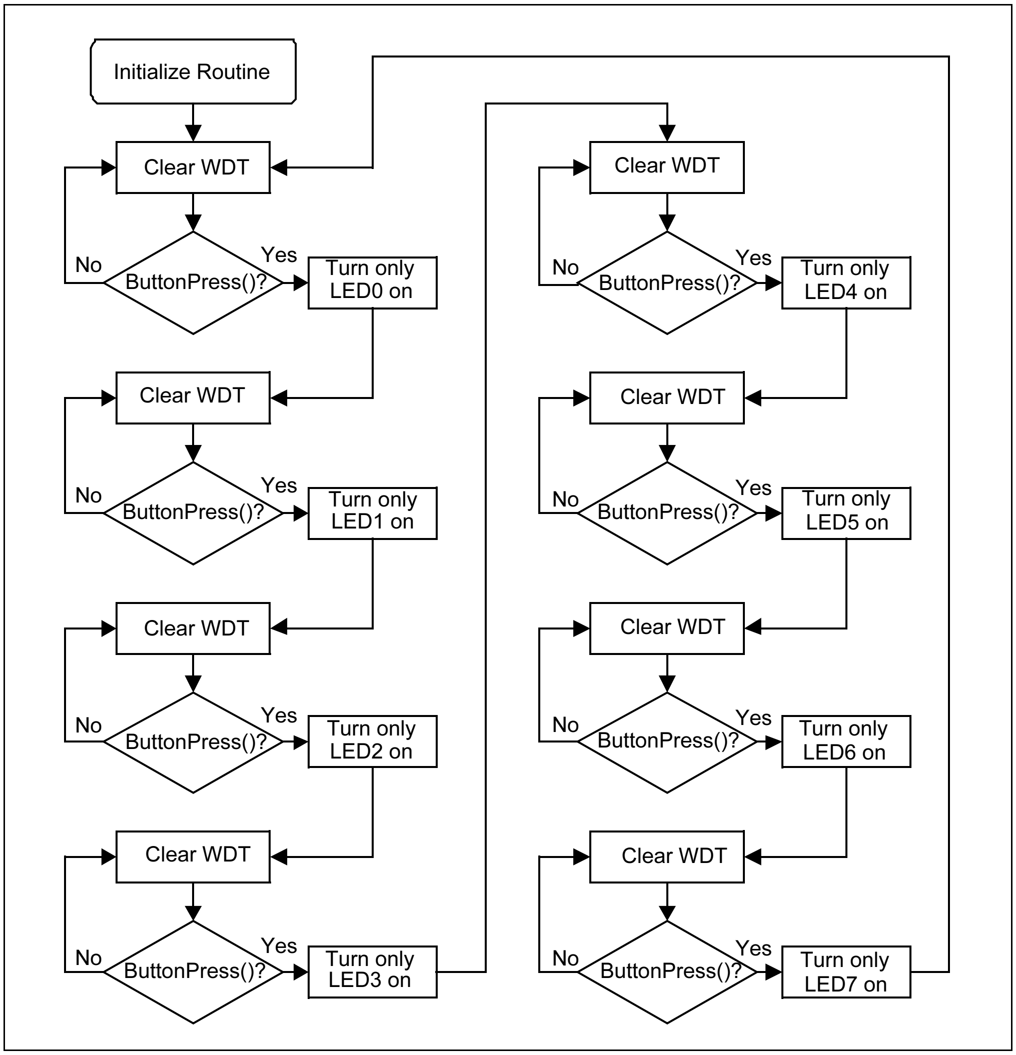
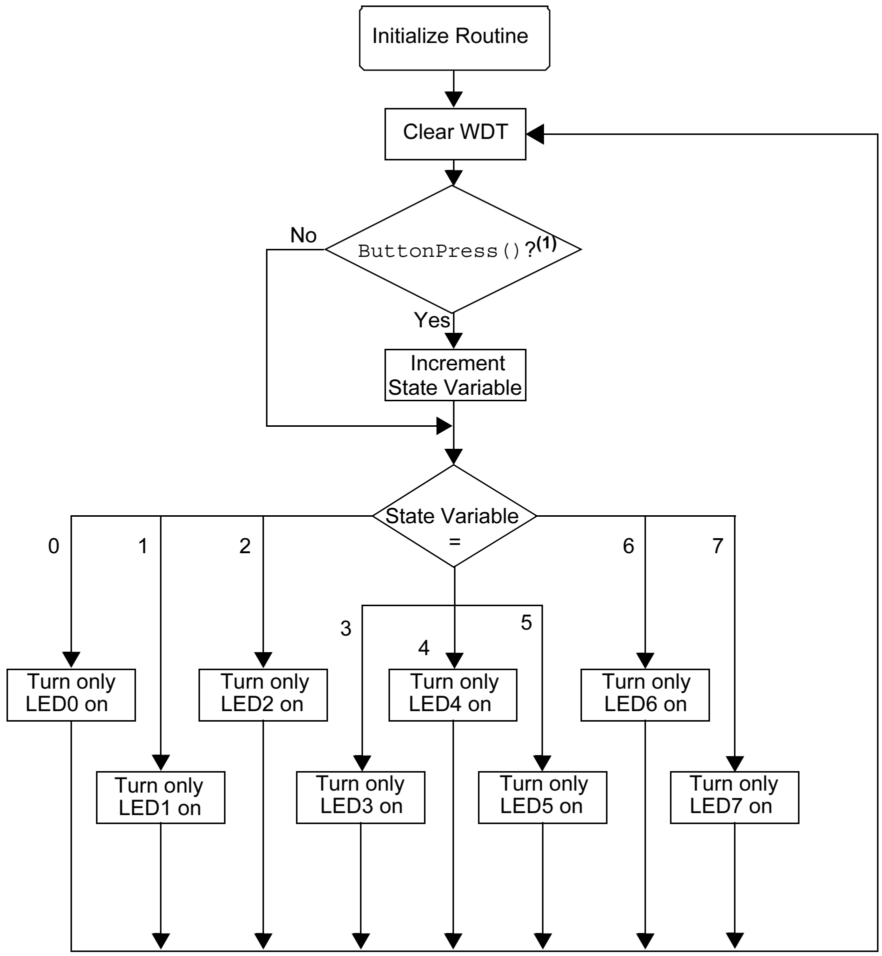


FIGURE 2-6: STATE MACHINE BASED CODE



Note 1: `ButtonPress()` detects when Switch 1 is pressed. This function also implements a debounce routine not shown. See Section 2.4.2 "Implementation" for details.

The fact that the state machine based firmware always returns to the same point in the code also makes the firmware easier to debug. When a bug is encountered, set a break point at the jump station. Then, step through the program state by state until the bug is found. An example of a bug would be the SV being modified incorrectly in one of the states. If this happens, the wrong state will be called the next time the program flow returns to the jump station. However, because the SV is being monitored, it will be very easy to see when an unintentional change is made to the SV and in which state the SV was incorrectly modified.

Note:	MPLAB IDE contains a built-in simulator. See the *MPLAB IDE v6.xx Quick Start Guide* available on the MPLAB IDE CD-ROM included with the PICkit 1 FLASH Starter Kit

Another benefit of state machines is firmware that incorporates state machines naturally promotes modular code. Modular code has its own list of benefits:

1. Upgrades and special features can be easily added to the code in later revisions or as a product evolves.
2. Modules can be cut and pasted into other applications quickly and easily.
3. Other developers will be able to understand the code in order to support it. The jump station, if commented well, can be an index to each of the software modules.

2.4.2 Implementation

2.4.2.1 GENERAL THOUGHT PROCESS

When implementing a FSM, first brainstorm all the states needed to complete a particular application. Once this is done, identify the first state. Next, the following question should be answered: “What needs to happen to exit this state, and what state will it exit to?” Usually there is more than one answer to this question. Depending on what happens while in a particular state, the state machine may advance a state, decrement a state or skip several states entirely. As mentioned before, it is generally a good idea to visually construct the state machine in the form of a flowchart. Finally, create a software module for each of the states and tie them together according to the flowchart just created.

2.4.2.2 TRANSLATING STATE MACHINES INTO ASSEMBLY AND C

Implementing a state machine in C is quite simple to visualize. C based state machines rely on the "switch" statement. The following example code shows a "switch" statement being used as a state machine.

EXAMPLE 2-1: SWITCH STATEMENT

```
switch (STATE) {
       case (State0):
              // turn LED0 on
              break;
       case (State1):
              // turn LED1 on
              break;
       case (State2);
              // turn LED2 on
              break;
       ... and so on
       default:
              STATE = State0  // if for some reason a undefined
              state occurs,
              // re-initialize the state machine
 }
```

Creating a state machine in assembly is a little more difficult. In assembly, the program flow is directed to the appropriate software module for a given state by incrementing the Program Counter by the state variable. Incrementing the Program Counter is comprised of incrementing PCL and PCLATH (when PCL overflows.) If a provision of increment PCLATH is not included, then there is a risk of jumping to the wrong spot in the program if PCL overflows. Immediately following the increment routine is a list of "`goto`" statements that direct the program flow to one of the states. This method is called a "computed `goto`". The following example code shows how to use a computed `goto` for a state machine.

EXAMPLE 2-2: COMPUTED GOTO

```
Initialize
   clrf       STATE             ;initialize state machine
   . . .

Main
   call       StateMachine
   . . .
   goto       Main

StateMachine
   movlw      high StateTable   ;set high order byte of program
   movwf      PCLATH            ;  counter appropriately
   movf       STATE, W          ;mask state variable to keep
   andlw      03h               ;  things under control
   addlw      low StateTable    ;add state variable to ROM address
   btfsc      STATUS C          ;  beginning State Table
   incf       PCLATH, F         ;overflows? yes, increment PCLATH
   movwf      PCL               ;move computed goto value into PC

StateTable
   goto       State0
   goto       State1
   goto       State2
   goto       State3

State0
   . . .
   incf       STATE, F          ;goto the next state
   return

State1
   . . .
   return
```

2.4.3 Implementing this Demo

The flowchart for this demo is shown in Figure 2-6. However, the flowchart does not show the debounce routine implemented in `ButtonPress()`. The debounce routine is based on the Brute Force Debounce (described in Tutorial 1, Section 2.3) with one slight modification, the debounce routine is implemented as a state machine. The Debounce state machine differs from the LED state machine where the states themselves modify the state variable. Implementing the debounce routine as a state machine is easier to understand than implementing it as looping code.

2.4.3.1 APPLICATIONS

As mentioned earlier in Section 2.4.1.2, state machines are useful in nearly every application. The LED library, in subsequent tutorials, utilizes state machines to light the LED similarly to the state machine implemented in this tutorial. State machines are useful for bit banging any number of communication protocols, receiving RF transmissions, controlling the speed of a motor – the list goes on and on. Understanding the states necessary to make the application work is a good way to begin implementing an application.

2.4.3.2 RUNNING THE DEMO

1. Program the state.hex code into the PIC12F629 PIC microcontroller using the PICkit 1 FLASH Starter Kit board and programming interface.
2. If the part is programmed successfully, The D0 LED will light up. Press the SW1 switch, located on the board, to sequence through the state machine. The D1 LED will light up, then the D2 and so on.

2.4.3.3 FILES REQUIRED FOR PROGRAM MODIFICATION

Assembly

- state.asm

HI-TECH C

- state.c
- state.h

2.5 TUTORIAL 3 – INTERRUPTS

This program demonstrates how to use the Timer0 and pin change interrupts onboard the PIC12F6XX. In addition, the program illustrates how the PIC12F6XX is multiplexing the LED's fast enough to give the visual representation that the LED's are all on at the same time when in fact the LED's are lit individually. Finally, this program uses the interrupt on-pin change to detect and debounce a button push which changes the rate at which the LED's are flashed.

This tutorial covers the following topics:

- How to flash LED's on the PICkit 1 FLASH Starter Kit board
- How to use Timer0 and pin change interrupts on the PIC12F6XX
- How to turn a source code file into a library file for easy reuse
- Useful applications that can use the concepts presented in this tutorial
- Files needed to customize the source code for the application

2.5.1 Design

One of the challenges of using an 8-pin PIC microcontroller is having enough pins for a robust application. The PICkit 1 FLASH Starter Kit utilizes design tips and tricks to get the most out of the 8/14-pin PIC microcontroller devices. In particular, a 12-LED array is implemented on the PICkit 1 FLASH Starter Kit by using only 4 pins. In this tutorial, only 8 LED's are implemented. See Table 2-1 for LED multiplexing. Also, see “TIP #2 Input/Output Multiplexing”, in the Microchip Tips 'n Tricks booklet for more details on LED multiplexing.

TABLE 2-1: LED MULTIPLEXING TRUTH TABLE

PIN	D0	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11
GP4	HI	LOW	HI	LOW	Z	Z	Z	Z	Z	Z	HI	LOW
GP5	LOW	HI	Z	Z	HI	LOW	Z	Z	HI	LOW	Z	Z
GP2	Z	Z	LOW	HI	LOW	HI	HI	LOW	Z	Z	Z	Z
GP1	Z	Z	Z	Z	Z	Z	LOW	HI	LOW	HI	LOW	HI

Legend: HI => Logic 1, LOW => Logic 0 and Z => TRISIO = 1

2.5.2 Implementation

The tutorial utilizes interrupts to make the LED operation transparent to the main program. The main program writes the value 0xFF to the LEDREGISTER. This flashes 8 LED's on the PICkit 1 FLASH Starter Kit board. In order to flash 4 LED's, for example, write 0x0F into the LEDREGISTER. The interrupt service routine uses a Timer0 interrupt for updating the LED array. A GP3 pin change interrupt detects a button push. The Timer0 prescaler is adjusted and changes the amount of time it takes for a Timer0 interrupt to happen. This gives the visual representation that the LED's are all on at the same time, or sequencing.

This tutorial introduces the intlib library. The intlib library contains the core functions for flashing the LEDs and debouncing the GP3 push button. The intlib library contains the functions Display and Debounce. The library also contains the general purpose register, LEDREGISTER, to flash LEDs. See Section 2.9.5, “Modifying the Source Code”, for more information on the required files needed to build this project in MPLAB. Also, see the source code files for additional comments on the implementation. For a high-level flowchart, see Figure 2-10.

2.5.3 Applications

This program is useful in the following applications:

1. Displaying an 8-bit value onto the LED array. See Section 2.6, Tutorial 4, on using the analog-to-digital converter for reading an analog potentiometer and displaying its value on the LED array.
2. Detecting a button push immediately.
3. Flashing LED Patterns – See Section 2.7, Tutorial 5, and Section 2.8, Tutorial 6, for displaying different LED patterns stored in data tables.

2.5.4 Running The Demo

1. Program the ledint.hex code to the PIC12F6XX.
2. After the HEX file is programmed to the device, the LED array displays all 8 LED's that appear to be on. To change the rate at which the LED's are flashed, push the SW1 button.

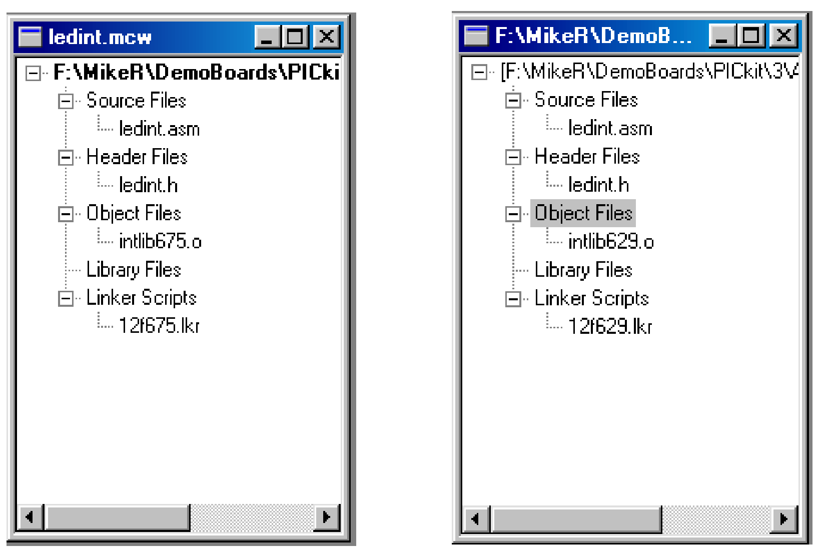
2.5.5 Modifying The Source Code

2.5.5.1 FILES REQUIRED FOR PROGRAM MODIFICATION

Assembly Source Code

- ledint.asm – Main file that contains the main program and interrupt routine
- ledint.h – Header file that defines the external program variables and routines
- intlib675.o or intlib629.o – Library file that contains the Display and Debounce routines for the PIC12F675 or PIC12F629 respectively
- 12f629.lkr or 12f675.lkr – Linker Script for PIC12F629 and PIC12F675 respectively
  (Linker Script located in C:\Program Files\MPLAB IDE\MCHIP_TOOLS)

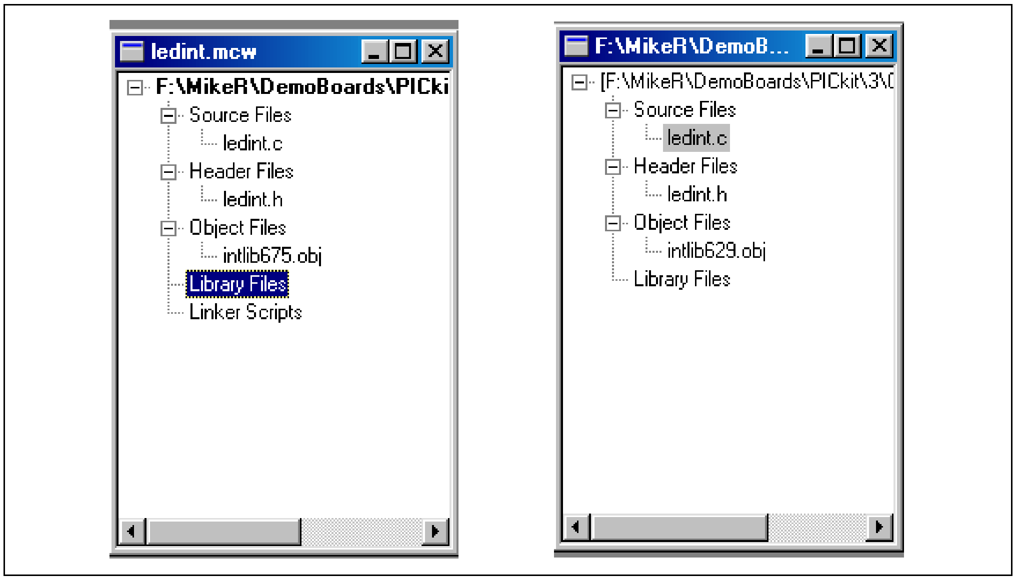
FIGURE 2-7: MPLAB PROJECT SETUP – ASSEMBLY



C Source Code

- ledint.c – Main file that contains the main program and interrupt routine
- ledint.h – Header file
- intlib675.obj or intlib629.obj – Library file that contains the Display and Debounce functions for the PIC12F675 or PIC12F629 respectively

FIGURE 2-8: MPLAB PROJECT SETUP – C



2.5.5.2 FILES REQUIRED FOR LIBRARY MODIFICATION

Assembly Source Code

- intlib.asm – Contains core Display and Debounce routines (When assembled, a intlib.o file will be created)

C Source Code

- intlib.c – Contains core Display and Debounce routines (When compiled, a intlib.obj file will be created)
- intlib.h – Header file

FIGURE 2-9: MPLAB PROJECT SETUP – LIBRARY MODIFICATIONS

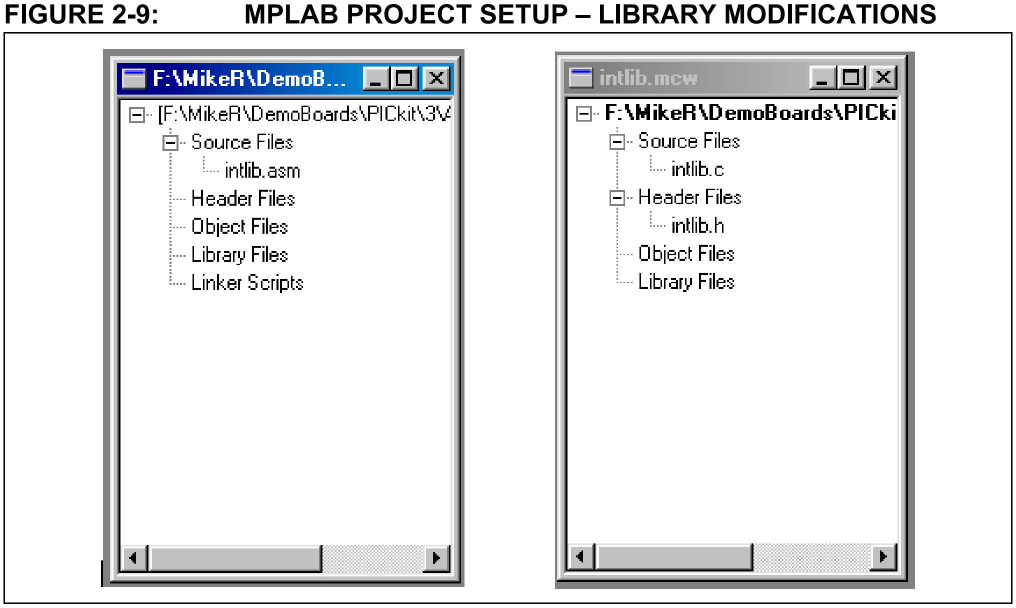
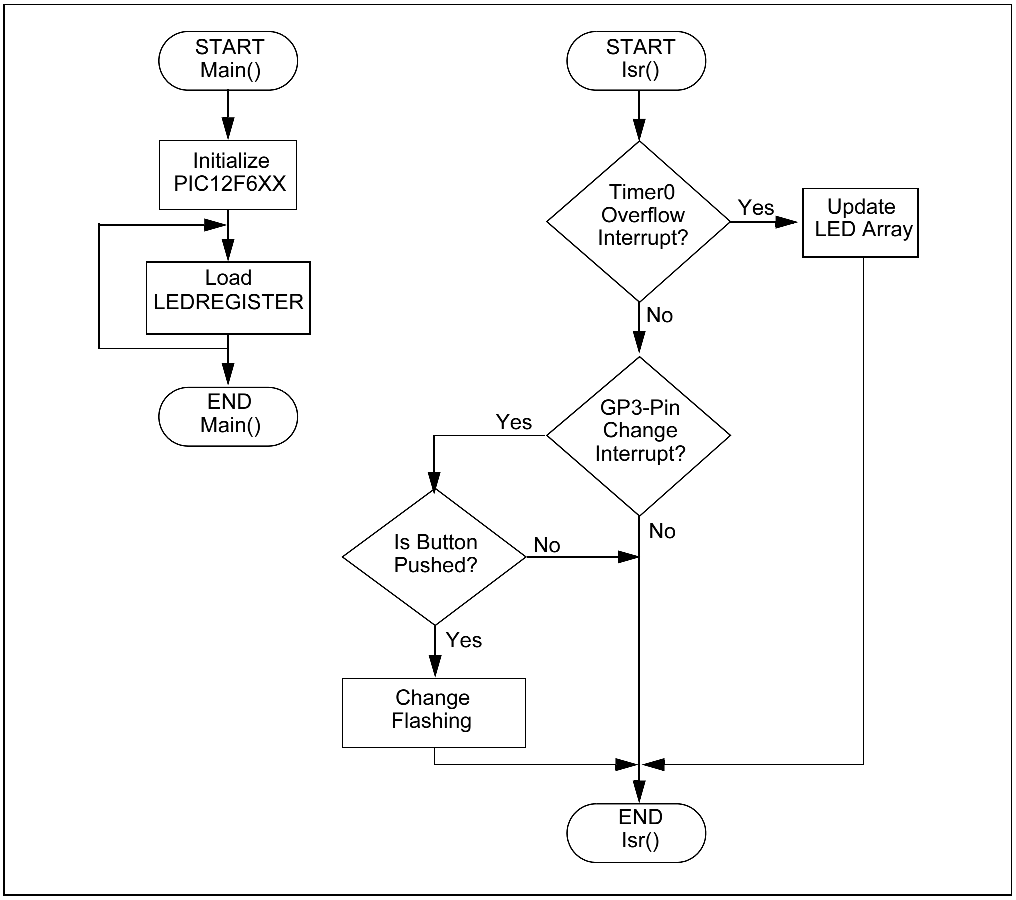


FIGURE 2-10: HIGH LEVEL FLOWCHART



2.6 TUTORIAL 4 – ANALOG-TO-DIGITAL CONVERTERS AND COMPARATORS

This tutorial is broken up into two programs which demonstrate how to use the analog-to-digital converter, the comparator and the internal voltage reference. The first program set is comp.asm (written in assembly) and comp.c (written in C). This program shows the very basic implementation of using the comparator with the internal voltage reference. The second program set is atod.asm (written in assembly) and atod.c (written in C). This program uses the LED display library to show the value of the analog-to-digital (A-D) converter.

2.6.1 Comparator Tutorial

For this tutorial, the comparator is configured as a dedicated comparator driving the GP2 pin directly. With <CM2:CM0> = 101, the comparator has multiplexed inputs. GP0/CIN+ is selected as the input to the VIN- by setting CIS = 1, thus making the analog potentiometer the one input. The internal voltage reference is used as the other input to the comparator on VIN+. The module compares the potentiometer voltage with the reference, and the logic is setup (CINV = 1) such that the output is high when the input voltage is higher than the reference. LED3 is driven directly by the comparator and is lit when the output of the module is high. To light D3, you must configure RA4 (GPIO4) and RA2 (GPIO2) as digital outputs via the TRIS register, RA4 is set low and RA2 is driven directly by the comparator without additional software overhead. The remaining I/O's are configured as high impedance inputs.

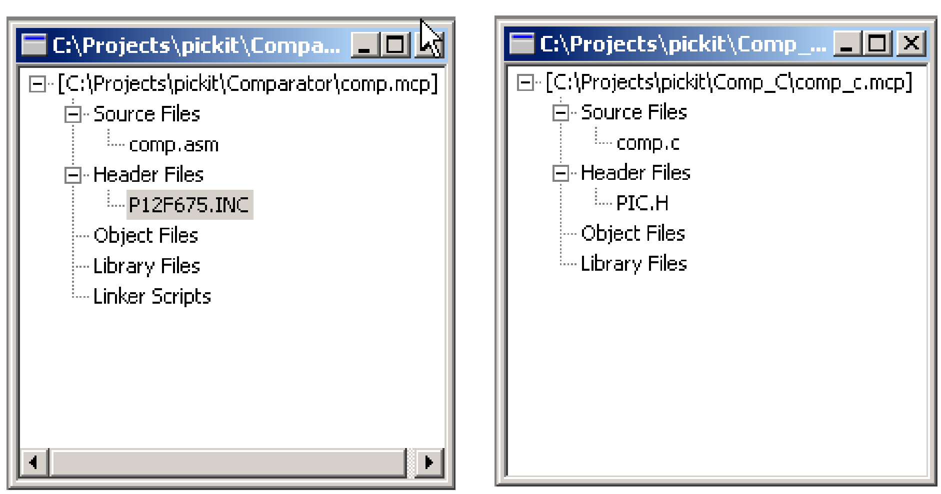
Note:	The schematics, as shown in Appendix A, display the 14-pin device pinout. This is compatible with 8-pin devices.

The internal voltage reference is essentially a variable resistor based voltage divider between VDD and VSS. Use the low range mode (VRR = 1) and set the internal reference to be 0.5 VDD by selecting <VR3:VR0> = 1100, thus CVREF = VDD*(12/24). By stepping through the different voltage reference settings, a basic-low resolution analog-to-digital converter can be implemented.

The comparator module has seven different modes. Three of the modes can drive an output pin directly. The software can monitor the output directly or create an interrupt on change. Bits CMIE and PEIE must be set to enable the comparator interrupt which can be used to wake the device from SLEEP.

Figure 2-11 shows the project setup for the assembly and C projects.

FIGURE 2-11: ASSEMBLY AND C PROJECT SETUP



2.6.2 Analog-to-Digital Converter Tutorial

This tutorial uses the PIC12F675 and demonstrates an interrupt based analog-to-digital conversion. TMR0 is set up with a prescaler of 4, thus creating an interrupt roughly every 1 ms. With every TMR0 interrupt, either the LED display routine is serviced (see Tutorial 3, Section 2.5) or the A/D routine is serviced depending on the flag that toggles with every interrupt. Noise is generated on VDD when the LED's are updated. Therefore, to reduce noise in the A/D process, either a new A/D conversion is done or the display is updated, but not simultaneously. The A/D interrupt source is not used because the service interval (2 ms) is much longer than the conversion period of 22 µs. The A/D module requires at least 4 µs for the sample capacitor to charge between acquisitions, but the program allows for about 2 ms. The result of the A/D is 10 bits, even though only the eight most significant bits are displayed on the LED's. The result is left justified (ADFM = 0) and the most significant byte is written to the LEDREGISTER to be displayed. The ANSEL register specifies which of the general purpose I/O pins are to be configured as analog inputs to the A/D module. In this case, the potentiometer's output serves as the input to AN0.

Figure 2-12 shows the source code files for the assembly and C projects respectively.

FIGURE 2-12: ASSEMBLY AND C SOURCE CODE FILES

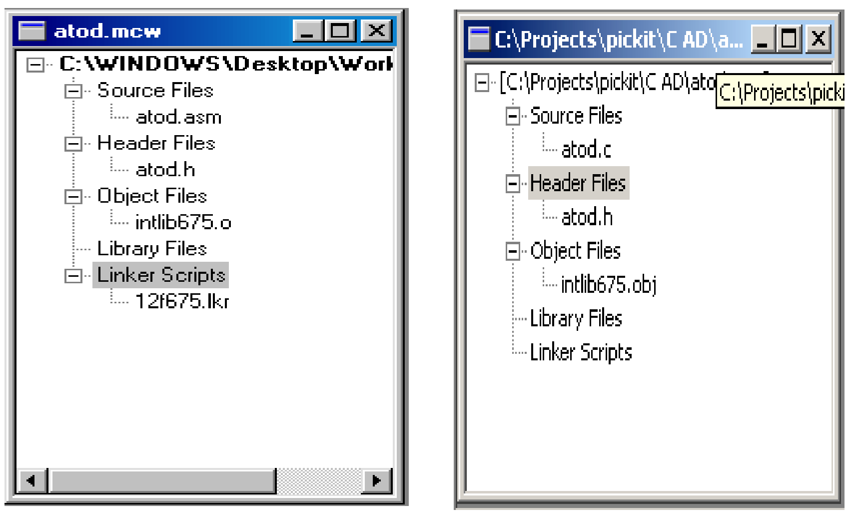
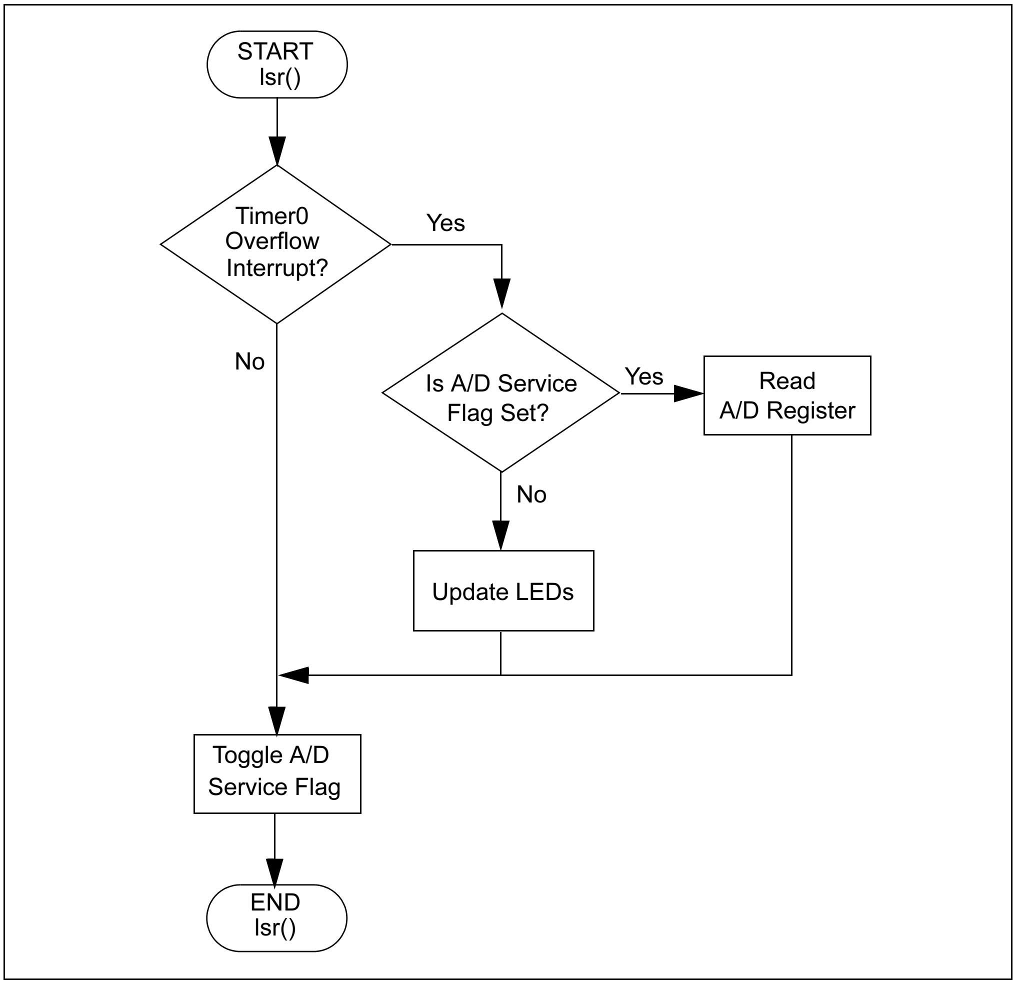


FIGURE 2-13: ANALOG-TO-DIGITAL CONVERSION



2.7 TUTORIAL 5 – PROGRAM MEMORY LOOK-UP ROUTINES

There is often a need to store constants or strings in a PIC microcontroller. Storing this information in program memory is the best solution as long as this data never needs to change and program memory is available. Program memory is non-volatile, therefore, it will maintain information regardless of VDD voltage levels or PIC microcontroller reset. This tutorial demonstrates how to retrieve data from Program Memory. It covers the following topics:

- What a program memory look-up table is
- How a program memory look-up table is implemented
- Why a program memory look-up table is useful

2.7.1 Design

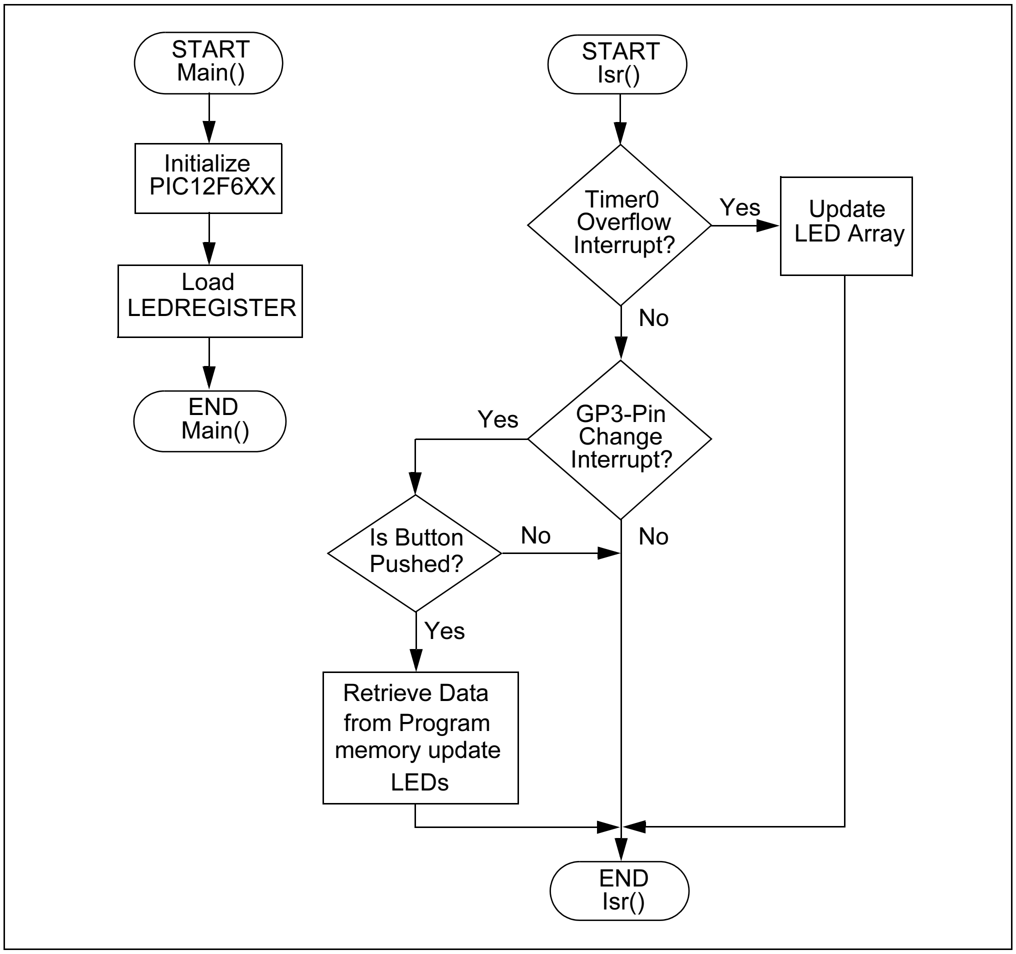
Constants stored in program memory are accessed via look-up tables. A look-up table is similar to a computed `goto` (see Tutorial 2, Section 2.4) only instead of a list of `goto` statements after incrementing the program counter, there is a list of `retlw` instructions. Each `retlw` instruction is followed by one byte of the information. Example 2-3 shows a look-up table for the string "Microchip" written in assembly language.

EXAMPLE 2-3: LOOK-UP TABLE WRITTEN IN ASSEMBLY

```
LookupProgramMemory
    movlw   high StartTable
    movwf   PCLATH
    movlw   low StartTable
    addwf   index, w
    btfsc   STATUS, C
    incf    PCLATH, f
    movwf   PCL
StartTable
    retlw   "M"
    retlw   "i"
    retlw   "c"
    retlw   "r"
    retlw   "o"
    retlw   "c"
    retlw   "h"
    retlw   "i"
    retlw   "p"
```

For this tutorial, constants corresponding to a sequence of LEDs are stored in a program memory look-up table. For instance, the first constant stored is 5F. This corresponds to the binary number "`01011111`". Each bit corresponds to an LED, therefore, LEDs D0, D1, D2, D3, D4 and D6 will be lit when this constant is accessed. After each look-up table, the value is displayed on the LEDs in the same fashion as discussed in Tutorial 3, Section 2.5, using the Timer0 interrupt. The appearance of more than one LED being lit at a time is possible because the LEDs are multiplexed fast enough that the human eye can not detect the LEDs being turned on and off. When SW1 is pressed, an interrupt-on-change is generated to increment the lookup to the next location. Figure 2-14 shows the flowchart for this example.

FIGURE 2-14: PROGRAM MEMORY LOOK-UP TABLE PROCESS



2.7.2 Applications

The lookup routines presented herein are useful in applications that require the following:

1. Retrieving calibration values.
2. Retrieving serial numbers.
3. Retrieving LED sequences.
4. Retrieving constants or strings in general that will not change over the lifetime of the PIC microcontroller.

2.7.3 Running The Demo

1. Program the pglookup.hex code to the PIC microcontroller.
2. After the HEX file is programmed to the device, the LED array should show the first look-up value in the 8 LEDs. To increment to the next look-up value, press SW1. See Table 2-2.

TABLE 2-2: DATA TABLE

Instruction	Byte
`retlw`	0x5F
`retlw`	0x06
`retlw`	0x3B
`retlw`	0x2F
`retlw`	0x66
`retlw`	0x6D
`retlw`	0x7D
`retlw`	0x07

2.8 TUTORIAL 6 – DATA EE LOOK-UP ROUTINES

2.8.1 Introduction

Tutorial 5 discussed storing and retrieving constants from program memory. The benefit of storing information in non-volatile program memory is when power is cycled to the microcontroller, the information is not lost. However, the main disadvantage is information stored in program memory can not change. RAM, on the other hand, offers the versatility of change but is volatile (it is cleared when power is cycled to the microcontroller.) Data EEPROM solves this problem by providing non-volatile readable/writable memory. An added benefit of Data EEPROM is a developer can free up valuable RAM by using data memory to store rarely accessed variables. This tutorial covers the following topics:

- How to implement Data EEPROM look-up routines
- Why Data EEPROM look-up routines are useful

2.8.2 Design

The PIC12F629/675 (DS41190) and PIC16F630/676 (DS40039) data sheets provide detailed instructions on how to access data memory. See the data sheets for timing specifications and limitations to the data memory. The data sheets are located on this CD and the Microchip web site (www.microchip.com).

The steps for reading the Data EEPROM are as follows:

1. Write the data memory location to the EEADR register.
2. Set EEPROM control bit RD (EECON1<0>).

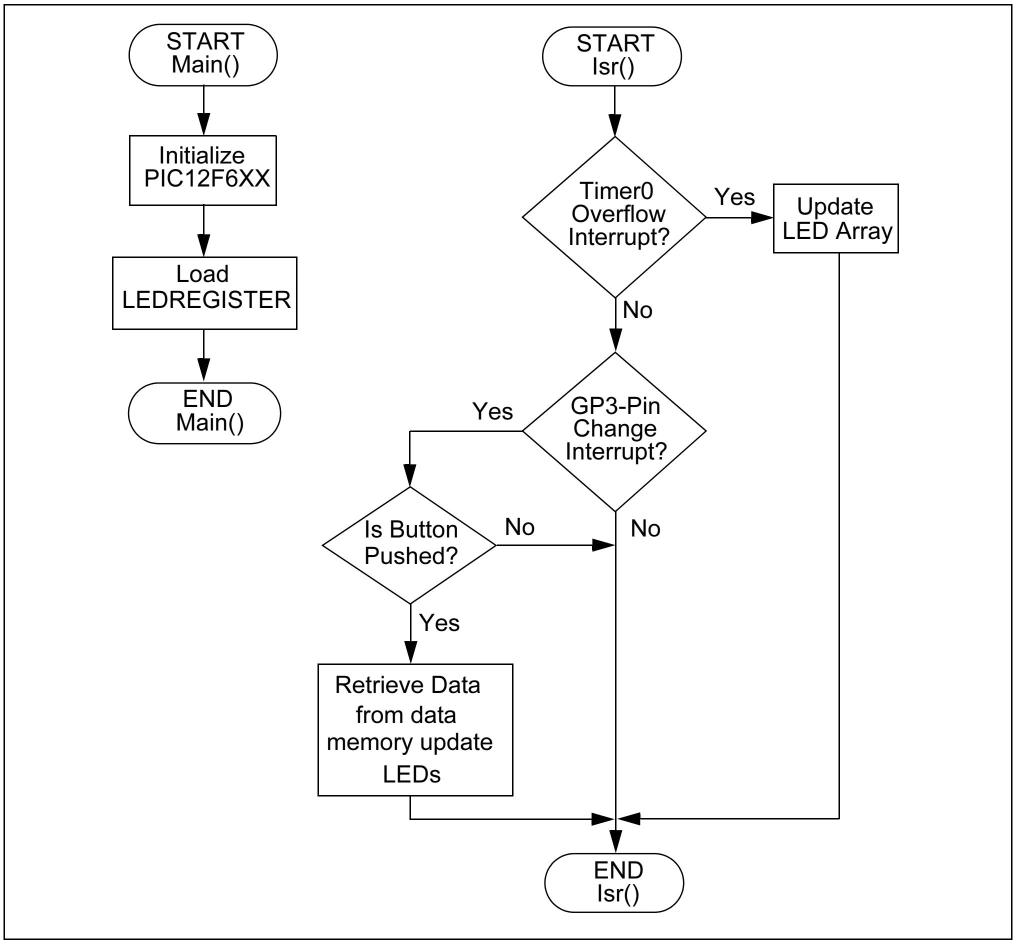
All data memory locations can be accessed using a single routine when an index variable is utilized. Example 2-4 shows how to use an index variable to read the Data Memory.

EXAMPLE 2-4: INDEX VARIABLE

```
LookupDEE
    movf      index,w        ; move data memory address pointer
    banksel   EEADR          ;  to EEADR
    movwf     EEADR
    bsf       EECON1,RD      ; read data
    movf      EEDATA,w       ; return with LED sequence in w
    return
```

As discussed in Tutorial 5, the returned value corresponds to an LED sequence. This value is displayed using the Timer0 interrupt. The LEDs are multiplexed fast enough to appear as though more than one LED is on at the same time. When SW1 is pressed, an Interrupt-on-change is generated and the next LED sequence is read from the data memory. Figure 2-15 shows the flowchart for this tutorial.

FIGURE 2-15: DATA EE LOOK-UP ROUTINES



2.8.3 Applications

The look-up routines presented herein are useful in applications that require the following:

1. Storing and retrieving calibration values.
2. Maintaining current identification information.
3. Data logging information.
4. In general, for any applications that require non-volatile variable memory.

2.8.4 Running The Demo

1. Program the dtlookup.HEX file into the PIC microcontroller.
2. After the HEX file is programmed into the device, the LED array should show the first look-up value in the 8 LED's. To increment to the next look-up value, press SW1. See Table 2-3.

TABLE 2-3: DATA TABLE

Instruction	Byte
`org`	2100h
`DE`	0x5F
`DE`	0x06
`DE`	0x3B
`DE`	0x2F
`DE`	0x66
`DE`	0x6D
`DE`	0x7D
`DE`	0x07

2.9 TUTORIAL 7 – FREQUENCY COUNTING WITH TIMER1 GATE

This program introduces the concept of auto-calibration of the PIC12F6XX internal RC oscillator using a known reference frequency. The PIC12F6XX has an internal RC oscillator capable of being calibrated to ±1%.

This tutorial covers the following:

- How to set up and use the Timer1Gate peripheral
- How to calibrate the PIC12F6XX internal RC oscillator
- Useful applications that use the concepts presented in this tutorial
- Files needed to customize source code for the application

2.9.1 Design

This program takes advantage of the TIMER1 Gate Peripheral onboard the PIC12F6XX for auto-calibration of the PIC12F6XX device. A 2.5 kHz reference signal is connected to pin GP4/Timer1Gate input on the PIC12F6XX device.

The PIC12F6XX internal RC oscillator has the capability to run at 4 MHz ±1%. Using Timer1Gate is advantageous because it can eliminate busy waiting on the PIC microcontroller. Using Timer1Gate allows the hardware to manage capturing of the reference signal low-edge pulse width while allowing the PIC12F6XX to process other events for a given amount of time. The time will depend on the period of the signal being measured. In this case, there is a 2.5 kHz reference signal. This allows 400 μs to go and process something else before we would need to read TIMER1 for a measurement.

2.9.2 Implementation

In this program, GP0 is used to output a test signal. If the PIC12F6XX internal RC oscillator is calibrated, the test signal will be a 5 kHz square wave. In addition, the program uses the GP3 push button input to select calibration mode. To turn on the 2.5 kHz fixed frequency source, select the box from the Board Controls area in the PICkit 1 FLASH Starter Kit control panel. See Figure 2-19 through Figure 2-22 for program flowcharts.

2.9.3 Applications

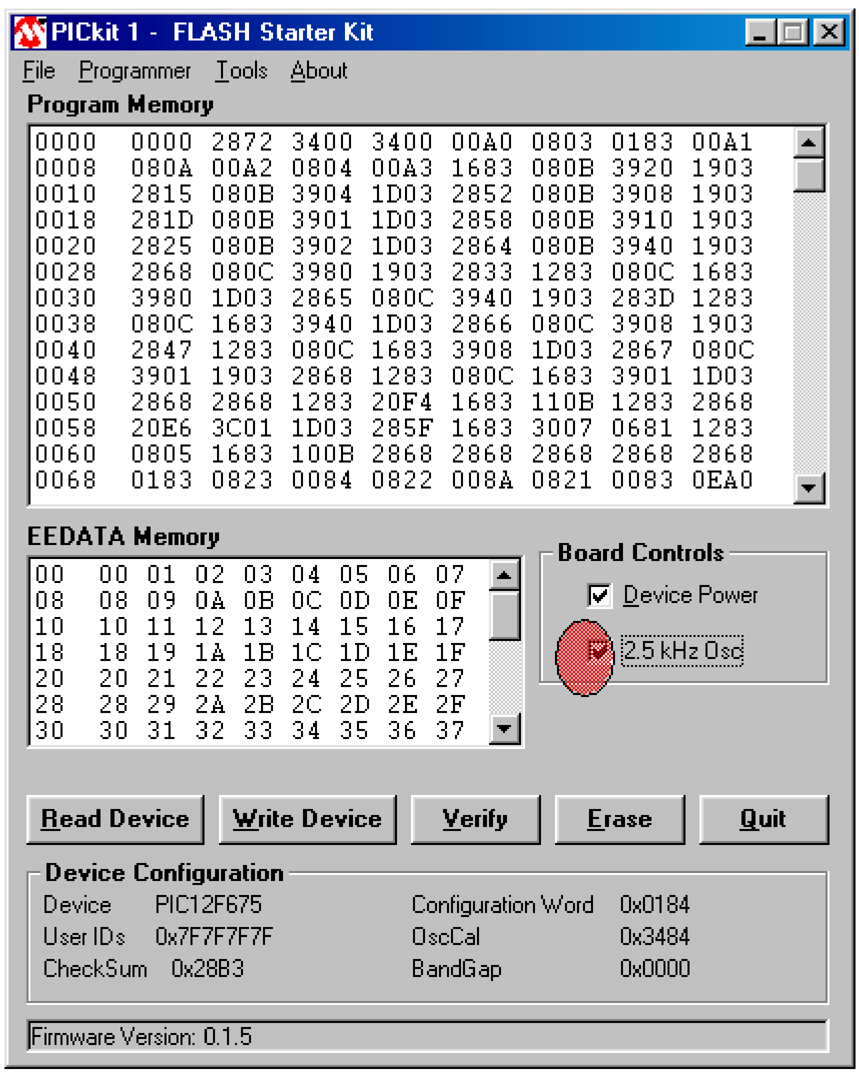
This program could be useful in the following applications:

1. High volume production environment.
2. Battery applications could use on-board calibration to recalibrate the internal RC oscillator as the battery voltage drops.
3. Applications that are exposed to a varying voltage and temperature ranges could have intelligent on-board recalibration.

2.9.4 Running The Demo

1. Program the autocal.hex code to the PIC12F6XX PIC microcontroller.
2. Once the device is programmed, LED D6 turns on indicating test mode.
3. Check the device calibration by connecting an oscilloscope probe or frequency counter to GP0 and compare the measurement to 5 kHz.
4. To calibrate the device, select the 2.5 kHz Osc checkbox and turn on the 2.5 kHz reference signal (in the Board Controls frame), as shown in Figure 2-16. Press the SW1 button on the PICkit 1 FLASH Starter Kit board. LED D7 will turn on when the button is pushed, this indicates calibration mode.
5. View the test signal output on GP0 using the oscilloscope, or frequency counter, and compare the measurements to the previous one before performing a calibration. The measurement will be within 1% of 5 kHz.

FIGURE 2-16: PICkit 1 FLASH STARTER KIT PROGRAMMING INTERFACE



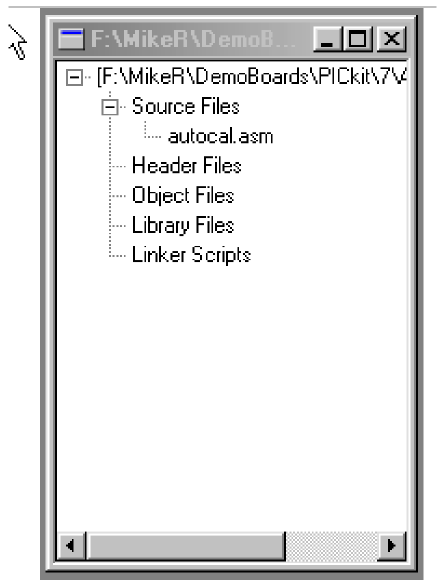
2.9.5 Modifying The Source Code

2.9.5.1 REQUIRED FILES FOR PROGRAM MODIFICATION

Assembly Code

- autocal.asm – This is the only file needed to build the project

FIGURE 2-17: MPLAB PROJECT SETUP – ASSEMBLY



C Code

- autocal.c – This is the main file which contains the main program, interrupt routine and functions
- autocal.h – Header File
- delay.obj – HI-TECH PICC™ Lite supplied delay function (Source code is located in C:\Picclite\samples\delay)

FIGURE 2-18: MPLAB PROJECT SETUP – C

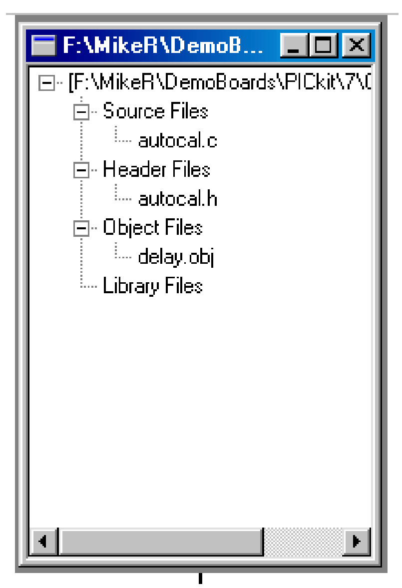


FIGURE 2-19: MAIN FLOW

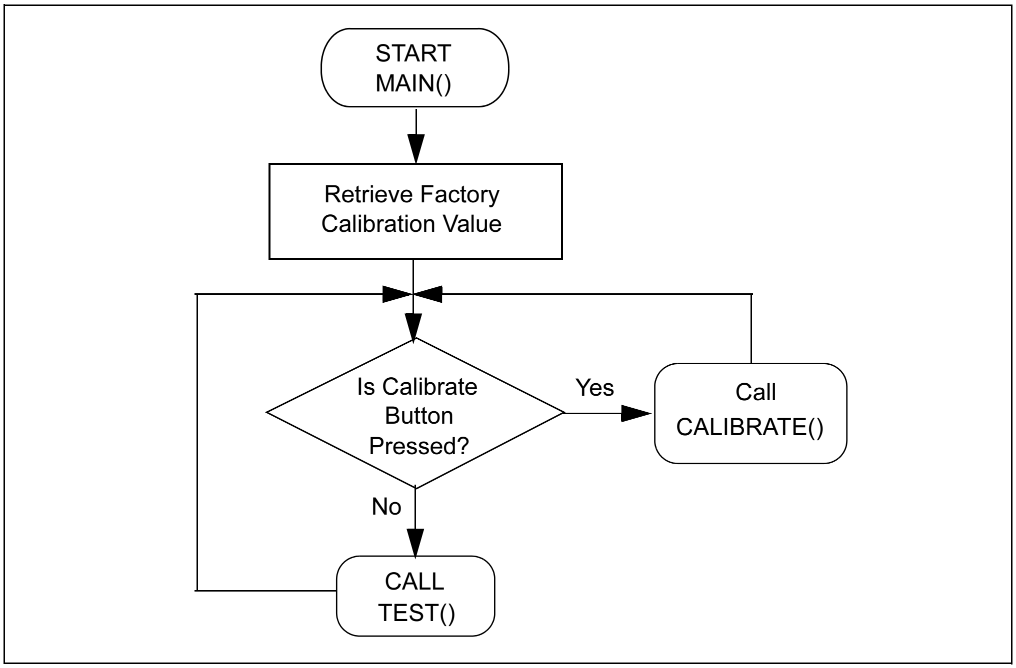


FIGURE 2-20: TEST FLOW

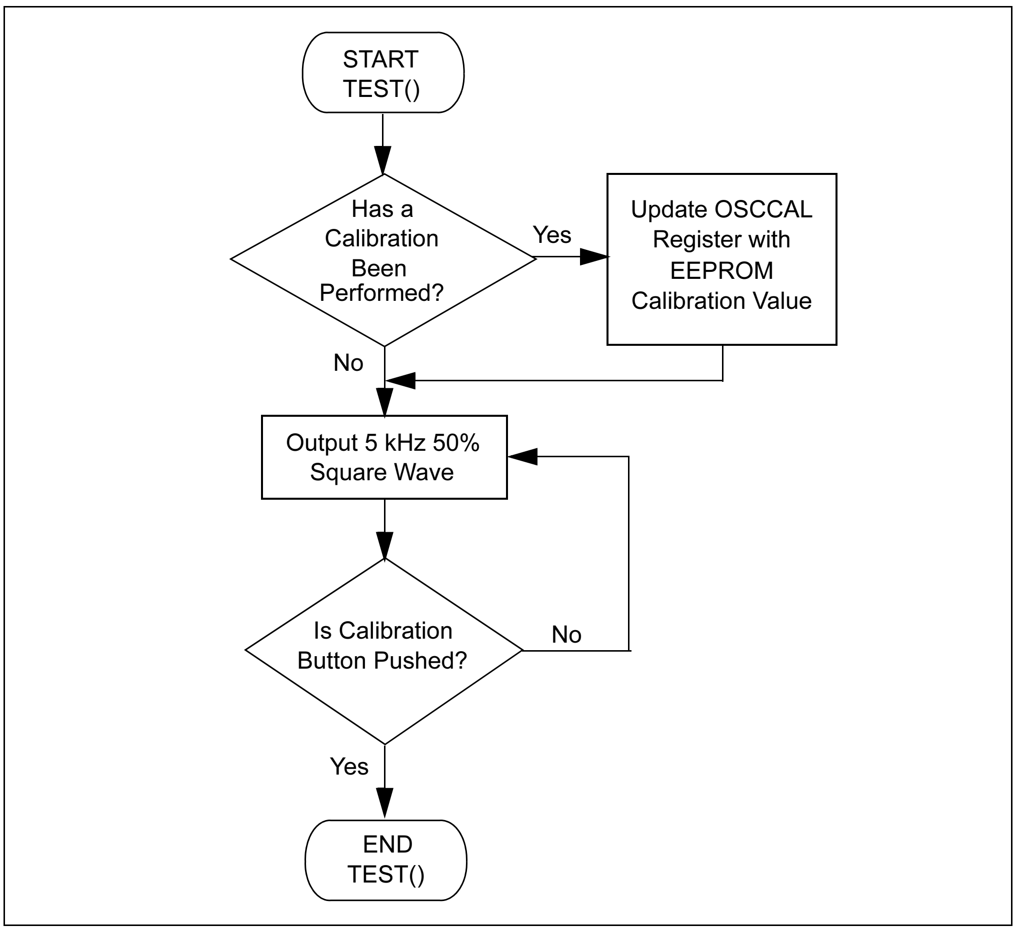


FIGURE 2-21: CALIBRATE FLOW

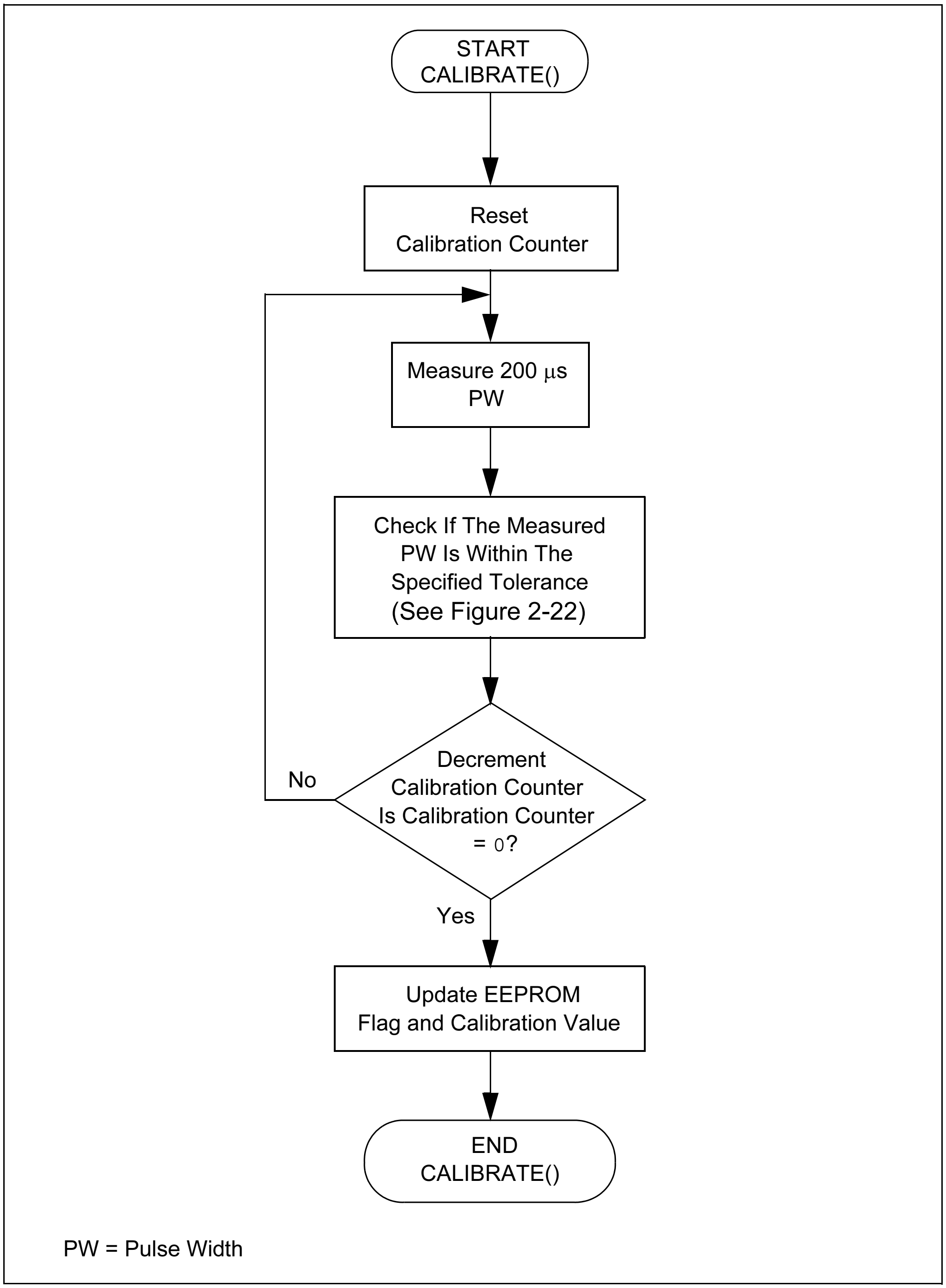
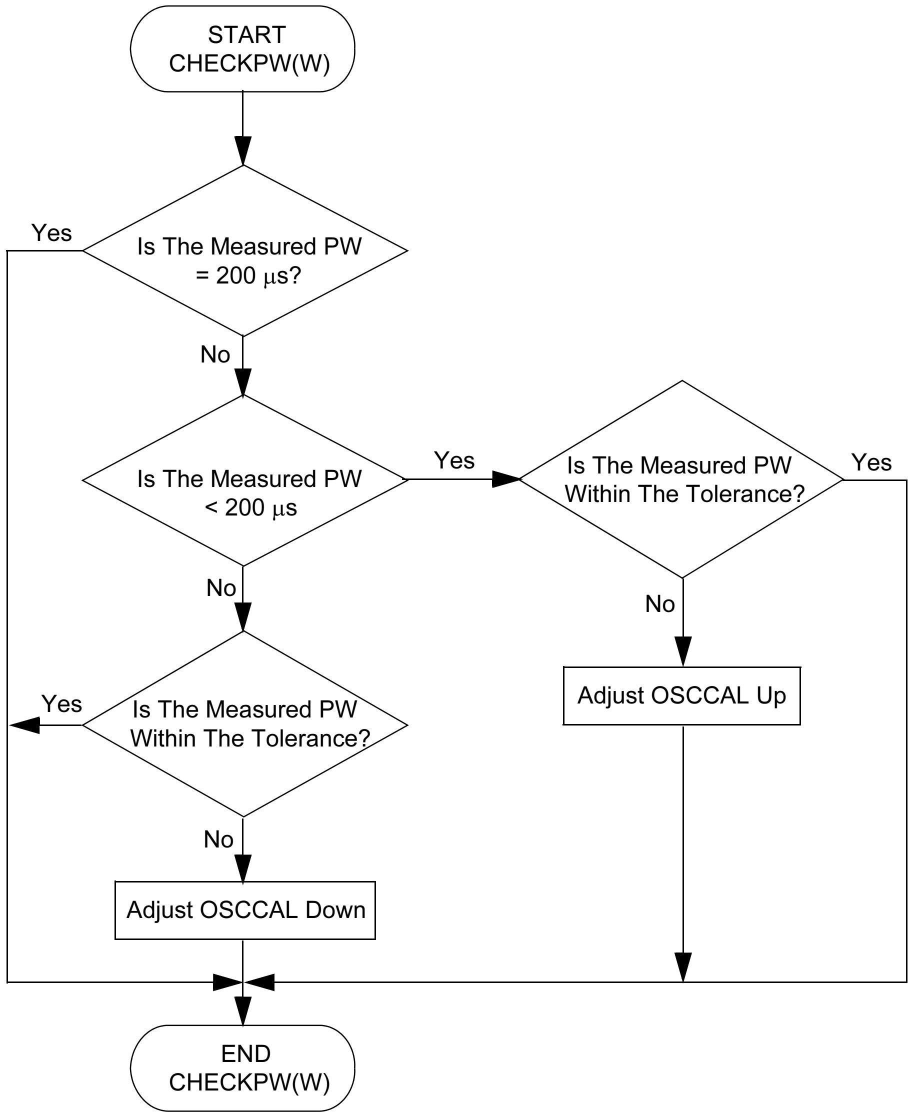


FIGURE 2-22: CHECKPW(W) FLOW



PW = Pulse Width

NOTES:

Chapter 3. Working with the Tutorial Software

3.1 INTRODUCTION

This chapter covers information needed to work with the tutorial software presented in Chapter 2.

3.2 HIGHLIGHTS

- Using the Tutorial Source Code
- Loading a Project

3.3 USING THE TUTORIAL SOURCE CODE

The source code files for each tutorial are provided on the CD-ROM. In order to use the tutorial code you will have to:

1. Create a new MPLAB project.
2. Configure the project for the PIC12F675.
3. Add the code to the project.
4. Compile the software.

Details for each of these steps can be found on the *MPLAB IDE v6.xx Quick Start Guide* available on the MPLAB IDE CD-ROM included with the PICkit 1 FLASH Starter Kit.

MPLAB is the integrated development environment supplied by Microchip Technology Inc. for developing software for PIC microcontroller. MPLAB is used to:

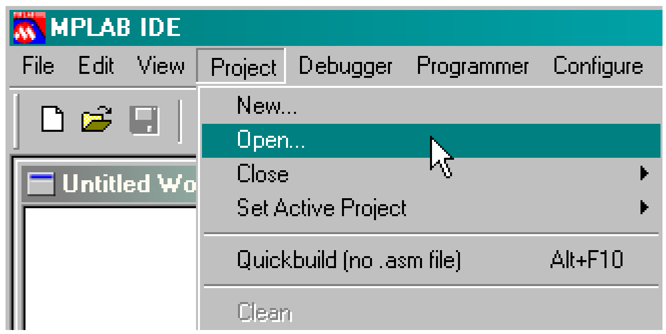
- Create source code using the built-in editor.
- Assemble, compile and link source code using various language tools. An assembler, linker and librarian come with MPLAB IDE. Supported C compilers are available from Microchip. Third party compilers may be supported also. Check the release notes or readme files for details.
- Debug the executable logic by watching program flow with the built-in simulator, or in real time with the MPLAB ICE 2000 emulator or MPLAB ICD 2 in-circuit debugger. Third party emulators may also be supported. Check the release notes or readme files for details.
- Make timing measurements with the simulator or emulator.
- View variables in watch windows.
- Additional information concerning the capabilities and the use of MPLAB is available on the MPLAB CD-ROM.

3.4 LOADING A PROJECT IN MPLAB

Loading a project in MPLAB IDE is accomplished with the following steps:

1. Launch MPLAB IDE.
2. Select *Project > Open*, as shown in Figure 3-1.
3. Browse and locate the project.
4. Click **OPEN**.

FIGURE 3-1: OPEN PROJECT

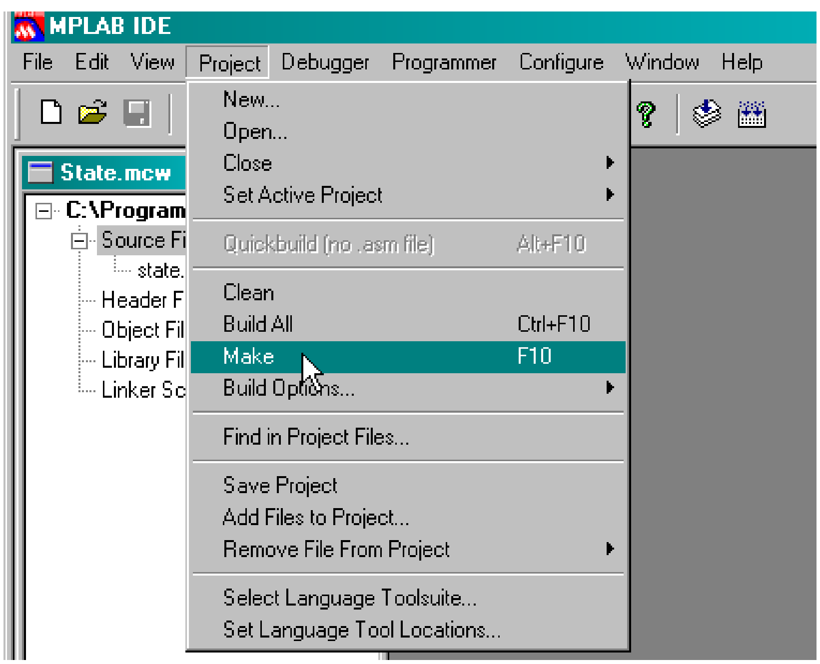


3.4.1 Compiling the Project

After loading a project, it is necessary to compile it. Select *Project > Make*, as shown in Figure 3-2.

A window will appear and show the progress. If there are no errors, the program can be simulated or downloaded into the PICkit 1 FLASH Starter Kit software. (See Chapter 2 for instructions on downloading the program).

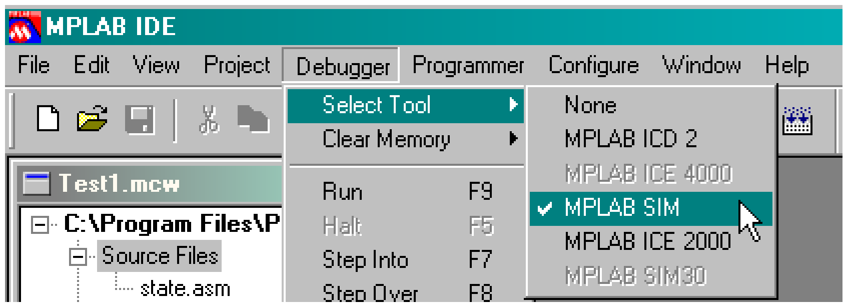
FIGURE 3-2: COMPILE PROJECT



3.4.2 Simulating the Project

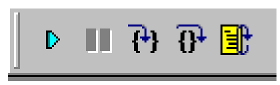
In order to simulate the program to see what the PIC microcontroller is actually doing with each instruction, select the MPLAB IDE Simulator debugger. Select _Debugger > Select Tool > MPLAB SIM_, as shown in Figure 3-3.

FIGURE 3-3: MPLAB SIMULATION

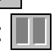
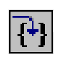
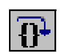
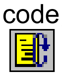


Once MPLAB SIM is selected, five buttons will appear on the right end of the menu toolbar, as shown in Figure 3-4.

FIGURE 3-4: SIMULATION TOOLBAR

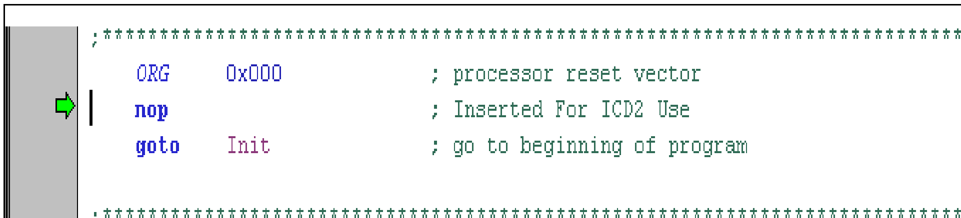


These buttons allow the user to:

1. Run code: 
2. Pause code: 
3. Single Step code through functions: 
4. Single Step code, but run through the functions: 
5. Reset code: 

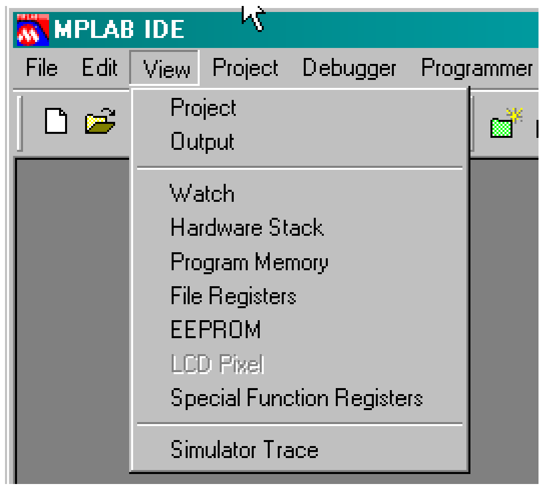
To view the code in single steps, press the single step button, the code window will show the instruction that will be executed next, as shown in Figure 3-5.

FIGURE 3-5: CODE WINDOW



In the View toolbar menu there are options to view the special function registers, program memory and other useful information, as shown in Figure 3-6.

FIGURE 3-6: VIEW MENU OPTIONS



To learn more about using MPLAB IDE, please refer to the *MPLAB IDE User's Guide* found on the MPLAB IDE CD-ROM, included in the PICkit 1 FLASH Starter Kit.

Chapter 4. PICkit™ 1 FLASH Starter Kit Hardware

4.1 INTRODUCTION

The PICkit 1 FLASH Starter Kit hardware was designed to be a low-cost introductory programmer and evaluation kit. The requirements of the hardware are as follows:

- Support the 8/14-pin FLASH PIC microcontrollers
- Program the 8/14-pin FLASH PIC microcontrollers
- Operate from a USB cable

4.2 HIGHLIGHTS

This chapter discusses:

- ICSP™ Techniques
- Programming Hardware
- USB Communications Protocol

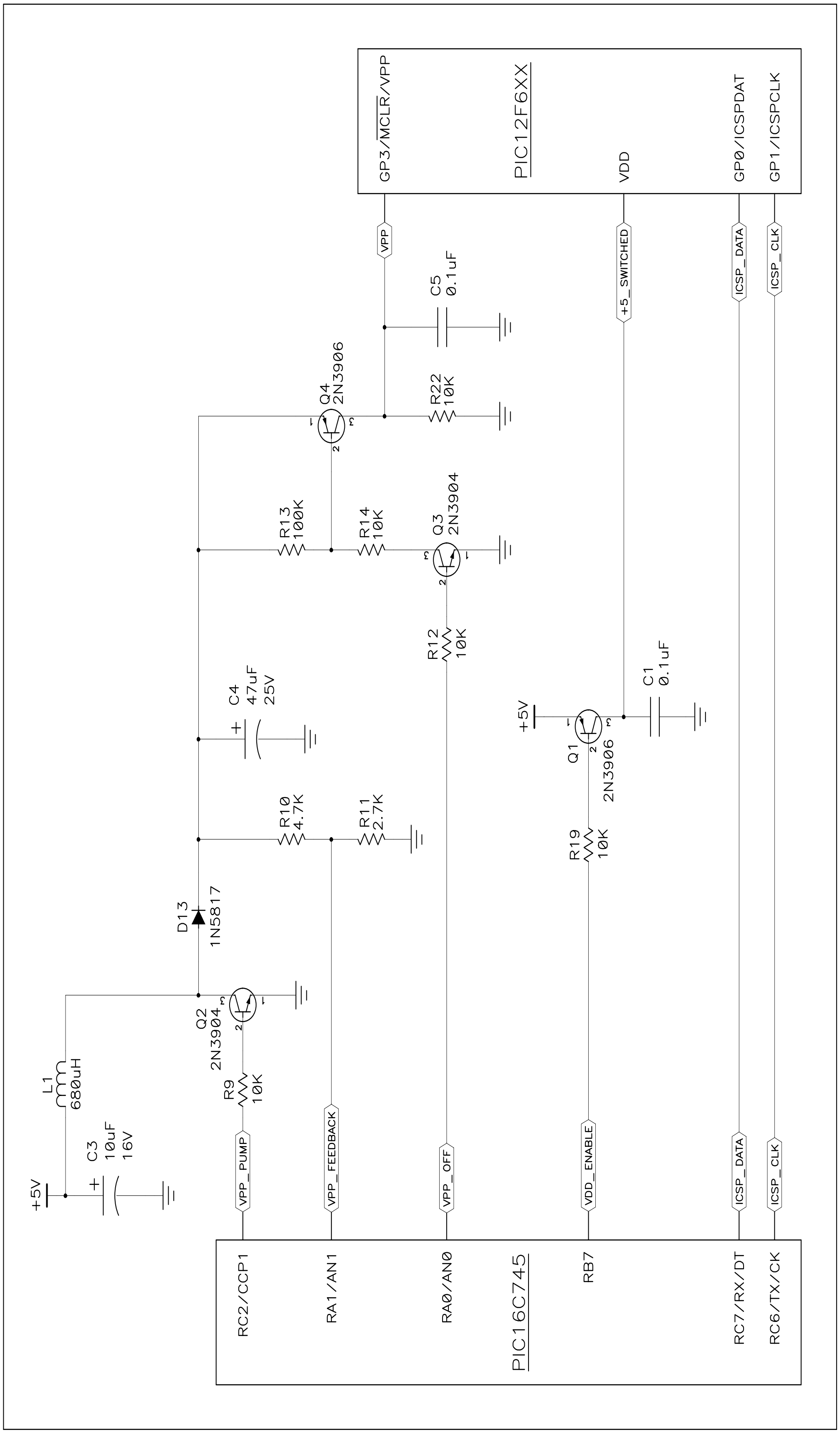
4.3 IN-CIRCUIT SERIAL PROGRAMMING™ (ICSP) TECHNIQUES

ICSP allows an engineer to design a circuit that will be built and then programmed later. The procedure is described in the programming specifications (DS41173 and DS41191). These documents can be found on the Microchip web site (http:\\www.microchip.com). ICSP requires a 12-13V power supply, control of the V_{DD} supply and two I/O pins to clock in the commands and data.

4.4 PROGRAMMING HARDWARE

The programmer portion of the PICkit 1 FLASH Starter Kit circuit is shown in Figure 4-1. Additional circuitry is present to connect to the USB and drive the evaluation LED's. Most of the circuitry in the figure is used to generate the +13V required for V_{PP}. This is generated by using the CCP of the PIC16C745 to pulse Q2 on and off. By pulsing Q2, L1 generates a burst of charge that is steered into the capacitor C4 by the diode D13. Each burst of charge adds to the voltage already in the capacitor. The size of the burst of charge is proportional to the on time of the PWM signal from CCP. The resistors R10 and R11 form a voltage divider that drops the 13V V_{PP} to a 4.5V feedback signal that is measured by AN1. Software running in the PIC16C745 periodically samples AN1 and computes a new PWM value. The PWM value is updated just over 500 times every second. This ensures good voltage regulation of the 13V and leaves enough CPU time to perform the programming task. The rest of the circuit is used to switch the V_{PP} voltage to the V_{PP} pin. Transistor Q4 is the switch for the V_{PP} voltage and Q3 is the driver for Q4. Transistor Q1 turns V_{DD} on and off allowing the target device to be reset. The programming I/O signals are generated by "bit-banging" RC6:7 of the PIC16C745 which drives the GPIO0:1 lines used by the PIC12F629/675.

FIGURE 4-1: PROGRAMMING HARDWARE



4.5 USB COMMUNICATIONS PROTOCOL

The USB protocol used by the PICkit 1 FLASH Starter Kit is a very simple command/response type protocol. Multiple commands can be put together to fill the 8 bytes of a USB packet. If a command cannot fill the 8 bytes and it is not desired to use a second command to fill the packet, the packet should be padded with ‘Z’ to indicate no operation.

4.5.1 Commands

- ‘W’ <word> – Write Program Memory. Loads the write latch, sends the write command and increments to the next address.
- ‘C’ <word> – Configuration memory write mode. Word parameter ignored. Use ‘W’ to write to configuration memory.
- ‘D’ <byte> – Write EE Data memory. Data is passed as the byte.
- ‘E’ – Bulk Erase Program Memory
- ‘e’ – Bulk Erase Data Memory
- ‘I’ <word> – Increment Address N times. N is passed as word.
- ‘P’ – Enter programming mode. Turns VPP and VDD on.
- ‘p’ – Exit Programming Mode. Turns VDD and VPP off.
- ‘R’ – Read Program Memory. ‘R’ always returns 4 words. If the end of PGM memory is reached, it pads with 0’s. It is the responsibility of the host software to determine if padding occurred by keeping track of the program counter.
- ‘r’ – Read EE Data Memory. ‘r’ always returns 8 bytes. If the end of Data memory is reached, it pads with 0’s. It is the responsibility of the host software to determine if padding occurred by keeping track of the program counter.
- ‘S’ <program memory length, data memory length> – Calculates Program Memory Checksum and Data Memory Checksum. The checksum is calculated on the first N_p words of the program memory and the first N_d bytes of the data memory. N_p and N_d are both words passed as the length parameter. The return value is 3 bytes in length: the first word is the Program Memory checksum, and the last byte is the Data Memory Checksum.
- ‘V’ <byte> – Power and special feature control. The byte following command is used to control. VDD power to the target and to enable/disable a 2.5 kHz 50% square wave.
- ‘v’ – Return version information. The following bytes are returned: <Major><Minor><Dot>.
- ‘Z’ – No operation. Use to pad packets to 8 bytes.

Note:	Word values are sent low byte first.

Source code files are located on the PICkit 1 FLASH Starter Kit CD.

NOTES:

Chapter 5. Troubleshooting

5.1 INTRODUCTION

This chapter describes common problems associated with using the PICkit 1 FLASH Starter Kit, and steps on how to resolve them.

5.2 FAQS

5.2.1 Program Does Not Work

Question:

My program does not work. What should I check?

Answer:

1. Are the configuration bits set in the source file? PICkit 1 FLASH Starter Kit depends on having the configuration bits set in the HEX file. The assembler uses the _CONFIG directive. When using the PICkit 1 FLASH Starter Kit's on-board evaluation socket, configure the internal oscillator. The internal oscillator also frees up two more pins for general I/O use.

   The assembler directive to select the internal oscillator, with all other functions off, might look like this:

   ```
   _CONFIG (_INTRC_OSC_NOCLKOUT & _WDT_OFF &_BODEN_OFF&_CP_OFF
      &_CPD_OFF)
   ```

   The following code shows how to set the configuration bits in Hi-Tech C:

   ```
   _CONFIG(UNPROTECT & BOREN & MCLRDIS & PWRTEN & WDTDIS & INTIO);
   ```

2. Are the pins multiplexed with other functions? If so, does the program initialize the control registers to select the function desired? A common problem occurs on PORTA where the analog inputs to the ADC is multiplexed with digital functions. The pins default to analog input. For digital output, write to the ANSEL register and make the pins digital I/O.

5.2.2 Device Will Not Program

Question:

The device will not program. All writes end with a "checksum verified failed" error message.

Answer:

1. Are the code protect bits set in the source code file? Currently, the device can only be code protected by selecting the *Tools > Code Protect Device* option in the PICkit 1 User's Interface.
2. The part may be damaged. Go to Microchip's web site (www.microchip.com) to request a new part.

5.2.3 Device Is Not Recognized

Question:

Receiving message "Insert Device", but there is a part in the socket.

Answer:

1. Verify the device in the socket is a PIC12F629, PIC12F675, PIC16F630 or PIC16F676. Other devices may be reported as "Insert Device".
2. Check for additional circuits attached to pins GP0 and GP1.
3. Check to see if the SW1 switch is pressed.

5.2.4 Current Limit Exceeded

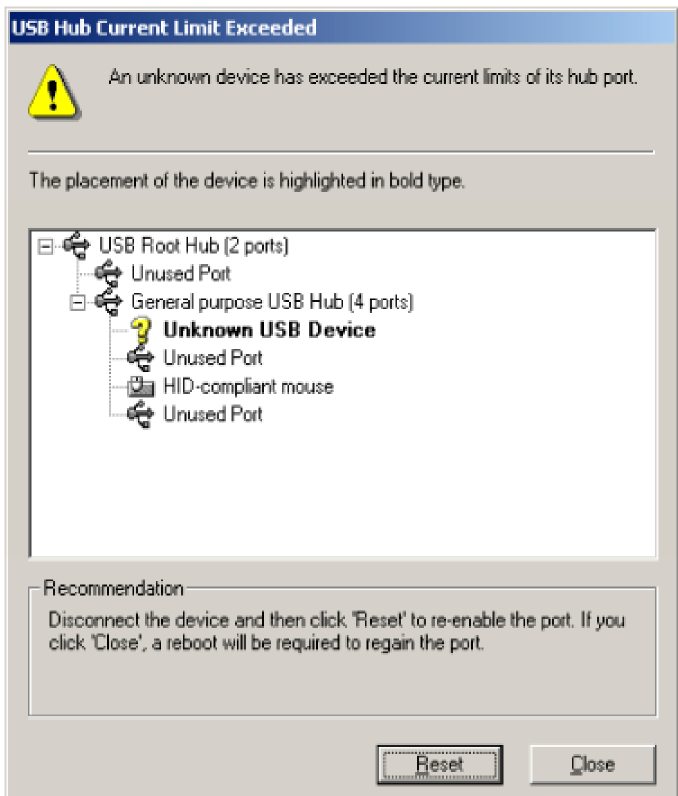
Question:

Receiving error message "USB Hub Current Limit Exceeded" from Microsoft Windows 2000.

Answer:

Check for shorts on the circuit board.

FIGURE 5-1: USB HUB CURRENT LIMIT EXCEEDED



5.2.5 Windows Driver

Question:

After plugging the PICkit 1 into the USB port, Windows 98 SE asks for a driver. Where is the driver?

Answer:

PICkit 1 uses the drivers included with Windows. When Windows 98 SE prompts for a driver, select "**Search for the best driver for your device**." Then select the check box next to "**Microsoft Windows Update**" and click **Next**. Windows will automatically install the appropriate driver. Do not use the ICD 2 USB driver.

5.2.6 Editing Device Memory

Question:

When using the PICkit 1 User's Interface to edit the actual contents of the memory. It will not allow date selection. Why not?

Answer:

The PICkit 1 User's Interface was developed to program a device. It was not intended to edit the contents of a device. Please use MPLAB to edit the contents of the device. The data in the window can be selected to cut and paste the date into another editor for use in other applications.

5.2.7 No Source Code

Question:

After moving the tutorial data files to a different location on the hard drive, the MPLAB simulator behaves strangely. When stepping through the code, a program memory window is displayed without the source code. What is wrong?

Answer:

The MPLAB version 6.13, and earlier, simulator does not support source level debugging when the path to the source code is > 64 characters long. Moving the data files to a location with a shorter path name will fix the problem. This will be fixed in a future version of the MPLAB software.

5.2.8 HI-TECH PICC LITE

Question:

Why does the default demonstration code not work correctly after compiling with the HI-TECH PICC LITE Compiler?

Answer:

Download the latest HI-TECH PICC LITE C Compiler from the HI-TECH web site www.htsoft.com.

NOTES:

Appendix A. Hardware Schematics

A.1 INTRODUCTION

This appendix contains the PICkit™ 1 hardware schematic diagrams.

A.2 HIGHLIGHTS

The diagrams in this appendix are:

- PICkit 1 Board Diagram
- LED Layout
- VPP Supply
- USB Control
- Prototype 1
- Prototype 2

FIGURE A-1: PICkit™ 1 BOARD DIAGRAM

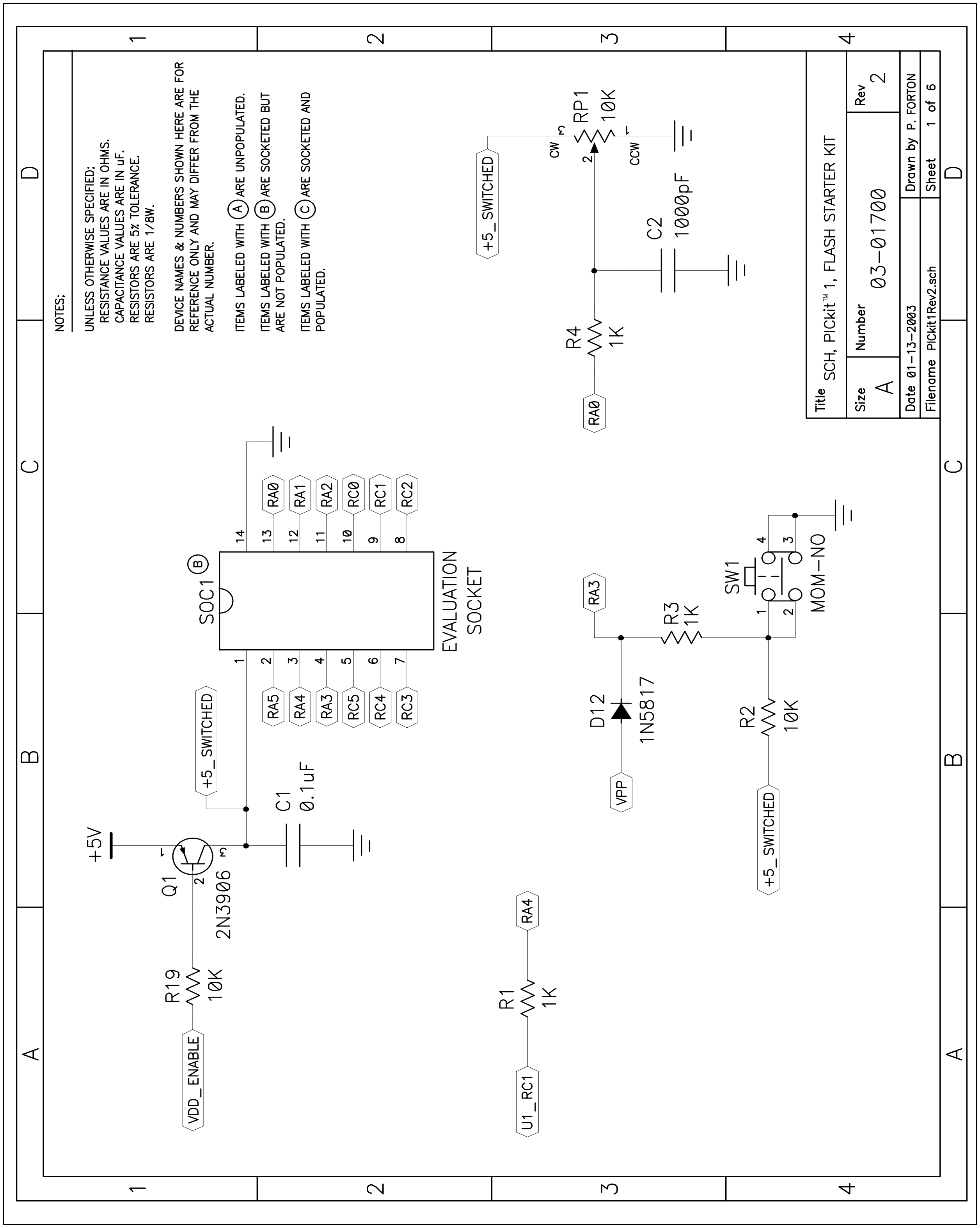


FIGURE A-2: LED LAYOUT

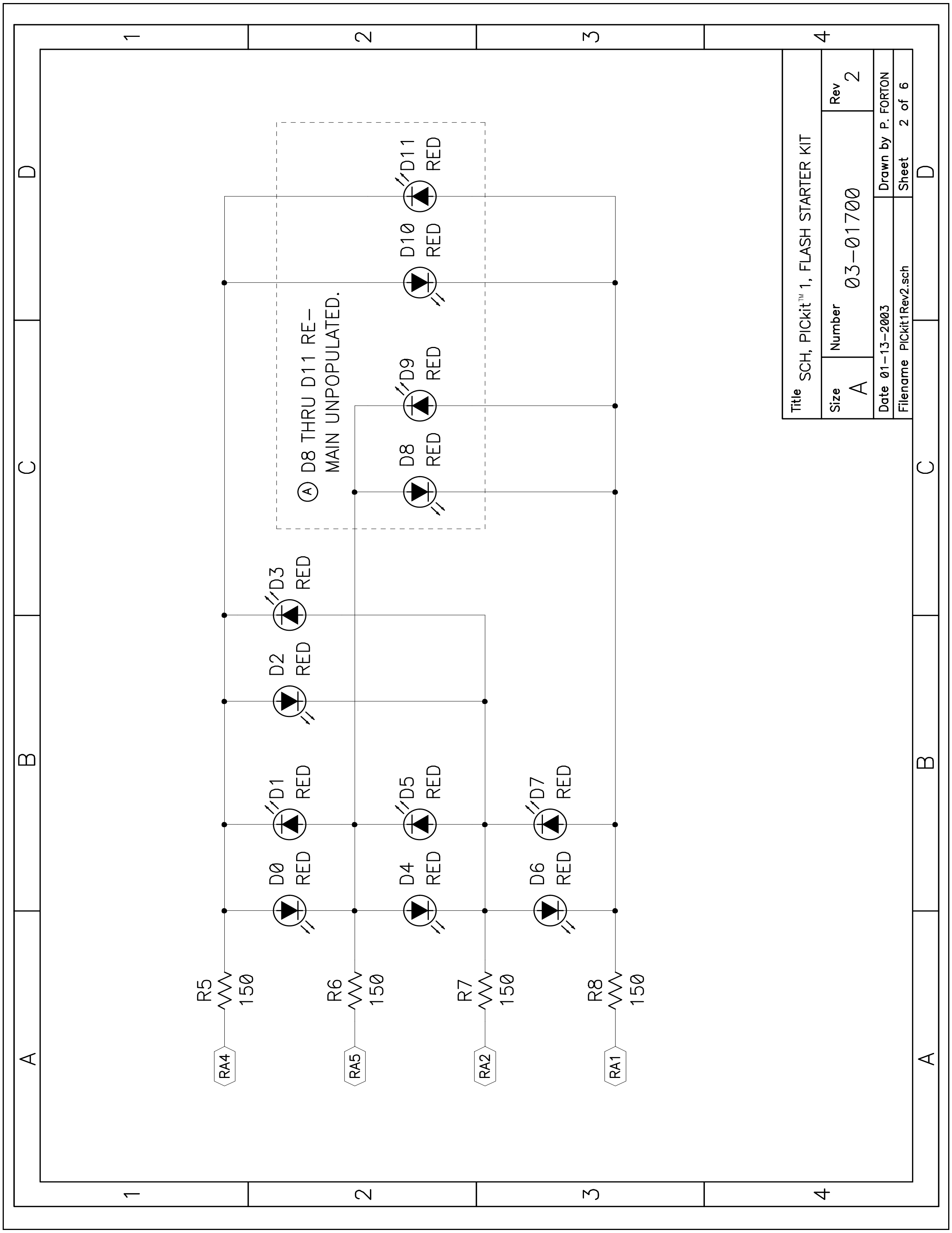


FIGURE A-3: VPP SUPPLY

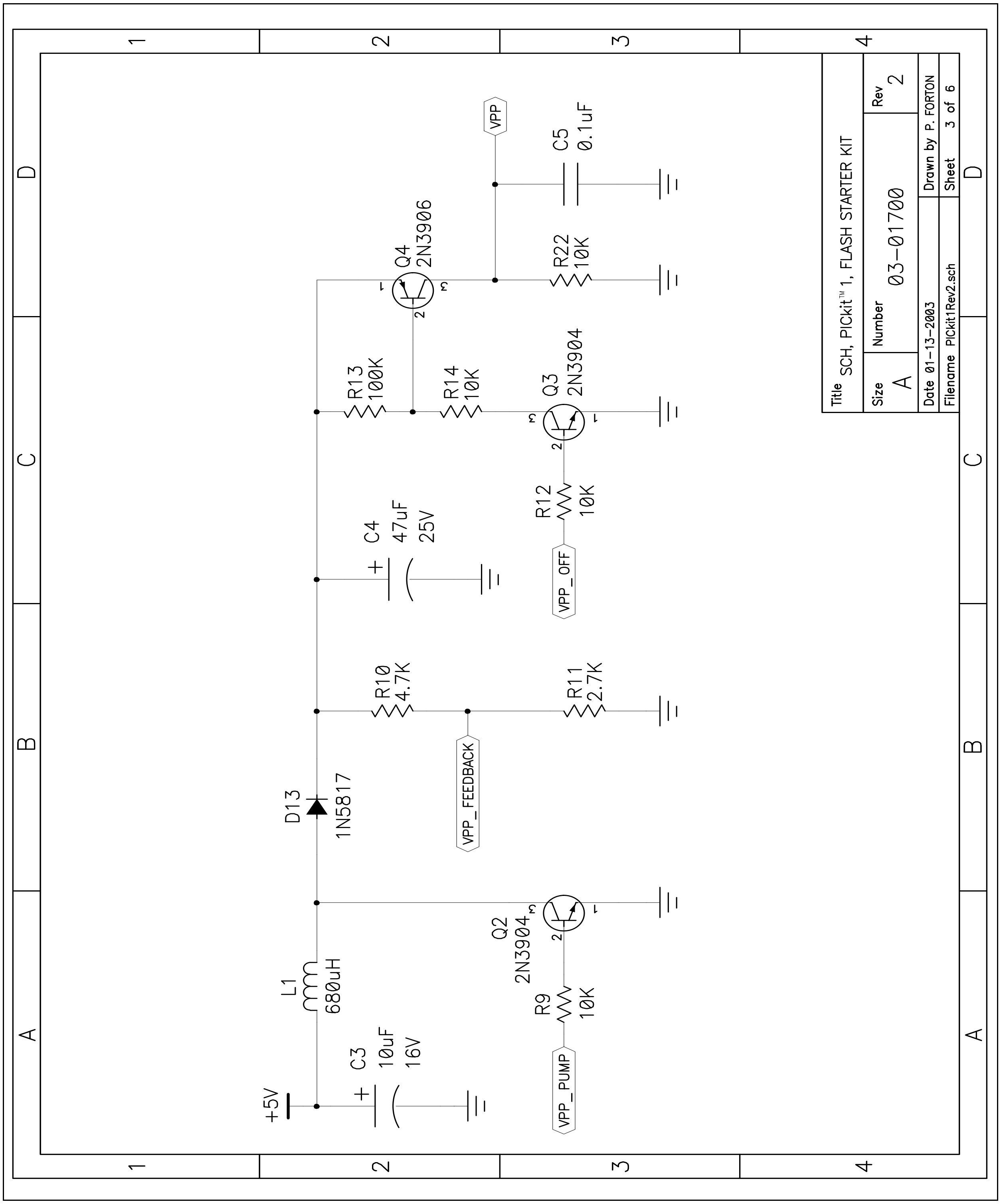


FIGURE A-4: USB CONTROL

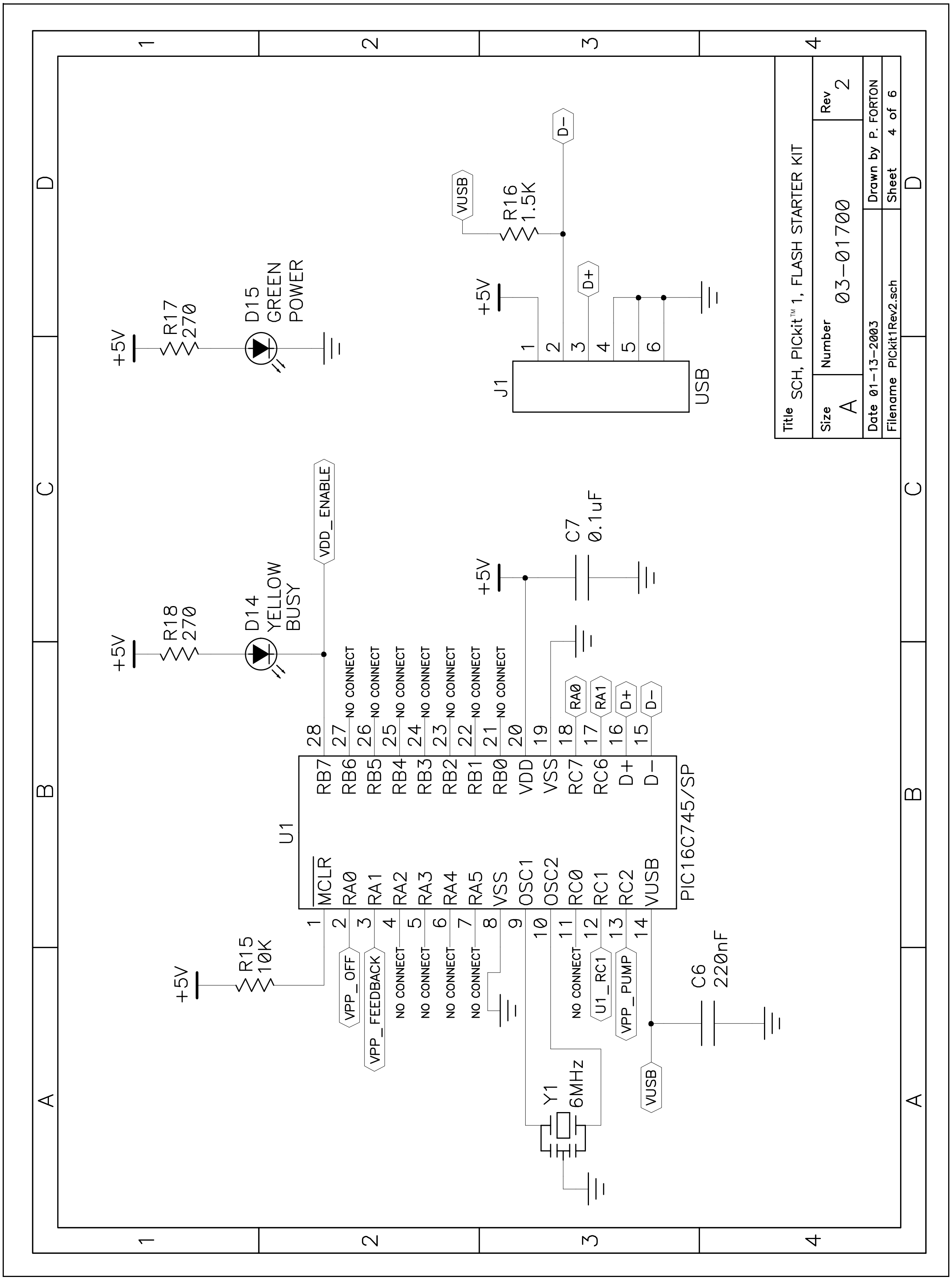


FIGURE A-5: PROTOTYPE 1

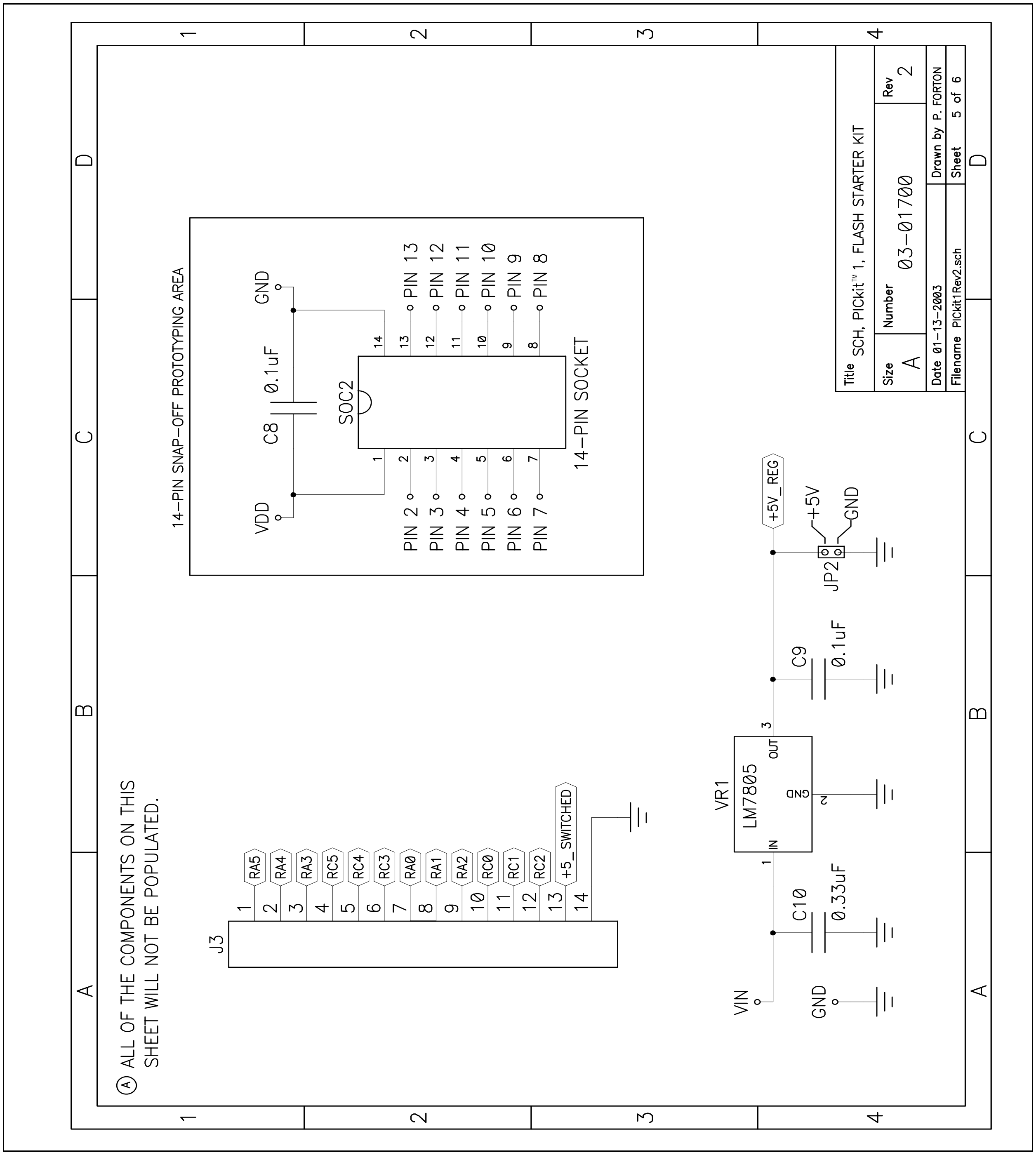
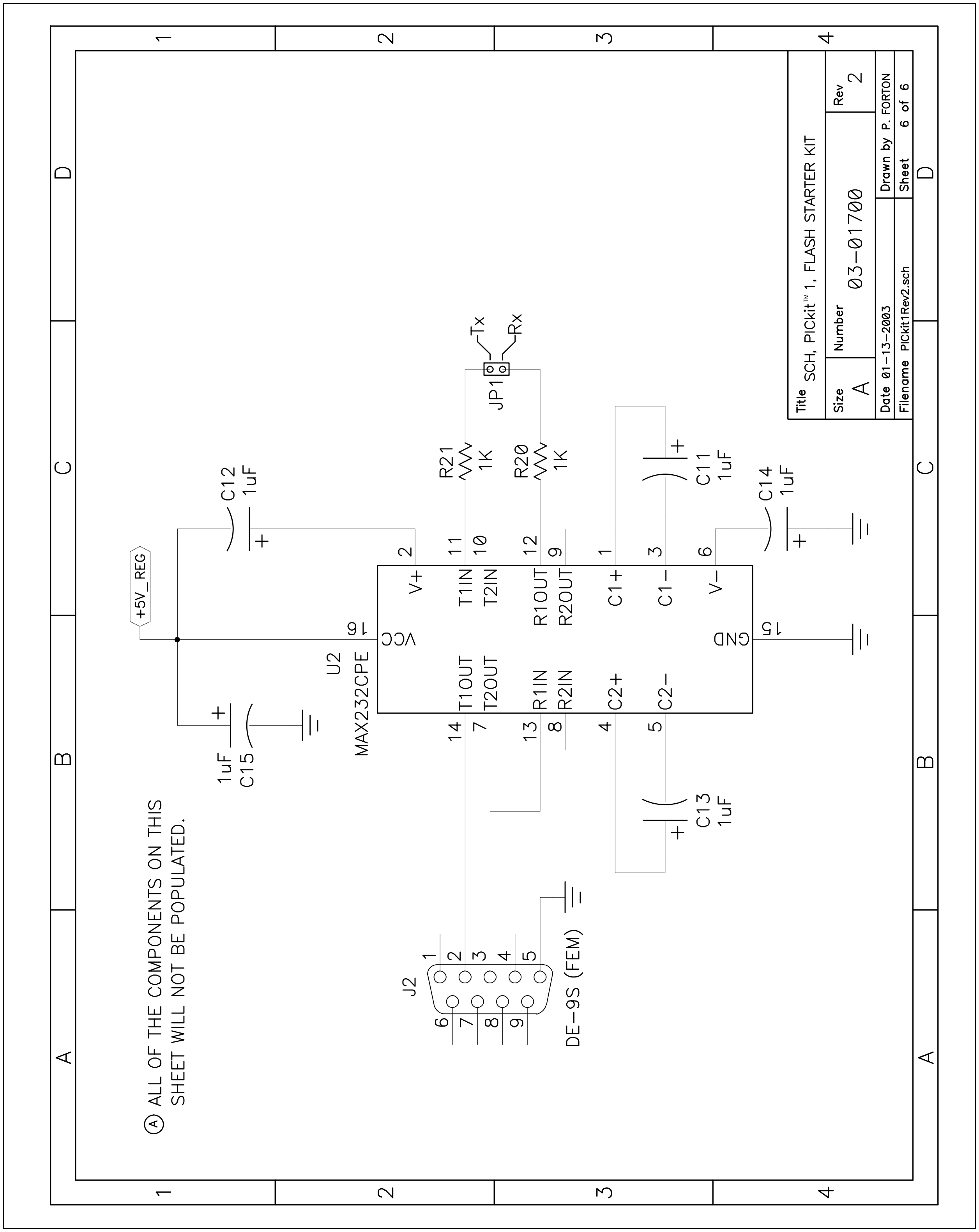


FIGURE A-6: PROTOTYPE 2



NOTES:

NOTES:

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