# MCP401X/2X Digital Potentiometer Evaluation Board User's Guide

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# MCP401X/2X EVALUATION BOARD USER'S GUIDE

## Table of Contents


**Preface ..... 1**

**Chapter 1. Product Overview**

1.1 Introduction ..... 5
1.2 What is the MCP402X Digital Potentiometer Evaluation Board? ..... 5
1.3 What the MCP402X Digital Potentiometer Evaluation Board Kit Includes ..... 6

**Chapter 2. Installation and Operation**

2.1 Introduction ..... 7
2.2 PCB Description ..... 7
2.3 Test and Operating Instructions ..... 10
2.4 Firmware Description ..... 17

**Appendix A. Schematic and Layouts**

A.1 Introduction ..... 19
A.2 Schematic ..... 20
A.3 MCP402X Board Layout – Top Layer + Silk-screen ..... 21
A.4 MCP402X Board Layout – Bottom Layer ..... 21
A.5 MCP402X Board Layout – Top Silkscreen ..... 22
A.6 MCP402X Board Layout – Bottom Layer + Silk-screen ..... 22

**Appendix B. Bill Of Materials (BOM)**

**Appendix C. Using the BFMP Programmer to Power the Board**

C.1 Powering the Board Using the BFMP Programmer ..... 25

**Appendix D. Potential Programming Issue of the MCP402XEV**

D.1 Introduction ..... 27

**Appendix E. 00066_MCP402XEV.ASM Source Code**

E.1 Introduction ..... 29

**Worldwide Sales and Service ..... 42**


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**NOTES:**


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# MCP401X/2X EVALUATION BOARD USER'S GUIDE

## Preface

### NOTICE TO CUSTOMERS

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**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.**

### INTRODUCTION

This chapter contains general information that will be useful to know before using the MCP402X Digital Potentiometer Evaluation Board. Items discussed in this chapter include:

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

### DOCUMENT LAYOUT

This document describes how to use the MCP402X Digital Potentiometer Evaluation Board. The manual layout is as follows:

- **Chapter 1. "Product Overview"** – Important information about the MCP402X Digital Potentiometer Evaluation Board.
- **Chapter 2. "Installation and Operation"** – Includes instructions on how to get started with this evaluation board.
- **Appendix A. "Schematic and Layouts"** – Shows the schematic and layout diagrams for the MCP402X Digital Potentiometer Evaluation Board.
- **Appendix B. "Bill Of Materials (BOM)"** – Lists the parts used to build the MCP402X Digital Potentiometer Evaluation Board.
- **Appendix C. "Using the BFMP Programmer to Power the Board"** – Shows how to interface the BFMP board with the MCP402X Digital Potentiometer Evaluation Board.
- **Appendix D. "Potential Programming Issue of the MCP402XEV"** – Discusses possible programming issues with Rev 1 and Rev 2 of the MCP402X Digital Potentiometer Evaluation Board.
- **Appendix E. "00066_MCP402XEV.ASM Source Code"** – Provides information about the application firmware, as well as the location of the source code.

## 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 |
| 'b*nnnn* | A binary number where *n* is a digit | 'b00100, 'b10 |
| 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` |
| Italic Courier New | A variable argument | *`file`*`.o`, where *`file`* can be any valid filename |
| `0x`*`nnnn`* | A hexadecimal number where *`n`* is a hexadecimal digit | `0xFFFF`, `0x007A` |
| 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 MCP402X Digital Potentiometer Evaluation Board. The following Microchip documents are available and recommended as supplemental reference resources.

**MCP4011/2/3/4**, *"Low-Cost, 64-Step Volatile Digital POT in SOT-23"* Data Sheet (DS21978).

**MCP4021/2/3/4**, *"Low-Cost NV Digital POT in SOT-23 with WiperLock™ Technology"* Data Sheet (DS21945).

**PIC10F200/202/204/206**, *"6-Pin, 8-Bit Flash Microcontrollers"* Data Sheet (DS41239)


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- Field Application Engineer (FAE)
- Technical Support
- Development Systems Information Line

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 B (December 2005)

- Updated to include MCP401X devices
- Enhancement of Operation Description
- Added **Appendix C. "Using the BFMP Programmer to Power the Board"** - Programming the MCP402X Digital Potentiometer Evaluation Board
- Added **Appendix D. "Potential Programming Issue of the MCP402XEV"**- A description of potential programming issues (and their solutions) with the MCP402X Digital Potentiometer Evaluation Board

### Revision A (April 2005)

- Initial Release of this Document

**NOTES:**


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# Chapter 1. Product Overview

## 1.1 INTRODUCTION

This chapter provides an overview of the MCP402X Digital Potentiometer Evaluation Board and covers the following topics:

- What is the MCP402X Digital Potentiometer Evaluation Board?
- What the MCP402X Digital Potentiometer Evaluation Board includes

## 1.2 WHAT IS THE MCP402X DIGITAL POTENTIOMETER EVALUATION BOARD?

The MCP402X Digital Potentiometer Evaluation Board (MCP402XEV) allows the system designer to quickly evaluate the operation of Microchip Technology's MCP401X/2X Digital Potentiometer products.

The MCP402X Digital Potentiometer Evaluation Board PCB was designed to support:

- 8-pin, 150 mil SOIC MCP4021-XXX/SN devices
- SOT-23-6 MCP4022-XXX/OT devices
- SOT-23-6 MCP4023-XXX/OT devices
- SOT-23-5 MCP4024-XXX/OT devices
- 8-pin, 150 mil SOIC MCP4011-XXX/SN devices
- SOT-23-6 MCP4012-XXX/OT devices
- SOT-23-6 MCP4013-XXX/OT devices
- SOT-23-5 MCP4014-XXX/OT devices

In addition to supporting the MCP401X/2X, the MCP402XEV also utilizes the SOT-23-6 PIC10F20X microcontroller.

The PIC10F20X is supplied with example firmware that debounces the **INCR** and **DECR** push buttons and generates the simple U/$\overline{D}$ protocol required by the MCP401X/2X to increment and decrement the potentiometer's wiper. It also generates the simple U/$\overline{D}$ protocol required by the MCP402X to lock and unlock the potentiometer's wiper.

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## 1.3 WHAT THE MCP402X DIGITAL POTENTIOMETER EVALUATION BOARD KIT INCLUDES

This MCP402X Digital Potentiometer Evaluation Board Kit includes:

- One populated Printed Circuit Board (PCB)
  - MCP4021-103/OT
  - PIC10F206-I/OT with `00066_MCP402XEV.HEX` programmed into memory
  - Two push button switches: one for Increment commands (INCR), one for Decrement commands (DECR)
  - Decoupling capacitors
  - 5 resistors to isolate the switches and create a voltage divider with the MCP4021-103/OT
- One blank PCB to allow rapid prototyping of a specific digital potentiometer configuration
- 2 samples each of the MCP4021-202/OT, MCP4021-502/OT, MCP4021-103/OT and MCP4021-503/OT
- 1 PIC10F20X-I/OT sample
- MCP401X/2X Digital Potentiometer Evaluation Board User's Guide (electronic version on CD) (DS51546)


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# Chapter 2. Installation and Operation

## 2.1 INTRODUCTION

The MCP402X Digital Potentiometer Evaluation Board provides a tested, out-of-the-box example of a MCP401X/2X application. The circuit description is described in **Section 2.2 "PCB Description"**, while the test and operating instructions are described in **Section 2.3 "Test and Operating Instructions"**. A supplied blank PCB allows rapid prototyping of the designer's specific MCP401X/2X device, along with other desired passive components (resistor and capacitors) and connection posts.

## 2.2 PCB DESCRIPTION

The MCP402X Digital Potentiometer Evaluation Board has the following features:

- 150 mil, 8-pin SOIC pinout (U1) supports the MCP4021 and MCP4011 devices
- SOT-23-6 pinout (U2) supports the MCP4022/23/24 and MCP4012/13/14 devices
- SOT-23-6 pinout (U3) supports the PIC10F20X devices
- Connection terminals can be left unpopulated for easy connection using small alligator clip leads (clamped across the edge of the board) or populated with either through-hole or surface-mount terminals
- Footprints for optional passive components for:
  - Power supply filtering
  - Device bypass capacitor
  - Terminal "A" pull-up resistor
  - Terminal "B" pull-down resistor
- Footprints for two switches:
  - **INCR** button operation can be detected by the PIC10F20X to generate Increment commands (move wiper toward terminal A)
  - **DECR** button operation can be detected by the PIC10F20X to generate Decrement commands (move wiper toward terminal B)
- Button sequence instructions are printed on the back of the PCB

**Appendix A.2 "Schematic"** illustrates the schematic for the MCP402XEV.

| **Note:** | The PIC10F20X firmware (`00066_MCP402XEV.HEX`) must be programmed into the microcontroller before the MCP402XEV is functional. |
|---|---|

### 2.2.1 Evaluating the MCP4021 and MCP4011

The MCP4021/11-XXXI/SN is an 8-pin digital potentiometer device with terminals A, B and W available on the device pins. Footprint U1 supports the 150 mil SOIC package. Resistors R2 and R3 are 2.5 kΩ on the populated PCB, along with the 10 kΩ MCP4021-103I/SN digital potentiometer. This creates a "windowed" voltage divider with a transfer function illustrated in Equation 2-1.

**EQUATION 2-1: WINDOWED POTENTIOMETER – VOLTAGE DIVIDER CALCULATION**

$$V_{wiper} = \frac{V_{DD} \cdot (R_{wb} + R3)}{R2 + R3 + R_{nom}} = \frac{5.0V \cdot ((d \cdot 10k)/63 + 2.5k)}{2.5k + 2.5k + 10k}$$

Where:

d = the wiper setting (0 to 63)

**Note 1:** **DO NOT** populate U2 if using U1.

**2:** The MCP4011 has high-voltage tolerant pins and, therefore, accepts high-voltage Increment and Decrement commands. Since this device is nonvolatile, the WiperLock™ Technology feature is not present.

### 2.2.2 Evaluating the MCP4022 and MCP4012

The MCP4022/12-XXXI/OT is a 6-pin, stand-alone digital rheostat with terminals A and W available on the device pins. Footprint U2 supports the SOT-23-6 package. An "INCR" command moves the wiper toward terminal A, thus causing the resistance across the rheostat to decrease. A "DECR" command moves the wiper toward terminal B, thus causing the resistance across the rheostat to increase.

**Note 1:** **DO NOT** populate U1 if using U2.

**2:** The included MCP4021 digital potentiometer samples could be used to evaluate the MCP4022 simply by not populating R3 and letting terminal B float.

**3:** The MCP4012 has high-voltage tolerant pins and, therefore, accepts high-voltage Increment and Decrement commands. Since this device is nonvolatile, the WiperLock™ Technology feature is not present.


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### 2.2.3 Evaluating the MCP4023 and MCP4013

The MCP4023/13-XXXI/OT is a 6-pin, grounded digital potentiometer with terminals A and W available on the device pins. Footprint U2 supports the SOT-23-6 package. Populating R2 will create a voltage divider with a transfer function illustrated in Equation 2-2.

**EQUATION 2-2: GROUNDED POTENTIOMETER – VOLTAGE DIVIDER CALCULATION**

$$V_{wiper} = \frac{V_{DD} \cdot R_{wb}}{R2 + R_{nom}} = \frac{5.0V \cdot (d \cdot 10k/63)}{2.5k + 10k}$$

Where:

d = the wiper setting (0 to 63)

**Note 1:** **DO NOT** populate U1 if using U2.

**2:** The included MCP4021 digital potentiometer samples could be used to evaluate the MCP4023 simply by shorting terminal B to GND.

**3:** The MCP4013 has high-voltage tolerant pins and, therefore, accepts high-voltage Increment and Decrement commands. Since this device is nonvolatile, the WiperLock™ Technology feature is not present.

### 2.2.4 Evaluating the MCP4024 and MCP4014

The MCP4024/14-xxxI/OT is a 5-pin, grounded digital rheostat with the W terminals available on the device pins. Footprint U2 supports the SOT-23-5 package. An “INCR” command moves the wiper toward terminal A, thus causing the resistance across the rheostat to increase. A “DECR” command moves the wiper toward terminal B, thus causing the resistance across the rheostat to decrease.

**Note 1:** **DO NOT** populate U1 if using U2.

**2:** The included MCP4021 digital potentiometer samples could be used to evaluate the MCP4024 simply by not populating $R_2$, letting terminal A float and by shorting terminal B to GND.

**3:** The MCP4014 has high-voltage tolerant pins and, therefore, accepts high-voltage Increment and Decrement commands. Since this device is nonvolatile, the WiperLock™ Technology feature is not present.

## 2.3 TEST AND OPERATING INSTRUCTIONS

The populated PCB is configured to create a voltage divider from $V_{DD}$ to $V_{SS}$ using a 2.5 kΩ pull-up resistor (R2), the MCP4021-103I/SN (10 kΩ) and a 2.5 kΩ pull-down resistor (R3). To quickly evaluate the digital potentiometer's performance, the following test equipment is required:

- 2.7V to 5.5V power supply
- Voltmeter or Digital Multimeter (DMM)

Figure 2-1 shows the Digital Potentiometer Evaluation Board PCB, components and the connection points that will be used in the step-by-step demonstration.

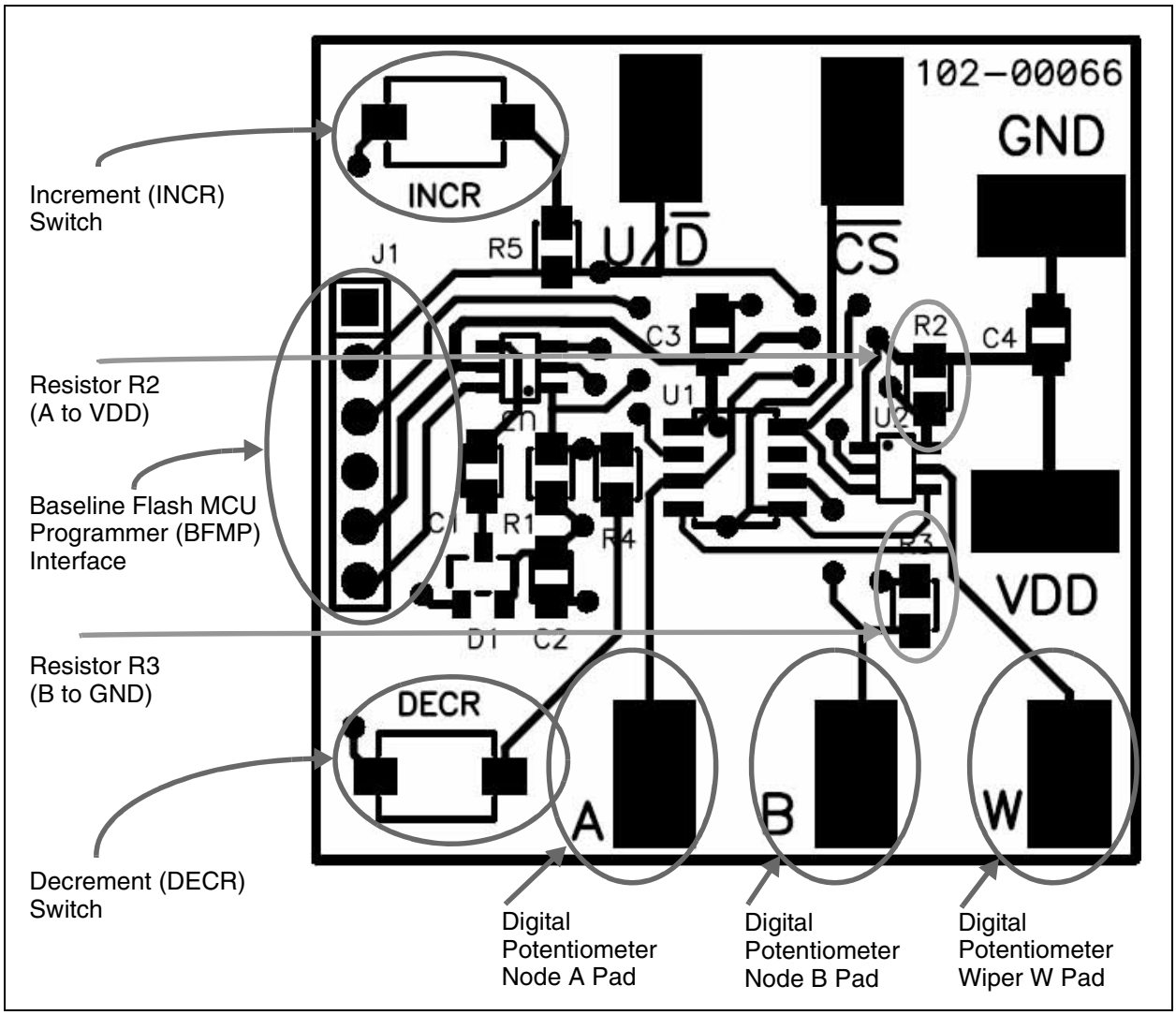


***FIGURE 2-1:*** *Digital Potentiometer Evaluation Board Overview.*


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### 2.3.1 Test Setup

1. Connect the power supply “+” to VDD and the “–” to GND.
2. Connect the voltmeter to the W terminal and GND.

The voltmeter should reflect the wiper setting with respect to Equation 2-3.

**EQUATION 2-3: POPULATED PCB – VOLTAGE DIVIDER CALCULATION**

$$V_{wiper} = \frac{V_{DD} \cdot (R_{wb} + R3)}{R2 + R3 + R_{AB}} = \frac{5.0V \cdot ((d \cdot 10k)/63 + 2.5k)}{2.5k + 2.5k + 10k}$$

Where:

d = the wiper setting (0 to 63)

Using R2 and R3 = 2.5 kΩ:

- If a 2 kΩ MCP4021 is utilized, the output range will be approximately 1.79V to 3.21V.
- If a 5 kΩ MCP4021 is utilized, the output range will be approximately 1.25V to 3.75V.
- If a 10 kΩ MCP4021 is utilized, the output range will be approximately 0.83V to 4.17V.
- If a 50 kΩ MCP4021 is utilized, the output range will be approximately 0.23V to 4.77V.

### 2.3.2 MCP402X Digital Potentiometer Evaluation Board Firmware Operation

The `00066_MCP402XEV.HEX` firmware programmed into the PIC10F20X provides a very simple interface to operate the MCP402X digital potentiometer. There are ten basic commands supported for the user to exercise the MCP402X digital potentiometer.

Table 2-1 shows the firmware commands of the Digital Potentiometer Evaluation Board.


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**TABLE 2-1: DIGITAL POTENTIOMETER EVALUATION BOARD FIRMWARE INCREMENT/DECREMENT COMMANDS**

| Command | | | | | | | | | Button Sequence | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| # | Increment/Decrement - (Low Voltage/High Voltage) | # of Steps | Saves Wiper Value in EEPROM | High Voltage on $\overline{CS}$ and U/$\overline{D}$ pins? | After Command Wiper is | | Works when Wiper is "locked" | MCP401x will INCR/DECR | #1 (Depress)[5] | #2 (Depress)[5] | #3 (Release) | #4 (Release) |
| | | | | | "locked" | "unlocked" | | | | | | |
| 1 | INCR - (Low Voltage) | 1[1] | Yes | No | — | — | No | Yes | INCR (**for < 2 sec**) | — | — | — |
| 2 | INCR - (High Voltage)[6] | 1[1] | Yes | Yes | — | Yes | Yes | Yes | INCR (**for < 2 sec**) | DECREMENT (**for < 2 sec**) | INCR | DECR |
| 3 | INCR - (High Voltage)[6] | 1[1] | Yes | Yes | Yes | — | Yes | Yes | INCR (**for < 2 sec**) | DECREMENT (**for < 2 sec**) | DECR | INCR |
| 4 | INCR - (Low Voltage) | 64[2] | Yes | No | — | — | No | Yes | INCR (**for > 2 sec**) | — | — | — |
| 5 | INCR - (High Voltage)[6] | 64[2] | Yes | Yes | — | Yes | Yes | Yes | INCR (**for < 2 sec**) | DECREMENT (**for > 2 sec**) | INCR | DECR |
| 6 | DECR - (Low Voltage) | 1[3] | Yes | No | — | — | No | Yes | DECR (**for < 2 sec**) | — | — | — |
| 7 | DECR - (High Voltage)[6] | 1[3] | Yes | Yes | — | Yes | Yes | Yes | DECR (**for < 2 sec**) | INCR (**for < 2 sec**) | DECR | INCR |
| 8 | DECR - (High Voltage)[6] | 1[3] | Yes | Yes | Yes | — | Yes | Yes | DECR (**for < 2 sec**) | INCR (**for < 2 sec**) | INCR | DECR |
| 9 | DECR - (Low Voltage) | 64[4] | Yes | No | — | — | No | Yes | DECR (**for > 2 sec**) | — | — | — |
| 10 | DECR - (High Voltage)[6] | 64[4] | Yes | Yes | — | Yes | Yes | Yes | DECR (**for < 2 sec**) | INCR (**for > 2 sec**) | DECR | INCR |

**Note 1:** Move wiper W towards node A (Increment wiper 1 step).

**2:** Move wiper W to node A (Increment wiper 64 steps). Forces the wiper setting to "full-scale" (wiper W = node A).

**3:** Move wiper W towards node B (Decrement wiper 1 step).

**4:** Move wiper W to node B (Decrement wiper 64 steps). Forces the wiper setting to "zero scale" (wiper W = node B).

**5:** If there is more than one sequence, the button sequence #1 must continue to be held down while progressing to sequence #2. Example: Command # 2. requires the **INCR** button to be depressed. Then, before 2 seconds elapses, the **DECR** button must be depressed. Next, before 2 seconds elapses, the **INCR** button must be released. The **DECR** button can then be released.

**6:** High-voltage commands require a system voltage ($V_{DD}$) greater than 5.0V to allow the simple charge pump to generate the $V_{IHH\ MIN}$ voltage for the $\overline{CS}$ pin.



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### 2.3.3 Running the Ratiometric Voltage Demo

Table 2-2 provides step-by-step instructions to perform a demonstration of the MCP402X Digital Potentiometer Evaluation Board. Measuring Ratiometric Voltage

**TABLE 2-2: MEASURING RATIOMETRIC VOLTAGE**

| Step | Action | Result |
|---|---|---|
| 1 | Power up the populated Digital Potentiometer Evaluation Board.<br>Voltage calculations use a system voltage of 5V. | — |
| | Board can be powered via a valid voltage (such as 5V) on the VDD and GND PCB Pads, or by connecting a BFMP programmer that is connected to an active PC's USB port (powered via the USB connection). | |
| 2 | Set DMM to measure the required voltage range (0V to 5.5V).<br>Connect the DMM ground connection to the evaluation board GND terminal and the DMM V/Ω connection to terminal W of the evaluation board. | — |
| 3 | Turn on DMM. | On DMM:<br>DMM will display the voltage determined by the current non-volatile setting of the wiper. |
| 4 | On the Digital Potentiometer Evaluation Board:<br>Implement Command #5 (see Table 2-1). | On the Digital Potentiometer Evaluation Board:<br>WiperLock™ Technology is disabled and the wiper is incremented from power-on position. |
| | | On DMM:<br>Voltage increments approximately 0.05V. |
| 5 | On the Digital Potentiometer Evaluation Board:<br>Implement Command #4 (see Table 2-1). | On the Digital Potentiometer Evaluation Board:<br>Wiper is forced to the full-scale position (Wiper W = node A). |
| | | On DMM:<br>Voltage equals approximately 4.17V. |
| 6 | On the Digital Potentiometer Evaluation Board:<br>Implement Command #6 (see Table 2-1). | On the Digital Potentiometer Evaluation Board:<br>Wiper is decremented one position from the full-scale position. |
| | | On DMM:<br>Voltage equals approximately 4.12V. |
| 7 | On the Digital Potentiometer Evaluation Board:<br>Implement Command #6 (see Table 2-1) 15 more times. | On the Digital Potentiometer Evaluation Board:<br>Wiper is decremented to the 25% position from node A (full-scale) to node B (zero-scale). |
| | | On DMM:<br>Voltage equals approximately 3.33V. |
| 8 | On the Digital Potentiometer Evaluation Board:<br>Turn off/disconnect power supply. | On DMM:<br>Voltage equals approximately 0V. |
| 9 | On the Digital Potentiometer Evaluation Board:<br>Reapply power to Digital Potentiometer Evaluation Board. | On DMM:<br>Voltage equals approximately 3.33V. This shows that the MCP4021 retained the last selected wiper setting. |
| 10 | On the Digital Potentiometer Evaluation Board:<br>Implement Command #3 (see Table 2-1). | On the Digital Potentiometer Evaluation Board:<br>Wiper is incremented one position and the wiper is locked (WiperLock Technology is enabled). |
| | | On DMM:<br>Voltage equals approximately 3.38V. |


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**TABLE 2-2: MEASURING RATIOMETRIC VOLTAGE (CONTINUED)**

| Step | Action | Result |
|---|---|---|
| 11 | On the Digital Potentiometer Evaluation Board:<br>Implement Command #1 (see Table 2-1). | On the Digital Potentiometer Evaluation Board:<br>Wiper is NOT moved due to the wiper being locked (WiperLock™ Technology is enabled). |
| | | On DMM:<br>Voltage equals approximately 3.38V. |
| 12 | On the Digital Potentiometer Evaluation Board:<br>Turn off/disconnect power supply. | On DMM:<br>Voltage equals approximately 0V. |
| 13 | On the Digital Potentiometer Evaluation Board:<br>Re-apply power to Digital Potentiometer Evaluation Board. | On DMM:<br>Voltage equals approximately 3.38V. This shows that the MCP4021 retained the last saved wiper setting. |

### 2.3.4 Wiper Voltages

Table 2-3 shows the relation between the wiper position and the voltage on the wiper when 5.0 volts is applied to the MCP402X Digital Potentiometer Evaluation Board where the resistors R2 and R3 are 2500Ω and the MCP4011 resistor value ($R_{AB}$) is 10 kΩ. Equation 2-4 shows the formula for these calculations.

**EQUATION 2-4: CALCULATING THE VOLTAGE ON THE MCP402X DIGITAL POTENTIOMETER EVALUATION BOARD**

$$Voltage\ at\ Wiper\ =\ System\ V_{DD} \bullet \frac{(R3 + (Wiper\ Position \bullet (R_{AB})/63))}{R3 + R_{AB} + R2}$$

Where:

System $V_{DD}$ = 5.0V

R2 = 2.5 kΩ

R3 = 2.5 kΩ

$R_{AB}$ = 10 kΩ

The typical step resistance for the 10 kΩ MCP4021 is approximately 158.73Ω. With a 5V supply and a 15 kΩ total resistance (2.5 kΩ + 2.5 kΩ + 10 kΩ), the delta voltage per step is approximately 0.053V.

**TABLE 2-3: WIPER POSITION AND CORRESPONDING VOLTAGE**

| Wiper | | | Wiper | | | Wiper | | | Wiper | |
|---|---|---|---|---|---|---|---|---|---|---|
| Position | Voltage (V) | | Position | Voltage (V) | | Position | Voltage (V) | | Position | Voltage (V) |
| 00(1) | 0.833 | | 16 | 1.680 | | 32 | 2.526 | | 48 | 3.373 |
| 01 | 0.866 | | 17 | 1.733 | | 33 | 2.579 | | 49 | 3.426 |
| 02 | 0.939 | | 18 | 1.786 | | 34 | 2.632 | | 50 | 3.479 |
| 03 | 0.992 | | 19 | 1.839 | | 35 | 2.685 | | 51 | 3.532 |
| 04 | 1.045 | | 20 | 1.892 | | 36 | 2.738 | | 52 | 3.585 |
| 05 | 1.098 | | 21 | 1.944 | | 37 | 2.791 | | 53 | 3.638 |
| 06 | 1.151 | | 22 | 1.997 | | 38 | 2.844 | | 54 | 3.690 |
| 07 | 1.204 | | 23 | 2.050 | | 39 | 2.897 | | 55 | 3.743 |
| 08 | 1.257 | | 24 | 2.103 | | 40 | 2.950 | | 56 | 3.796 |
| 09 | 1.310 | | 25 | 2.156 | | 41 | 3.003 | | 57 | 3.849 |
| 10 | 1.362 | | 26 | 2.209 | | 42 | 3.056 | | 58 | 3.902 |
| 11 | 1.415 | | 27 | 2.262 | | 43 | 3.108 | | 59 | 3.955 |
| 12 | 1.468 | | 28 | 2.315 | | 44 | 3.161 | | 60 | 4.008 |
| 13 | 1.521 | | 29 | 2.368 | | 45 | 3.214 | | 61 | 4.061 |
| 14 | 1.574 | | 30 | 2.421 | | 46 | 3.267 | | 62 | 4.114 |
| 15 | 1.627 | | 31 | 2.474 | | 47 | 3.320 | | 63(2) | 4.167 |

**Note 1:** This is zero-scale, wiper is connected to terminal B.

**2:** This is full-scale, wiper is connected to terminal A.


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## 2.4 FIRMWARE DESCRIPTION

The 000066_MCP402XEV.ASM source code was written using assembly language for the PIC10F206 microcontroller. Refer to **Appendix E. "00066_MCP402XEV.ASM Source Code"**. The firmware initializes its I/O so that it can poll the **INCR** and **DECR** buttons every millisecond. If the button has been depressed for 40 out of 50 ms, it is considered to be debounced and asserted. The button state is used to determine if a new "Action State" is desired. This simple state machine then decodes the desired action. Once the desired command has been determined, a subroutine that performs the desired command is executed. The low-voltage commands are driven directly from the PIC10F206 I/O, but the high-voltage commands require some additional hardware to generate the required 8V signal.

When a high-voltage command is required, the PIC10F206's unique OSCOUT feature is utilized. The OSCOUT function allows the instruction clock to be driven on GP2/OSCOUT under software control. A simple charge pump consisting of 2 – 0.01 µF capacitors and a BAV99 dual diode is constructed as seen in **Appendix A.2 "Schematic"**. When the OSCOUT is enabled, a 1 MHz clock drives the charge pump that produces an 8.4V signal on the MCP401X/2X's $\overline{CS}$ pin (assuming $V_{DD}$ = 5.0V). Utilizing such a charge pump requires special attention to the timing of the $\overline{CS}$ & U/$\overline{D}$ signals.

Refer to the comments in the 00066_MCP402XEV.ASM source code for more details on the firmware's operation. Refer to **Appendix E. "00066_MCP402XEV.ASM Source Code"**.

**NOTES:**


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# Appendix A. Schematic and Layouts

## A.1 INTRODUCTION

This appendix contains the following schematics and layout diagrams for the MCP402X Digital Potentiometer Evaluation Board.

- Schematic – Shows the schematic of the MCP402X Digital Potentiometer Evaluation Board. The populated PCB was built using this schematic.
- Board Layout – Top Layer + Silk-screen
- Board Layout – Top Silk-Screen
- Board Layout – Bottom Layer + Silk-screen
- Board Layout – Bottom Layer

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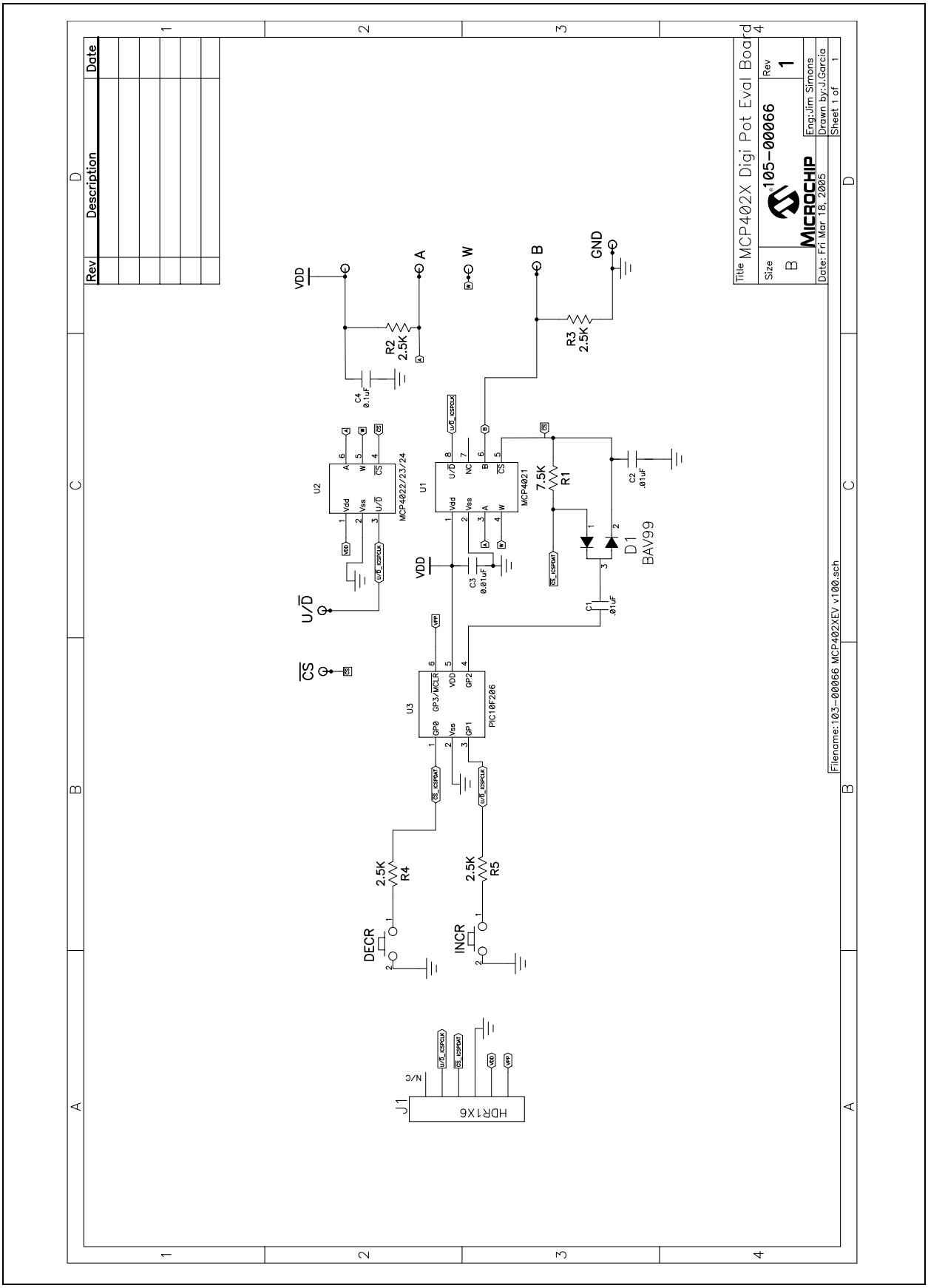
## A.2 SCHEMATIC





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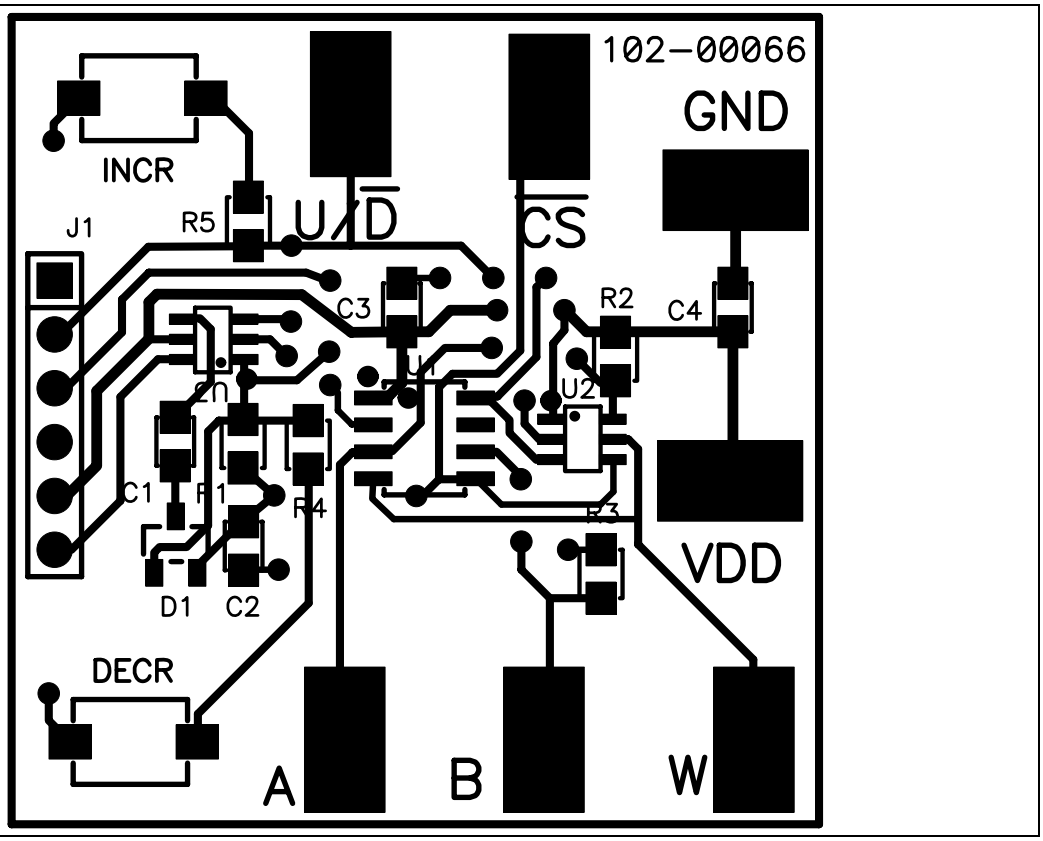
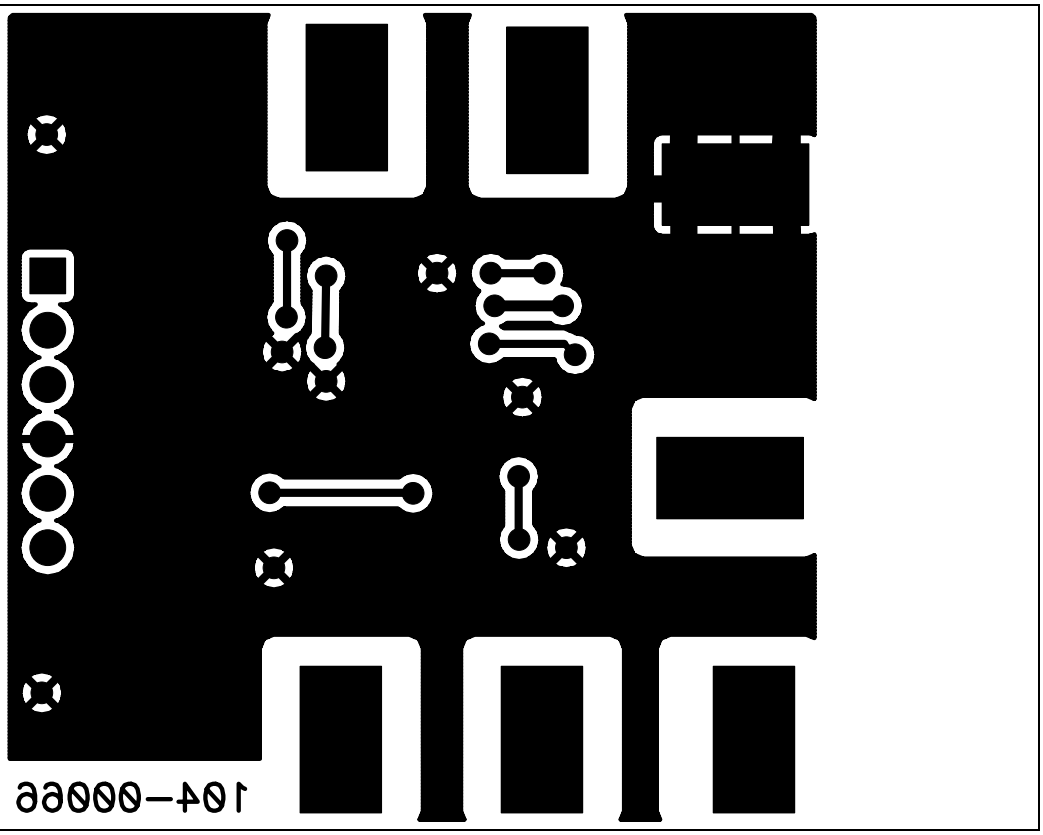
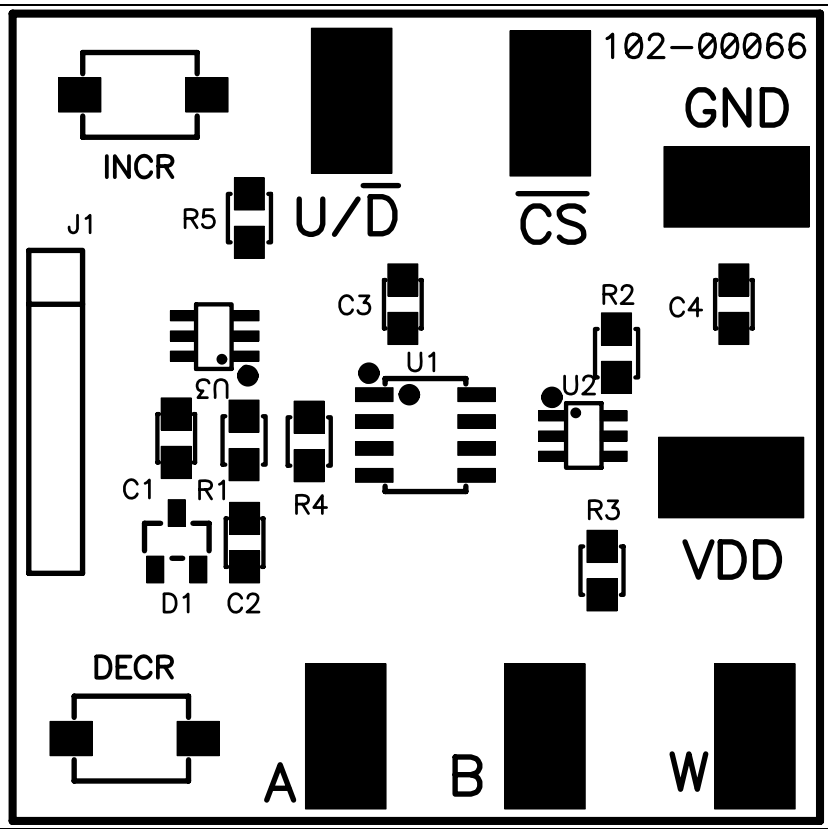
## A.3 MCP402X BOARD LAYOUT – TOP LAYER + SILK-SCREEN



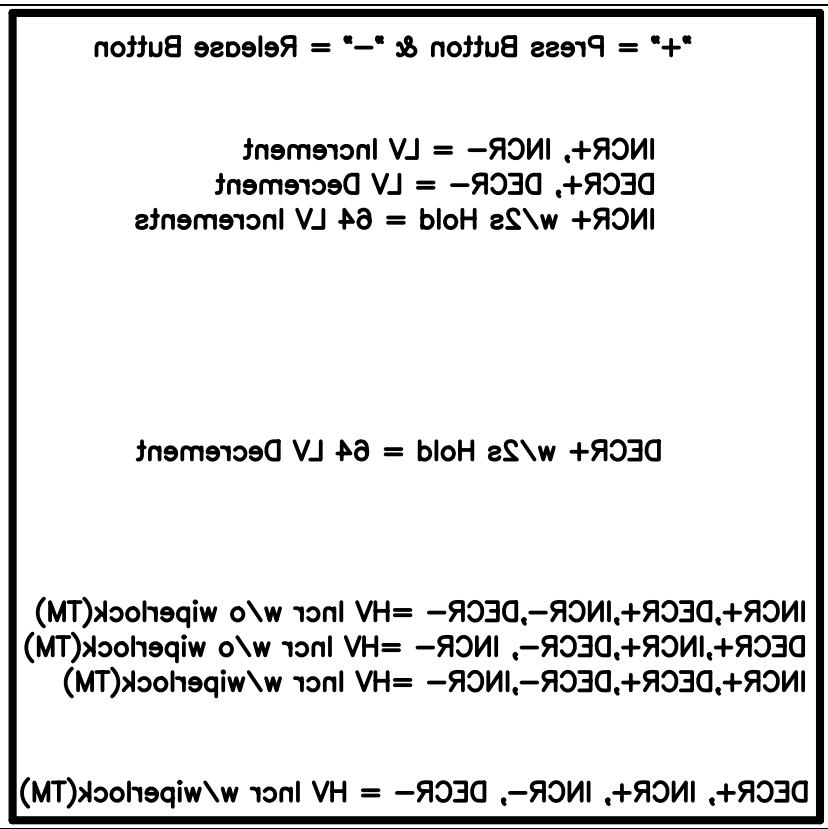

## A.4 MCP402X BOARD LAYOUT – BOTTOM LAYER



## A.5 MCP402X BOARD LAYOUT – TOP SILK-SCREEN




## A.6 MCP402X BOARD LAYOUT – BOTTOM LAYER + SILK-SCREEN





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# Appendix B. Bill Of Materials (BOM)

**TABLE B-1: BILL OF MATERIALS**

| Qty | Reference | Description | Manufacturer | Part Number |
|---|---|---|---|---|
| 2 | C1,C2,C3 | Cap 0.01 µF 50V CERAMIC X7R 0805 | Kemet® | C0805C103K5RACTU |
| 1 | C4 | Cap .1 µF 25V CERAMIC X7R 0805 | Panasonic® Corporation – ECG | ECJ-2VB1E104K |
| 1 | D1 | Dual Diode, SOT-23-3, May substitute with Fairchild® BAV99 | ON Semiconductor® | BAV99LT1 |
| 2 | INCR, DECR | Switch LT Touch 6X3.5 100 GF SMD | Panasonic Corporation – ECG | EVQ-PJS04K |
| 1 | J1 | Conn Header 6pos .100 VERT TIN (Optional) | Molex®/Waldom® Electronics Corp | 22-28-4061 |
| 1 | R1 | Res 7.5 kΩ 1/10W 1% 0805 SMD | Panasonic Corporation – ECG | ERJ-6ENF5111V |
| 2 | R2,R3 | Res 2.5 kΩ 1/10W 1% 0805 SMD | Panasonic Corporation – ECG | ERJ-6ENF5111V |
| 2 | R4,R5 | Res 2.5 kΩ 1/10W 1% 0805 SMD | Panasonic Corporation – ECG | ERJ-6ENF5111V |
| 1 | U1 | MCP4021-103/SN 10 kΩ Digital Potentiometer | Microchip Technology Inc. | MCP4021-103/SN |
| 1 | U3 | PIC10F206, 6-Pin, 8-Bit Flash Microcontrollers | Microchip Technology Inc. | PIC10F206-I/OT |
| 1 | U2 | MCP4022/23/24 5/6 Pin Digital Potentiometer (Optional) | Microchip Technology Inc. | MCP4024-502/OT |
| 7 | A,B,W,VDD,GND, U/$\overline{D}$,CS | Test Point PC Compact SMT (Optional) | Keystone® Electronics | 5016 |

**NOTES:**


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# Appendix C. Using the BFMP Programmer to Power the Board

## C.1 POWERING THE BOARD USING THE BFMP PROGRAMMER

The BFMP programmer (PG164101) uses a 6-pin interface for programming. The PICkit™ 2 Flash Starter Kit (PG164120 or DV164120) uses the same interface.

The MCP402X Digital Potentiometer Evaluation Board (MCP402XEV) plugs into the BFMP (or PICkit™ 2 Flash Starter Kit) in the orientation shown in Figure C-1.

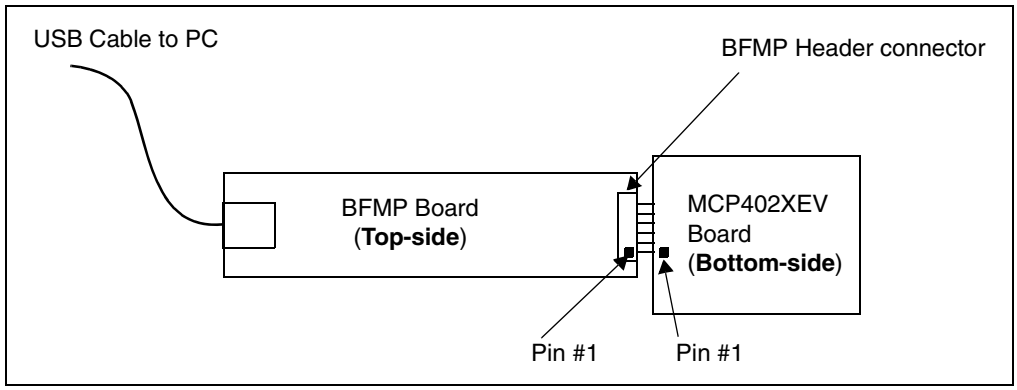


***FIGURE C-1:*** *BFMP Hardware and MCP402X Digital Potentiometer Evaluation Board.*

These programmers use the PICkit™ 1 Baseline Flash Programmer software. This GUI should be configured as shown in Figure C-2. Selecting **Device Power** causes the BFMP to power the attached board all the time (not just during programming). This allows the MCP402X Digital Potentiometer Evaluation Board to be easily demonstrated without needing to carry a power supply (although a DMM is still required).

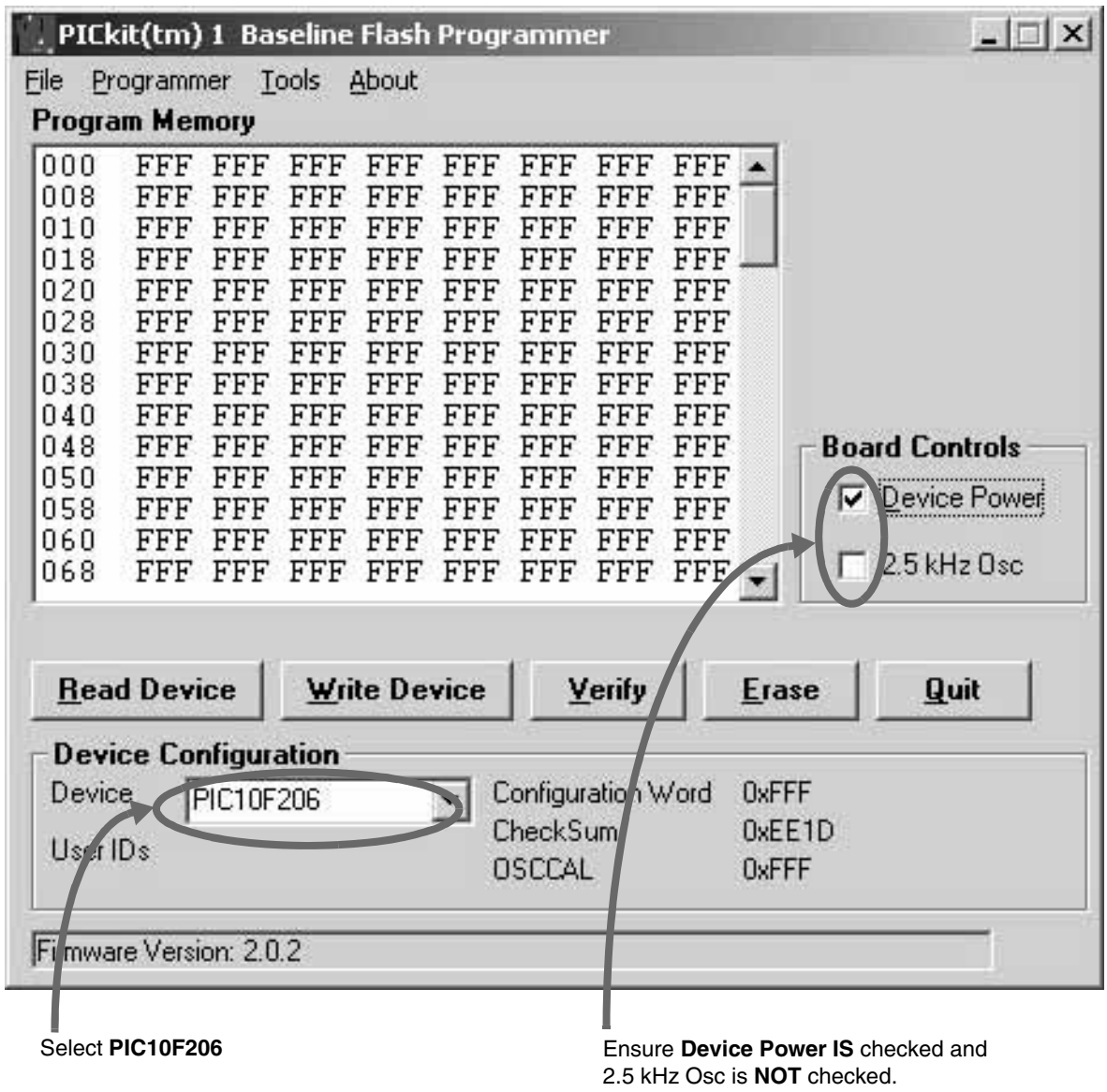


***FIGURE C-2:*** *PICkit™ 1 Baseline Flash Programmer - Configuration #2.*

| **Note:** | When programming the MCP402X Digital Potentiometer Evaluation Board, under *"Board Controls"*, DO NOT check **Device Power**. This ensures that the PIC10F206 is only powered during the programming cycle. |
|---|---|


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# Appendix D. Potential Programming Issue of the MCP402XEV

## D.1 INTRODUCTION

When programming the MCP402XEV with a Microchip programmer (such as the BPMF or MPLAB® ICD 2), the PIC10F206 may not program correctly due to the load on the ICSPDAT pin. **This issue relates to PCBs marked 104-00066 and 104-00066R2.**

Due to the current path to ground that is present with the D1 and R1 components through capacitor C2, the programming voltage on the ICSPDAT signal may not meet the voltage requirements of the PIC10F206 GP1 pin.

To address this when programming the board, lift up one of the terminals of capacitor C2 (see Figure D-1). This will stop the ICSPDAT signal voltage from being loaded down while capacitor C2 is charging. The schematic is shown in Figure D-2.

After programming, capacitor C2 must be reconnected to the circuit. This is because this circuit generates the high voltage for the high voltage commands.

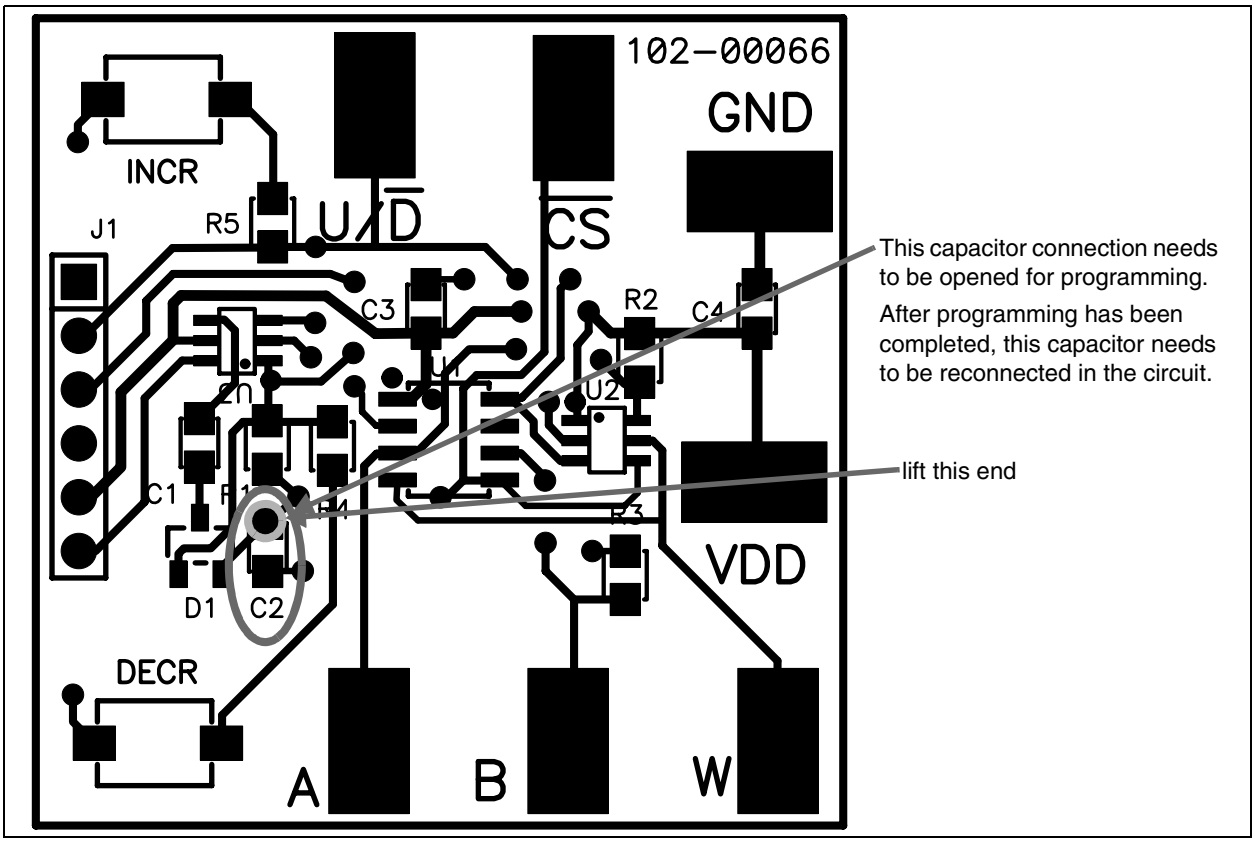


***FIGURE D-1:*** *MCP402XEV R2 PCB Layout – ECN #1.*

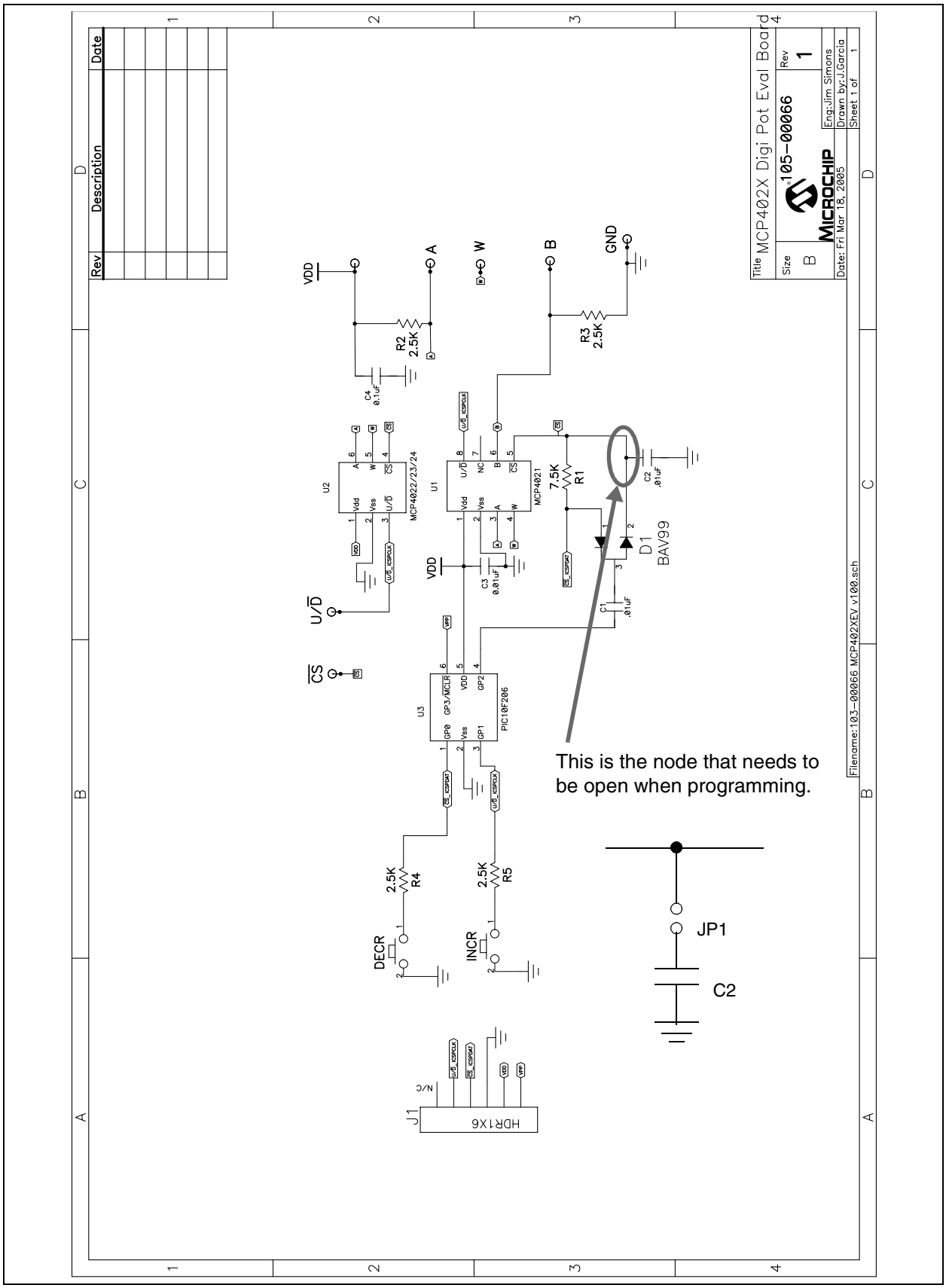


***FIGURE D-2:*** *MCP402XEV R2 Schematic PCB R2, ECN #1.*


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# Appendix E. 00066_MCP402XEV.ASM Source Code

## E.1 INTRODUCTION

This appendix documents the example PIC10F20X source code used on the populated PCB. The source code is described in detail by the comments within the.ASM file. The 00066_MCP402XEV.ASM, PIC10F206.INC and MCP402XEV.HEX files can be found on the Microchip web site (www.microchip.com) and on the included CD.

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**TABLE E-1: 00066_MCP402XEV.ASM SOURCE CODE**

```
  TITLE "MCP402XEV Firmware"
;*******************************************************************************************
; Author:   Jim Simons
; Tools:    MPLAB(r) 7.10 using MPLINK(tm)
; Editor:   ComicSans 8pt w/8 character Tabs
; Files:    00066_MCP402XEV.asm
;           p10f206.inc
;
; Description:  Exercise the MCP402x devices using the MCP402x EV board.
;               Simply use the INCR & DECR buttons to execute the INCR & DECR serial commands.
;
; Serial Commands      Action                                                          State
; _______________      ______                                                          _____
; LV Increment w/EE    Depress UP, Release UP    LVwEE = 1                             3
; LV Decrement w/EE    Depress DOWN, Release DOWN  LVwEE = 1                           4
; LV Increment w/o EE  Depress UP, Release UP    LVwEE = x                             3
; LV Decrement w/o EE  Depress DOWN, Release DOWN  LVwEE = x                           4
; LV 64 Increments     Depress UP, Hold for 2s, Release UP                             1
; LV 64 Decrements     Depress DOWN, Hold for 2s, Release DOWN                         2
; HV Incr w/o WL       Depress UP, Depress DOWN, Release UP, Release DOWN              11
; HV Decr w/o WL       Depress DOWN, Depress UP, Release DOWN, Release UP              12
; HV 64 Incr w/o WL    Depress UP, Depress DOWN, Hold for 2s, Release UP, Release DOWN  5
; HV 64 Decr w/o WL    Depress DOWN, Depress UP, Hold for 2s, Release DOWN, Release UP  6
; HV Incr w/WL         Depress UP, Depress DOWN, Release DOWN, Release UP              13
; HV Decr w/WL         Depress DOWN, Depress UP, Release UP, Release DOWN              14
;
```

**TABLE E-1: 00066_MCP402XEV.ASM SOURCE CODE (CONTINUED)**

```
;*******************************************************************************************************
; Connections/Schematic
;*******************************************************************************************************
;
; MCP pin     MCP4021     MCP4022     MCP4023     MCP4024
; _______     _______     _______     _______     _______
; 1           Vdd         Vdd         Vdd         Vdd
; 2           Vss         Vss         Vss         Vss
; 3           A           U/D         U/D         U/D
; 4           W           CS          CS          CS
; 5           CS          W           W           W
; 6           B           A           A           -
; 7           -           -           -           -
; 8           U/D         -           -           -
;
; MCP402x     PIC10F206                   Ext Components
; _______     _________                   ______________
; Vdd         Vdd                         0.1uF - Vss
; Vss         Vss                         -
; A           -                           2.5k - Vdd
; W           -                           -
; B           -                           2.5k - Vss
; CS          GP0/ICSPDAT (int pu)        2.5k - DECR - Vss, 7.5k - CS & BAV99
; U/D         GP1/ICSPCLK (int pu)        2.5k - INCR - Vss
; -           GP2/OSCOUT                  0.01uF - BAV99 - 0.01uF - Vss
; -           GP3/Vpp (int pu)            optional SW or Jumper put on BFMP header pins 4 & 6
;
;*******************************************************************************************************
; Assemble Time Variables
SaveWiper   equ   1   ; comment this line prevent LV commands from Saving the Wiper
;
;*******************************************************************************************************
; Configure the PIC
;*******************************************************************************************************

  list      p=10F206    ; list directive to define processor
  #include <p10F206.inc>  ; processor specific variable definitions

  __CONFIG  _MCLRE_OFF & _CP_OFF & _WDT_ON

  ERRORLEVEL -302
```

**TABLE E-1: 00066_MCP402XEV.ASM SOURCE CODE (CONTINUED)**

```
;*******************************************************************************************
; General Pupose Register Definitions
;*******************************************************************************************
GPRS        UDATA
State         res     1     ; variable to track the "state" value
                            ; this code functions as a state machine
                            ; bits 3:0 stores the state 0-15 indicator
                            ; bits 7:6 stores the debounced button states
OldState      res     1     ; allows program to see if State changed
Exit          res     1     ; variable to count the number ms to test for a button press
DebounceUP    res     1     ; variable to count the number of ms UP was pressed
DebounceDOWN  res     1     ; variable to count the number of ms DOWN was pressed
DLYCNT1       res     1     ; variable for the delay subroutines
DLYCNT2       res     1     ; variable for the delay subroutines

 #define     UD      GPIO,1     ; GP1 tied to UD & has "INCR" switch connected via 2.2k resistor
 #define     CS      GPIO,0     ; GP0 tied to CS & has "DECR" switch connected via 2.2k resistor
 #define     UP      GPIO,1     ; Momentary switch UP
 #define     DOWN    GPIO,0     ; Momentary switch DOWN
 #define     CP      GPIO,2     ; OSCOUT pin for Charge Pump
 #define     PowerDown GPIO,3   ; Vpp for programming & PowerDown input to put uC to SLEEP

 #define    HV_CS    OSCCAL,FOSC4  ; Drives CS to HVDD (drive CS high first)

 #define    UP_State   State,7   ; Debounced UP State - using bits 5:4 are critical
 #define    DOWN_State State,6   ; Debounced DOWN State - using bits 5:4 are critical

;*******************************************************************************************
; Reset Code
;*******************************************************************************************
RESET     CODE              ; processor reset vector + 1
;ResetVector                ; Device resets to 0x1FF to get the factory calibration
    goto    Start           ; Lower half of memory reserved for subroutines

;*******************************************************************************************
; Main Code
;*******************************************************************************************
MAIN      CODE
Start
Init_Oscillator
; Internal RC calibration value is placed at location 0xFF by Microchip
; as a movlw k, where the k is a literal value.
    movwf   OSCCAL          ; update register with factory cal value
;   bcf     OSCCAL,FOSC4    ; make sure the FOSC4 is disabled to shut charge pump off

StateMachineReset
    movlw   b'11110011'     ; Disable the Comparator & make inputs digital
    movwf   CMCON0
;   bcf     CMCON0, CMPON   ; needs to be on to get GP2 as a General Purpose Output
    movlw   b'10011010'     ; disable Wake-Up on Pin Change,
                            ; enable weak pullups for button inputs
                            ; T0CS must be 0 for GP2 TRIS to be active
                            ; set up for 72ms WDT
    option
Init
    clrf    State
    clrf    OldState
    call    InitGPIO        ; make GP0/DECR/CS & GP1/INCR/UD outputs, block undesired U/D commands
```

**TABLE E-1: 00066_MCP402XEV.ASM SOURCE CODE (CONTINUED)**

```
ButtonCheck               ; Debounce Buttons
    btfss   PowerDown     ; If pulled low, put uC to SLEEP
    goto    LowPowerMode
    bsf     UP_State
    bsf     DOWN_State    ; initialize Button_State to indicate no button pressed
    movlw   .50           ; debounce the buttosns for 50mS to see if pressed
    movwf   Exit
    movlw   .40           ; if pushed for 40 of 50 tests, then valid UP
    movwf   DebounceUP
    movwf   DebounceDOWN
DebounceLoop
    call    GPIO_TestUP   ; make GP1/INCR/UD an input (w/pu enabled)
    movlw   .99
    call    VAR5TcyDELAY  ; 5 + (99*5) = 500us
    btfss   UP
    decfsz  DebounceUP,f
    goto    CheckDOWN
    bcf     UP_State      ; UP Button Pressed
CheckDOWN
    call    GPIO_TestDOWN ; make GP0/DECR/CS an input (w/pu enabled)
    movlw   .99
    call    VAR5TcyDELAY  ; 5 + (99*5) = 500us
    btfss   DOWN
    decfsz  DebounceDOWN,f
    goto    DebounceLoopTest
    bcf     DOWN_State    ; DOWN Button Pressed
DebounceLoopTest
    decfsz  Exit,f
    goto    DebounceLoop

    call    InitGPIO      ; make GP0/DECR/CS & GP1/INCR/UD outputs, block undesired U/D commands
    movf    State,w
    call    DetermineState    ; subroutine to determine the next state
    movwf   State
    xorwf   OldState,w
    btfss   STATUS,Z
    call    PerformState      ;State changed, now do something
    movlw   .5
    call    VAR1000TcyDELAY   ; Make sure EE Write Cycle has finished
    movf    State,w
    movwf   OldState
    goto    ButtonCheck       ; Loop for button presses

;*****************************************************************************************
; State Machine Code
;*****************************************************************************************
State0      goto    StateMachineReset ; State 0, no action, shouldn't get here

State1                        ; UP button pressed
    movlw   .200              ; 200x10mS = 2s
    movwf   Exit
```

**TABLE E-1: 00066_MCP402XEV.ASM SOURCE CODE (CONTINUED)**

```
Loop1_2sec
    call    GPIO_TestDOWN     ; make GP0/DECR/CS an input (w/pu enabled)
    movlw   .5                ; 5ms delay
    call    VAR1000TcyDELAY
    btfss   DOWN              ; if DOWN gets pressed, exit
    retlw   .1
    call    GPIO_TestUP       ; make GP1/INCR/UD an input (w/pu enabled)
    movlw   .5                ; 5ms delay
    call    VAR1000TcyDELAY
    btfsc   UP                ; if UP gets released, exit
    retlw   .1
    decfsz  Exit,f
    goto    Loop1_2sec
    call    InitGPIO      ; make GP0/DECR/CS & GP1/INCR/UD outputs, block undesired U/D commands
    movlw   .64
    call    LV_Increment
;   movlw   .4
;   call    VAR1000TcyDELAY   ; add a 4mS delay for E/W cycle
    call    GPIO_TestUP       ; make GP1/INCR/UD an input (w/pu enabled)
LV_IncrExit
    clrwdt
    btfss   UP                ; if UP gets released, exit
    goto    LV_IncrExit
    clrf    State
    retlw   .1
State2                        ; DOWN button pressed
    movlw   .200              ; 200x10mS = 2s
    movwf   Exit
Loop2_2sec
    call    GPIO_TestUP       ; make GP1/INCR/UD an input (w/pu enabled)
    movlw   .5                ; 5ms delay
    call    VAR1000TcyDELAY
    btfss   UP                ; if UP gets pressed, exit
    retlw   .2
    call    GPIO_TestDOWN     ; make GP0/DECR/CS an input (w/pu enabled)
    movlw   .5                ; 5ms delay
    call    VAR1000TcyDELAY
    btfsc   DOWN              ; if DOWN gets released, exit
    retlw   .2
    decfsz  Exit,f
    goto    Loop2_2sec
    call    InitGPIO      ; make GP0/DECR/CS & GP1/INCR/UD outputs, block undesired U/D commands
undesired U/D commands
    movlw   .64
    call    LV_Decrement
;   movlw   .4
;   call    VAR1000TcyDELAY  ; add a 4mS delay for E/W cycle
    call    GPIO_TestDOWN    ; make GP0/DECR/CS an input (w/pu enabled)
LV_DecrExit
    clrwdt
    btfss   DOWN             ; if DOWN gets released, exit
    goto    LV_DecrExit
    clrf    State
    retlw   .2
State3                        ; LV Increment
    call    InitGPIO      ; make GP0/DECR/CS & GP1/INCR/UD outputs, block undesired U/D commands
    movlw   .1
    call    LV_Increment
    clrf    State
    retlw   .3
```

**TABLE E-1: 00066_MCP402XEV.ASM SOURCE CODE (CONTINUED)**

```
State4                          ; LV Decrement
    call    InitGPIO      ; make GP0/DECR/CS & GP1/INCR/UD outputs, block undesired U/D commands
    movlw   .1
    call    LV_Decrement
    clrf    State
    retlw   .4
State5                          ; Both buttons pressed
    movlw   .200                ; 200x10mS = 2s
    movwf   Exit
Loop5_2sec
    call    GPIO_TestUP         ; make GP1/INCR/UD an input (w/pu enabled)
    movlw   .5                  ; 5ms delay
    call    VAR1000TcyDELAY
    btfsc   UP                  ; if UP gets released, exit
    retlw   .5
    call    GPIO_TestDOWN       ; make GP0/DECR/CS an input (w/pu enabled)
    movlw   .5                  ; 5ms delay
    call    VAR1000TcyDELAY
    btfsc   DOWN                ; if DOWN gets released, exit
    retlw   .5
    decfsz  Exit,f
    goto    Loop5_2sec
    call    InitGPIO      ; make GP0/DECR/CS & GP1/INCR/UD outputs, block undesired U/D commands
    movlw   .64
    call    HV_Increment_WL_Disable
;   movlw   .4
;   call    VAR1000TcyDELAY  ; add a 4mS delay for E/W cycle
HV_IncrExit clrwdt
    call    GPIO_TestDOWN       ; make GP0/DECR/CS an input (w/pu enabled)
    movlw   .10
    call    VAR1000TcyDELAY  ; add a 10mS delay for settling time
    btfss   DOWN                ; if DOWN gets released, exit
    goto    HV_IncrExit
    call    GPIO_TestUP         ; make GP1/INCR/UD an input (w/pu enabled)
    movlw   .10
    call    VAR1000TcyDELAY  ; add a 10mS delay for settling time
    btfss   UP                  ; if UP gets released, exit
    goto    HV_IncrExit
    clrf    State
    retlw   .5
State6
    movlw   .200                ; 200x10mS = 2s
    movwf   Exit
Loop6_2sec
    call    GPIO_TestUP         ; make GP1/INCR/UD an input (w/pu enabled)
    movlw   .5                  ; 5ms delay
    call    VAR1000TcyDELAY
    btfsc   UP                  ; if UP gets released, exit
    retlw   .6
    call    GPIO_TestDOWN       ; make GP0/DECR/CS an input (w/pu enabled)
    movlw   .5                  ; 5ms delay
    call    VAR1000TcyDELAY
    btfsc   DOWN                ; if DOWN gets released, exit
    retlw   .6
    decfsz  Exit,f
    goto    Loop6_2sec
    call    InitGPIO      ; make GP0/DECR/CS & GP1/INCR/UD outputs, block undesired U/D commands
    movlw   .64
    call    HV_Decrement_WL_Disable
;   movlw   .4
;   call    VAR1000TcyDELAY   ; add a 4mS delay for E/W cycle
```

**TABLE E-1: 00066_MCP402XEV.ASM SOURCE CODE (CONTINUED)**

```
HV_DecrExit clrwdt
    call    GPIO_TestUP       ; make GP1/INCR/UD an input (w/pu enabled)
    movlw   .10
    call    VAR1000TcyDELAY   ; add a 10mS delay for settling time
    btfss   UP                ; if UP gets released, exit
    goto    HV_DecrExit
    call    GPIO_TestDOWN     ; make GP0/DECR/CS an input (w/pu enabled)
    movlw   .10
    call    VAR1000TcyDELAY   ; add a 10mS delay for settling time
    btfss   DOWN              ; if DOWN gets released, exit
    goto    HV_DecrExit
    clrf    State
    retlw   .6
State7
State8
State9
State10
State11                       ; HV Increment w/o WL
    call    InitGPIO      ; make GP0/DECR/CS & GP1/INCR/UD outputs, block undesired U/D commands
    movlw   .1
    call    HV_Increment_WL_Disable
    clrf    State
    retlw   .11
State12                       ; HV Increment w/o WL
    call    InitGPIO      ; make GP0/DECR/CS & GP1/INCR/UD outputs, block undesired U/D commands
    movlw   .1
    call    HV_Decrement_WL_Disable
    clrf    State
    retlw   .12
State13                       ; HV Decrement w/WL
    call    InitGPIO      ; make GP0/DECR/CS & GP1/INCR/UD outputs, block undesired U/D commands
    call    HV_Increment_WL_Enable
    clrf    State
    retlw   .13
State14                       ; HV Decrement w/WL
    call    InitGPIO      ; make GP0/DECR/CS & GP1/INCR/UD outputs, block undesired U/D commands
    call    HV_Decrement_WL_Enable
    clrf    State
    retlw   .14
State15
    goto    StateMachineReset

;*****************************************************************************************************
; Low Power Mode
;*****************************************************************************************************
LowPowerMode
    movlw   b'11111000'       ; make all I/O pins an output
    tris    GPIO
    movlw   b'11111111'
    movwf   GPIO              ; output high
    movlw   b'10011111'       ; disable Wake-Up on Pin Change,
                              ; enable weak pullups for button inputs
                              ; T0CS must be 0 for GP2 TRIS to be active
                              ; set up for 2.3ms WDT
    option
    sleep                     ; put into lowest power setting
    goto    Start             ; shouldn't get here

SUBS    CODE
```

**TABLE E-1: 00066_MCP402XEV.ASM SOURCE CODE (CONTINUED)**

```
;*************************************************************************************************
; State Machine Subroutines
;*************************************************************************************************
DetermineState
    swapf   State,f
    rrf     State,f
    rrf     State,w
    andlw   b'00111111'   ; mask invalid states
    addwf   PCL,f
S0_00   retlw   .0      ; both buttons pressed at same time, shouldn't be here
S0_01   retlw   .1      ; UP button pressed, change state
S0_10   retlw   .2      ; DOWN button pressed, change state
S0_11   retlw   .0      ; no change
S1_00   retlw   .5      ; both buttons pressed, change state
S1_01   retlw   .1      ; no change
S1_10   retlw   .0      ; shouldn't be here, reset state
S1_11   retlw   .3      ; UP button released, change state
S2_00   retlw   .6      ; both buttons pressed, change state
S2_01   retlw   .0      ; shouldn't be here, reset state
S2_10   retlw   .2      ; no change
S2_11   retlw   .4      ; DOWN button released, change state
S3_00   retlw   .0      ; shouldn't be here, reset state
S3_01   retlw   .0      ; shouldn't be here, reset state
S3_10   retlw   .0      ; shouldn't be here, reset state
S3_11   retlw   .0      ; shouldn't be here, reset state
S4_00   retlw   .0      ; shouldn't be here, reset state
S4_01   retlw   .0      ; shouldn't be here, reset state
S4_10   retlw   .0      ; shouldn't be here, reset state
S4_11   retlw   .0      ; shouldn't be here, reset state
S5_00   retlw   .5      ; no change
S5_01   retlw   .7      ; DOWN button released, change state
S5_10   retlw   .9      ; UP button released, change state
S5_11   retlw   .0      ; shouldn't be here, reset state
S6_00   retlw   .6      ; no change
S6_01   retlw   .10     ; DOWN button released
S6_10   retlw   .8      ; UP button released
S6_11   retlw   .0      ; shouldn't be here, reset state
S7_00   retlw   .5      ; both buttons pressed again, change state
S7_01   retlw   .7      ; no change
S7_10   retlw   .0      ; shouldn't be here, reset state
S7_11   retlw   .13     ; UP button released, change state
S8_00     retlw   .6      ; both buttons pressed again, change state
S8_01     retlw   .0      ; shouldn't be here, reset state
S8_10     retlw   .8      ; no change
S8_11     retlw   .14     ; DOWN button released, change state
S9_00     retlw   .5      ; both buttons pressed again, change state
S9_01     retlw   .0      ; shouldn't be here, reset state
S9_10     retlw   .9      ; no change
S9_11     retlw   .11     ; DOWN button released, change state
S10_00    retlw   .6      ; both buttons pressed again, change state
S10_01    retlw   .10     ; no change
S10_10    retlw   .0      ; shouldn't be here, reset state
S10_11    retlw   .12     ; DOWN button released, change state
S11_00    retlw   .0      ; shouldn't be here, reset state
S11_01    retlw   .0      ; shouldn't be here, reset state
S11_10    retlw   .0      ; shouldn't be here, reset state
S11_11    retlw   .0      ; shouldn't be here, reset state
S12_00    retlw   .0      ; shouldn't be here, reset state
S12_01    retlw   .0      ; shouldn't be here, reset state
S12_10    retlw   .0      ; shouldn't be here, reset state
S12_11    retlw   .0      ; shouldn't be here, reset state
S13_00    retlw   .0      ; shouldn't be here, reset state
S13_01    retlw   .0      ; shouldn't be here, reset state
```

**TABLE E-1: 00066_MCP402XEV.ASM SOURCE CODE (CONTINUED)**

```
S13_10    retlw   .0      ; shouldn't be here, reset state
S13_11    retlw   .0      ; shouldn't be here, reset state
S14_00    retlw   .0      ; shouldn't be here, reset state
S14_01    retlw   .0      ; shouldn't be here, reset state
S14_10    retlw   .0      ; shouldn't be here, reset state
S14_11    retlw   .0      ; shouldn't be here, reset state
S15_00    retlw   .0      ; shouldn't be here, reset state
S15_01    retlw   .0      ; shouldn't be here, reset state
S15_10    retlw   .0      ; shouldn't be here, reset state
S15_11    retlw   .0      ; shouldn't be here, reset state


PerformState
    movf    State,w
    andlw   b'00001111'   ; mask all states >15
    addwf   PCL,f         ; jump to desired State
    retlw   .0            ; State 0, no action
    goto    State1        ; (2s for repeating LV increment)
    goto    State2        ; (2s for repeating LV decrement)
    goto    State3
    goto    State4
    goto    State5        ; (2s for repeating HV increment)
    goto    State6        ; (2s for repeating HV decrement)
    retlw   .7            ; State 7, no action
    retlw   .8            ; State 8, no action
    retlw   .9            ; State 9, no action
    retlw   .10           ; State 10, no action
    goto    State11
    goto    State12
    goto    State13
    goto    State14
    goto    StateMachineReset ; State 15... shouldn't be here

;*************************************************************************************************
InitGPIO
    movlw   b'00001011'   ; initialize UP and DOWN switches to be high & CP to be low.
    movwf   GPIO
    movlw   b'11111100'   ; make GP0/DECR/CS & GP1/INCR/UD outputs, block undesired U/D commands
    tris    GPIO
    retlw   b'11000000'
GPIO_TestUP
    movlw   b'00001011'   ; initialize UP and DOWN switches to be high & CP to be low.
    movwf   GPIO
    movlw   b'11111100'   ; make both GP0/DECR/CS & GP1/INCR/UD outputs, prevent undesired U/D
commands
    tris    GPIO
    movlw   b'11111110'   ; make GP1/INCR/UD an input (w/pu enabled)
    tris    GPIO
    retlw   b'10000000'
GPIO_TestDOWN
    movlw   b'00001011'   ; initialize UP and DOWN switches to be high & CP to be low.
    movwf   GPIO
    movlw   b'11111100'   ; make both GP0/DECR/CS & GP1/INCR/UD outputs, prevent undesired U/D
commands
    tris    GPIO
    movlw   b'11111101'   ; make GP0/DECR/CS an input (w/pu enabled)
    tris    GPIO
    retlw   b'01000000'
```

**TABLE E-1: 00066_MCP402XEV.ASM SOURCE CODE (CONTINUED)**

```
;*****************************************************************************************************
; Button Isolation Subroutines
;*****************************************************************************************************
; Low Voltage Increment & Decrement Subroutines
;*****************************************************************************************************
LV_Increment
    movwf   Exit         ; load the loop counter
    bsf     UD
    goto    $+1          ; creates a 3us total delay
    bcf     CS
    movlw   .100         ; 5*100 = 500us delay to pull down CS
    movwf   DLYCNT1
DLOOP_LVI
    clrwdt               ;or NOP
    nop
    decfsz   DLYCNT1,f
    goto     DLOOP_LVI
LV_IncrLoop
    bcf      UD
    goto    $+1
    bsf     UD
    goto    $+1           ; creates a 3us total delay
    decfsz  Exit,f        ; Have we incremented the wiper enough?
    goto    LV_IncrLoop
 IFDEF  SaveWiper
    bcf     UD
    goto    $+1           ; creates a 3us total delay
 ENDIF
    bsf     CS
    retlw   0x00          ; Follow w/long delay to ramp CS & EEPROM Write Cycle

LV_Decrement
    movwf   Exit          ; load the loop counter
    bcf     UD
    goto    $+1           ; creates a 3us total delay
    bcf     CS
    movlw   .100          ; 5*100 = 500us delay to pull down CS
    movwf   DLYCNT1
DLOOP_LVD
    clrwdt    ;or NOP
    nop
    decfsz  DLYCNT1,f
    goto    DLOOP_LVD
 IFDEF  SaveWiper
    goto    LV_DecrLoop+4     ; skip first Decrement since final edge is rising
 ENDIF
LV_DecrLoop
    bsf     UD
    goto    $+1               ; creates a 3us total delay
    bcf     UD
    goto    $+1               ; creates a 3us total delay
    decfsz  Exit,f            ; Have we decremented the wiper enough?
    goto    LV_DecrLoop
 IFDEF  SaveWiper
    bsf     UD
    goto    $+1               ; creates a 3us total delay
 ENDIF
    bsf     CS                ; Follow w/long delay to ramp CS & EEPROM Write Cycle
    retlw   0x01
```

**TABLE E-1: 00066_MCP402XEV.ASM SOURCE CODE (CONTINUED)**

```
;*****************************************************************************************************
; High Voltage Increment & Decrement Subroutines
;*****************************************************************************************************
HV_Increment_WL_Disable
    movwf   Exit              ; load the loop counter
    bsf     UD
    goto    $+1               ; creates a 3us total delay
    bsf     HV_CS             ; starts 1Mhz Charge Pump
    movlw   .100              ; 5*100 = 500us delay for Charge Pump ramp time
    movwf   DLYCNT1
DLOOP_HVI
    clrwdt    ;or NOP
    nop
    decfsz  DLYCNT1,f
    goto    DLOOP_HVI
HV_IncrLoop
    bcf     UD
    goto    $+1               ; creates a 3us total delay
    bsf     UD
    goto    $+1               ; creates a 3us total delay
    decfsz  Exit,f            ; Have we incremented the wiper enough?
    goto    HV_IncrLoop
    bcf     HV_CS             ; shut off 1Mhz Charge Pump
    bcf     CS                ; helps pull the signal down from HV
    goto    $+1
    bsf     CS
    retlw   0x02              ; Follow w/long delay to discharge pump & EEPROM Write Cycle

HV_Decrement_WL_Disable
    movwf   Exit              ; load the loop counter
    bcf     UD
    goto    $+1               ; creates a 3us total delay
    bsf     HV_CS             ; starts 1Mhz Charge Pump
    movlw   .100              ; 5*100 = 500us delay for Charge Pump ramp time
    movwf   DLYCNT1
DLOOP_HVD
    clrwdt    ;or NOP
    nop
    decfsz  DLYCNT1,f
    goto    DLOOP_HVD
HV_DecrLoop
    bsf     UD
    goto    $+1             ; creates a 3us total delay
    bcf     UD
    goto    $+1             ; creates a 3us total delay
    decfsz  Exit,f          ; Have we decremented the wiper enough?
    goto    HV_DecrLoop
    bcf     HV_CS           ; shut off 1Mhz Charge Pump
    bcf     CS              ; helps pull the signal down from HV
    goto    $+1
    bsf     CS
    retlw   0x03            ; Follow w/long delay to discharge pump & EEPROM Write Cycle

HV_Increment_WL_Enable
    bsf     UD
    goto    $+1             ; creates a 3us total delay
    bsf     HV_CS           ; starts 1Mhz Charge Pump
    movlw   .100            ; 5*100 = 500us delay for Charge Pump ramp time
    movwf   DLYCNT1
```

**TABLE E-1: 00066_MCP402XEV.ASM SOURCE CODE (CONTINUED)**

```
DLOOP_HVIWL
    clrwdt    ;or NOP
    nop
    decfsz  DLYCNT1,f
    goto    DLOOP_HVIWL
    bcf     UD
    goto    $+1             ; creates a 3us total delay
    bsf     UD
    goto    $+1             ; creates a 3us total delay
    bcf     UD
    goto    $+1             ; creates a 3us total delay
    bcf     HV_CS           ; shut off 1Mhz Charge Pump
    bcf     CS              ; helps pull the signal down from HV
    goto    $+1
    bsf     CS
    retlw   0x04            ; Follow w/long delay to discharge pump & EEPROM Write Cycle

HV_Decrement_WL_Enable
    bcf     UD
    bsf     CS
    goto    $+1             ; creates a 3us total delay
    bsf     HV_CS           ; starts 1Mhz Charge Pump
    movlw   .100            ; 5*100 = 500us delay for Charge Pump ramp time
    movwf   DLYCNT1
DLOOP_HVDWL
    clrwdt    ;or NOP
    nop
    decfsz  DLYCNT1,f
    goto    DLOOP_HVDWL
    bsf     UD
    goto    $+1             ; creates a 3us total delay
    bcf     HV_CS           ; shut off 1Mhz Charge Pump
    bcf     CS              ; helps pull the signal down from HV
    goto    $+1
    bsf     CS
    retlw   0x05            ; Follow w/long delay to discharge pump & EEPROM Write Cycle
;*****************************************************************************************
; VARIABLE DELAY SUBROUTINES
;*****************************************************************************************
;   DLYCNT1 = F9h = 249d    DLYCNT2 = W
;   DELAY = T((4 DLYCNT1 + 4) DLYCNT2 + 4)
;
; ex. To create a 300ms delay when using a 4Mhz osc, 300-250 = 50
;   movlw .50   ;load .50 into WREG
;   call  VAR1000TcyDELAY ;call VAR1000TcyDELAY = 50ms delay w/4MHz Osc
;   call  VAR1000TcyDELAY ;call VAR1000TcyDELAY = 250ms delay w/4MHz Osc
;         ;total = 300ms delay
;************
; The value in W at the time of the CALL = x.  Delay = 1000Tcy*x
VAR1000TcyDELAY
    movwf   DLYCNT2          ; LOADS CONTROLLING DLY # INTO PRIMARY COUNTER
DLOOP2
    movlw   .249             ; MAXIMIZES THE SECONDARY DLY COUNTER
    movwf   DLYCNT1
DLOOP1
    clrwdt    ;or NOP
    decfsz  DLYCNT1,f        ; DECREMENT AND TEST SECONDARY LOOP FOR ZERO
    goto    DLOOP1           ; CONTINUE SECONDARY LOOP
    decfsz  DLYCNT2,f        ; DECREMENT AND TEST PRIMARY DLY COUNTER
    goto    DLOOP2           ; CONTINUE PRIMARY LOOP
    retlw   .250             ; preload W for the next CALL VAR1000TcyDELAY
```

**TABLE E-1: 00066_MCP402XEV.ASM SOURCE CODE (CONTINUED)**

```
;************
;   VARIABLE 5 Tcy DELAY UP TO 256*5Tcy+5Tcy
;   DLYCNT1 = W
;   DELAY = T(1 + 5 DLYCNT1 - 1) + CALL + RETLW
;
; ex. To create a 250us delay, (250/5)-1 = 49
;   movlw   .49     ;load .49 into WREG
;   call    VAR5TcyDELAY  ;call VAR5TcyDELAY
;************
; The value in W at the time of the CALL = x.  Delay = 5*Tcy + 5Tcy
VAR5TcyDELAY
    movwf   DLYCNT1          ; LOADS CONTROLLING DLY # INTO PRIMARY COUNTER
DLOOP3  clrwdt    ;or NOP
    nop
    decfsz  DLYCNT1,f        ; DECREMENT AND TEST ZERO
    goto    DLOOP3           ; CONTINUE LOOP
    retlw   .250             ; preload W for the next CALL VAR5TcyDELAY
;*****************************************************************************************

   end
```

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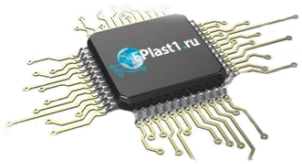
- Экспресс доставка в любую точку России;
- Техническая поддержка проекта, помощь в подборе аналогов, поставка прототипов;
- Система менеджмента качества сертифицирована по Международному стандарту ISO 9001;
- Лицензия ФСБ на осуществление работ с использованием сведений, составляющих государственную тайну;
- Поставка специализированных компонентов (Xilinx, Altera, Analog Devices, Intersil, Interpoint, Microsemi, Aeroflex, Peregrine, Syfer, Eurofarad, Texas Instrument, Miteq, Cobham, E2V, MA-COM, Hittite, Mini-Circuits,General Dynamics и др.);

Помимо этого, одним из направлений компании «ЭлектроПласт» является направление «Источники питания». Мы предлагаем Вам помощь Конструкторского отдела:

- Подбор оптимального решения, техническое обоснование при выборе компонента;
- Подбор аналогов;
- Консультации по применению компонента;
- Поставка образцов и прототипов;
- Техническая поддержка проекта;
- Защита от снятия компонента с производства.




**Как с нами связаться**

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