

I/O Expansion Using the MCP23X08 and PIC10F202

Author: Pat Richards
Microchip Technology Inc.

INTRODUCTION

This application note discusses using the MCP23008 and MCP23S08 GPIO Expanders with a 6-pin PIC10F202 microcontroller unit (MCU). The discussion is based on the MCP23X08 Evaluation Board, P/N: MCP23008DM.

An I/O expander is used to increase the I/O capability of microcontrollers. The microcontroller performs the master functions for the serial interface (either through the appropriate hardware interface or via a software-implemented interface). The MCP23X08 acts as a slave device.

The MCP23X08 8-bit GPIO family consists of two devices which differ only in the serial interface:

- MCP23008 - I²C™ interface
- MCP23S08 - SPI™ interface

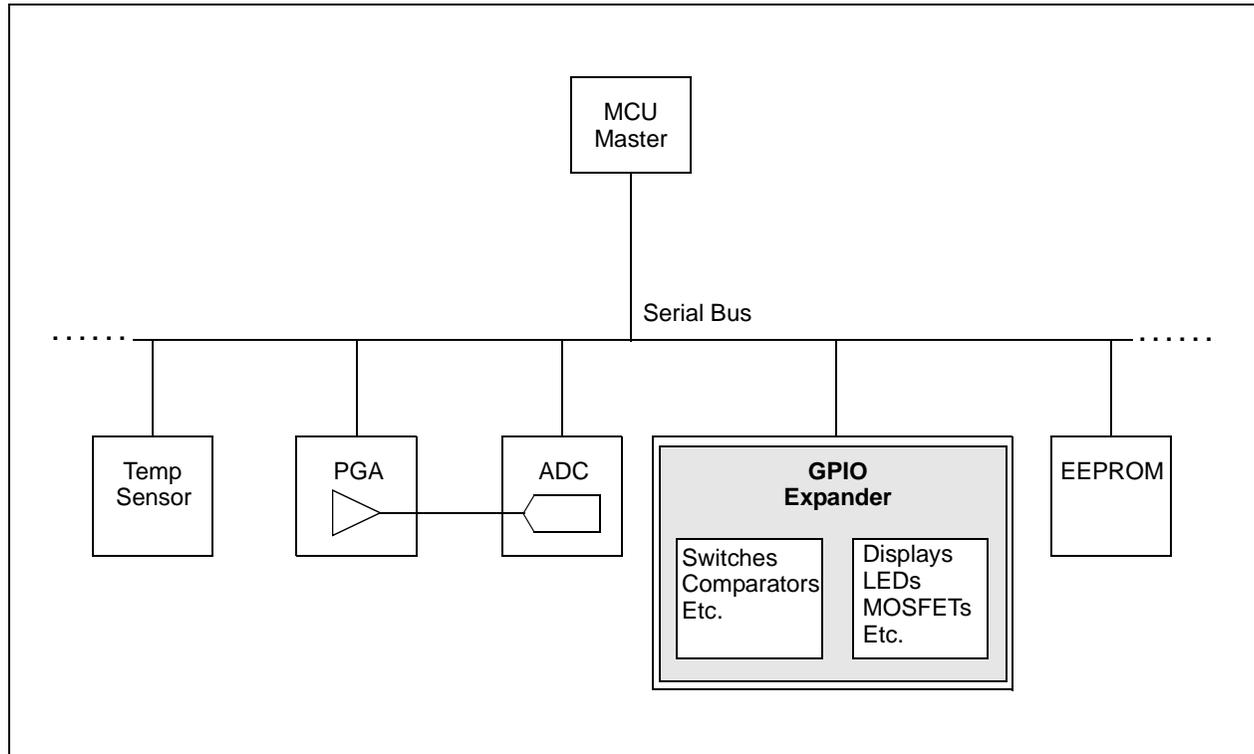
In addition to the serial interface listed, the MCP23X08 implements the following features:

- 8-bit GPIO bidirectional port
- Hardware address pins for allowing multiple MCP23X08 devices on the same bus
- Interrupt output with programmable polarity and function
- Configurable interrupt sources
- Reset input
- Polarity inversion capability for automatically inverting the polarity on the port.

This application note does not detail all of the features of the MCP23X08. Refer to the MCP23008/MCP23S08 Data Sheet, "8-Bit I/O Expander with Serial Interface" (DS21919), for more information.

The PIC10F202 communicates with the MCP23008 using the I²C protocol, and with the MCP23S08 using the SPI protocol.

FIGURE 1: GPIO EXPANDER EXAMPLE



AN972

INTERFACING TO THE MCP23X08

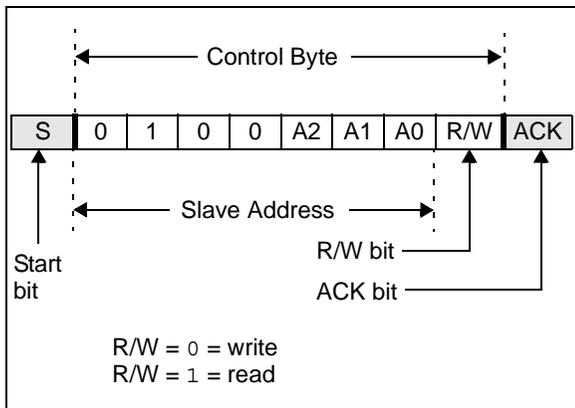
The MCP23008 has an I²C interface. While this application note does not discuss the I²C protocol in detail, an overview as it relates to the MCP23008 is provided.

Interfacing using the I²C™ Protocol

DEVICE ADDRESSING

The I²C specification describes two addressing formats: 10-bit addressing and 7-bit addressing. The MCP23008 is compatible with the 7-bit addressing format. The MCP23008 slave address contains four fixed bits and three user-defined hardware address bits (pins A2, A1 and A0). Figure 2 shows the control byte format for the MCP23008. Refer to the MCP23008/MCP23S08 Data Sheet, "8-Bit I/O Expander with Serial Interface" (DS21919), for more information.

FIGURE 2: MCP23008 CONTROL BYTE



START AND STOP CONDITIONS

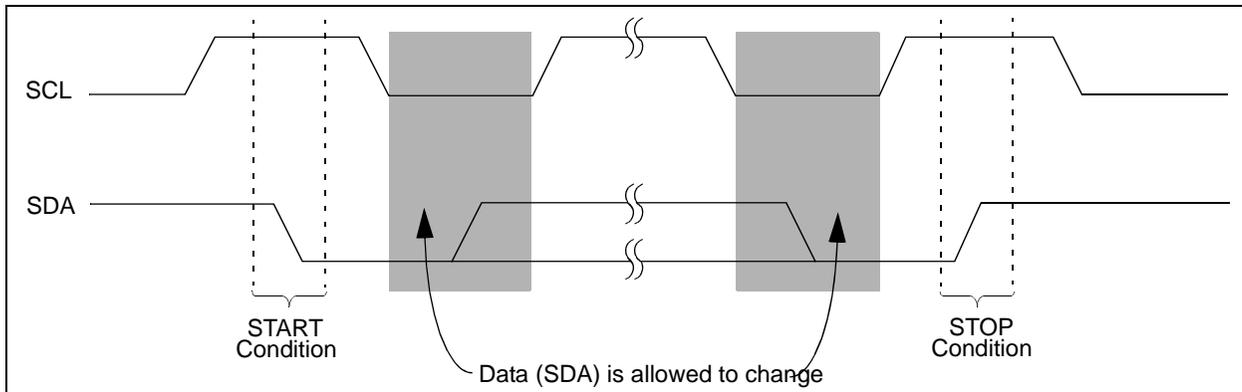
START Condition:

Data transfers are initiated by the master issuing a START condition during a bus idle period. To generate a START condition, both the clock (SCL) and data (SDA) start out high. SDA is then brought low, generating the START condition. See Figure 3.

STOP Condition:

Data transfers are terminated (and the bus released) by the master issuing a STOP condition. To generate a STOP condition, SCL starts out high and SDA starts out low. SDA is then brought high, generating a STOP condition. See Figure 3.

FIGURE 3: I²C™ BUS START/STOP BITS TIMING



WRITING TO THE MCP23008

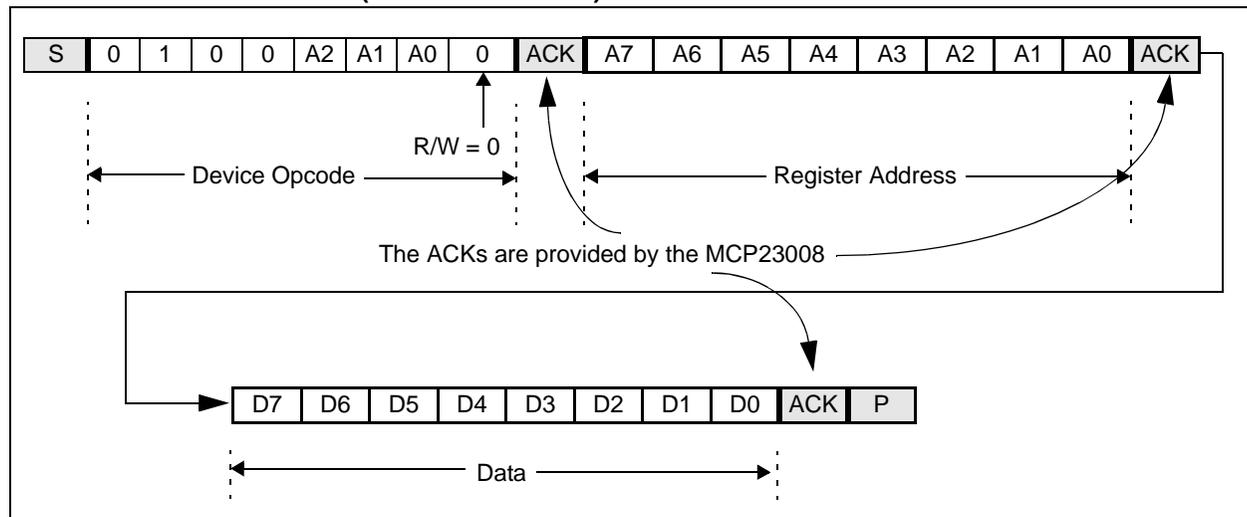
The Write operation (Figure 4) proceeds as follows:

- Master issues a start condition
- Master sends device opcode (slave address + R/W bit) with the R/W bit **cleared**
- MCP23008 sends an ACK
- Master sends the register address of the MCP23008
- MCP23008 sends an ACK
- Master sends the data (8 bits)

- MCP23008 sends an ACK
- Master issues a STOP condition

Note: While the MCP23008 is capable of sequential writes and reads, this application note only implements byte writes and reads. Refer to the MCP23008/MCP23S08 Data Sheet, "8-Bit I/O Expander with Serial Interface" (DS21919), for more information about sequential operations.

FIGURE 4: MCP23008 (I²C™ INTERFACE) BYTE WRITE OPERATION



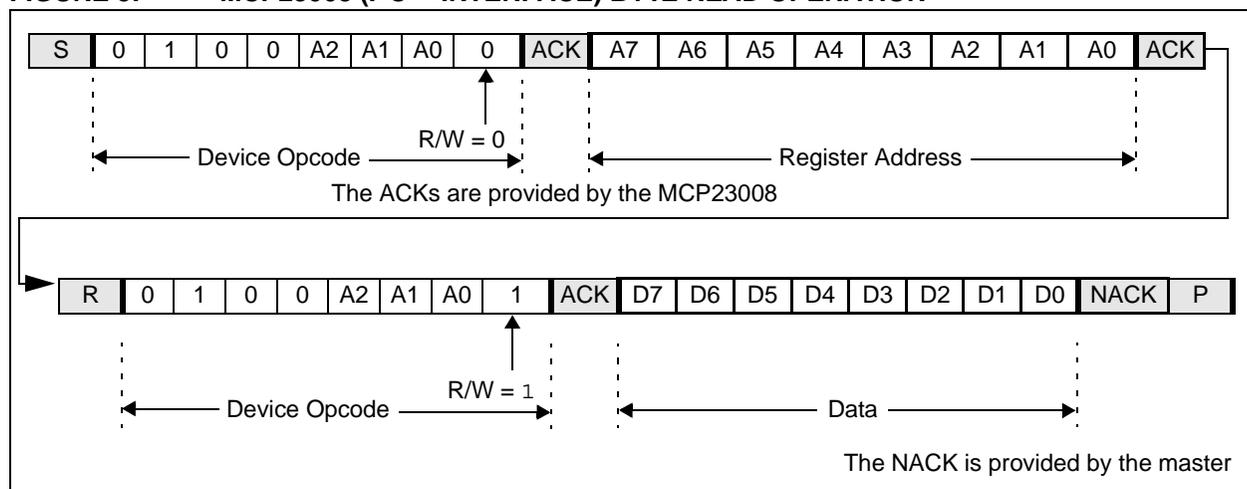
READING FROM THE MCP23008

Read operations (Figure 5) start with the write command, as shown in the upper-half of Figure 4. The remaining sequence follows:

- Master issues a re-start condition (which is basically the same as a START condition)
- Master sends device opcode (slave address + R/W bit) with the R/W bit **set**

- MCP23008 sends an ACK
- Master clocks data out of the MCP23008
- Master sends a No-ACK (NACK). Note, if another byte is to be read, the master would send an ACK instead
- Master sends a STOP condition

FIGURE 5: MCP23008 (I²C™ INTERFACE) BYTE READ OPERATION



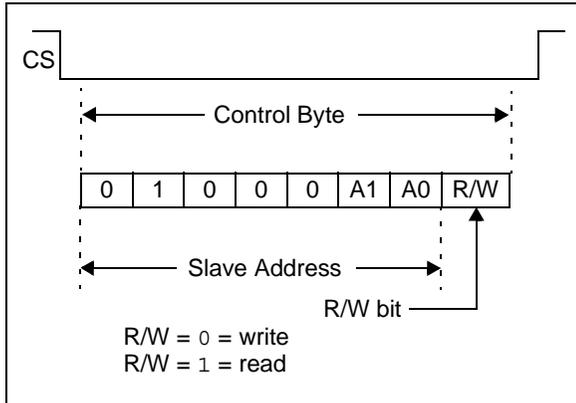
AN972

Interfacing using the SPI™ Protocol

DEVICE ADDRESSING

The MCP23S08 slave address contains five fixed bits and two user-defined hardware address bits (pins A1 and A0). Figure 6 shows the control byte format for the MCP23008. Refer to the MCP23008/MCP23S08 Data Sheet, “8-Bit I/O Expander with Serial Interface” (DS21919), for more information.

FIGURE 6: MCP23S08 CONTROL BYTE



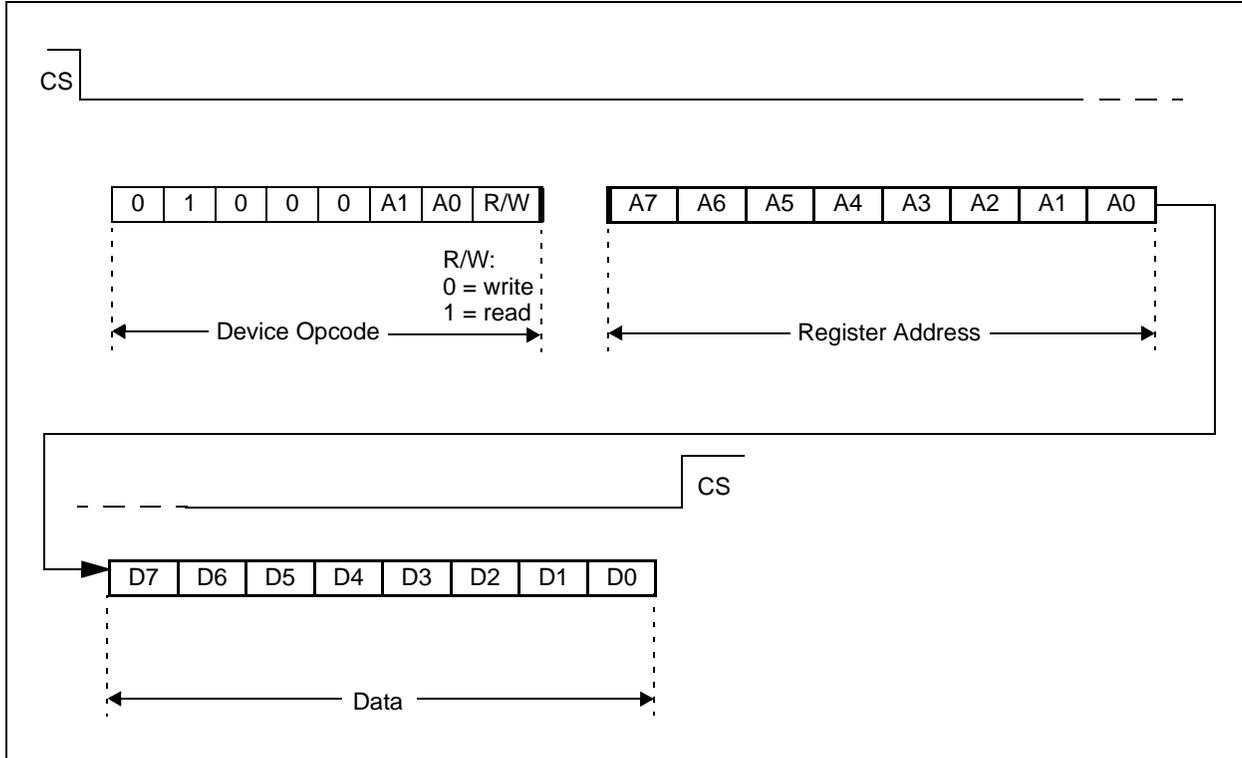
WRITING TO THE MCP23S08

The Write operation (Figure 7) is begun by lowering \overline{CS} . The Write command (slave address with R/W bit **cleared**) is then clocked into the device. The opcode is then followed by an address and at least one data byte.

READING FROM THE MCP23S08

Like the write operation, the read operation (Figure 7) is started by lowering \overline{CS} . The read command (slave address with R/W bit **set**) is then clocked into the device. The opcode is followed by an address and at least one data byte is clocked out of the device.

FIGURE 7: MCP23S08 (SPI™ INTERFACE) BYTE WRITE AND READ OPERATION



FIRMWARE DISCUSSION

For this application note, the I²C and SPI drivers are implemented in firmware.

The firmware code is written in Microchip MPASM™ Assembler and MPLAB® IDE version 6.62 and is available free-of-charge on the Microchip web site (www.microchip.com).

Table 1 shows the files used.

TABLE 1: MPASM™ ASSEMBLER SOURCE CODE FILES

| File Name | Description |
|-------------|------------------|
| 00010R1.ASM | Main source code |
| 00010R1.LKR | Linker script |

Subroutines Used

The linker (00010R1.LKR) reserves the entire lower half (except for the reset code which reserves two locations) of the program space (1/2 page) for the subroutines. This can be seen in the linker file:

```
SECTION NAME=SUBROUTINES ROM=page0
CODEPAGE NAME=page0 START=0x02 END=0x0FF
```

TABLE 2: SUBROUTINES

| Name | Description |
|--------------|--|
| I2CByteWrite | Writes a byte to the MCP23008 (I ² C™) |
| I2CByteRead | Reads a byte from the MCP23008 (I ² C) |
| I2CClockByte | Clocks 8-bits in the I ² C format. The data to be clocked is placed in "DataByte" variable |
| I2CStart | Applies a start condition (I ² C) |
| I2CStop | Applies a stop condition (I ² C) |
| I2CACK | The PIC10F202 sends an ACK on the I ² C bus. |
| NoACK | The PIC10F202 sends a No ACK (NACK) on the I ² C bus |
| IsACK? | Detects if the MCP23008 generated an ACK |
| SPIByteWrite | Writes a byte to the MCP23S08 (SPI™) |
| SPIByteRead | Reads a byte from the MCP23S08 (SPI) |
| SPIClockByte | Clocks 8-bits in the SPI format. The data to be clocked is placed in "DataByte" variable |
| ClockMode00 | Sets the SPI clock in idle high. This is called at the beginning and end of the SPIByteWrite and SPIByteRead routines. |

Flow Diagrams

FIGURE 8: MAIN PROGRAM FLOW

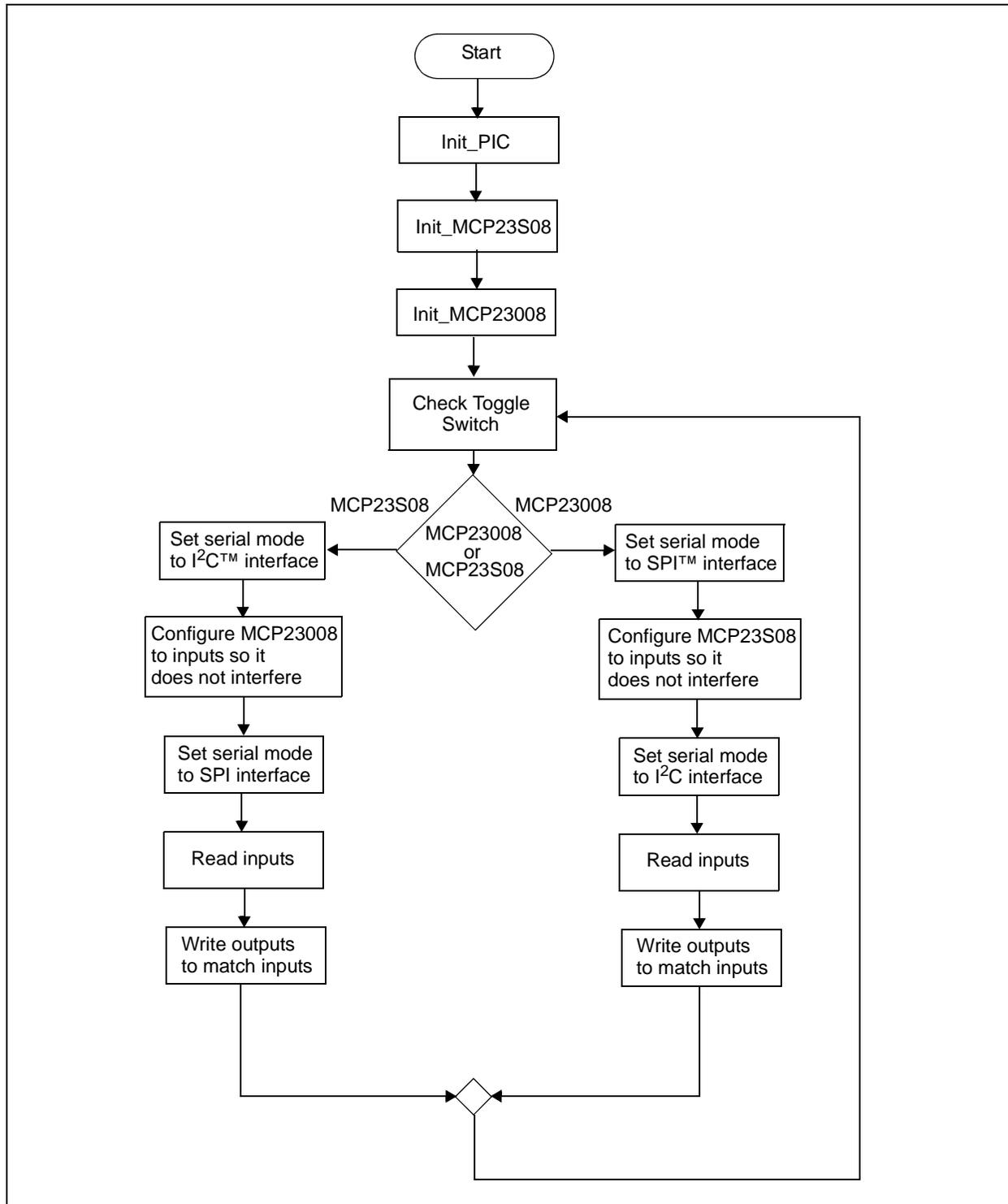


FIGURE 9: I²C™ BYTE WRITE

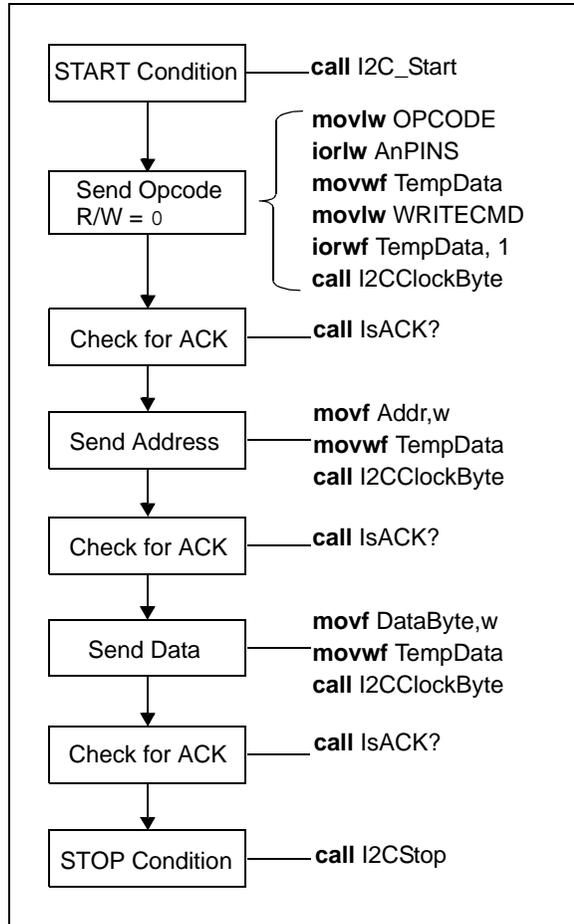


FIGURE 10: I²C™ BYTE READ

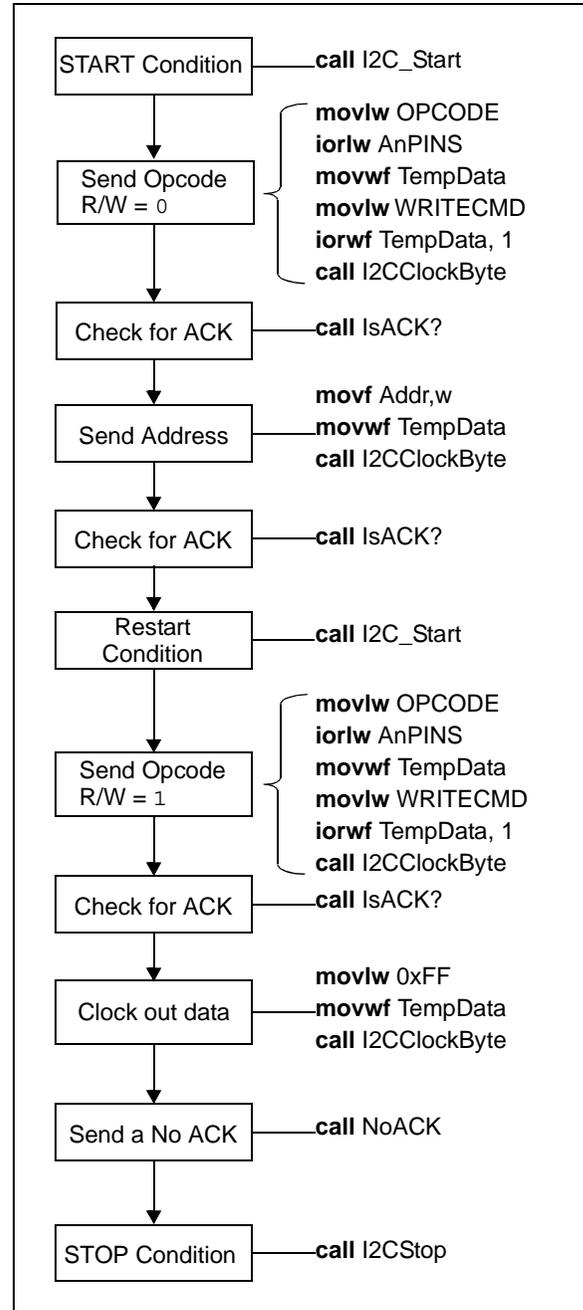


FIGURE 11: SPI™ BYTE WRITE

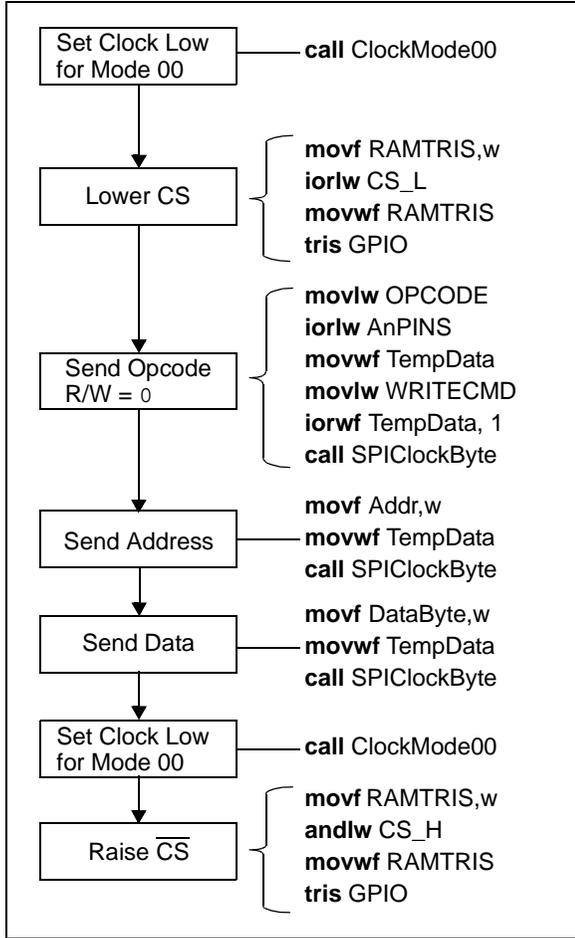
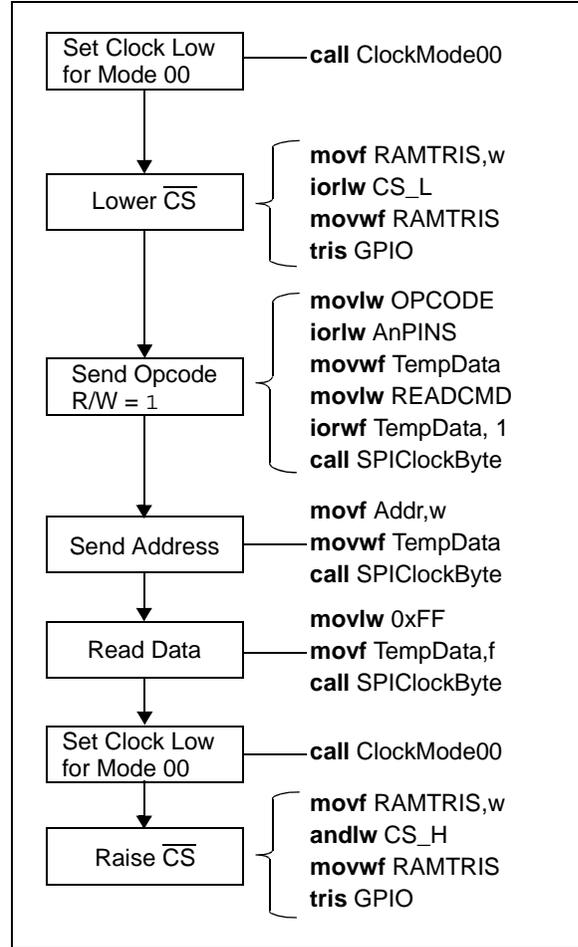


FIGURE 12: SPI™ BYTE READ



APPLICATION BOARD

Evaluation Board Overview

The MCP23008/MCP23S08 Evaluation Board is a simple demonstration of some of the MCP23X08 capabilities. The board consists of a 6-pin PIC10F202 and two MCP23X08 devices (1 – MCP23008 with an I²C interface and 1 – MCP23S08 with a SPI interface). Additionally, there is a 4-bit DIP switch, four output LEDs, three headers and several unpopulated jumpers. Refer to Figure 13 for more information regarding the following topics.

PICmicro[®] MCU, MCP23X08 AND SELECTOR SWITCH

The PIC10F202 communicates with either device, depending on a selector switch setting. When the switch (SW1) is placed in the left position, the MCP23008 is selected for communication. When placed in the right position, the MCP23S08 is selected.

INPUT SWITCHES AND OUTPUT LEDs

The board is populated with a 4-bit DIP switch and four LEDs. The switches are connected to four GPIO pins configured as inputs, while the LEDs are connected to four GPIO pins configured as outputs.

When an input switch is toggled, the corresponding LED is toggled. This is explained more in the following sections.

HEADERS AND JUMPERS

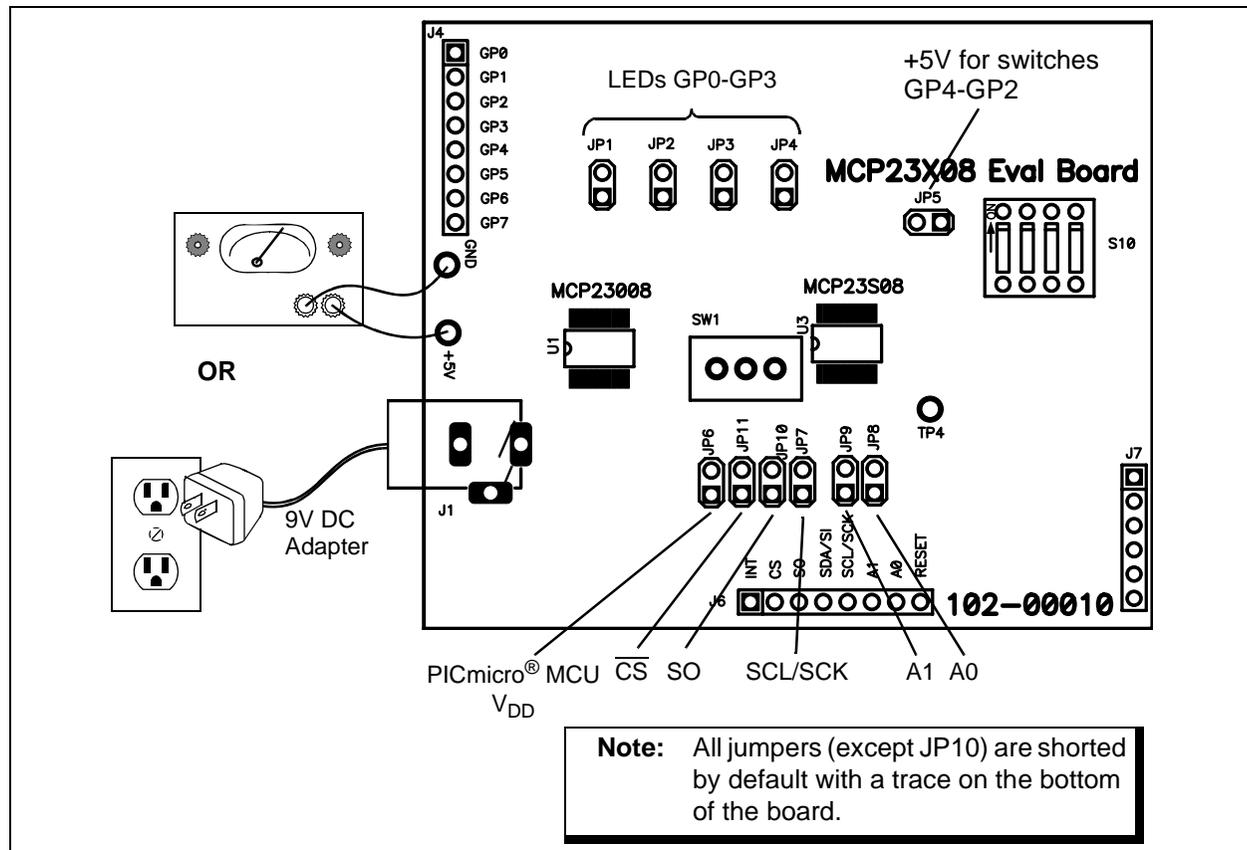
There are two headers that are associated with the MCP23X08 and one header for the Baseline Flash Microcontroller Programmer (BFMP) board, which is used to program the PIC10F202.

Note: MPLAB[®] ICD 2 can also be used with this header if the standard ICD 2 cable is modified to a flat connector.

There are several jumpers (not populated) on the board. The purpose of the jumpers is to isolate the MCP23X08 pins from the PIC10F202, LEDs and switches so that another MCU can be used to evaluate the MCP23X08.

Note: All of the jumper locations (except for JP10) are shorted on the bottom of the board by default. The trace on the bottom of the board must be cut, and the location populated, if the jumper is to have a function.

FIGURE 13: BLOCK DIAGRAM OF MCP23X08 EVALUATION BOARD



AN972

APPENDIX A: SCHEMATICS

FIGURE A-1: BOARD SCHEMATIC - (SHEET 1 OF 4)

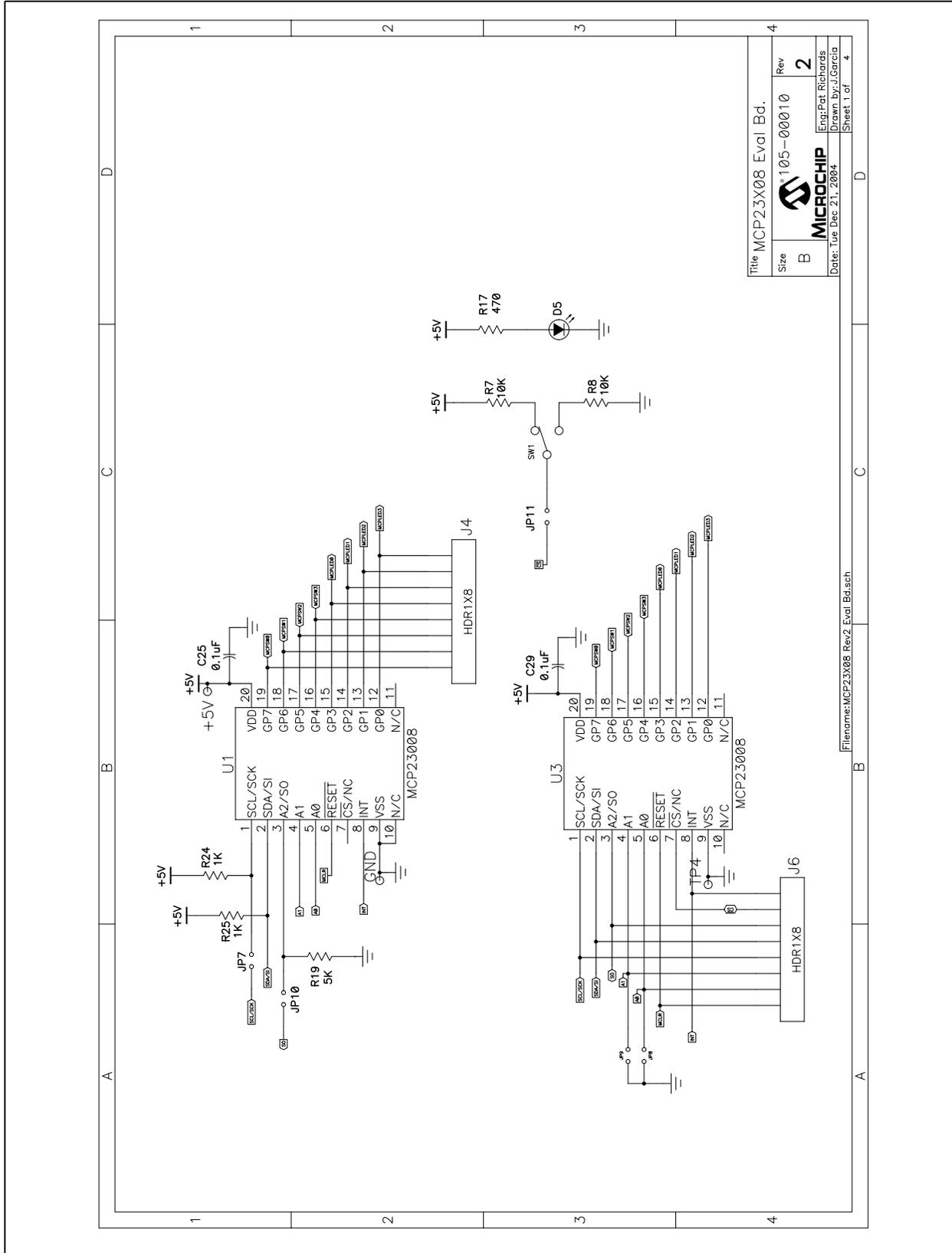
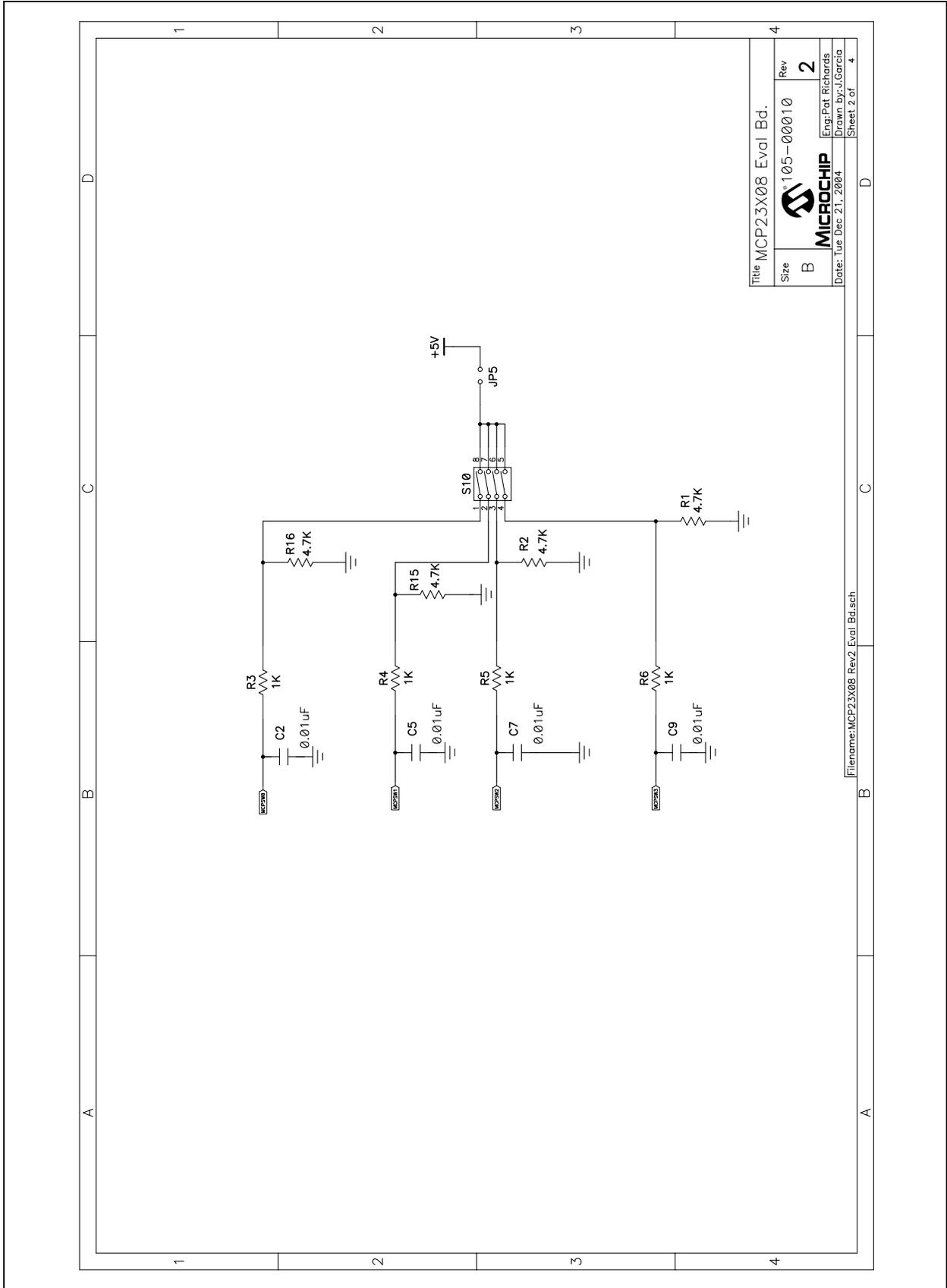


FIGURE A-2: BOARD SCHEMATIC - (SHEET 2 OF 4)



AN972

FIGURE A-3: BOARD SCHEMATIC - (SHEET 3 OF 4)

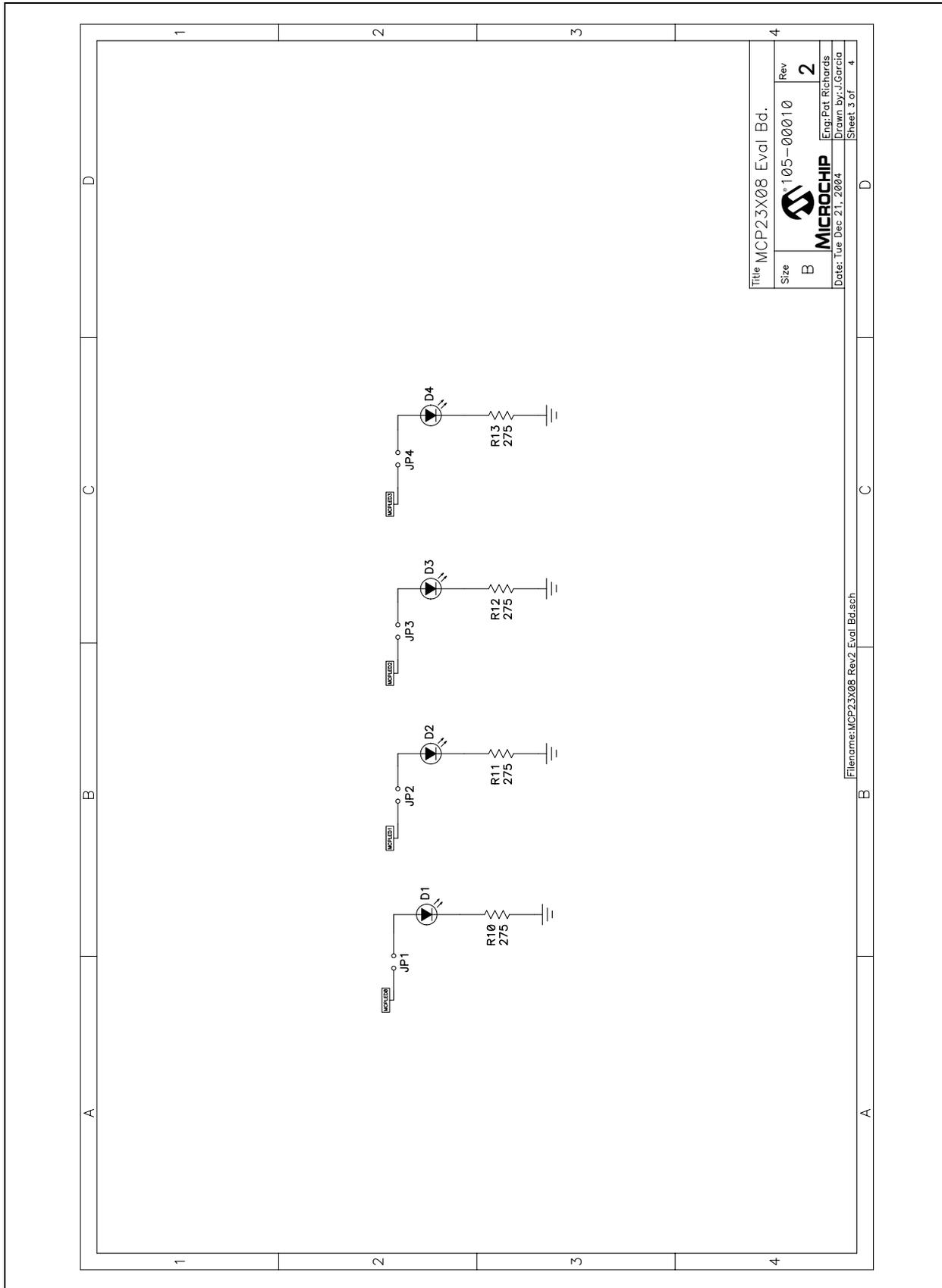
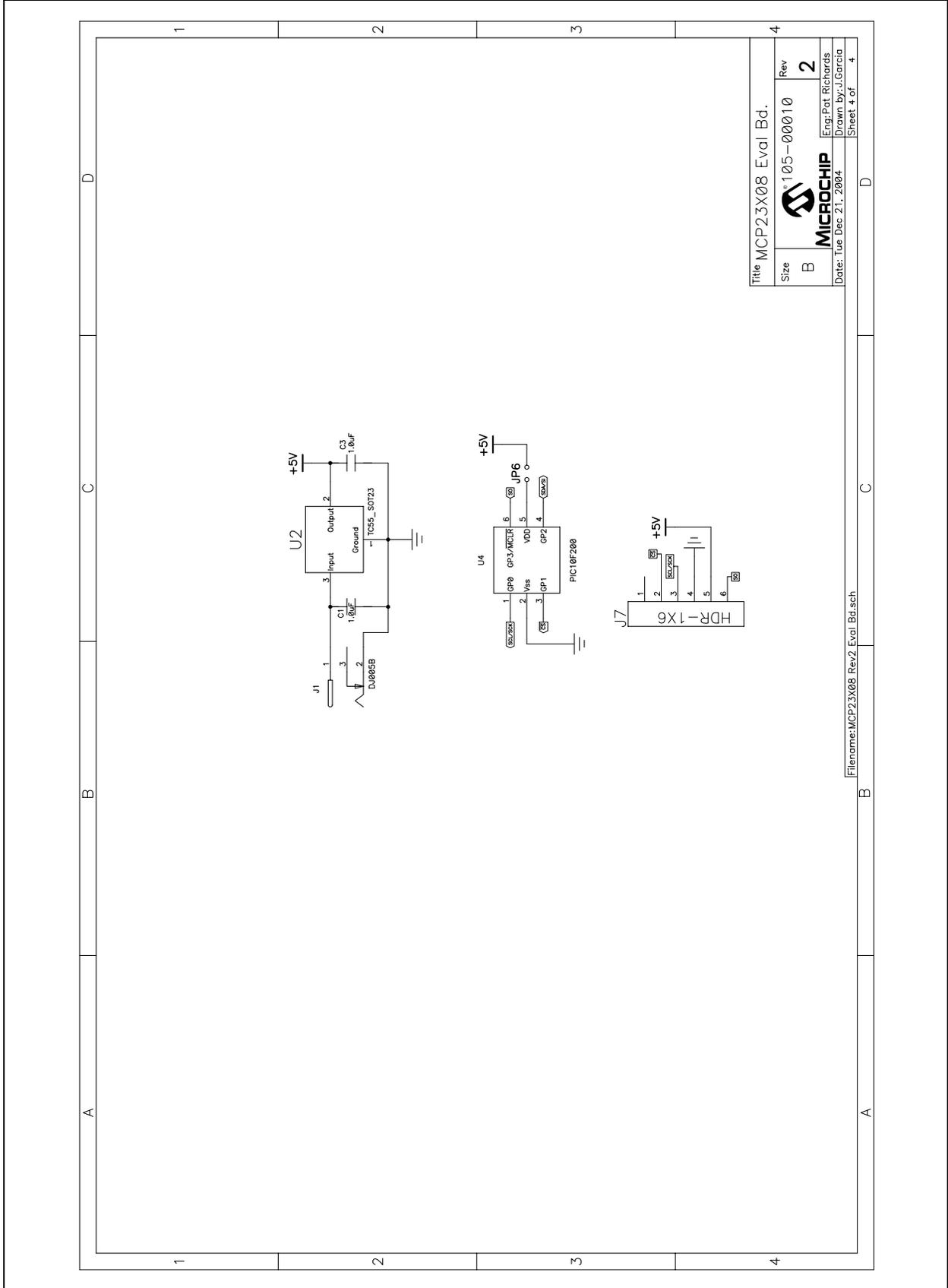


FIGURE A-4: BOARD SCHEMATIC - (SHEET 4 OF 4)



| | |
|-------------------------|-------|
| Title MCP23X08 Eval Bd. | |
| Size B | Rev 2 |
| Date: Tue Dec 21, 2004 | |
| Eng.: Pat Richards | |
| Drawn By: J.Garcia | |
| Sheet 4 of 4 | |

Filename: MCP23X08 Rev2 Eval Bd.sch

APPENDIX B: EVALUATION BOARD FIRMWARE

For the latest version of the MCP23X08 Evaluation Board firmware, visit the Microchip web site at www.microchip.com.

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

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

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

Information contained in this publication regarding device applications and the like is provided only for your convenience and may be superseded by updates. It is your responsibility to ensure that your application meets with your specifications. MICROCHIP MAKES NO REPRESENTATIONS OR WARRANTIES OF ANY KIND WHETHER EXPRESS OR IMPLIED, WRITTEN OR ORAL, STATUTORY OR OTHERWISE, RELATED TO THE INFORMATION, INCLUDING BUT NOT LIMITED TO ITS CONDITION, QUALITY, PERFORMANCE, MERCHANTABILITY OR FITNESS FOR PURPOSE. Microchip disclaims all liability arising from this information and its use. Use of Microchip's products as critical components in life support systems is not authorized except with express written approval by Microchip. No licenses are conveyed, implicitly or otherwise, under any Microchip intellectual property rights.

Trademarks

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

AmpLab, FilterLab, Migratable Memory, MXDEV, MXLAB, PICMASTER, SEEVAL, SmartSensor and The Embedded Control Solutions Company are registered trademarks of Microchip Technology Incorporated in the U.S.A.

Analog-for-the-Digital Age, Application Maestro, dsPICDEM, dsPICDEM.net, dsPICworks, ECAN, ECONOMONITOR, FanSense, FlexROM, fuzzyLAB, In-Circuit Serial Programming, ICSP, ICEPIC, MPASM, MPLIB, MPLINK, MPSIM, PICKit, PICDEM, PICDEM.net, PICLAB, PICtail, PowerCal, PowerInfo, PowerMate, PowerTool, rLAB, rPICDEM, Select Mode, Smart Serial, SmartTel and Total Endurance are trademarks of Microchip Technology Incorporated in the U.S.A. and other countries.

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

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

© 2005, Microchip Technology Incorporated, Printed in the U.S.A., All Rights Reserved.

 Printed on recycled paper.

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

Microchip received ISO/TS-16949:2002 quality system certification for its worldwide headquarters, design and wafer fabrication facilities in Chandler and Tempe, Arizona and Mountain View, California in October 2003. The Company's quality system processes and procedures are for its PICmicro® 8-bit MCUs, KEELOQ® code hopping devices, Serial EEPROMs, microperipherals, nonvolatile memory and analog products. In addition, Microchip's quality system for the design and manufacture of development systems is ISO 9001:2000 certified.



WORLDWIDE SALES AND SERVICE

AMERICAS

Corporate Office
2355 West Chandler Blvd.
Chandler, AZ 85224-6199
Tel: 480-792-7200
Fax: 480-792-7277
Technical Support:
<http://support.microchip.com>
Web Address:
www.microchip.com

Atlanta
Alpharetta, GA
Tel: 770-640-0034
Fax: 770-640-0307

Boston
Westford, MA
Tel: 978-692-3848
Fax: 978-692-3821

Chicago
Itasca, IL
Tel: 630-285-0071
Fax: 630-285-0075

Dallas
Addison, TX
Tel: 972-818-7423
Fax: 972-818-2924

Detroit
Farmington Hills, MI
Tel: 248-538-2250
Fax: 248-538-2260

Kokomo
Kokomo, IN
Tel: 765-864-8360
Fax: 765-864-8387

Los Angeles
Mission Viejo, CA
Tel: 949-462-9523
Fax: 949-462-9608

San Jose
Mountain View, CA
Tel: 650-215-1444
Fax: 650-961-0286

Toronto
Mississauga, Ontario,
Canada
Tel: 905-673-0699
Fax: 905-673-6509

ASIA/PACIFIC

Australia - Sydney
Tel: 61-2-9868-6733
Fax: 61-2-9868-6755

China - Beijing
Tel: 86-10-8528-2100
Fax: 86-10-8528-2104

China - Chengdu
Tel: 86-28-8676-6200
Fax: 86-28-8676-6599

China - Fuzhou
Tel: 86-591-8750-3506
Fax: 86-591-8750-3521

China - Hong Kong SAR
Tel: 852-2401-1200
Fax: 852-2401-3431

China - Shanghai
Tel: 86-21-5407-5533
Fax: 86-21-5407-5066

China - Shenyang
Tel: 86-24-2334-2829
Fax: 86-24-2334-2393

China - Shenzhen
Tel: 86-755-8203-2660
Fax: 86-755-8203-1760

China - Shunde
Tel: 86-757-2839-5507
Fax: 86-757-2839-5571

China - Qingdao
Tel: 86-532-502-7355
Fax: 86-532-502-7205

ASIA/PACIFIC

India - Bangalore
Tel: 91-80-2229-0061
Fax: 91-80-2229-0062

India - New Delhi
Tel: 91-11-5160-8631
Fax: 91-11-5160-8632

Japan - Kanagawa
Tel: 81-45-471- 6166
Fax: 81-45-471-6122

Korea - Seoul
Tel: 82-2-554-7200
Fax: 82-2-558-5932 or
82-2-558-5934

Singapore
Tel: 65-6334-8870
Fax: 65-6334-8850

Taiwan - Kaohsiung
Tel: 886-7-536-4818
Fax: 886-7-536-4803

Taiwan - Taipei
Tel: 886-2-2500-6610
Fax: 886-2-2508-0102

Taiwan - Hsinchu
Tel: 886-3-572-9526
Fax: 886-3-572-6459

EUROPE

Austria - Weis
Tel: 43-7242-2244-399
Fax: 43-7242-2244-393

Denmark - Ballerup
Tel: 45-4450-2828
Fax: 45-4485-2829

France - Massy
Tel: 33-1-69-53-63-20
Fax: 33-1-69-30-90-79

Germany - Ismaning
Tel: 49-89-627-144-0
Fax: 49-89-627-144-44

Italy - Milan
Tel: 39-0331-742611
Fax: 39-0331-466781

Netherlands - Drunen
Tel: 31-416-690399
Fax: 31-416-690340

England - Berkshire
Tel: 44-118-921-5869
Fax: 44-118-921-5820