MCP4728 Evaluation Board User's Guide

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MCP4728 EVALUATION BOARD USER'S GUIDE

Preface

NOTICE TO CUSTOMERS

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

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

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

INTRODUCTION

This chapter contains general information that will be useful to know before using the MCP4728 Evaluation Board. Items discussed in this chapter include:

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

DOCUMENT LAYOUT

This document describes how to use the MCP4728 Evaluation Board with PICkit™ Serial Analyzer. The manual layout is as follows:

- **Chapter 1. "Quick Start Instructions"** – this chapter provides an overview of the MCP4728 Evaluation Board and instructions on how to use the MCP4728 Evaluation Board with the PICkit™ Serial Analyzer.
- **Appendix A. "Schematic and Layouts"** – shows the schematic and layout diagrams for the MCP4728 Evaluation Board.
- **Appendix B. "Bill Of Materials (BOM)"** – lists the parts used to build the MCP4728 Evaluation Board.
- **Appendix C. "MCP4728 Read/Write Commands"** – shows the read/write commands for the MCP4728 Evaluation Board.

CONVENTIONS USED IN THIS GUIDE

This manual uses the following documentation conventions:

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}`
Lowercase 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 lowercase characters) or a specific example (in uppercase characters).	`char isascii (char, `*`ch`*`);`
Interface (Arial font):		
Underlined, italic text with right arrow	A menu selection from the menu bar	*File > Save*
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*

RECOMMENDED READING

This user's guide describes how to use MCP4728 Evaluation Board. Other useful documents are listed below. The following Microchip documents are available and recommended as supplemental reference resources.

PICkit™ Serial Analyzer User’s Guide, DS51647

Consult this document for instructions on how to use the PICkit Serial Analyzer hardware and software.

MCP4728 Data Sheet, “*12-Bit, Quad Digital-to-Analog Converter with EEPROM Memory” DS22187*

This data sheet provides detailed information regarding for the MCP4728 Digital-to-Analog Converter.

THE MICROCHIP WEB SITE

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- **General Technical Support** – Frequently Asked Questions (FAQs), technical support requests, online discussion groups, Microchip consultant program member listing
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- Local Sales Office
- 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 A (June 2009)

- Initial Release of this Document.

NOTES:

Chapter 1. Quick Start Instructions

1.1 INTRODUCTION

The following sections provide an overview of the MCP4728 Evaluation Board and instructions on how to program the DAC register and the EEPROM of the MCP4728 using the PICkit™ Serial Analyzer. The following sections cover the topics:

- Description of the MCP4728 Evaluation Board
- How to use the MCP4728 Evaluation Board with the PICkit Serial Analyzer

1.2 DESCRIPTION OF THE MCP4728 EVALUATION BOARD

The purpose of the MCP4728 Evaluation Board is to provide an easy way of evaluating the MCP4728's performance and functionality with a minimum of work.

The MCP4728 Evaluation Board contains a MCP4728 (which is a 4-channel, 12-bit Digital-to-Analog Converter), an interface connector for the PICkit Serial Analyzer, and I^2C test point terminals.The user can evaluate this board by using the PICkit Serial Analyzer or by providing the I^2C serial communication signals through the I^2C test terminals.

Using the MCP4728 Evaluation Board, the user can evaluate the functionality of the MCP4728 device, such as: (a) Writing and reading the DAC registers and EEPROM of each channel, (b) Selecting the reference voltage, (c) Measuring the DAC output voltage, (d) Checking the $\overline{\text{LDAC}}$ pin feature, etc.

The MCP4728 Evaluation Board is designed to work friendly with the PICkit Serial Analyzer (DV164122). The PICkit Serial Analyzer (P/N: DV164122) is used for writing and reading the DAC configuration and register data. The PICkit Serial Analyzer consists of hardware and PC GUI. It is highly recommended that the users order this MCP4728 Evaluation Board and the PICkit Serial Analyzer at same time.

- The MCP4728 supports standard mode (100 kHz), fast mode (400 kHz), and high speed mode (3.4 MHz) of the I^2C serial communications. This evaluation board has 5 kΩ for the I^2C pull-up resistors and supports up to the fast mode. If the user needs to evaluate the device with high speed mode (3.4 MHz), please replace the R1 and R2 with lower values (less than 1 kΩ).

Note:	The MCP4728 Evaluation Board can be used without the PICkit Serial Analyzer as long as the V_{DD}, SCL, and SDA are provided through the J1 connector. This board does not include MCU.

The MCP4728 Evaluation Board has test points for SDL, SDA, and DAC outputs. By connecting an oscilloscope to these I^2C test points, the user can examine the data communications through the I^2C™ bus line and observe the resulting analog output (at V_{OUT} terminals) using a multimeter. Refer to **Appendix A. "Schematic and Layouts"**.

FIGURE 1-1: Front View of the MCP4728 Evaluation Board.

TABLE 1-1: TEST TERMINALS ON THE MCP4728 EVALUATION BOARD

Test Terminals	Description
V_{OUT} A	DAC channel A output
V_{OUT} B	DAC channel B output
V_{OUT} C	DAC channel C output
V_{OUT} D	DAC channel D output
SCL	This terminal is connected to the I^2C SCL pin of the MCP4728. (See **Note 1**).
SDA	This terminal is connected to the I^2C SDA pin of the MCP4728. (See **Note 1**).
RDY/$\overline{\text{BUSY}}$	This terminal is used to monitor the RDY/$\overline{\text{BUSY}}$ pin of the MCP4728 device.
$\overline{\text{LDAC}}$	Access terminal to the $\overline{\text{LDAC}}$ pin of the MCP4728.
S1	Switch to change the logic input to the $\overline{\text{LDAC}}$ input pin. It provides logic "low" when pressed.
JP1	Jumper to select the V_{DD} source to the MCP4728 Evaluation Board. If it is connected, the V_{DD} from the J1 connector is connected. If disconnected, it selects the V_{DD} source from VDD1 terminal.
JP2	Jumper to connect the $\overline{\text{LDAC}}$ pin to V_{SS}. (You can disconnect this jumper when S1 is used.)
VDD1	V_{DD} monitoring or connection pin. If the V_{DD} is provided from J1 connector (PICkit Serial Analyzer), then this test point monitors the V_{DD} voltage. You can also connect a new V_{DD} to this test terminal.
GND	Connected to common ground plane of the PC Board.

Note 1: This terminal is used to monitor the SCL or SDA signals. You can also provide the SCL or SDA signals through these pins.

1.3 GETTING STARTED WITH PICKIT SERIAL ANALYZER

Figure 1-1 shows the MCP4728 Evaluation Board, and Figure 1-2 shows the connection of the MCP4728 Evaluation Board and PICkit Serial Analyzer.

The following steps describe how to use them together:

1. Connect the MCP4728 Evaluation Board's 6-pin socket to the PICkit Serial Analyzer as shown in Figure 1-2.
2. Connect the oscilloscope probes to the SCL and SDA test terminals (optional).
3. Connect a multimeter to one of the DAC's output test terminal.
4. V_{DD} Selection: You can use the V_{DD} from the PICkit Serial Analyzer or use your own external V_{DD}. The JP1 connector selects the V_{DD} path.

   (a) Connect JP1, if using V_{DD} from PICkit Serial Analyzer,

   (b) Disconnect JP1 and apply V_{DD} at $V_{DD}1$ pin, if you are using an external V_{DD}.

- I^2C device code of MCP4728: `'1100'`
- A2, A1, A0 Address Bits: Pre-programmed to `'000'`.

5. **Connecting V_{DD}:** LED D1 turns on when V_{DD} is applied. The PICkit Serial Analyzer will provide V_{DD} automatically, if it is connected to the PC. Make sure LED D1 turns on.
6. Use the PICkit Serial Analyzer PC GUI to send I^2C write and read commands.

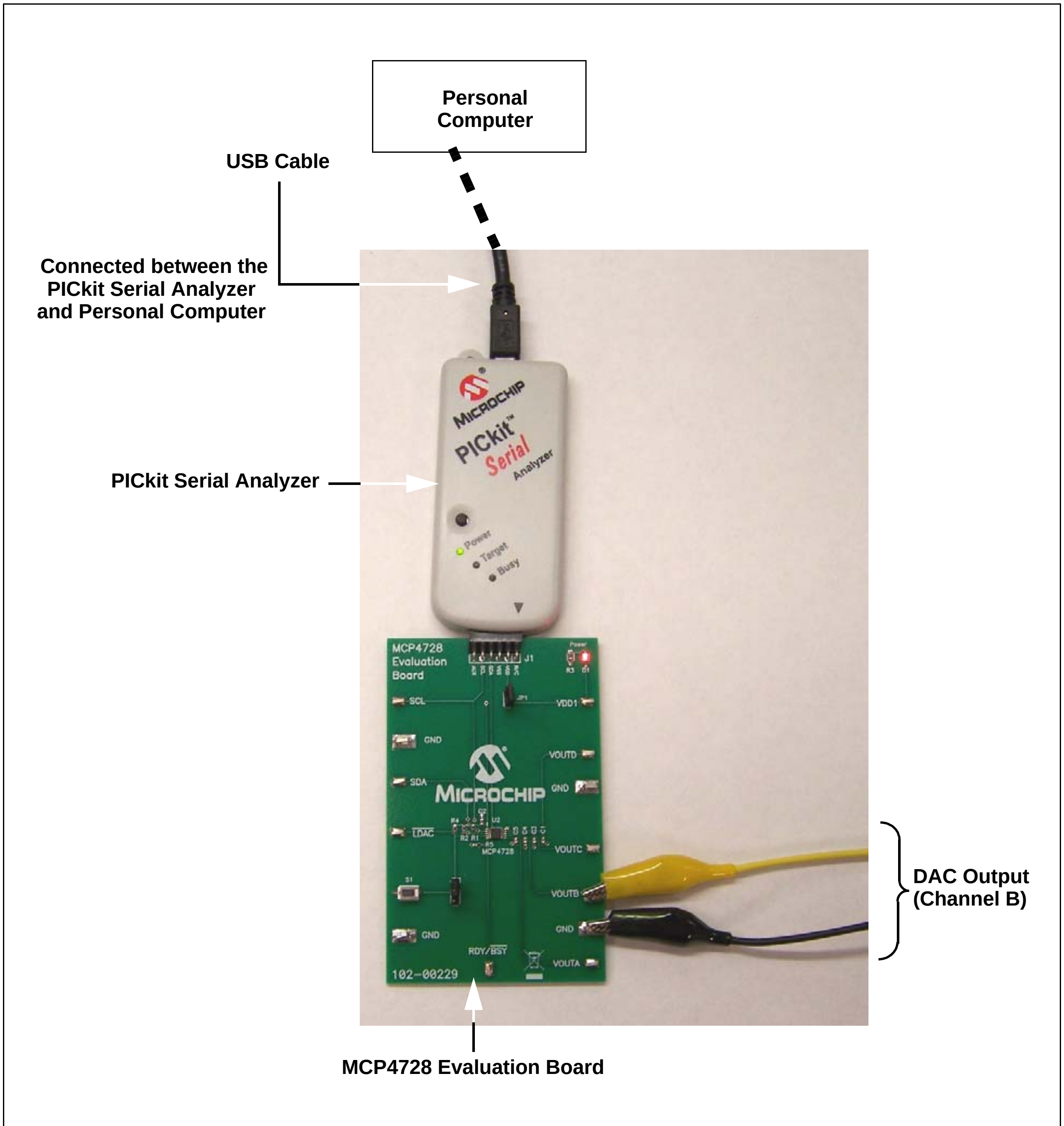


FIGURE 1-2: *MCP4728 Evaluation Board with the PICkit Serial Analyzer.*

1.3.1 PICkit Serial Analyzer PC Software Setup for the MCP4728 Evaluation Board

The following steps describe how to set up and use the PICkit Serial Analyzer PC Graphic User Interface (GUI).

1. Install the PICkit Serial Analyzer software onto your personal computer (PC).
2. Connect the USB cable between the PICkit Serial Analyzer and the PC.
3. Run the PICkit Serial PC Software: It will open to the following GUI. Click the **Next** button and follow the instructions.

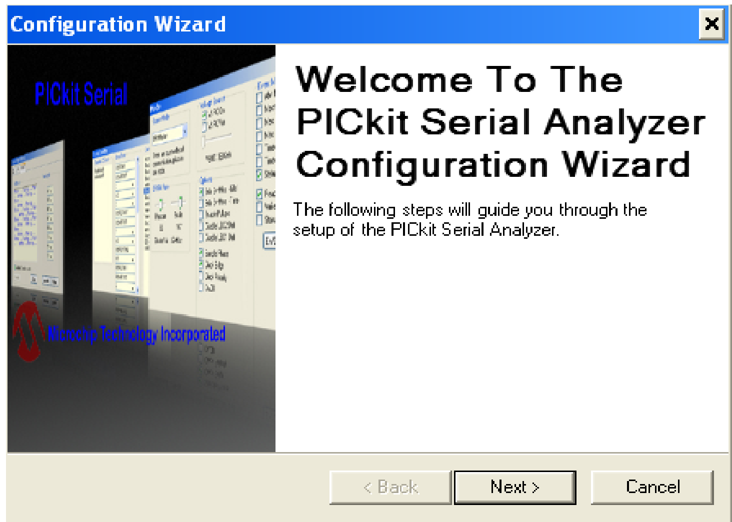


FIGURE 1-3: PICkit Serial Analyzer Configuration Wizard Welcome Window.

4. Select the Communication Mode type: **I^{2}C Master**, and click the **Next** button.

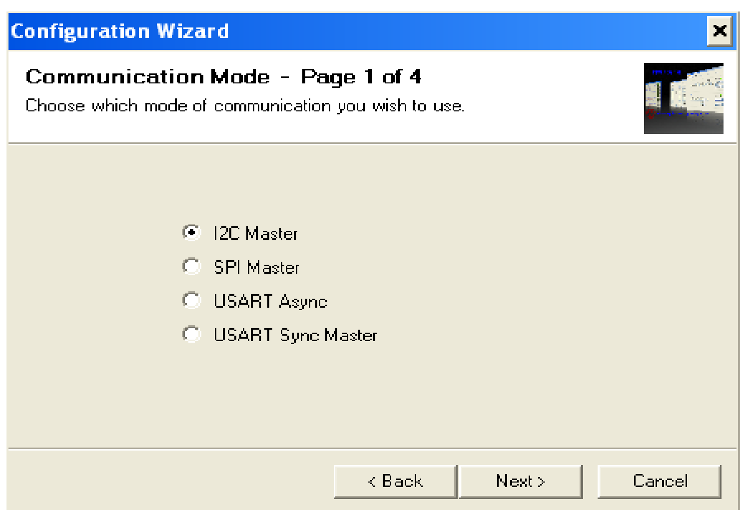


FIGURE 1-4: Step 1 - Communication Mode Selection.

5. Select 100 kHz or 400 kHz. Either one will be fine. Click the **Next** button.

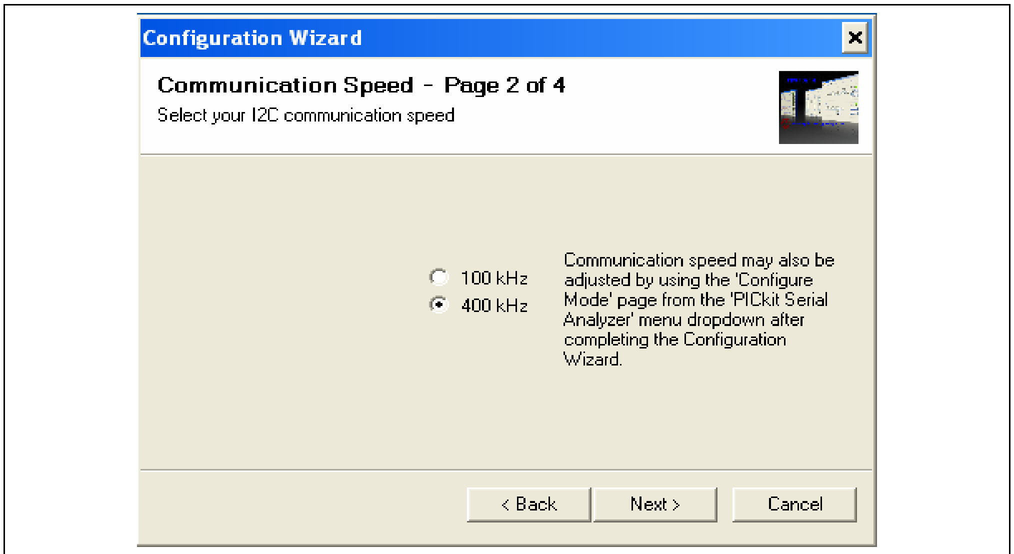


FIGURE 1-5: *Step 2 - I^2C Communication Speed Selection.*

Note: The MCP4728 device supports the I^2C bus data rate up to 3.4 MHz, but the current version of the PICkit Serial Analyzer supports the I^2C bus data rate up to 400 kHz only.

6. Select **No** on Enable Pull-ups and click the **Next** button.

Note: The MCP4728 Evaluation Board has its own pull-up resistors.

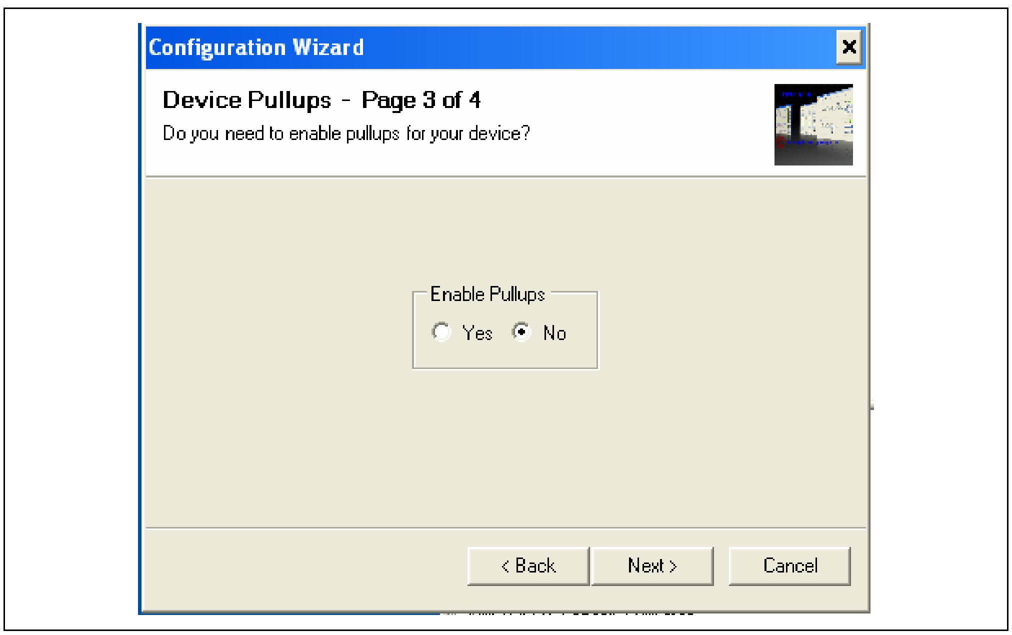


FIGURE 1-6: *Step 3 - Device Pull-Ups Window.*

7. Select the V_{DD} voltage of the MCP4728 Evaluation Board and click the **Next** button.

Case 1: When you use V_{DD} from the PICkit Serial Analyzer:

If you choose **PICkit Serial will power your device** and **5 Volts** as shown below, the MCP4728 Evaluation Board is powered by the 5V DC from the PICkit Serial Analyzer through the JP1 jumper. In this case, make sure that the JP1 jumper on the MCP4728 Evaluation Board is connected.

Case 2: When you use your own V_{DD}:

You can also provide your own V_{DD} voltage by applying a V_{DD} voltage at VD1 test point. In this case, make sure that the JP1 jumper is disconnected.

FIGURE 1-7: *Step 4 - Voltage Source Selection Window.*

8. Click the **OK** button. You have made all of the PICkit Serial Analyzer Configuration Setups. You are now ready to read/write MCP4728 registers and EEPROM.

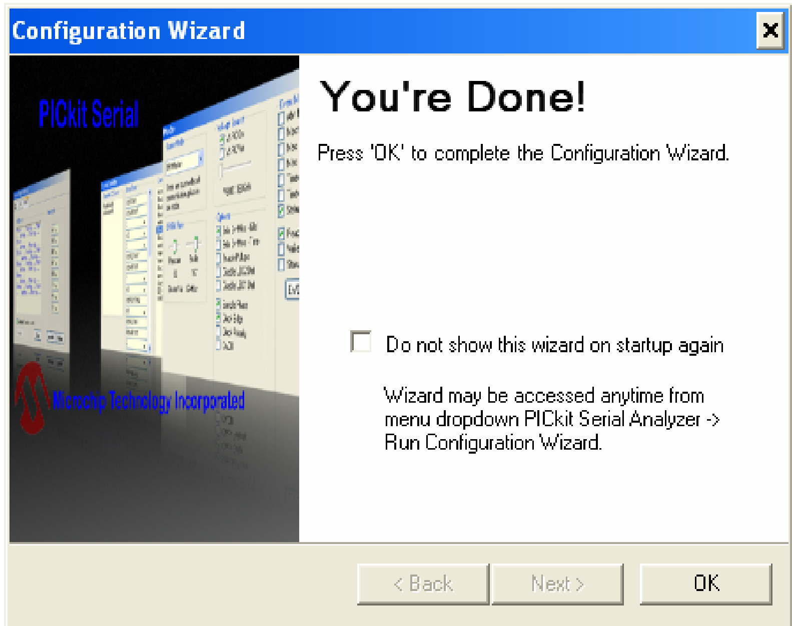


FIGURE 1-8: *Configuration Wizard - Finishing Step.*

1.3.2 Creating Script Files:

A script file that is running on the PICkit Serial PC GUI is needed for the communications between the PICkit Serial Analyzer and the MCP4728 Evaluation Board. The following steps show how to create script files and how to use them. Refer to the PICkit Serial Analyzer User's Guide (DS51647) for creating the Script file.

- Select **Communication -----> Script ---> Script Builder**

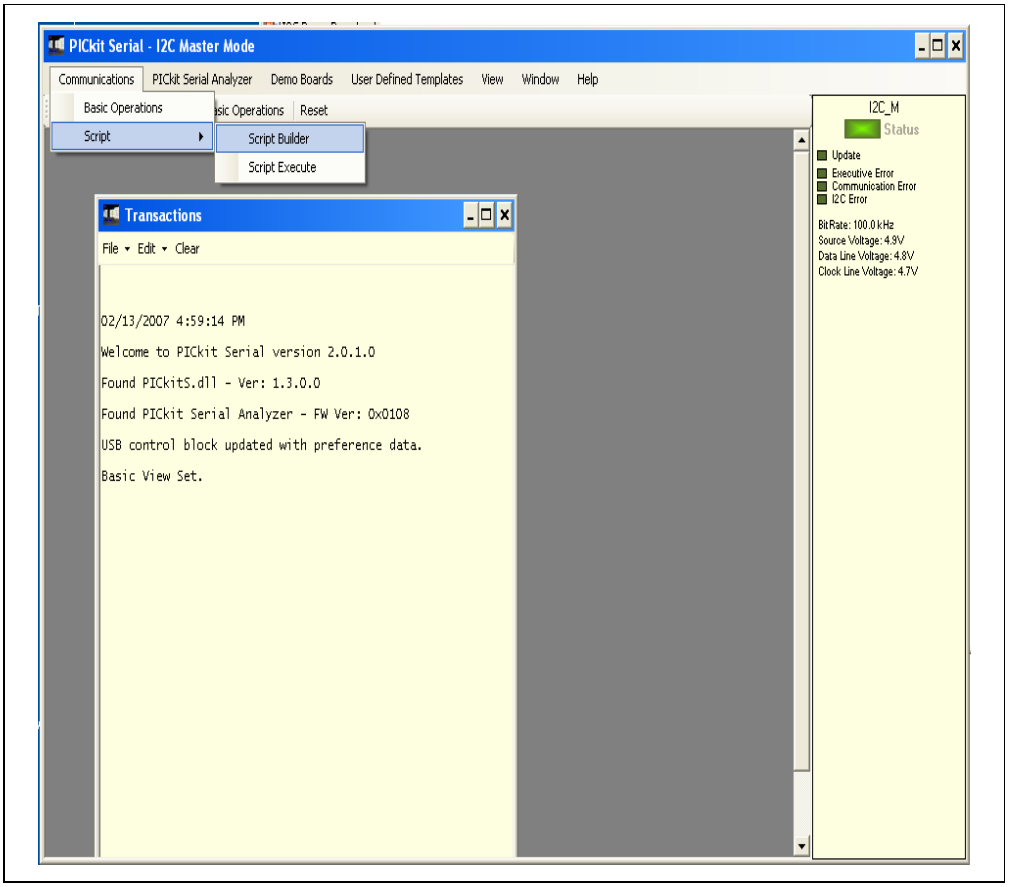


FIGURE 1-9: *Creating a Script File with Script Builder.*

1.3.2.1 CREATING SCRIPT FILE FOR CONFIGURATION BYTE WRITING

1. Click on **WriteBlockAddrA8** in "Example I^2C Scripts" column.

   This will result in filling in the spaces under the **Script Detail** column.
   You can now modify the **Script Detail** column parameters by clicking with the right mouse button.

How to modify the parameters box in Script Details:

1. Under the **Script Detail** box, select the item in the parameter box.
2. Right click the mouse button. An option box will appear to the right of your selection. These are the options available for the parameter selected.
3. Select the desired option and delete or insert the parameter box.
4. Keep the parameters in order as shown in the next examples.

> **Note:** The following examples need knowledge on the MCP4728 Registers and Command protocols. Please refer to the **Appendix C. "MCP4728 Read/Write Commands"** and the MCP4728 Data Sheet for more details.

1.3.2.2 **EXAMPLE 1:** SELECTING VOLTAGE REFERENCE OF EACH DAC CHANNEL

You can select the voltage reference of each channel individually. The choices are: external (V_{DD}) or internal reference voltage (V_{REF} = 2.048V). Figure 1-10 shows an example of writing a script file on the PICkit Serial PC GUI.

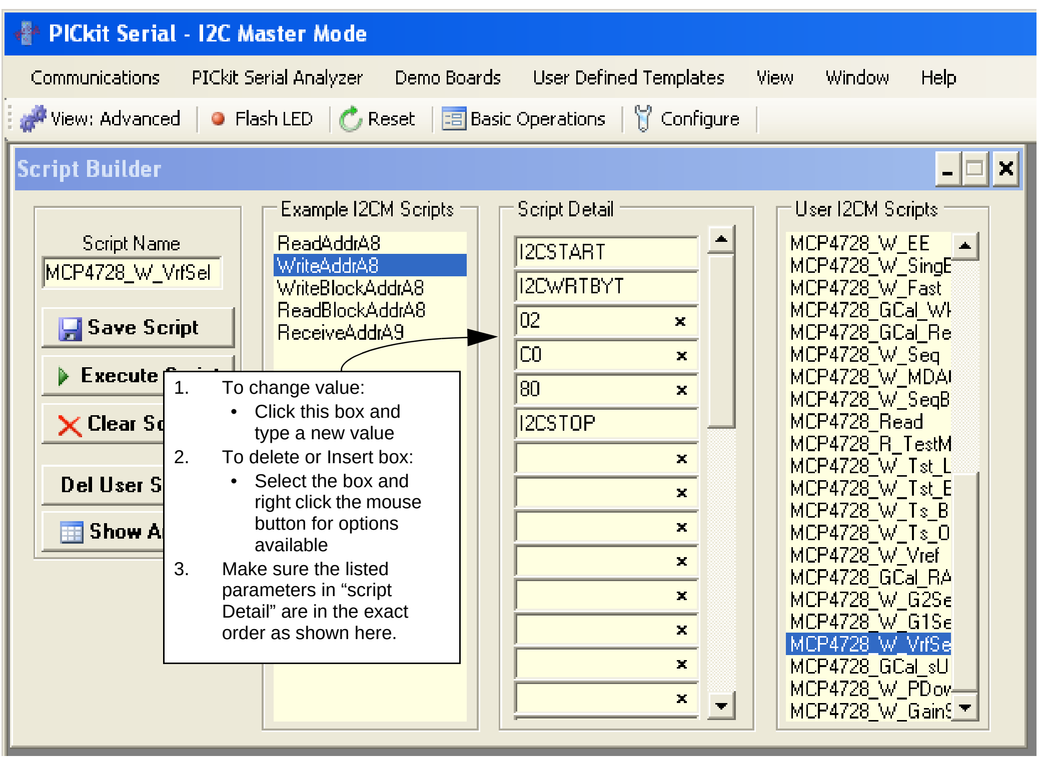


FIGURE 1-10: *Creating a new Script file to select V_{REF} of each DAC channel. In this example, external V_{REF} (V_{REF} =V_{DD}) is selected for all DAC channels.*

- Modify the parameters in the **Script Detail** column as below:

```
Script Detail

I2CSTART    *
I2CWRTBYT   *
   02     -------->  This means there are two bytes to send.
   C0     -------->  Address byte = 1100-0000 (See Note).
   80     -------->  1'st byte (000-0000) selecting external VREF.
I2CSTOP     *
```

> **Note:** All 6 parameters above must be listed in order. The parameters with * are not modifiable. The MCP4728 device on the evaluation board has I^2C address bits (A2, A1, A0) = (0,0,0).

1.3.2.3 SAVE THE SCRIPT FILE AND PROGRAMMING THE MCP4728 DAC REGISTERS

1. Type in a script file name (i.e., MCP4728_W_VrfSel) in the space below the **Script Name** menu.
2. Click **Save Script** button.
3. Click **Execute Script** button.

> **Note:** At this point, the PICkit Serial Analyzer transmits the I^2C Write Command to the MCP4728 device. The saved file name will appear in the **Users I2C Scripts** column, and can be re-used any time by selecting the file name.

4. You can also see the SCL and SDA waveforms using an Oscilloscope.

> **Note:** When you click on the "Execute Script" menu, the "Busy" LED on the PICkit Serial Analyzer will momentarily turn on and then turn off. If the LED remains ON, a communications problem has occurred. Remove the PICkit Serial Analyzer from your computer and recheck the parameter values, including the order of parameters under the "Script Detail" column including the I^2C address of the device, and try again until the "Busy" LED turns OFF immediately after sending the I^2C command.

1.3.2.4 EXAMPLE 2: SELECTING GAIN OF EACH DAC CHANNEL

You can select the Gain of each channel individually. Figure 1-11 shows an example of writing a new script file on the PICkit Serial PC GUI for selecting the gain option. In this example, Gain of 1 is selected.

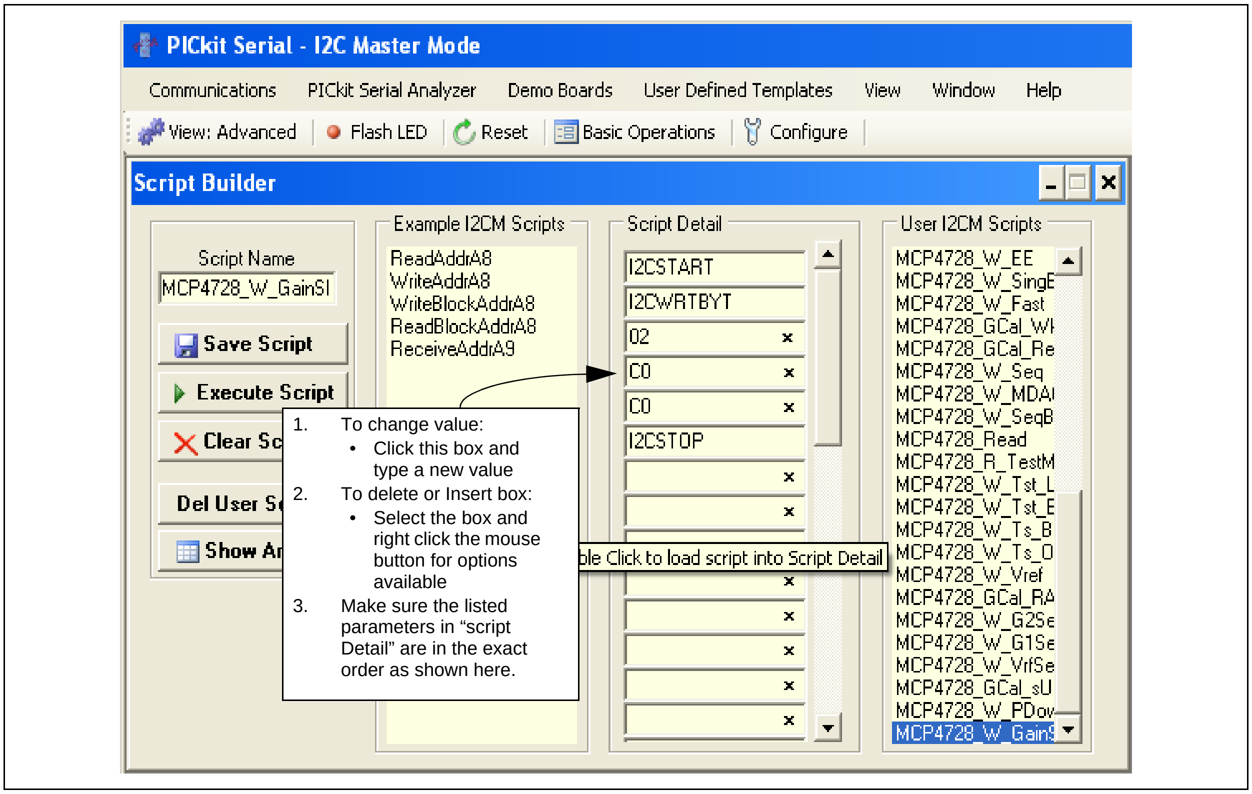


FIGURE 1-11: *Writing Script file to select V_{REF} of each DAC channel. In this example, Gain of 1 is selected for all DAC channels.*

- Parameters in the Script Detail column:

Script Detail	
I2CSTART	*
I2CWRTBYT	*
02	-----> This means there are two bytes to send.
C0	-----> Address byte = 1100-0000 (See **Note**).
C0	---- > Selecting the gain of each channel (0: Gain of 1, 1: gain of 2)
I2CSTOP	*

Note: All parameters above must be listed in order. The parameter above with * are not modifiable. The MCP4728 device on the evaluation board has I^2C address bits (A2, A1, A0) = (0,0,0).

1.3.2.5 SAVE THE SCRIPT FILE AND PROGRAMMING THE MCP4728 DAC REGISTERS

1. Type in any script name (i.e., MCP4728_W_GainSl) in the space below the **Script Name** menu.
2. Click **Save Script** button.
3. Click **Execute Script** button.

> **Note:** At this point, the PICkit Serial transmits the I^2C Write Command to the MCP4728 device. The saved file name will appear in **Users I2C Scripts** column, and can be re-used any time by selecting the file name.

4. You can also see the SCL and SDA waveforms using the Oscilloscope.

> **Note:** When you click on the “Execute Script” menu, the “Busy” LED on the PICkit Serial Analyzer will momentarily turn on and then turn off. If the LED remains ON, a communications problem has occurred. Remove the PICkit Serial Analyzer from your computer and recheck the parameter values including the order of parameters under the “Script Detail” column including the I2C address of the device, and try again until the “Busy” LED turns OFF immediately after sending the I^2C command.

1.3.2.6 **EXAMPLE 3:** WRITING DAC REGISTERS WITH A FAST WRITE COMMAND

Note:	Please refer to the MCP4728 data sheet for the Fast Write Command structure before excising this example.

Figure 1-12 shows an example of writing a script file on PICkit Serial PC GUI for a Fast Write Command. This command writes to the DAC input registers and power-down selection bits. The data are sent sequentially from channel A to the channel D. EEPROM is not affected. This device updates the DAC output registers (V_{OUT}) when $\overline{LDAC}$ pin is low.

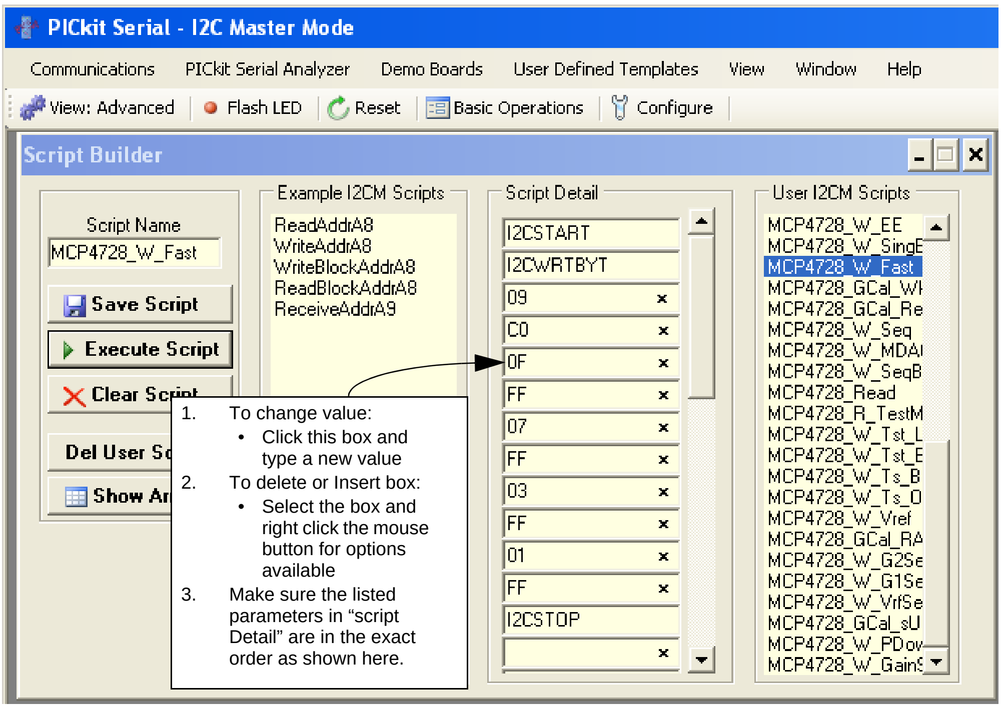


FIGURE 1-12: *Writing Script File to Write Each DAC Register with a Fast Write Command Using the PICkit Serial Analyzer.*

- Parameters in the Script Detail column:

Script Detail	
I2CSTART	*
I2CWRTBYT	*
09	-------> This means there are nine bytes to send.
C0	-------> Address byte = 1100-0000 (See **Note**).
0F	-------> 1st byte of DAC A Register (Channel A) = 0000-1111
FF	-------> 2nd byte of DAC A Register (Channel A) = 1111-1111
07	-------> 1st byte of DAC B Register (Channel B) = 0000-0111
FF	-------> 2nd byte of DAC B Register (Channel B) =1111-1111
03	-------> 1st byte of DAC C Register (Channel C) = 0000-0011
FF	-------> 2nd byte of DAC C Register (Channel C) = 1111-1111
01	-------> 1st byte of DAC D Register (Channel D) = 0000 -0001
FF	-------> 2nd byte of DAC D Register (Channel D) = 1111-1111
I2CSTOP	*

> **Note:** All parameters above must be listed in order. The parameter above with * are not modifiable. The MCP4728 device on the evaluation board has I^2C address bits (A2, A1, A0) = (0,0,0).

1.3.2.7 SAVE THE SCRIPT FILE AND PROGRAMMING THE MCP4728 DAC REGISTERS

1. Type in any script name (i.e., MCP4728_W_Fast) in the space below the **Script Name** menu.
2. Click **Save Script** button.
3. Click **Execute Script** button.

> **Note:** At this point, the PICkit Serial transmits the I^2C Write Command to the MCP4728 device. The saved file name will appear in **Users I2C Scripts** column, and can be re-used any time by selecting the file name.

4. You can also see the SCL and SDA waveforms using the Oscilloscope.

> **Note:** When you click on the “Execute Script” menu, the “Busy” LED on the PICkit Serial Analyzer will momentarily turn on and then turn off. If the LED remains ON, a communications problem has occurred. Remove the PICkit Serial Analyzer from your computer and recheck the parameter values including the order of parameters under the “Script Detail” column including the I^2C address of the device, and try again until the “Busy” LED turns OFF immediately after sending the I^2C command.

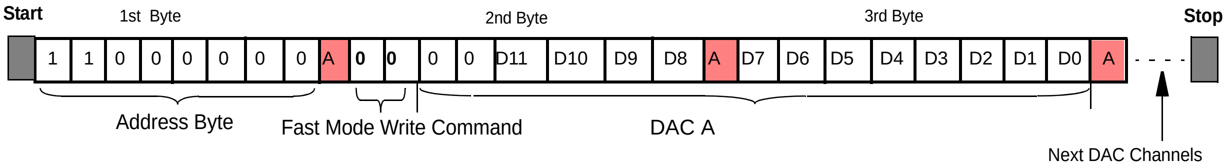
5. Read the V_{OUT} voltage at the V_{OUT} test pads:

In order to update the DAC output register, the $\overline{LDAC}$ pin must be “Low”.

- Press “S1” button in the MCP4728 Evaluation Board.

The device will update the V_{OUT} as soon as the $\overline{LDAC}$ pin switch S1 is pressed.

You can now measure the DAC output voltages (V_{OUT} A, V_{OUT} B, V_{OUT} C, V_{OUT} D) using a voltmeter. When Examples 1, 2, and 3 are executed sequentially, all channels use an internal reference. Figure 1-13 shows the expectation of each DAC channel outputs.



The following example shows when the device receives the Fast Write command with the following data:

DAC Input Data of Channel A = 001111-11111111
DAC Input Data of Channel B = 000111-11111111
DAC Input Data of Channel C = 000011-11111111
DAC Input Data of Channel D = 000001-11111111

$$V_{OUT} = \frac{(V_{REF} \times D_n)}{4096} G_x$$

(A) Channel A Output:

In Script file, Dn for Channel A = 0FFF (hex) = 4095 (decimal)

$$V_{OUT}\ A = \frac{(V_{DD} \times 4095)}{4096} = V_{DD}\left(\frac{4096-1}{4096}\right) = V_{DD}\left(1 - \frac{1}{4096}\right) = V_{DD} - LSB$$

(B) Channel B Output:

In Script file, Dn for Channel B = 07FF (hex) = 2047 (decimal)

$$V_{OUT}\ B = \frac{(V_{DD} \times 2047)}{4096} = V_{DD}\left(\frac{2048-1}{4096}\right) = \frac{V_{DD}}{2}\left(1 - \frac{2}{4096}\right) = \frac{V_{DD}}{2} - LSB$$

(C) Channel C Output:

In Script file, Dn for Channel C = 03FF (hex) = 1023 (decimal)

$$V_{OUT}\ C = \frac{V_{DD} \times 1023}{4096} = V_{DD}\left(\frac{1024-1}{4096}\right) = \frac{V_{DD}}{4}\left(1 - \frac{4}{4096}\right) = \frac{V_{DD}}{4} - LSB$$

(D) Channel D Output:

In Script file, Dn for Channel D = 01FF (hex) = 511 (decimal)

$$V_{OUT}\ D = \frac{V_{DD} \times 511}{4096} = V_{DD}\left(\frac{512-1}{4096}\right) = \frac{V_{DD}}{8}\left(1 - \frac{8}{4096}\right) = \frac{V_{DD}}{8} - LSB$$

FIGURE 1-13: *V_{OUT} for Example 3: Fast Write Command for Various V_{OUT}. V_{REF} = V_{DD} and Gain = 1 for All Channels.*

1.3.2.8 EXAMPLE 4: MULTI-WRITE COMMAND FOR DAC INPUT REGISTERS

This command writes to the multiple DAC input registers, one register at a time. The writing channel register is defined by the DAC selection bits (DAC1, DAC0). EEPROM is not affected by this command.

Figure 1-14 shows an example of creating the PICkit Script file. In this example, the the PICkit Serial Analyzer sends a write command to the DAC input registers A and B.

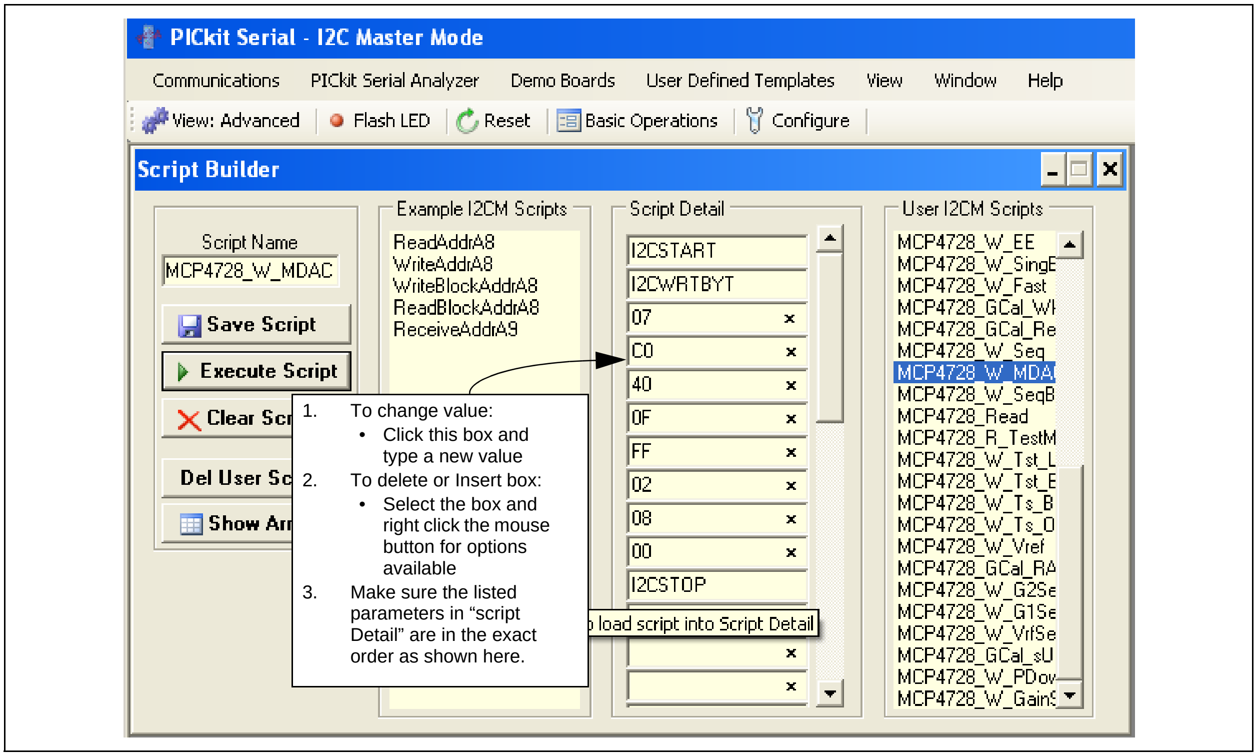


FIGURE 1-14: *Writing Script file to Write Channel A for FFFh and Channel B for 800h Using a Multi-write Command.*

- Parameters in the Script Detail column:

```
Script Detail

I2CSTART     *
I2CWRTBYT    *
  07       -------> This means there are seven bytes to send.
  C0       -------> Address byte = 1100-0000 (See Note).
  40       -------> Command Type and Selecting Channel A DAC
  0F       -------> Configuration register bits and data nibble
  FF       -------> Data byte
  02       -------> Selecting Channel B DAC
  08       -------> Configuration register bits and data nibble
  00       -------> Data byte
I2CSTOP      *
```

> **Note:** All parameters above must be listed in order. The parameters above with * are not modifiable. The MCP4728 device on the evaluation board has I^2C address bits (A2, A1, A0) = (0,0,0).

1.3.2.9 SAVE THE SCRIPT FILE AND PROGRAMMING THE MCP4728 DAC REGISTERS

1. Type in any script name (i.e., MCP4728_W_MDAC) in the space below the **Script Name** menu.
2. Click **Save Script** button.
3. Click **Execute Script** button.

> **Note:** At this point, the PICkit Serial transmits the I^2C Write Command to the MCP4728 device. The saved file name will appear in **Users I2C Scripts** column, and can be re-used any time by selecting the file name.

4. You can also see the SCL and SDA waveforms using the Oscilloscope.

> **Note:** When you click on the "Execute Script" menu, the "Busy" LED on the PICkit Serial Analyzer will momentarily turn on and then turn off. If the LED remains ON, a communications problem has occurred. Remove the PICkit Serial Analyzer from your computer and recheck the parameter values including the order of parameters under the "Script Detail" column including the I^2C address of the device, and try again until the "Busy" LED turns OFF immediately after sending the I^2C command.

5. Read the V_{OUT} voltage at the V_{OUT} test pins:

Since the $\overline{UDAC}$ bit is set to "0" in the command, the device will update the V_{OUT} A and V_{OUT} B as soon as the command is executed regardless of the condition of the $\overline{LDAC}$ pin switch S1.

$$V_{OUT} = \frac{(V_{REF} \times D_n)}{4096} G_x$$

(A) Channel A Output:

In Script file, Dn for Channel A = 0FFF (hex) = 4095 (decimal)

$$V_{OUT}A = \frac{(V_{DD} \times 4095)}{4096} = V_{DD}\left(\frac{4096 - 1}{4096}\right) = V_{DD}\left(1 - \frac{1}{4096}\right) = V_{DD} - LSB$$

(B) Channel B Output:

In Script file, Dn for Channel B = 0800 (hex) = 2048 (decimal)

$$V_{OUT}B = \frac{(V_{DD} \times 2048)}{4096} = \frac{V_{DD}}{2}$$

(C) Channel C Output:

No change. The device maintains its output with previous settings.

(D) Channel D Output:

No change. The device maintains its output with previous settings.

Where:

V_{REF}	=	V_{DD} if external VREF is selected
	=	2.048V if internal VREF is selected.
D_n	=	Input code
LSB	=	VREF/4096

Note that Dn and Gain (G_x) must be selected with the following conditions:

$$V_{OUT} = \frac{(V_{REF} \times D_n)}{4096} G_x \leq V_{DD}$$

Figure 1-15: V_{OUT} for Example 4: Multi-Write Command for Channels A and B with $V_{REF} = V_{DD}$ and Gain = 1.

1.3.2.10 EXAMPLE 5: SINGLE WRITE COMMAND FOR DAC INPUT REGISTER AND EEPROM

This command writes to a single DAC input register and its EEPROM. Both input register and EEPROM are written at the acknowledge pulse of the input data byte. The EEPROM program activity can be monitored through the RDY/$\overline{BSY}$ bit and pin. See the MCP4728 data sheet for details.

Figure 1-16 shows an example of writing a script file. In this example, the PICkit Serial Analyzer sends a single write command to the MCP4728 for the DAC A (Channel A) input register.

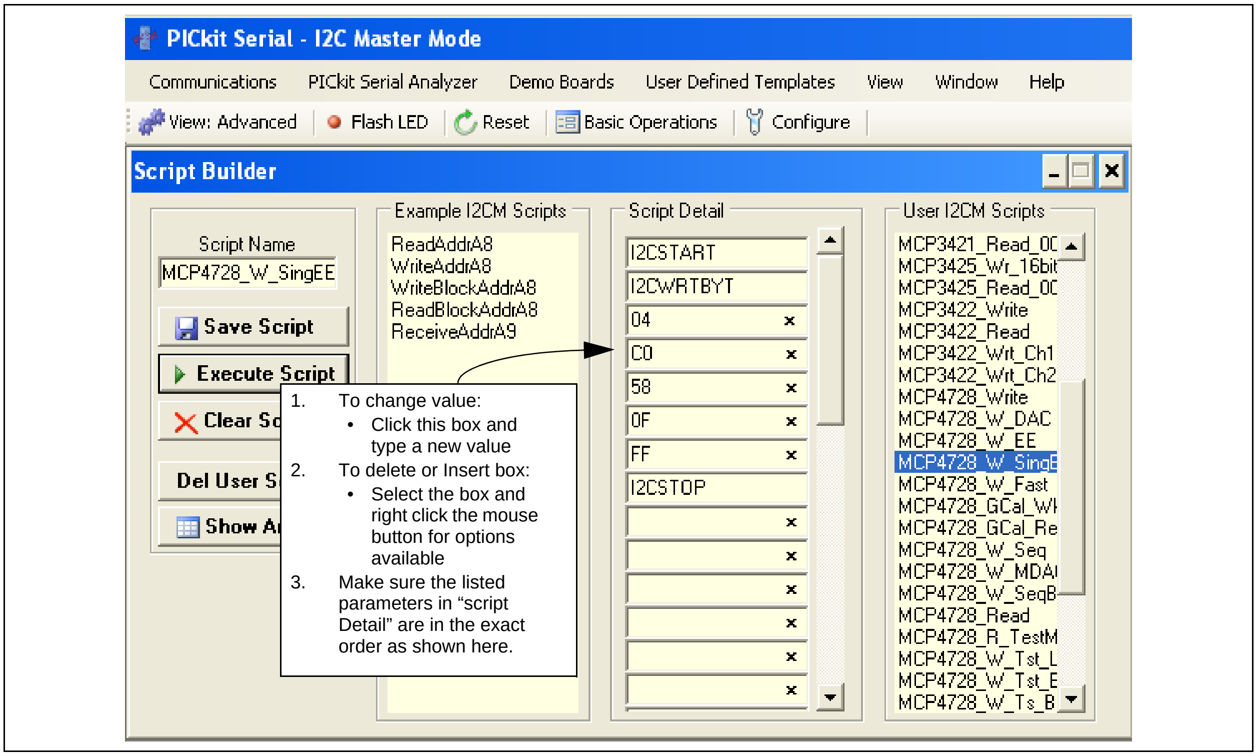


FIGURE 1-16: Writing Script File to Write the Channel A Register and its EEPROM with FFFh Using a Single Write Command. The Channel A output is updated immediately with the ACK Pulse. This example uses UDAC Bit, instead of using $\overline{LDAC}$ pin, to update the DAC output.

- Parameters in the Script Detail column:

Script Detail	
I2CSTART	*
I2CWRTBYT	*
04	-------> This means there are four bytes to send.
C0	-------> Address byte = 1100-0000 (See **Note**).
58	-------> Command Type and selection of Channel A.
0F	-------> Configuration register bits and data nibble for Channel A.
FF	-------> Data byte for Channel A (register and its EEPROM).
I2CSTOP	*

> **Note:** All parameters above must be listed in order. The parameter above with * are not modifiable. The MCP4728 device on the evaluation board has I^{2}C address bits (A2, A1, A0) = (0,0,0).

1.3.2.11 SAVE THE SCRIPT FILE AND PROGRAMMING THE MCP4728 DAC REGISTERS

1. Type in any script name (i.e., MCP4728_W_SingEE) in the space below the **Script Name** menu.
2. Click **Save Script** button.
3. Click **Execute Script** button.

> **Note:** At this point, the PICkit Serial transmits the I^2C Write Command to the MCP4728 device. The saved file name will appear in **Users I2C Scripts** column, and can be re-used any time by selecting the file name.

4. You can also see the SCL and SDA waveforms using the Oscilloscope.

> **Note:** When you click on the “Execute Script” menu, the “Busy” LED on the PICkit Serial Analyzer will momentarily turn on and then turn off. If the LED remains ON, a communications problem has occurred. Remove the PICkit Serial Analyzer from your computer and recheck the parameter values including the order of parameters under the “Script Detail” column including the I2C address of the device, and try again until the “Busy” LED turns OFF immediately after sending the I^2C command.

5. Read the V_{OUT} voltage at the V_{OUT} test pins:

Since the $\overline{UDAC}$ bit is set to “0” in the command, the device will update the channel A (V_{OUT} A) output as soon as the command is executed regardless of the condition of the $\overline{LDAC}$ pin switch S1.

$$V_{OUT} = \frac{(V_{REF} \times D_n)}{4096} G_x$$

(A) Channel A Output:

In Script file, Dn for Channel A = 0FFF (hex) = 4095 (decimal)

$$V_{OUT}A = \frac{(V_{DD} \times 4095)}{4096} = V_{DD}\left(\frac{4096-1}{4096}\right) = V_{DD}\left(1 - \frac{1}{4096}\right) = V_{DD} - LSB$$

(B) Channel B Output:

No change. Keep its output with previous settings.

(C) Channel C Output:

No change. Keep its output with previous settings.

(D) Channel D Output:

No change. Keep its output with previous settings.

Where:

V_{REF}	=	V_{DD} if external V_{REF} is selected
	=	2.048V if internal V_{REF} is selected.
D_n	=	Input code
LSB	=	V_{REF}/4096

Note that Dn and Gain (G_x) must be selected with the following conditions:

$$V_{OUT} = \frac{(V_{REF} \times D_n)}{4096} G_x \leq V_{DD}$$

FIGURE 1-17: *V_{OUT} for Example 5: Single Write Command for Channel A: V_{REF} = V_{DD} and Gain = 1.*

1.3.2.12 **EXAMPLE 6:** SEQUENTIAL WRITE FOR DAC INPUT REGISTERS AND EEPROM

This command writes to the DAC input registers and EEPROM sequentially from a start channel to the channel D. The input register is written at the ACK pulse of the input data byte of each register. However, the EEPROM are written altogether at the same time sequentially at the end of the last byte. The EEPROM writing activity can be monitored through the RDY/BSY bit and pin. See the MCP4728 data sheet for details.

Figure 1-18 shows an example of writing a script file on PICkit Serial PC GUI for this command.

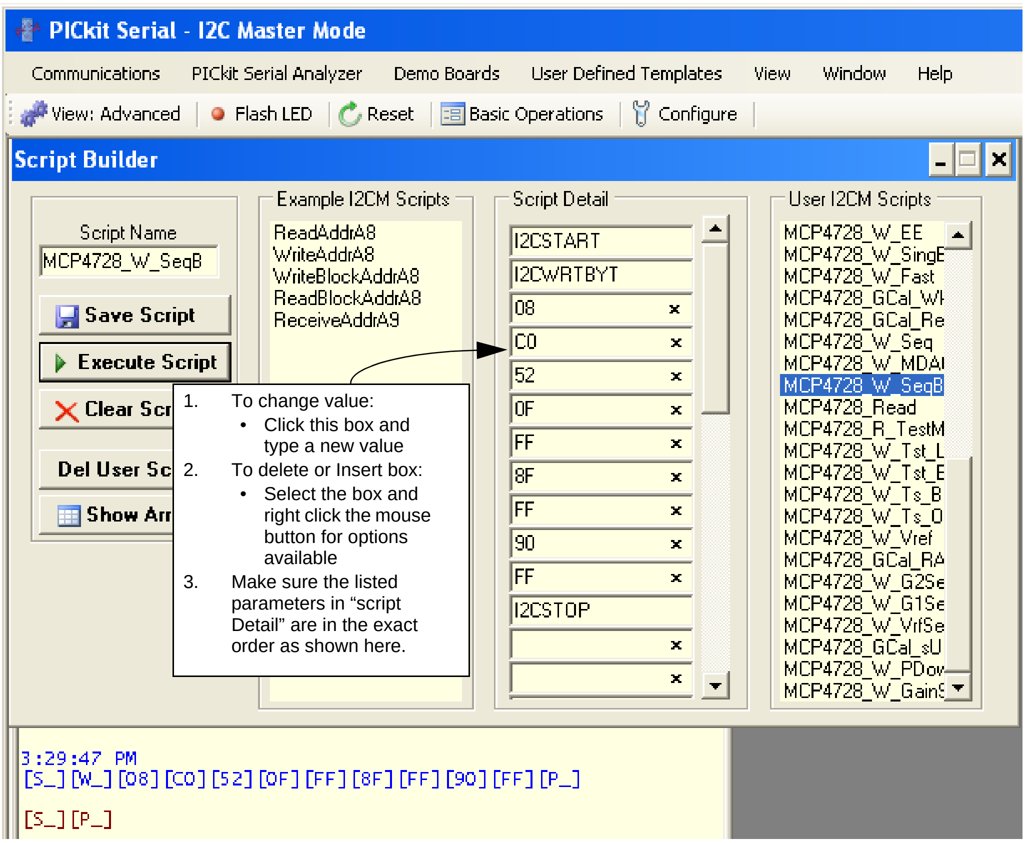


FIGURE 1-18: *Writing Script file to write the Channel B to Channel D. This command writes to both the input registers and EEPROM: (a) Channel B Settings: $V_{REF} = V_{DD}$ and Gain = 1. (b) Channel C Settings: V_{REF} = Internal (2.048V), Gain = 1. (c) Channel D Settings: V_{REF} = Internal (2.048V), Gain = 2. The DAC outputs are updated immediately with the ACK pulse. This example uses the UDAC bit to update the DAC outputs.*

- Parameters in the Script Detail column:

```
Script Detail

I2CSTART     *
I2CWRTBYT    *
   08        -------> This means there are eight bytes to send.
   C0        -------> Address byte = 1100-0000 (See Note).
   52        -------> Command Type and Ch. B is a starting channel
   0F        -------> Configuration register bits and data nibble for Ch. B
   FF        -------> Data byte for Ch. B
   8F        -------> Configuration register bits and data nibble for Ch. C
   FF        -------> Data byte for Ch. C
   90        -------> Configuration register bits and data nibble for Ch. D
   FF        -------> Data byte for Ch. D
I2CSTOP      *
```

> **Note:** All parameters above must be listed in order. The parameter above with * are not modifiable. The MCP4728 device on the evaluation board has I^{2}C address bits (A2, A1, A0) = (0,0,0).

1.3.2.13 SAVE THE SCRIPT FILE AND PROGRAMMING THE MCP4728 DAC REGISTERS

1. Type in any script name (i.e., MCP4728_W_SeqB) in the space below the **Script Name** menu.
2. Click **Save Script** button.
3. Click **Execute Script** button.

> **Note:** At this point, the PICkit Serial transmits the I^{2}C Write Command to the MCP4728 device. The saved file name will appear in **Users I2C Scripts** column, and can be re-used any time by selecting the file name.

4. You can also see the SCL and SDA waveforms using the Oscilloscope.

> **Note:** When you click on the “Execute Script” menu, the “Busy” LED on the PICkit Serial Analyzer will momentarily turn on and then turn off. If the LED remains ON, a communications problem has occurred. Remove the PICkit Serial Analyzer from your computer and recheck the parameter values including the order of parameters under the “Script Detail” column including the I^{2}C address of the device, and try again until the “Busy” LED turns OFF immediately after sending the I^{2}C command.

5. Read the V_{OUT} voltage at the V_{OUT} test terminals:

Since the $\overline{\text{UDAC}}$ bit is set to “0” in the command, the device will update the V_{OUT} B, C, and D outputs as soon as the command is executed regardless of the condition of the $\overline{\text{LDAC}}$ pin switch S1.

$$V_{OUT} = \frac{(V_{REF} \times D_n)}{4096} G_x$$

(A) DAC A Output:

No change. Keep its output with previous settings.

(B) DAC B Output:

In Script file, $V_{REF} = V_{DD}$, Gain (G_X) = 1, Dn for Channel B = 0FFF (hex) = 4095 (decimal)

$$V_{OUT}B = \frac{(V_{DD} \times 4095)}{4096} G_x = V_{DD}\left(\frac{4096-1}{4096}\right) = V_{DD}\left(1 - \frac{1}{4096}\right) = V_{DD} - LSB$$

(C) DAC C Output:

In Script file, V_{REF} = Internal, Gain (G_X) = 1, Dn for Channel C = 0FFF (hex) = 4095 (decimal)

$$V_{OUT}C = \frac{(V_{REF} \times 4095)}{4096} G_x = V_{REF}\left(\frac{4096-1}{4096}\right) = V_{REF}\left(1 - \frac{1}{4096}\right) = V_{REF} - LSB$$

$$= 2.0475$$

where V_{REF} = internal = 2.048V, LSB =0.5 mV

(D) DAC D Output:

In Script file, V_{REF} = Internal, Gain = 2, Dn for Channel D = 00FF (hex) = 255 (decimal)

$$V_{OUT}D = \frac{V_{REF} \times 255}{4096} G_x = V_{REF}\left(\frac{255}{4096}\right)2 = V_{REF}(0.06226)(2) = 0.255V$$

where V_{REF} = internal = 2.048V

Where:

V_{REF}	=	V_{DD} if external V_{REF} is selected
	=	2.048V if internal V_{REF} is selected.
D_n	=	Input code
LSB	=	$V_{REF}/4096$

Note that Dn and Gain (Gx) must be selected with the following conditions:

$$V_{OUT} = \frac{(V_{REF} \times D_n)}{4096} G_x \leq V_{DD}$$

FIGURE 1-19: *V_{OUT} for Example 6: V_{OUT} after Sequential Write Command.*

1.3.2.14 **EXAMPLE 7:** TESTING EEPROM FEATURES

The device will upload the EEPROM data to both input and output DAC registers (a) during power-up sequence or (b) when it receives the General Call Reset command. One of these conditions makes the analog outputs available immediately with their current EEPROM settings. Note that the Power-Down bit must be cleared for the output.

- **Testing Procedure:**

a. Write to the EEPROM with one of the examples shown earlier (i.e., **Section 1.3.2.12 "Example 6: Sequential Write for DAC Input Registers and EEPROM"**).

b. Measure and record the analog voltage of each channel (V_{OUT}) using a multimeter.

c. Turn-off the V_{DD} of the device. If you are using the V_{DD} from the PICkit Serial Analyzer, disconnect JP1 connect.

d. Turn-back on the V_{DD} again and measure the analog voltage (V_{OUT}) of each channel again. Confirm the V_{OUT} is the same as in Step (b).

1.3.2.15 **EXAMPLE 8:** READING DAC REGISTERS AND EEPROM

This example shows how to read back the DAC input registers and EEPROM data.

Figure 1-20 shows the PICkit Serial script file to read all DAC input registers and EEPROM data. Once this file is executed, the PC GUI will show you the contents of the registers and EEPROM.

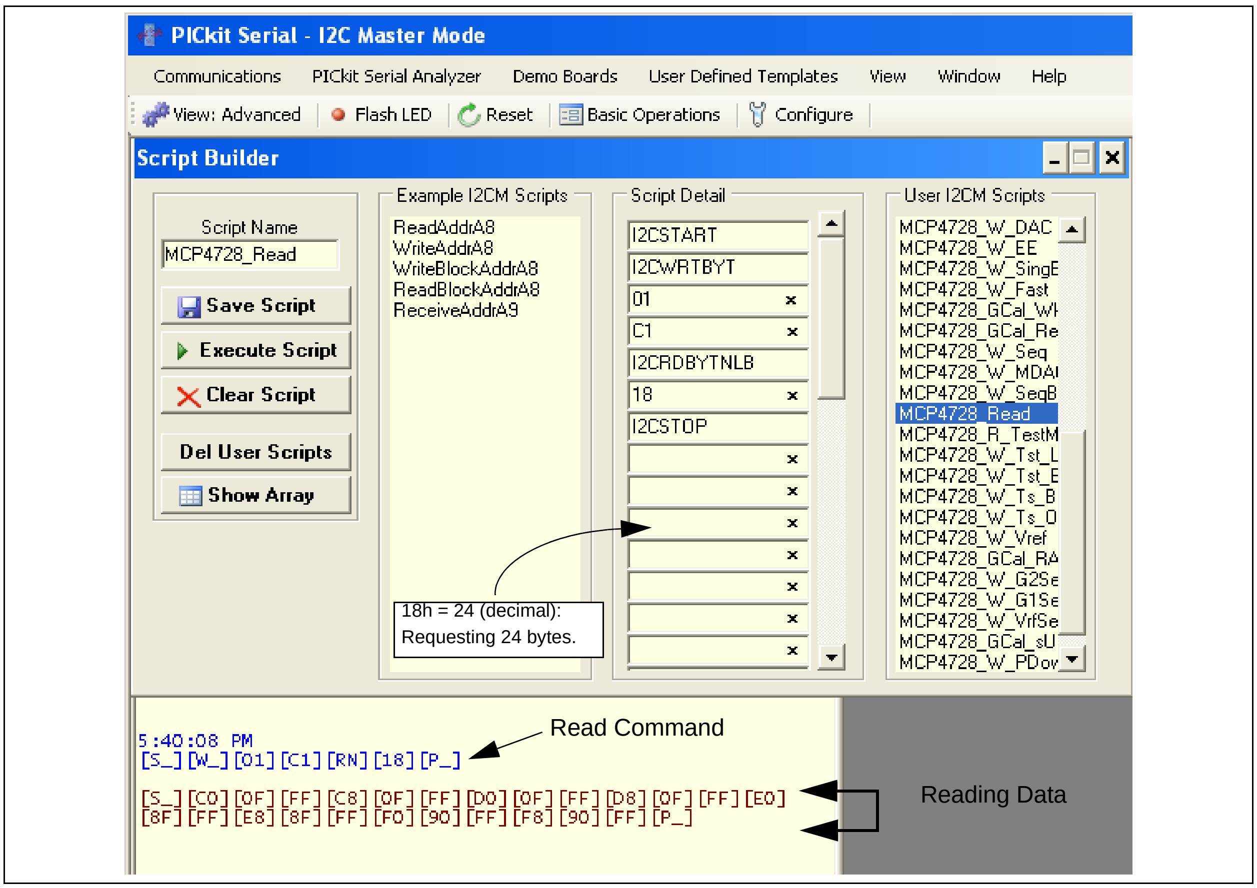
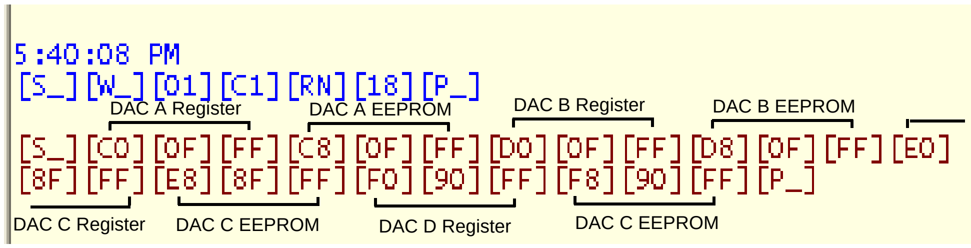


FIGURE 1-20: *Reading the DAC Registers and its EEPROM with a Read Command. See* Figure 1-21 *for Details in Reading Data.*

> **Note:** In Figure 1-20, the script file called “MCP4728_Read” was created, saved and executed.



Ch. A Register: C0-0F-FF:	$V_{REF} = V_{DD}$, G_A = x1, Data = FFFh
Ch. A EEPROM: C8-0F-FF:	$V_{REF} = V_{DD}$, G_A = x1, Data = FFFh
Ch. B Register: D0-0F-FF:	$V_{REF} = V_{DD}$, G_A = x1, Data = FFFh
Ch. B EEPROM: D8-0F-FF:	$V_{REF} = V_{DD}$, G_A = x1, Data = FFFh
Ch. C Register: E0-8F-FF:	$V_{REF} = V_{DD}$, G_A = x1, Data = FFFh
Ch. C EEPROM: E8-0F-FF:	$V_{REF} = V_{DD}$, G_A = x1, Data = FFFh
Ch. D Register: F0-90-FF:	$V_{REF} = V_{DD}$, G_A = x2, Data = 0FFh
Ch. D EEPROM: F8-90-FF:	$V_{REF} = V_{DD}$, G_A = x2, Data = 0FFh

FIGURE 1-21: *The contents of the Registers and EEPROM. The order of the contents: Channel A Register and EEPROM, and Channel B Register and EEPROM, and so on sequentially. See the Read Command and Device Output details in MCP4728 Data Sheet.*

1.3.2.16 **EXAMPLE 9:** WRITE POWER-DOWN SELECTION BITS IN DAC INPUT REGISTER

This command writes power-down bits to the DAC input registers.

Figure 1-22 shows an example of writing a new script file for Power-Down mode.

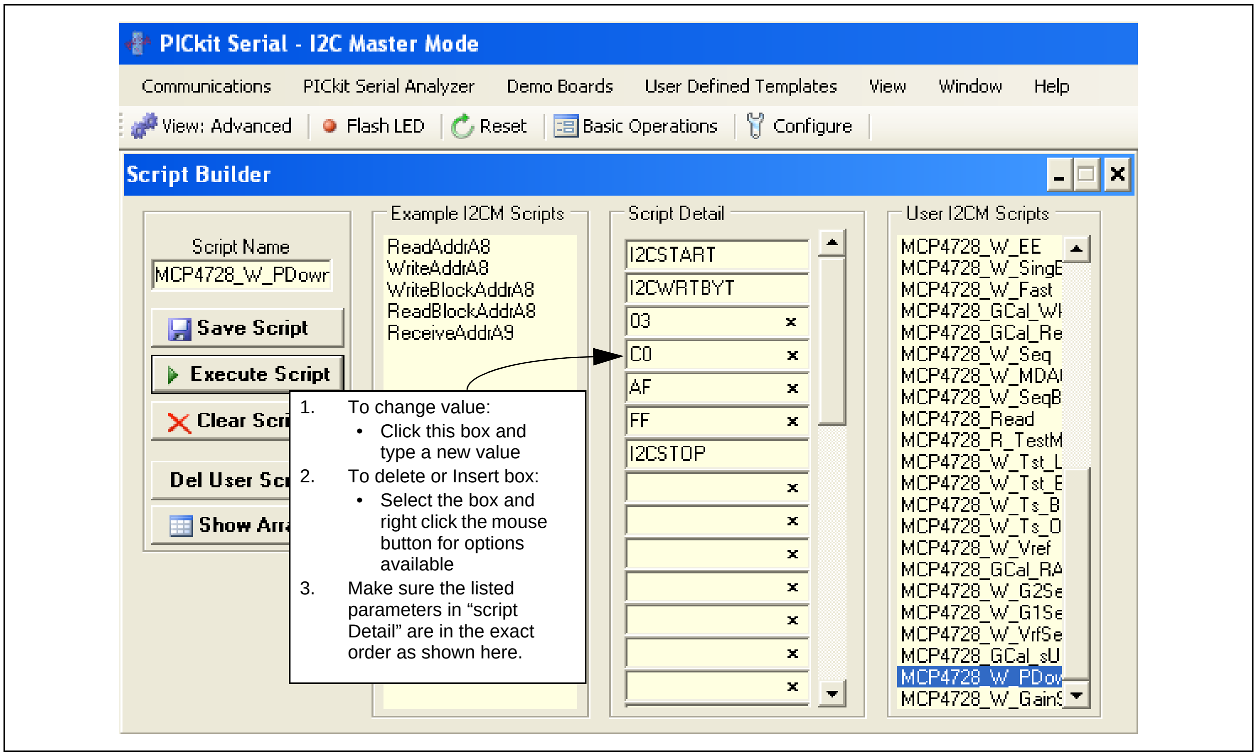


FIGURE 1-22: Writing Script file to write the power-down bits. The channel outputs are updated immediately with the ACK pulse. This command does not require UDAC bit or LDAC pin change.

- Parameters in the Script Detail column:

```
Script Detail

I2CSTART     *
I2CWRTBYT    *
03          -------> This means there are three bytes to send.
C0          -------> Address byte = 1100-0000 (See Note).
AF          -------> Command Type and Power-Down bits for Chs. A and B.
FF          -------> Power-Down bits for Channels C and D.
I2CSTOP      *
```

> **Note:** All parameters above must be listed in order. The parameter above with * are not modifiable. The MCP4728 device on the evaluation board has I^2C address bits (A2, A1, A0) = (0,0,0).

1.3.2.17 SAVE THE SCRIPT FILE AND PROGRAMMING THE MCP4728 DAC REGISTERS

1. Type in any script name (i.e., MCP4728_W_PDown) in the space below the **Script Name** menu.
2. Click **Save Script** button.
3. Click **Execute Script** button.

> **Note:** At this point, the PICkit Serial transmits the I^2C Write Command to the MCP4728 device. The saved file name will appear in **Users I2C Scripts** column, and can be re-used any time by selecting the file name.

4. You can also see the SCL and SDA waveforms using the Oscilloscope.

> **Note:** When you click on the “Execute Script” menu, the “Busy” LED on the PICkit Serial Analyzer will momentarily turn on and then turn off. If the LED remains ON, a communications problem has occurred. Remove the PICkit Serial Analyzer from your computer and re-check the parameter values including the order of parameters under the “Script Detail” column including the I^2C address of the device, and try again until the “Busy” LED turns OFF immediately after sending the I^2C command.

5. Read the V_{OUT} voltage at the V_{OUT} test pins:

Once this command is executed, all analog voltage outputs (V_{OUT}) will be “zero”, and the analog output pins (V_{OUT}) are internally connected with about 500 kΩ.

NOTES:

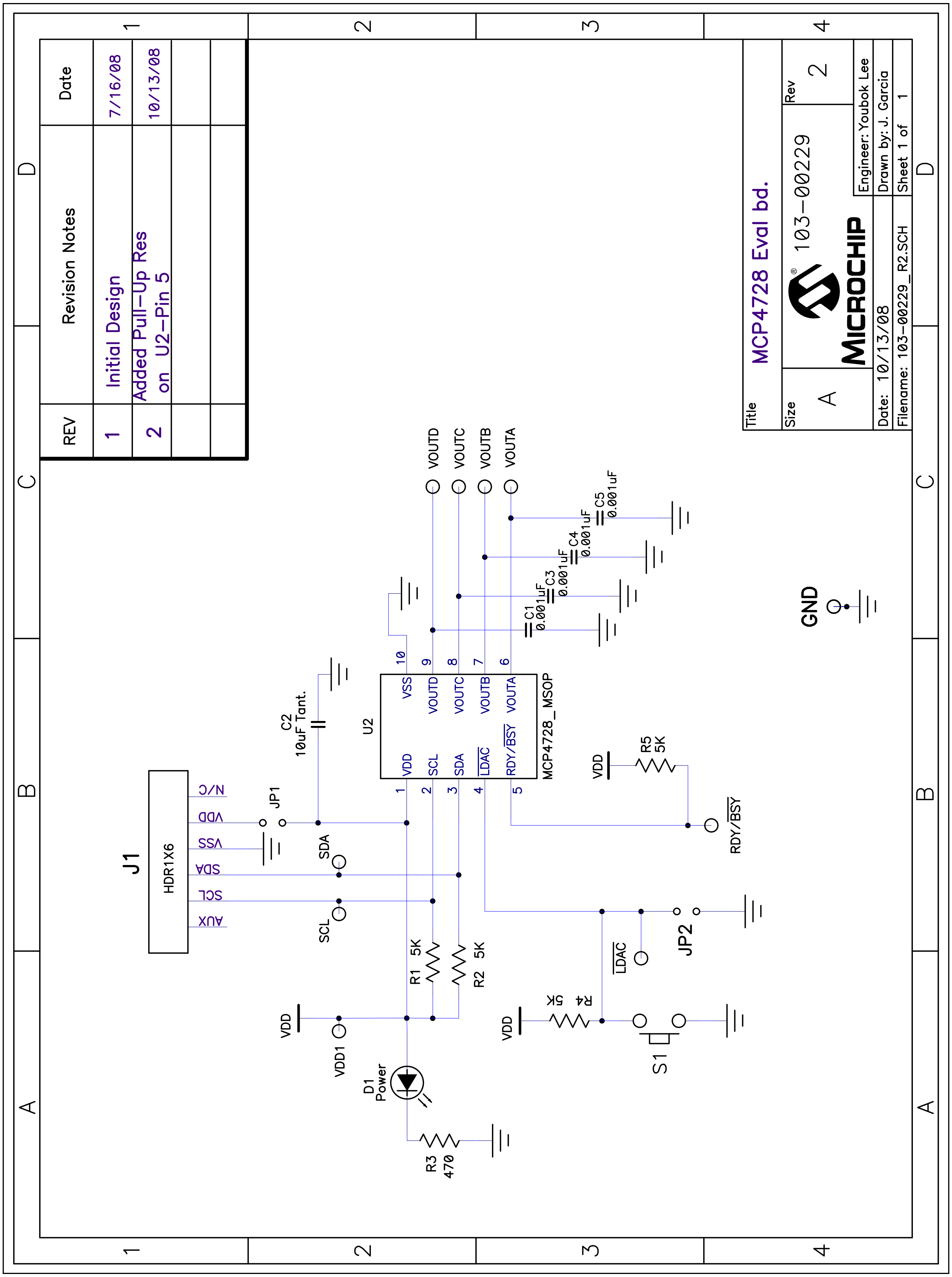
Appendix A. Schematic and Layouts

A.1 INTRODUCTION

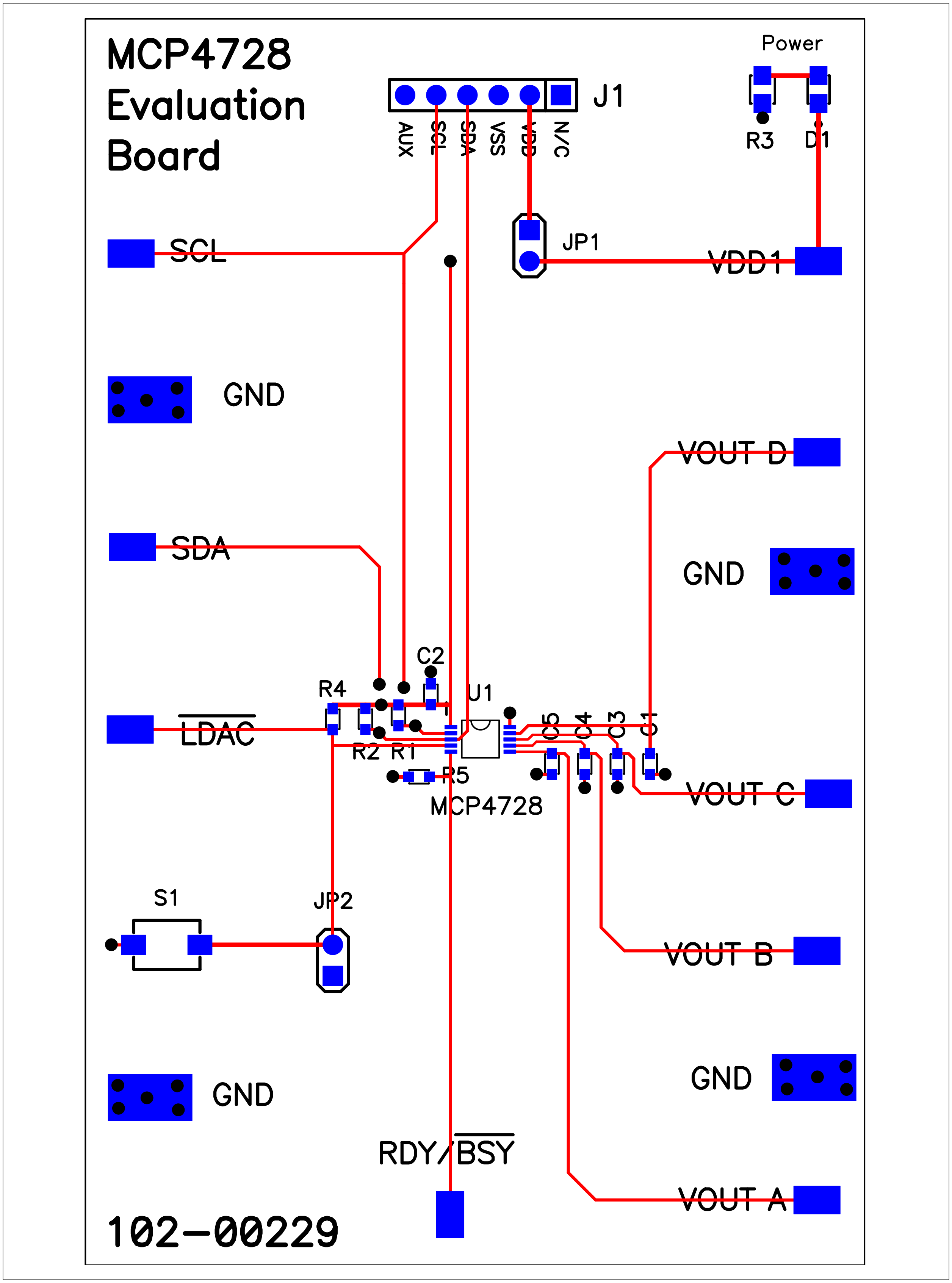
This appendix contains the following schematics and layouts for the MCP4728 Evaluation Board:

- Board – Schematic
- Board – Top Silk, Top Pads, and Top Copper Layer
- Board – Top Copper and Pads Layer
- Board – Top Pads and Silk Layer
- Board – Bottom Copper Layer

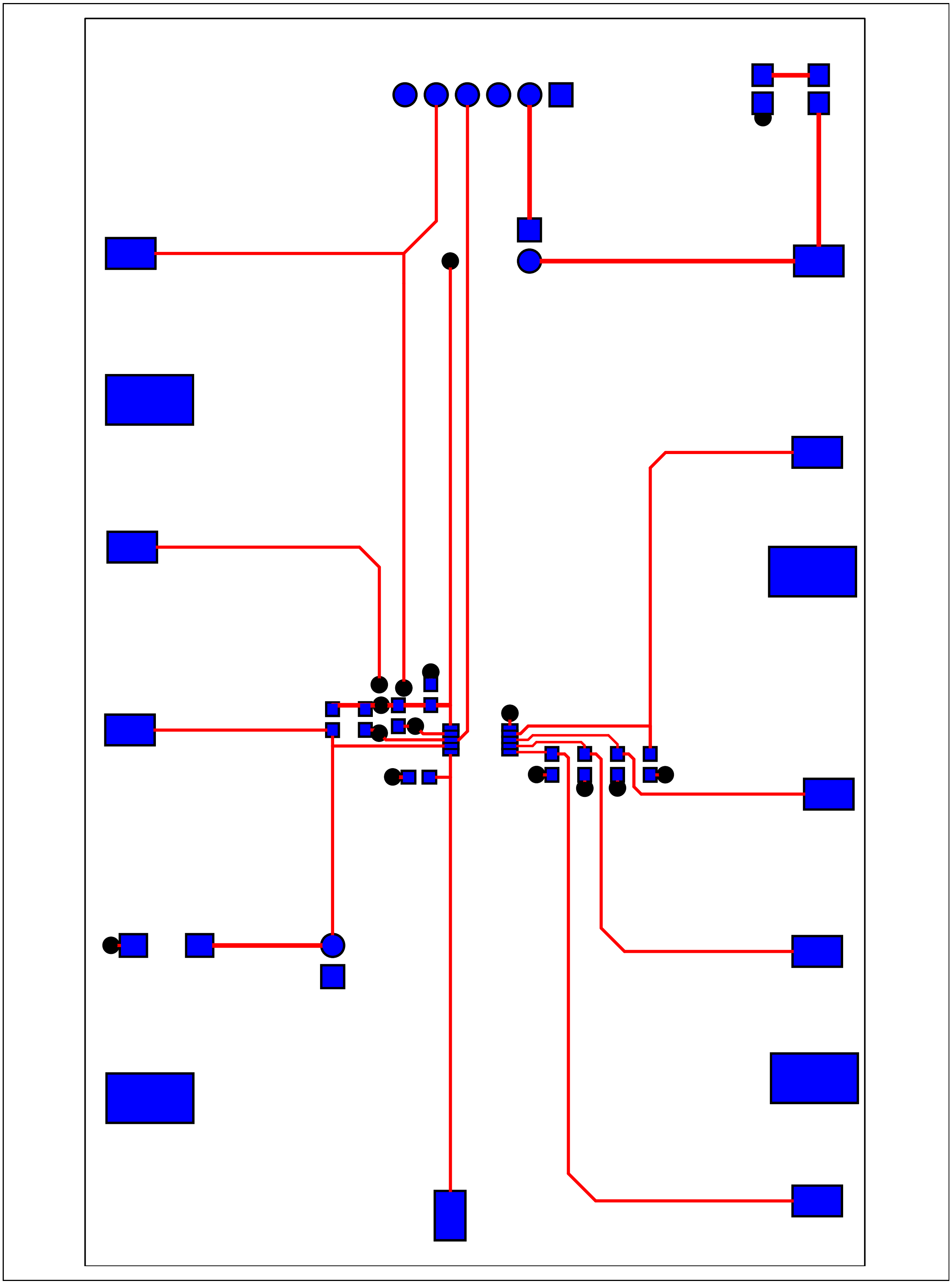
A.2 BOARD – SCHEMATIC



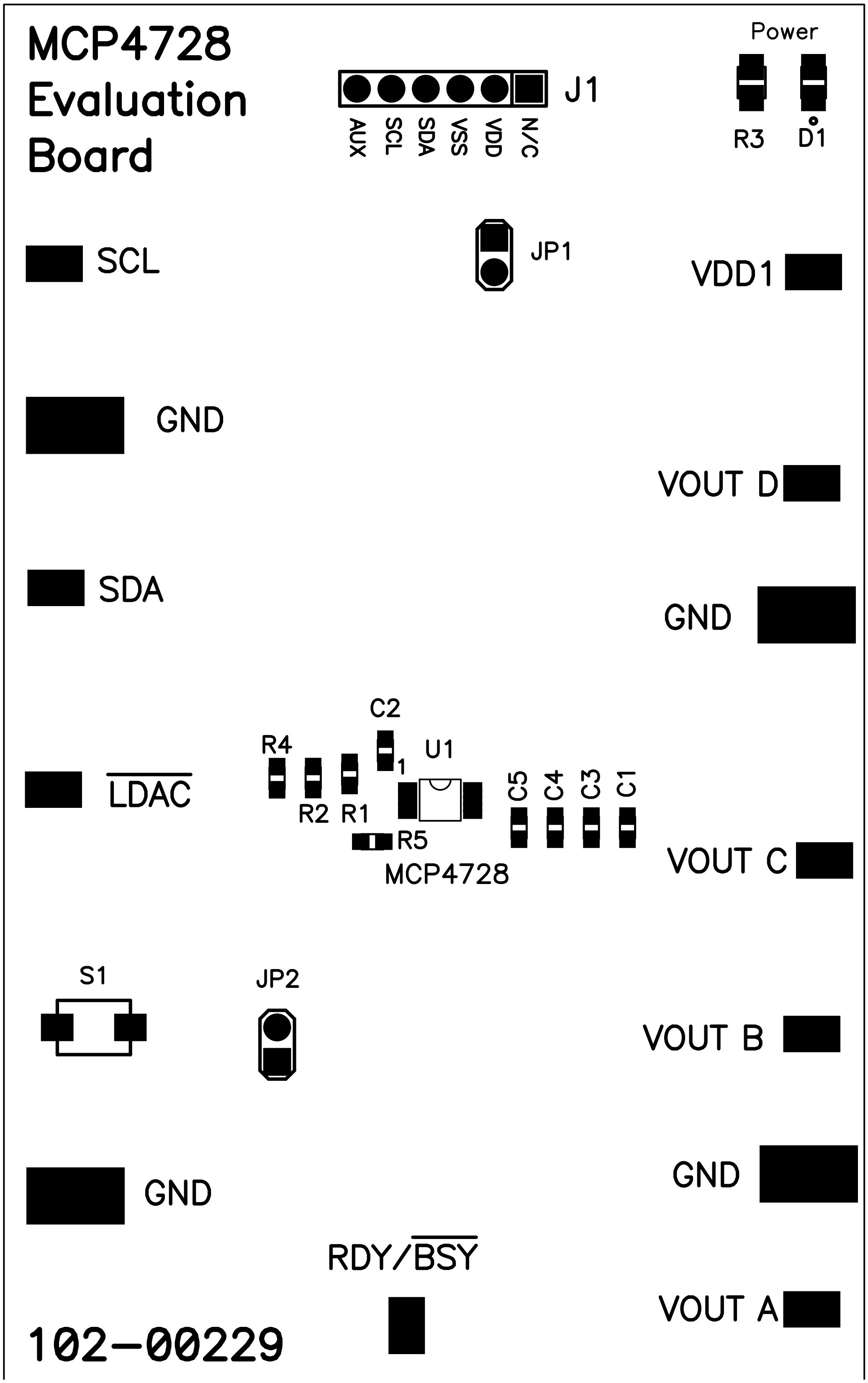
A.3 BOARD – TOP SILK, TOP PADS AND TOP COPPER



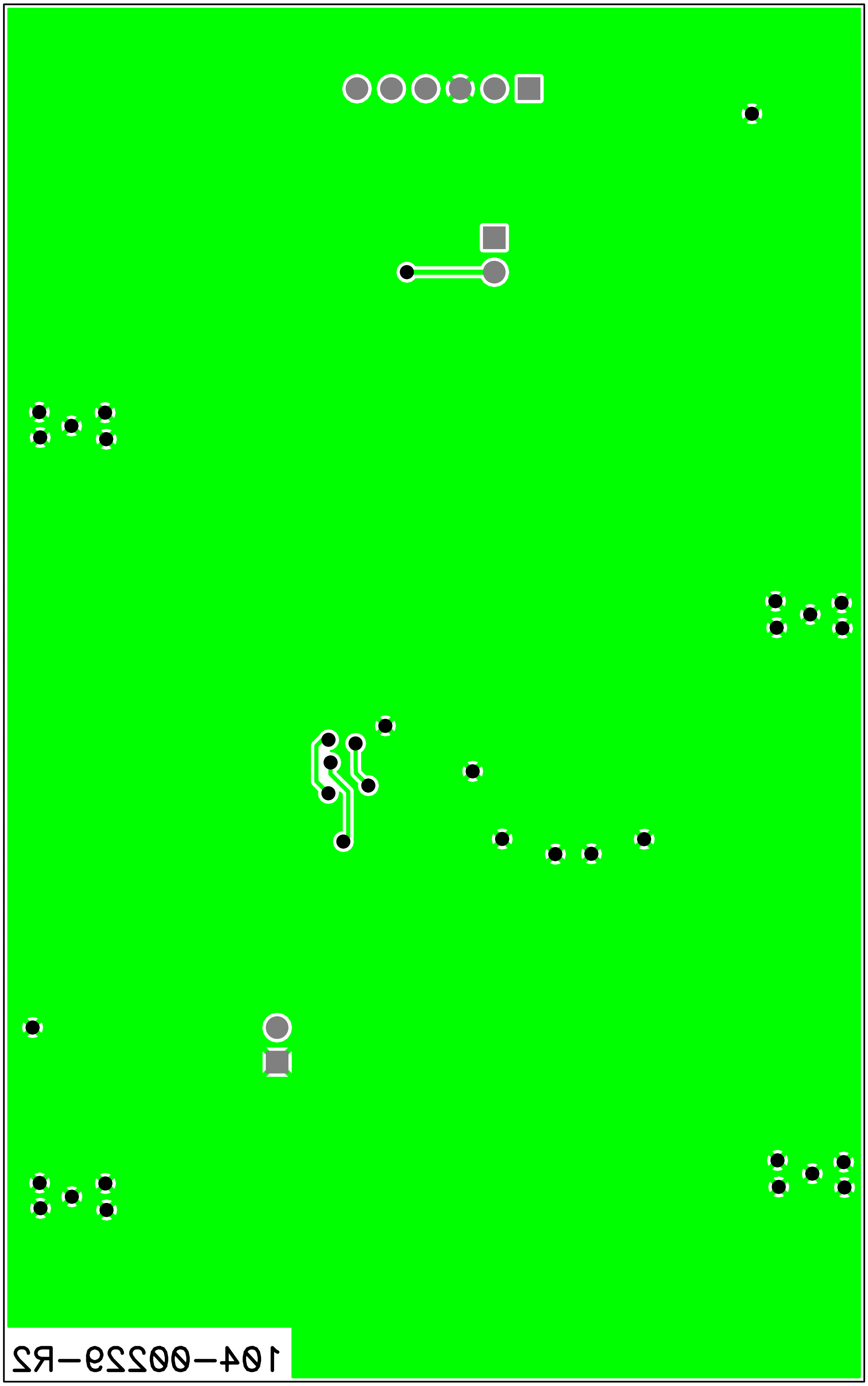
A.4 BOARD – TOP COPPER AND PADS



A.5 BOARD – TOP PADS AND SILK



A.6 BOARD – BOTTOM COPPER LAYER



Appendix B. Bill Of Materials (BOM)

TABLE B-1: BILL OF MATERIALS

Qty	Reference	Description	Manufacturer	Part Number
4	C1, C3, C4, C5	CAP 1000PF 50V CERAMIC X7R 0603	Panasonic® - ECG	ECJ-1VB1H102K
1	C2	CAP CERAMIC 10UF 6.3V X5R 0603	Panasonic - ECG	ECJ-1VB0J106M
1	D1	LED RED CLEAR 0805 SMD	Lite-On Inc	LTST-C170CKT
1	J1	CONN HEADER 6POS .100 R/A TIN	Molex®/Waldom® Electronics Corp	22-05-2061
2	JP1, JP2	CONN HEADER 2POS .100 VERT TIN	Molex/Waldom Electronics Corp	22-03-2021
1	PCB	RoHS Compliant Bare PCB, MCP4728 Evaluation board	Microchip Technology Inc.	104-00229
4	R1, R2, R4, R5	RES 4.99K OHM 1/10W 1% 0603 SMD	Panasonic - ECG	ERJ-3EKF4991V
1	R3	RES 470 OHM 1/8W 5% 0805 SMD	Panasonic - ECG	ERJ-6GEYJ471V
13	RDY/~BSY, SCL, SDA, VDDA, VOUTA, VOUTB, VOUTC, VOUTD, LDAC, GND	TEST POINT PC COMPACT SMT	Keystone Electronics®	5016
1	S1	SWITCH LIGHT TOUCH 160GF SMD	Panasonic - ECG	EVQ-PPBA25
1	U1		Microchip Technology Inc.	MCP4728-E/UN

Note 1: The components listed in this Bill of Materials are representative of the PCB assembly. The released BOM used in manufacturing uses all RoHS-compliant components.

NOTES:

Appendix C. MCP4728 Read/Write Commands

C.1 INTRODUCTION

Table summarizes the write command types and their functions. The write command is defined by using three write command type bits (C2, C1, C0) and two write function bits (W1, W0). Writing and reading the I^{2}C address bits are not demonstrated with the PICKit Serial Analyzer. Please see the MCP4728 data sheet for more details on the commands.

TABLE C-1: WRITE COMMAND TYPES

Command Field			Write Function		Command Name	Function
C2	**C1**	**C0**	**W1**	**W0**		
Fast Mode Write						
0	0	X	Not Used		Fast Write for DAC Input Registers	This command writes to the DAC input registers sequentially with limited configuration bits. The data is sent sequentially from channels A to D. The input register is written at the acknowledge clock pulse of the channel's last input data byte. EEPROM is not affected. **(Note 1)**
Write DAC Input Register and EEPROM						
0	1	0	0	0	Multi-Write for DAC Input Registers	This command writes to multiple DAC input registers, one DAC input register at a time. The writing channel register is defined by the DAC selection bits (DAC1, DAC0). EEPROM is not affected. **(Note 2)**
			1	0	Sequential Write for DAC Input Registers and EEPROM	This command writes to both the DAC input registers and EEPROM sequentially. The sequential writing is carried out from a starting channel to channel D. The starting channel is defined by the DAC selection bits (DAC1 and DAC0). The input register is written at the acknowledge clock pulse of the last input data byte of each register. However, the EEPROM data is written altogether at the same time sequentially at the end of the last byte. **(Note 2),(Note 3)**
			1	1	Single Write for DAC Input Register and EEPROM	This command writes to a single selected DAC input register and its EEPROM. Both the input register and EEPROM are written at the acknowledge clock pulse of the last input data byte. The writing channel is defined by the DAC selection bits (DAC1 and DAC0). **(Note 2),(Note 3)**
Write I^{2}C Address Bits (A2, A1, A0)						
0	1	1	Not Used		Write I^{2}C Address Bits	This command writes new I^{2}C address bits (A2, A1, A0) to the DAC input register and EEPROM.

Note 1: The analog output is updated when $\overline{LDAC}$ pin is (or changes to) "Low". $\overline{UDAC}$ bit is not used for this command.

2: The DAC output is updated when $\overline{LDAC}$ pin or $\overline{UDAC}$ bit is "Low".

3: The device starts writing to the EEPROM on the acknowledge clock pulse of the last channel. The device does not execute any command until RDY/$\overline{BSY}$ bit comes back to "High".

4: The input and output registers are updated at the acknowledge clock pulse of the last byte. The update does not require $\overline{LDAC}$ pin or $\overline{UDAC}$ bit conditions. EEPROM is not affected.

TABLE C-1: WRITE COMMAND TYPES (CONTINUED)

Command Field			Write Function		Command Name	Function
C2	C1	C0	W1	W0		
Write V_{REF}, Gain, and Power-Down Select Bits (Note 4)						
1	0	0	Not Used		Write Reference (V_{REF}) selection bits to Input Registers	This command writes reference (V_{REF}) selection bits of each channel.
1	1	0	Not Used		Write Gain selection bit to Input Registers	This command writes Gain selection bits of each channel.
1	0	1	Not Used		Write Power-Down bits to Input Registers	This command writes Power-Down bits of each channel.

Note 1: The analog output is updated when $\overline{\text{LDAC}}$ pin is (or changes to) "Low". $\overline{\text{UDAC}}$ bit is not used for this command.

2: The DAC output is updated when $\overline{\text{LDAC}}$ pin or $\overline{\text{UDAC}}$ bit is "Low".

3: The device starts writing to the EEPROM on the acknowledge clock pulse of the last channel. The device does not execute any command until RDY/$\overline{\text{BSY}}$ bit comes back to "High".

4: The input and output registers are updated at the acknowledge clock pulse of the last byte. The update does not require $\overline{\text{LDAC}}$ pin or $\overline{\text{UDAC}}$ bit conditions. EEPROM is not affected.

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