



MCP6XXX Amplifier Evaluation Board 3 User's Guide

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MCP6XXX AMPLIFIER EVALUATION BOARD 3 USER'S GUIDE

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Preface

NOTICE TO CUSTOMERS

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

Documents are identified with a "DS" number. This number is located on the bottom of each page, in front of the page number. The numbering convention for the DS number is "DSXXXXA", where "XXXX" 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 MCP6XXX Amplifier Evaluation Board 3. 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 MCP6XXX Amplifier Evaluation Board 3. The manual layout is as follows:

- **Chapter 1. "Product Overview"** - Provides the important information about the MCP6XXX Amplifier Evaluation Board 3.
- **Chapter 2. "Installation and Operation"** – Covers the installation and operation of the MCP6XXX Amplifier Evaluation Board 3. It lists the required tools, shows how to set up the board, and demonstrates how to verify the amplifier operation.
- **Appendix A. "Schematic and Layouts"** – Shows the schematic and board layouts for the MCP6XXX Amplifier Evaluation Board 3.
- **Appendix B. "Bill of Materials (BOM)"** – Lists the parts used to build the MCP6XXX Amplifier Evaluation Board 3.

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CONVENTIONS USED IN THIS GUIDE

This manual uses the following documentation conventions:

DOCUMENTATION CONVENTIONS

Description	Represents	Examples
Arial font:		
Italic characters	Referenced books	<i>MPLAB[®] IDE User's Guide</i>
	Emphasized text	...is the <i>only</i> 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	<u><i>File>Save</i></u>
Bold characters	A dialog button	Click OK
	A tab	Click the Power tab
N'Rnnnn	A number in verilog format, where N is the total number of digits, R is the radix and n is a digit.	4'b0010, 2'hF1
Text in angle brackets < >	A key on the keyboard	Press <Enter>, <F1>
Courier New font:		
Plain Courier New	Sample source code	#define START
	Filenames	autoexec.bat
	File paths	c:\mcc18\h
	Keywords	_asm, _endasm, static
	Command-line options	-Opa+, -Opa-
	Bit values	0, 1
	Constants	0xFF, 'A'
Italic Courier New	A variable argument	<i>file.o</i> , where <i>file</i> can be any valid filename
Square brackets []	Optional arguments	mcc18 [options] <i>file</i> [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 MCP6XXX Amplifier Evaluation Board 3. Other useful documents are listed below. The following Microchip documents are available and recommended as supplemental reference resources.

MCP6021/2/3/4 Data Sheet, “Rail-to-Rail Input/Output, 10 MHz Op Amps” (DS21685)

This data sheet provides detailed information regarding the MCP602X product family.

THE MICROCHIP WEB SITE

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

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

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- Distributor or Representative
- Local Sales Office
- Field Application Engineer (FAE)
- Technical Support
- Development Systems Information Line

Customers should contact their distributor, representative or field application engineer 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 (July 2007)

- Initial Release of this Document.

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NOTES:

Chapter 1. Product Overview

1.1 INTRODUCTION

The MCP6XXX Amplifier Evaluation Board 3 is described by the following:

- Assembly # : 114-00153
- Order # : MCP6XXXEV-AMP3
- Name: MCP6XXX Amplifier Evaluation Board 3

Items discussed in this chapter include:

- **Section 1.2 “MCP6XXX Amplifier Evaluation Board 3 Kit Contents”**
- **Section 1.3 “Microchip’s Web-Based Mindi™ Analog Simulator Tool”**
- **Section 1.4 “MCP6XXX Amplifier Evaluation Board 3 Description”**

1.2 MCP6XXX AMPLIFIER EVALUATION BOARD 3 KIT CONTENTS

- MCP6XXX Amplifier Evaluation Board 3 - One partially assembled board
- Important Information “Read First”
- Accessory Bag - Contains loose parts for populating sockets on board
- Analog and Interface Products Demonstration Boards CD-ROM (DS21912)
 - MCP6XXX Amplifier Evaluation Board 3 User’s Guide (DS51673)



FIGURE 1-1: MCP6XXX Amplifier Evaluation Board 3 Kit.

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1.3 MICROCHIP'S WEB-BASED MINDI™ ANALOG SIMULATOR TOOL

The Mindi™ Analog Simulator tool is an innovative software tool that simplifies analog circuit design. The Mindi™ Analog Simulator tool supports the following application circuits: 1) Active Filters, 2) Amplifiers, 3) Battery Chargers, and 4) DC-to-DC Converters. The Amplifier Designer provides full schematic diagrams of the amplifier application circuit with recommended component values and displays the responses in frequency and time domains.

The Mindi™ Analog Simulator tool is a free web-based design tool available on the Microchip web site at <http://www.microchip.com> under “**Online Simulation Tools**” or by going directly to the Mindi web site at <http://www.microchip.com/mindi>. The circuit simulator within the Mindi™ Analog Simulator tool can be downloaded and installed on a personal computer (PC) for more convenient simulations. Modified circuit files can also be downloaded to the PC.

1.4 MCP6XXX AMPLIFIER EVALUATION BOARD 3 DESCRIPTION

MCP6XXX Amplifier Evaluation Board 3 is intended to support the difference amplifier circuits which are generated by the Mindi™ Amplifier Designer.

The MCP6XXX Amplifier Evaluation Board 3 has the following features:

- All amplifier resistors and capacitors are socketed
- All of the component labels on board keep consistent with those on schematic generated in the Mindi™ Amplifier Designer
- Supports all Microchip single op amps
 - PDIP-8 package (e.g., MCP6021) are socketed
 - SOIC-8 package can be accommodated; see **Section 2.4.3 “Amplifier Modifications Using 8-Pin SOIC Op Amps”**
- Test points for connecting lab equipment
- Single supply configuration

Figure 1-2 shows the block diagram of the MCP6XXX Amplifier Evaluation Board 3. Lab equipment can be attached (via test points) to measure the amplifier response.

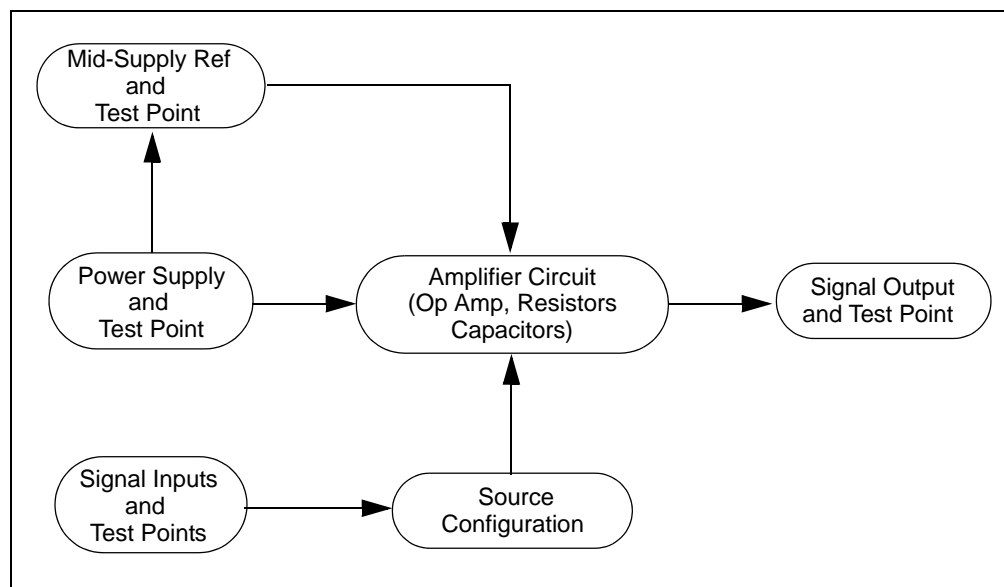


FIGURE 1-2: MCP6XXX Amplifier Evaluation Board 3 Block Diagram.

Chapter 2. Installation and Operation

2.1 INTRODUCTION

This chapter shows how to set up the MCP6XXX Amplifier Evaluation Board 3.

Items discussed in this chapter include:

- Required Tools
- MCP6XXX Amplifier Evaluation Board 3 Set-Up
- MCP6XXX Amplifier Evaluation Board 3 Operation

2.2 REQUIRED TOOLS

- Lab power supply
- Lab signal source (e.g., function generator)
- Lab measurement equipment (e.g., oscilloscope)

2.3 MCP6XXX AMPLIFIER EVALUATION BOARD 3 SET-UP

The MCP6XXX Amplifier Evaluation Board 3 supports difference amplifier. This section details the conversion of these topologies to the MCP6XXX Amplifier Evaluation Board 3. Figure 2-1 shows the circuit diagram for the board.

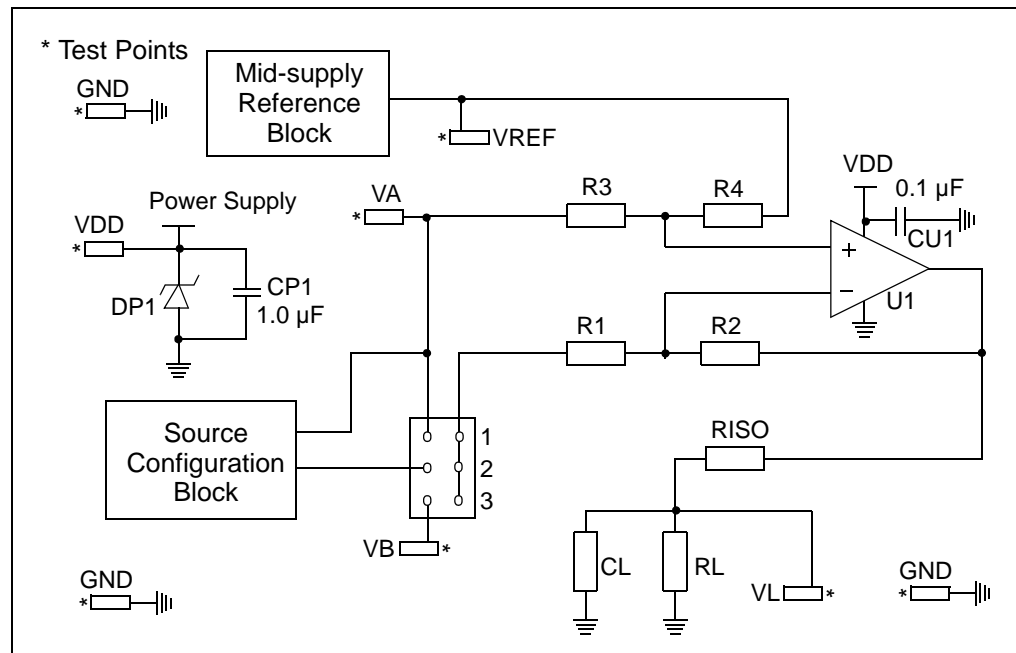


FIGURE 2-1: MCP6XXX Amplifier Evaluation Board 3 Circuit Diagram.

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The power supply voltage needs to be in the allowed range for the installed op amps. Any of Microchip's op amps that operate below 5.5V can be used. Moreover, the power supply is protected by a zener diode with nominal voltage 6.2V and bypassed by a 1.0 μ F capacitor. (See **Figure 2-3: "Power Supply Block."**)

The mid-supply reference consists of a voltage divider and a buffer amplifier. (See **Figure 2-4: "Mid-Supply Reference Block."**)

The resistors that are part of an amplifier are placed in pin sockets which are labeled. All of the component labels on board keep consistent with those on the schematic generated in the Mindi™ Amplifier Designer. The op amps are bypassed by 0.1 μ F capacitors and the single op amp U1 can have either a PDIP-8 or SOIC-8 package.

- PDIP-8 packages are inserted into the DIP-8 socket to the right of the U1 label
- SOIC-8 packages can be accommodated; see **Section 2.4.3 "Amplifier Modifications Using 8-Pin SOIC Op Amps"**

The (surface mount) test points for power supply, ground, input signal and output signal allow lab equipment to be connected to the board. The MCP6XXX Amplifier Evaluation Board 3 top view is shown in Figure 2-2.

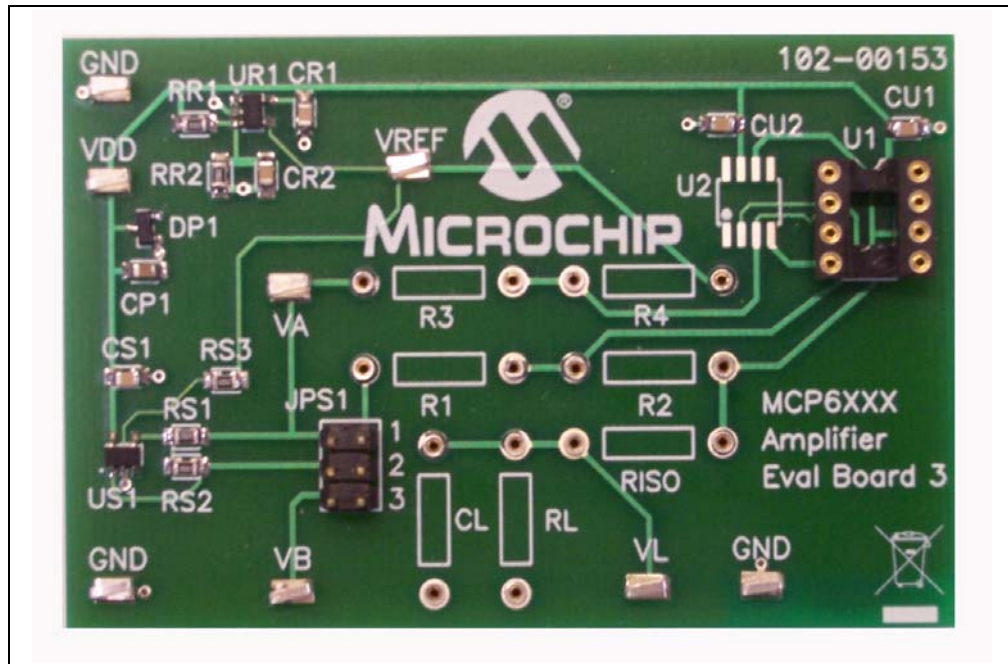


FIGURE 2-2: MCP6XXX Amplifier Evaluation Board 3 Top View.

2.3.1 Top Level Amplifier Circuit Diagrams

2.3.1.1 POWER SUPPLY BLOCK

The power supply is protected by a zener diode and bypassed by a capacitor. Figure 2-3 shows the circuit diagram for the power supply. $C_{P1} = 1.0 \mu\text{F}$.

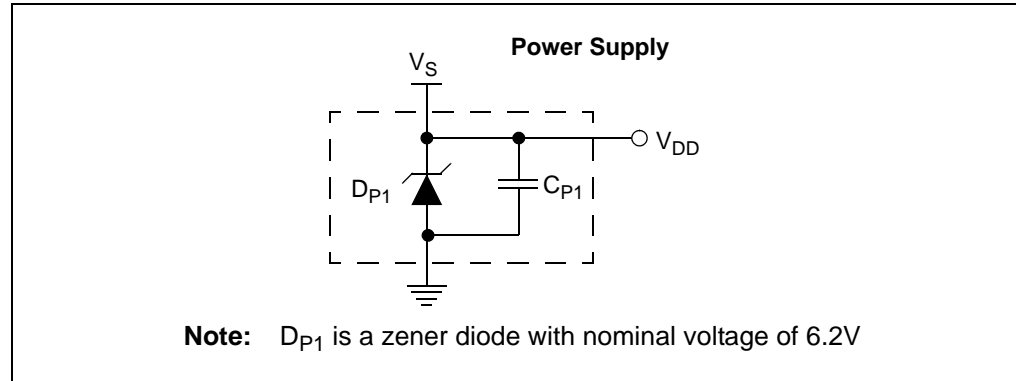


FIGURE 2-3: Power Supply Block.

2.3.1.2 MID-SUPPLY REFERENCE BLOCK

The mid-supply reference consists of a voltage divider and a buffer amplifier. Figure 2-4 shows the circuit diagram for the mid-supply reference.

$C_{R1} = C_{R2} = 0.1 \mu\text{F}$, $R_{R1} = R_{R2} = 20.0 \text{ k}\Omega$.

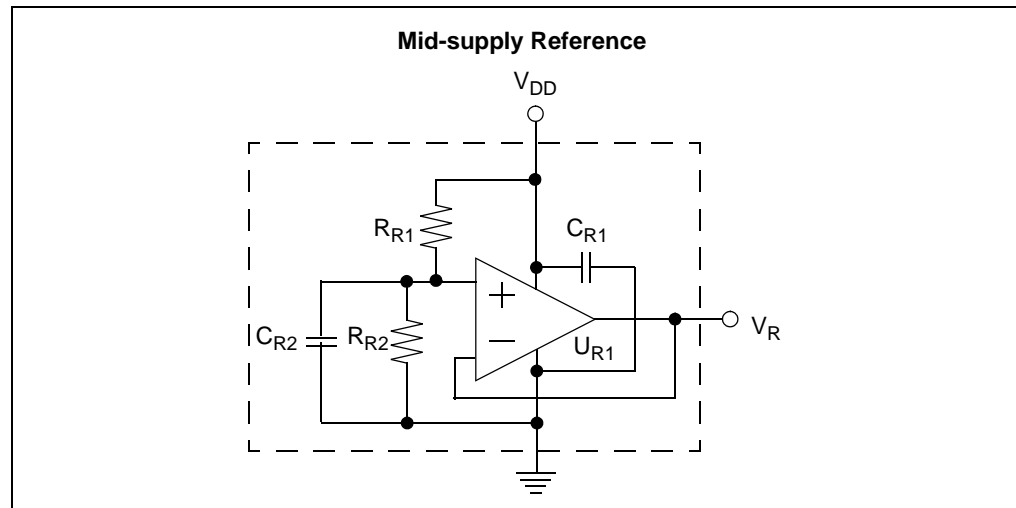


FIGURE 2-4: Mid-Supply Reference Block.

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2.3.1.3 OUTPUT LOAD BLOCK

The output load consists of a capacitor and two resistors. Figure 2-5 shows the circuit diagram for the output load. R_{ISO} is used to stabilize the amplifier when it drives a large capacitive load (C_L). R_{ISO} is a short circuit (0Ω) when C_L is small.

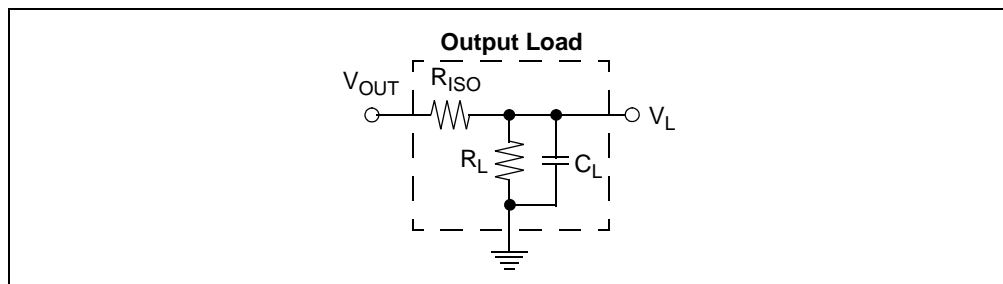


FIGURE 2-5: Output Load Block.

2.3.1.4 DIFFERENCE AMPLIFIER

- Amplifies the difference between two voltages, while rejecting the common mode (average) input voltage. Output voltage is shifted by a reference voltage for single supply
- The Mindi™ Amplifier Designer gives design recommendations for the difference amplifier circuit; see the circuit diagram shown in Figure 2-6
 - Fill the sockets with the recommended resistors and capacitors

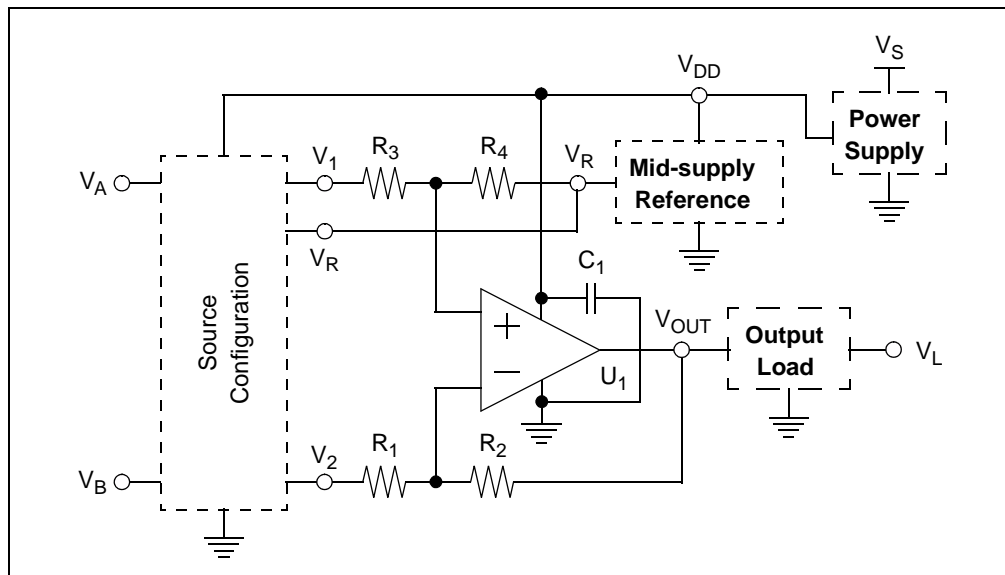


FIGURE 2-6: Difference Amplifier Circuit Diagram.

- Source configuration consists of an inverting amplifier and a jumper. Figure 2-4 shows the circuit diagram for the source configuration.
 $C_{S1} = 0.1 \mu\text{F}$, $R_{S1} = R_{S2} = 20.0 \text{ k}\Omega$, $R_{S3} = 10.0 \text{ k}\Omega$

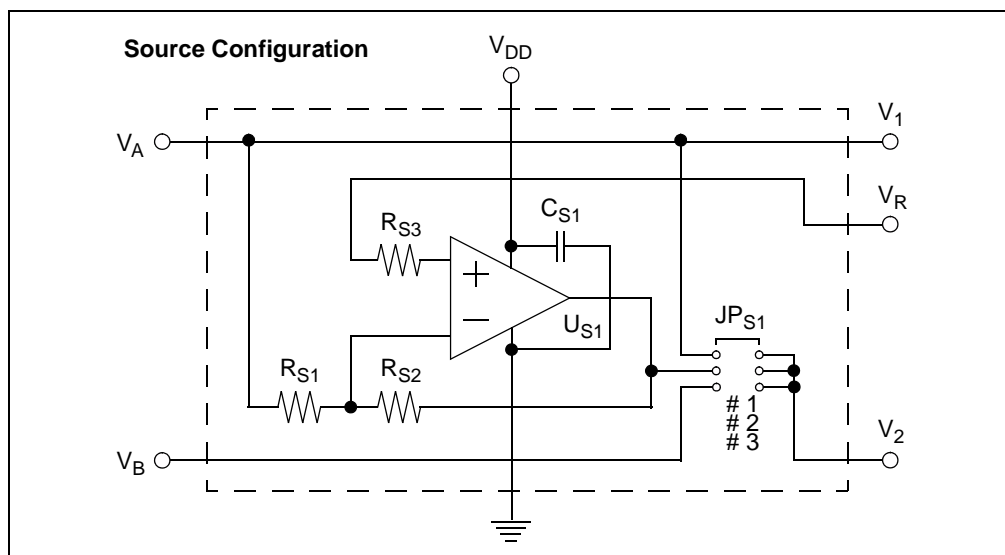


FIGURE 2-7: Source Configuration Block.

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The jumper JP_{S1} positions have the following effects:

Jumper JP _{S1} Position	Effects		
	V ₁ =	V ₂ =	
1	V _A	V _A	V _A is a common mode input signal
2	V _A	-V _A	V _A is a differential mode input signal
3	V _A	V _B	V _A and V _B are connected directly to V ₁ and V ₂

Note 1: When JP_{S1} is in position 2, V₂ is actually described by the following equation:

$$\begin{aligned}
 V_2 &= V_R - (V_A - V_R)(R_{S2}/R_{S1}) \\
 &= V_R(I + R_{S2}/R_{S1}) - V_A(R_{S2}/R_{S1})
 \end{aligned}$$

It is assumed that R_{S2} = R_{S1}.

Figure 2-8 shows an example supported by the MCP6XXX Amplifier Evaluation Board 3. It is assumed that V_A is a differential mode input signal.

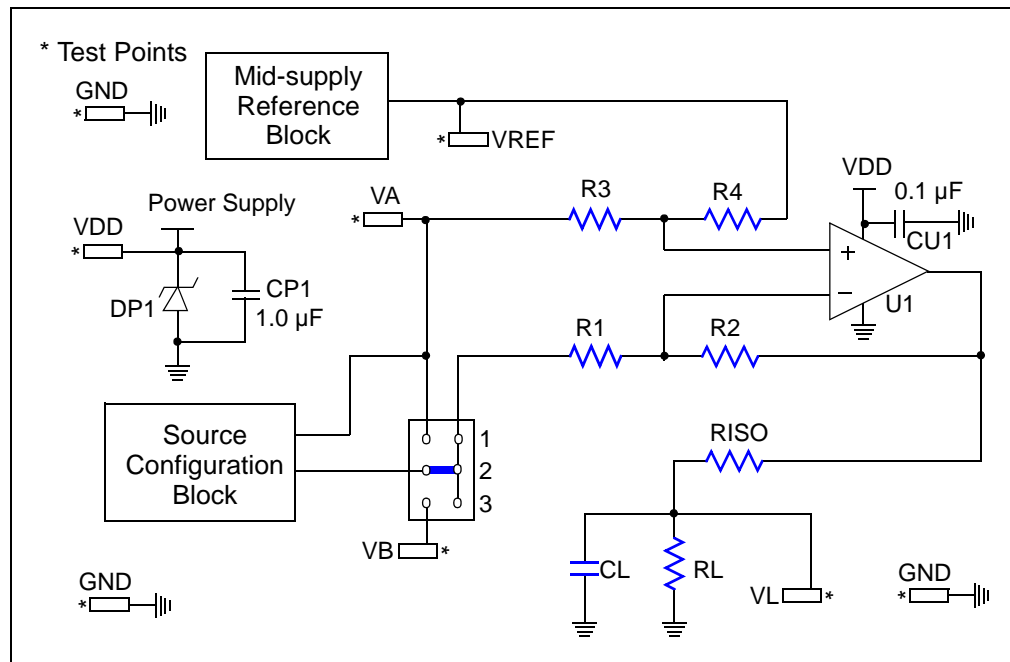


FIGURE 2-8: Difference Amplifier Example Supported by the MCP6XXX Amplifier Evaluation Board 3.

2.4 MCP6XXX AMPLIFIER EVALUATION BOARD 3 OPERATION

Items discussed in this section include:

- Building the Amplifier
- Testing the Amplifier
- Amplifier Modification: Using 8-Pin SOIC Op Amps

2.4.1 Building the Amplifier

The accessory bag that comes with this kit makes it quick and easy to evaluate the amplifier described below, which was designed in the Mindi™ Amplifier Designer.

This amplifier is described as follows:

- Difference Amplifier (Single Supply Configuration)
- Power Supply Voltage is 5.0V
- Differential Mode Input Signal
- Desired Closed Loop Gain is 1 V/V
- Load Capacitance is 56 pF

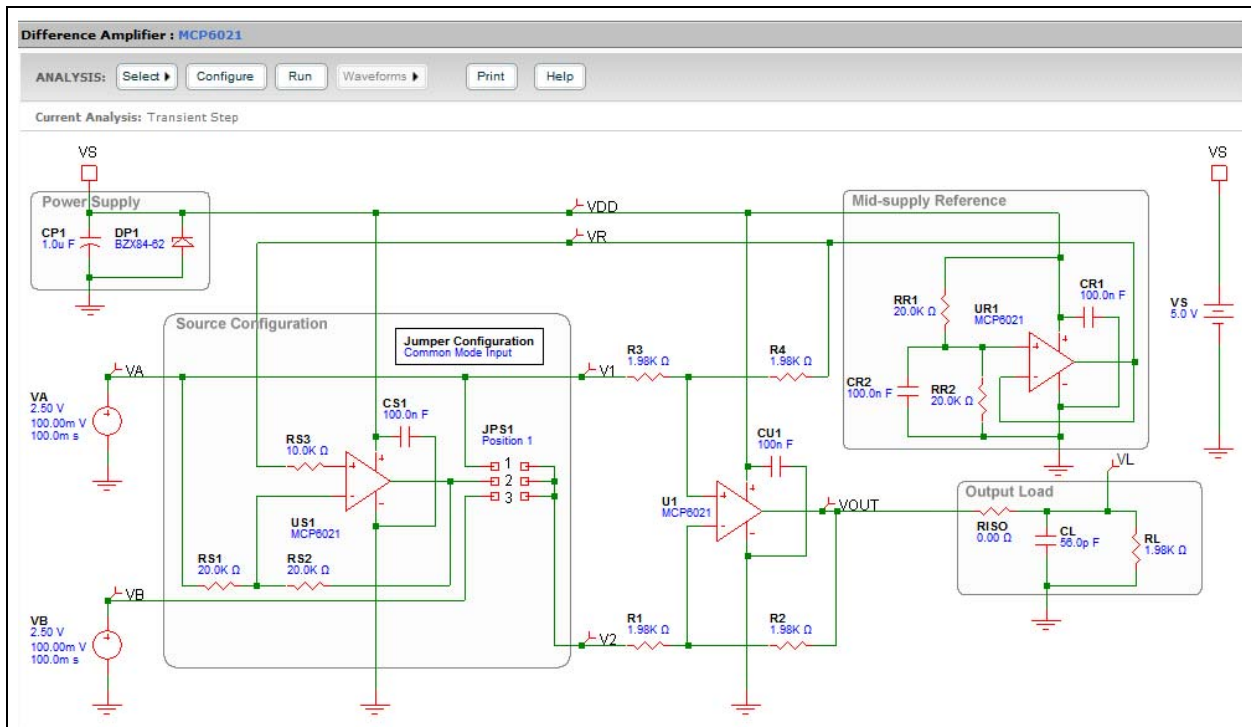


FIGURE 2-9: Difference Amplifier Designed In the Mindi™ Amplifier Designer.

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Figure 2-10 shows the same circuit redrawn to emphasize the difference amplifier.

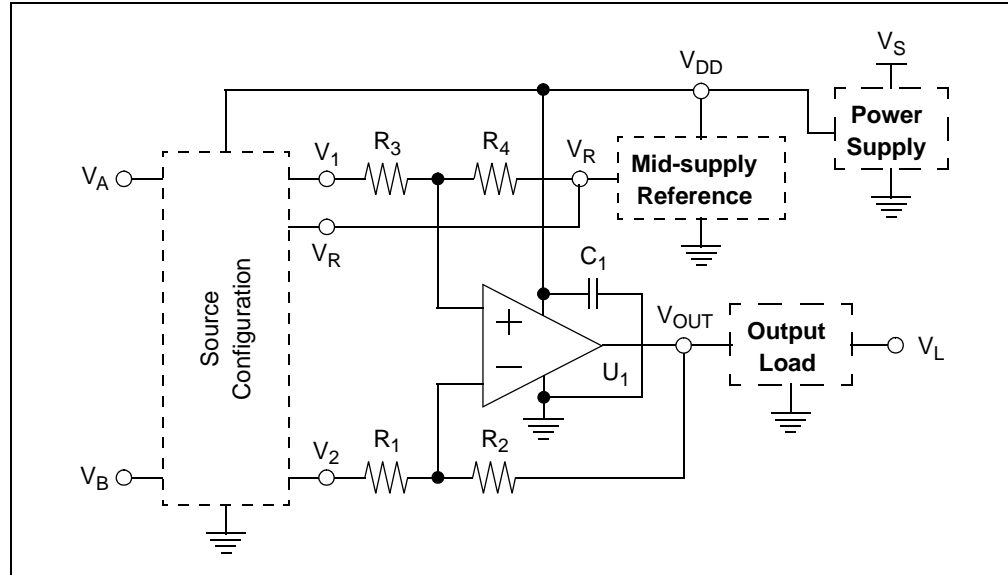


FIGURE 2-10: Difference Amplifier Supported by the MCP6XXX Amplifier Evaluation Board 3 Kit.

Each of the components in Figure 2-10 that needs to be inserted in a socket on the MCP6XXX Amplifier Evaluation Board 3 is listed in Table 2-1.

TABLE 2-1: AMPLIFIER COMPONENTS LIST

PCB Labels	Component Values
R1	1.98 k Ω
R2	1.98 k Ω
R3	1.98 k Ω
R4	1.98 k Ω
RISO	0 Ω
RL	1.98 k Ω
CL	56 pF
U1	MCP6021, PDIP-8, 10 MHz

For the differential mode input signal, the jumper JP_{S1} position is listed in Table 2-2.

TABLE 2-2: JUMPER POSITION

Jumper	Position
JPS1	2

Installation and Operation

The fully assembled difference amplifier circuit diagram is shown in Figure 2-11.

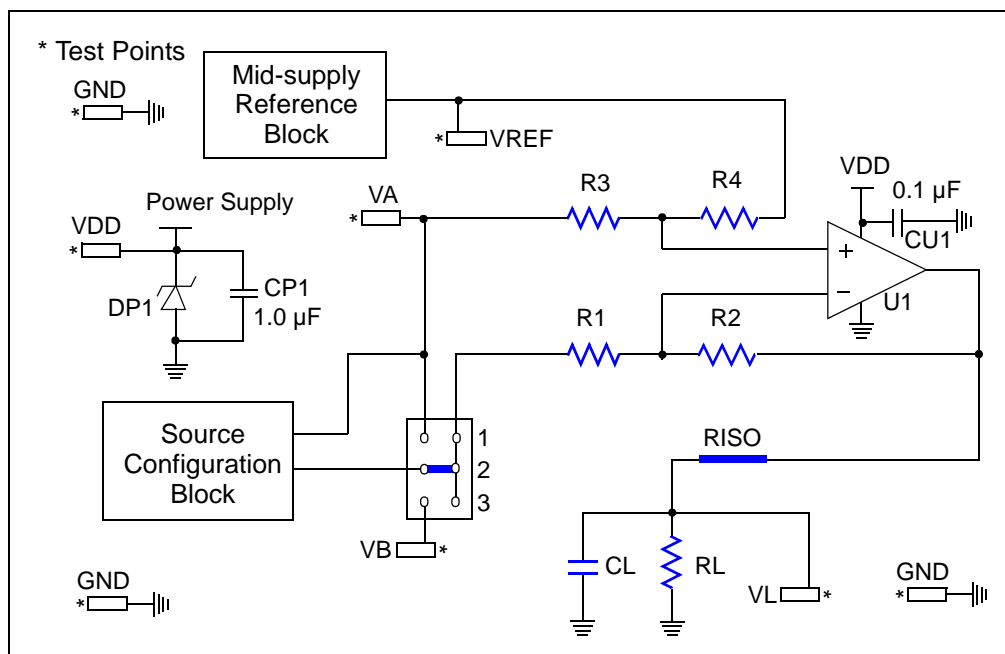


FIGURE 2-11: Fully Assembled Difference Amplifier Supported by the MCP6XXX Amplifier Evaluation Board 3.

The fully assembled MCP6XXX Amplifier Evaluation Board 3 top view is shown in Figure 2-12.

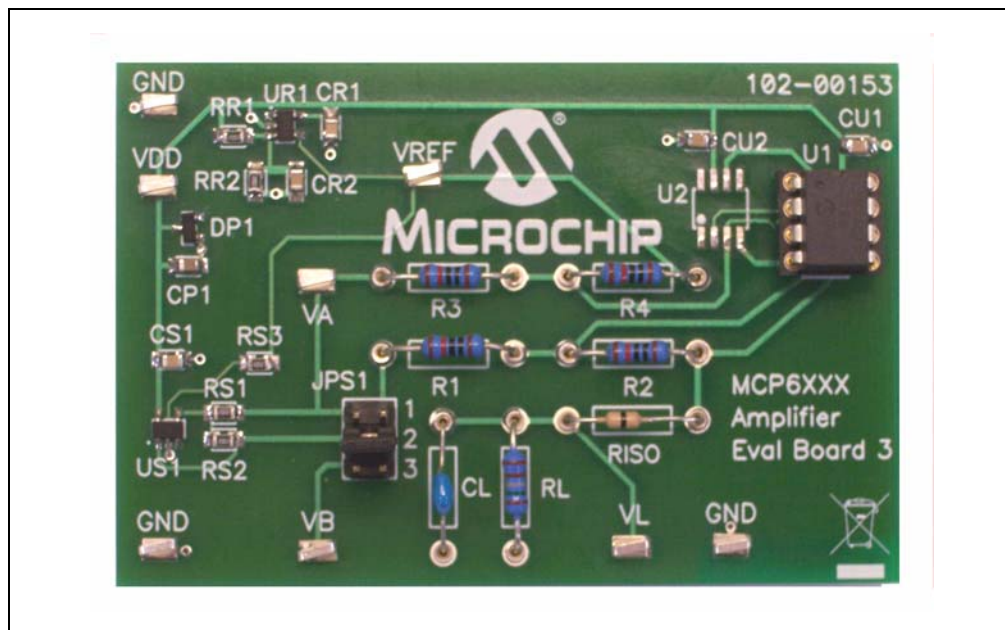


FIGURE 2-12: Picture of the Difference Amplifier Supported by the MCP6XXX Amplifier Evaluation Board 3.

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2.4.2 Testing the Amplifier

2.4.2.1 CHECKING THE TEST POINTS

The (surface mount) test points for power supply, ground, input signal and output signal allow lab equipment to be connected to the board. Figure 2-13 shows the test points to check.

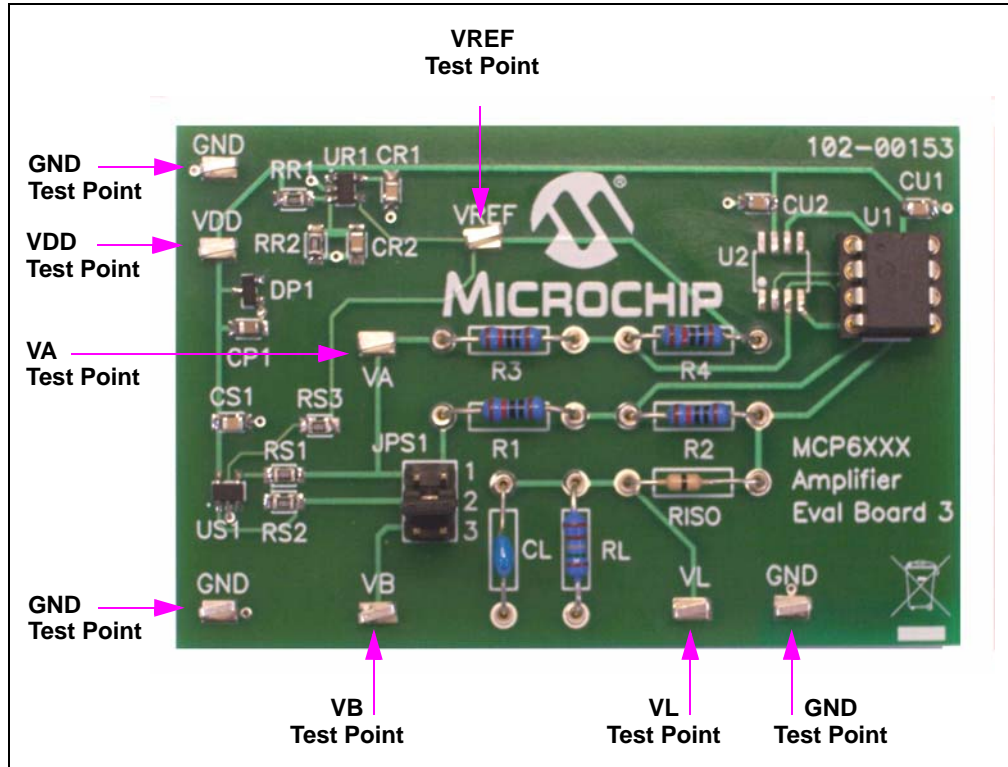


FIGURE 2-13: Checking the Test Points.

2.4.2.2 TRANSIENT RESPONSES

This difference amplifier was built, and its responses were measured. A MCP6021 op amp, 1% resistors, and 5% capacitors were used. Notice how close the measured and simulated data are.

2.4.2.2.1 Transient Step Response

In Bench Measurement:

- Set V_{IN} as a differential mode signal with a step amplitude of 2.0V and a center voltage of 2.5V. (i.e. V_{IN} starts 1.0V below center and ends 1.0V above center)
- The measured step response is shown in Figure 2-14. It is a signal with a step amplitude of 4.0V and a center voltage of 2.5V. (i.e. V_{OUT} starts 2.0V below center and ends 2.0V above center)

Note: The center voltage of V_{IN} is set at $V_{REF} = V_{DD}/2$ (For $V_{DD} = 5.0V$, $V_{REF} = 2.5V$)

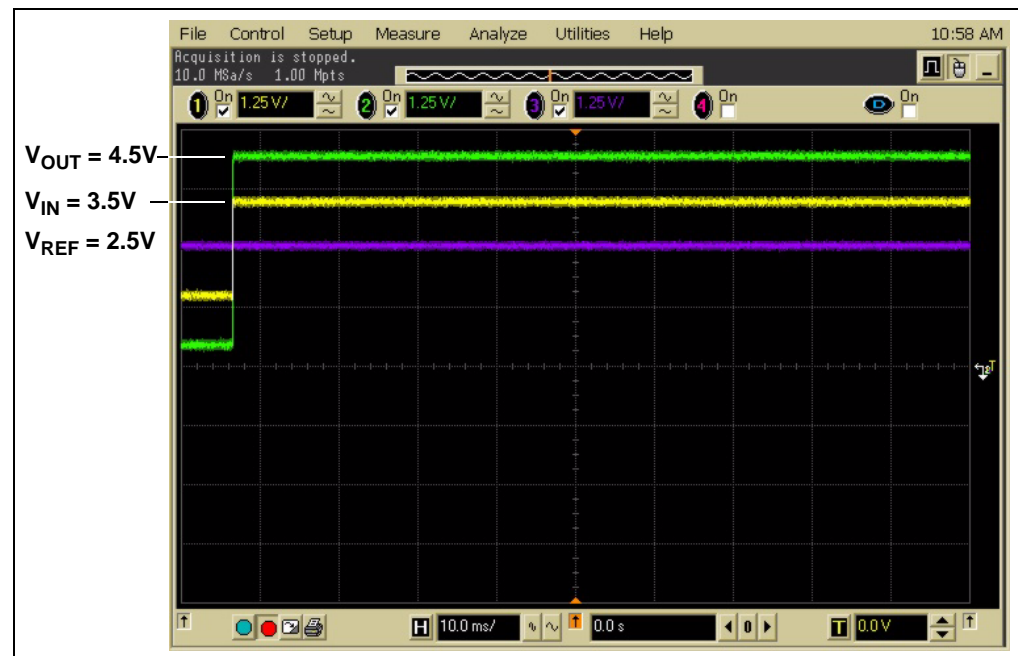


FIGURE 2-14: Measured Step Response.

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In the Mindi™ Amplifier Designer:

- Set V_{IN} as a differential mode signal with a step amplitude of 2.0V and a center voltage of 2.5V. (i.e. V_{IN} starts 1.0V below center and ends 1.0V above center)
- The simulated step response is shown in Figure 2-15. It is a signal with a step amplitude of 4.0V and a center voltage of 2.5V. (i.e. V_{OUT} starts 2.0V below center and ends 2.0V above center)

Note: The center voltage of V_{IN} is set at $V_{REF} = V_{DD}/2$ (For $V_{DD} = 5.0V$, $V_{REF} = 2.5V$)

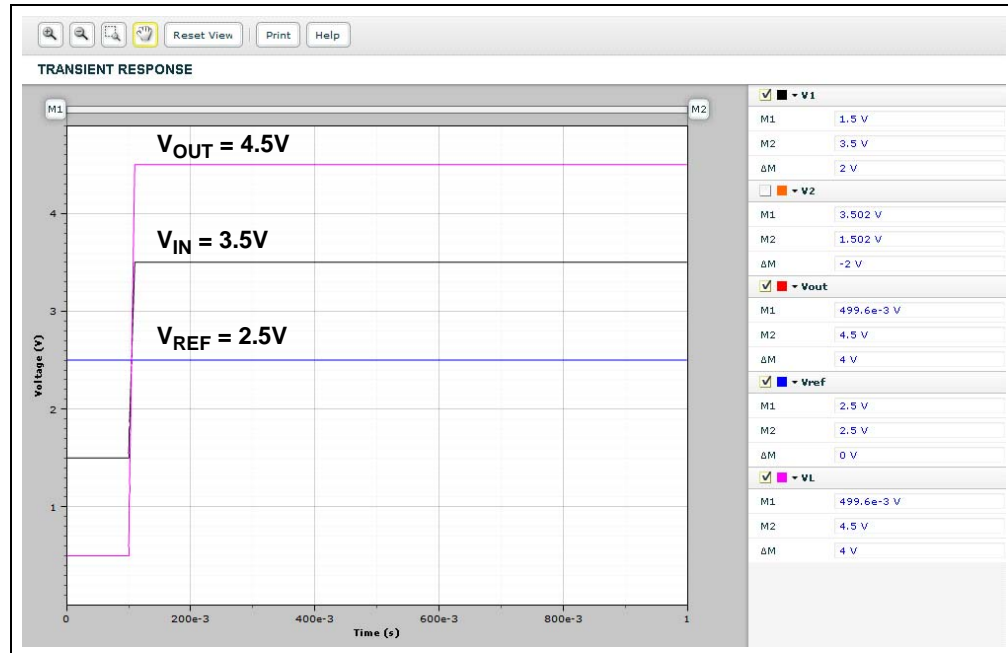


FIGURE 2-15: Simulated Step Response.

2.4.2.2.2 Transient Sine Wave Response

In Bench Measurement:

- Set V_{IN} as a sine wave with a frequency of 100.0 Hz, a peak-to-peak voltage of 2.0V and a center voltage of 2.5V
- The measured sine wave response is shown in Figure 2-16. It is a sine wave signal with a frequency of 100.0 Hz, a peak-to-peak voltage of 4.0V and a center voltage of 2.5V

Note: The center voltage of V_{IN} is set at $V_{REF} = V_{DD}/2$ (For $V_{DD} = 5.0V$, $V_{REF} = 2.5V$)

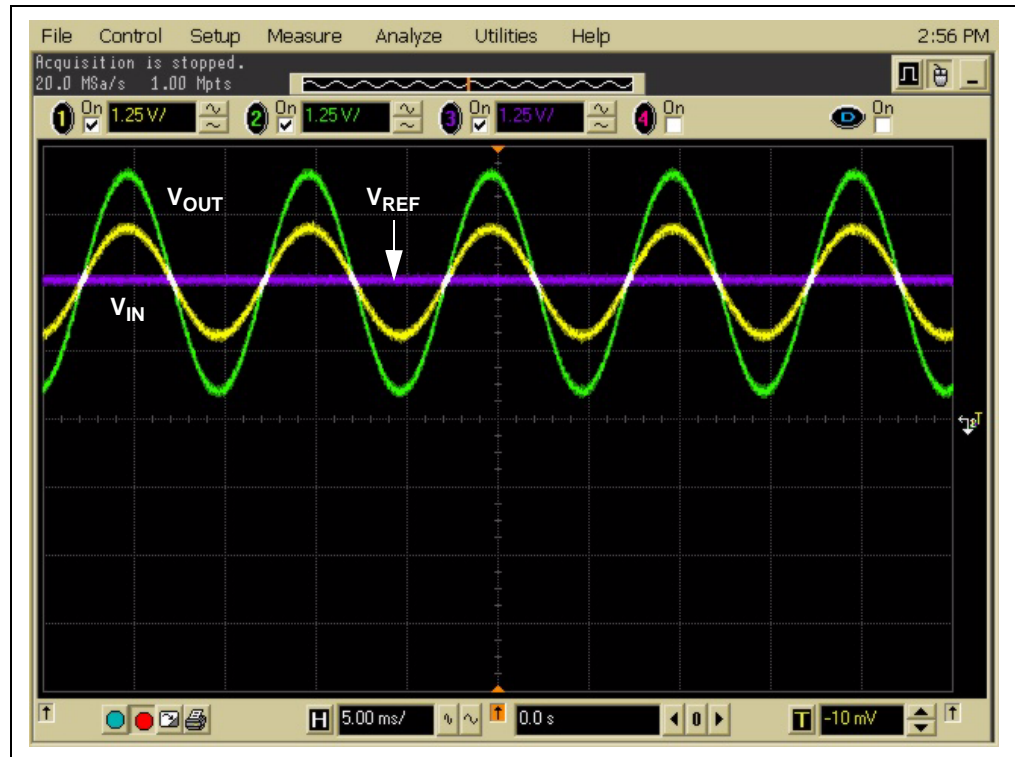


FIGURE 2-16: Measured Sine Wave Response.

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In the Mindi™ Amplifier Designer:

- Set V_{IN} as a sine wave with a frequency of 100.0 Hz, a peak-to-peak voltage of 2.0V and a center voltage of 2.5V
- The simulated sine wave response is shown in Figure 2-17. It is a sine wave signal with a frequency of 100.0 Hz, a peak-to-peak voltage of 4.0V and a center voltage of 2.5V

Note: The center voltage of V_{IN} is set at $V_{REF} = V_{DD}/2$ (For $V_{DD} = 5.0V$, $V_{REF} = 2.5V$)

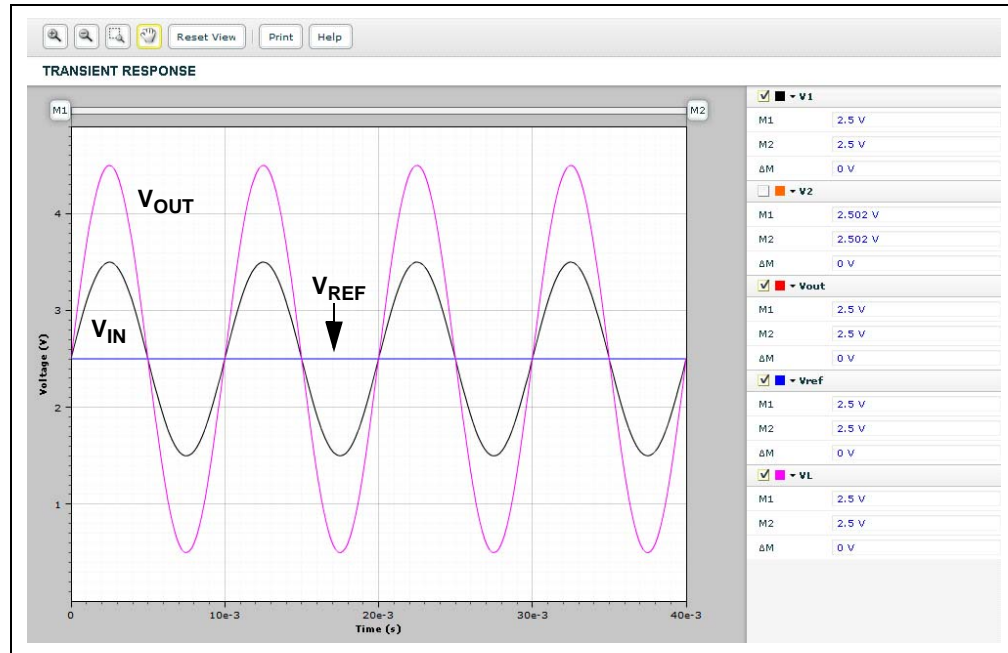


FIGURE 2-17: Simulated Sine Wave Response.

2.4.3 Amplifier Modifications Using 8-Pin SOIC Op Amps

There are two options available to use single op amps in SOIC-8 packages (150 mil wide):

- Soldering onto the MCP6XXX Amplifier Evaluation Board 3, or
- Soldering it onto a separate board which is connected to the DIP-8 socket

Note: The DIP-8 socket must be empty; only one op amp can be used at a time.

Figure 2-18 shows a SOIC-8 op amp soldered onto the MCP6XXX Amplifier Evaluation Board 3.

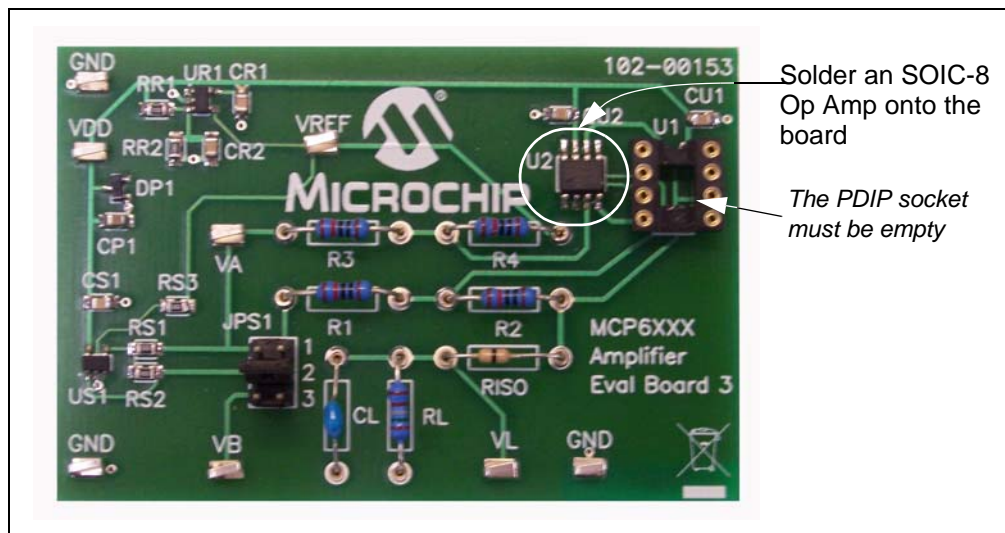


FIGURE 2-18: Op Amp in SOIC-8 package soldered onto MCP6XXX Amplifier Evaluation Board 3.

Figure 2-19 shows a SOIC-8 op amp and a DIP-8 socket, soldered onto the 8-Pin SOIC/MSOP/TSSOP/DIP Evaluation Board available from Microchip Technology Inc. (order # SOIC8EV). The two interconnect strips on the bottom are Samtec part # BBS-14-T-B or equivalent and are soldered into the through holes for the DIP-8 socket. Figure 2-20 shows this board plugged into the MCP6XXX Amplifier Evaluation Board 3.

Note: Insert the interconnect strips into the DIP-8 socket on the MCP6XXX Amplifier Evaluation Board 3. Place the SOIC8EV board on the top of the interconnect strips with the same pin orientation. Now solder the strips to the top board; this procedure ensures correct alignment of the strips. Clip the pins flush with the top surface of the SOIC8EV board, then solder the SOIC-8 op amp on the top.

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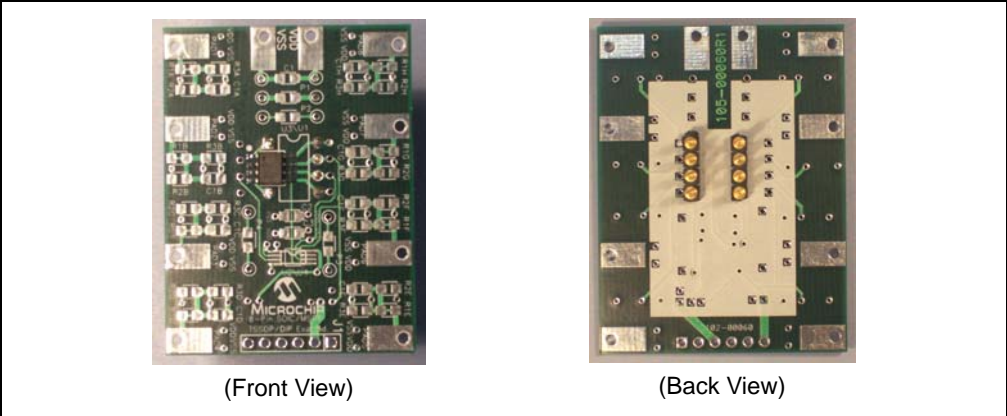


FIGURE 2-19: Op Amp in SOIC-8 package soldered onto a separate board.

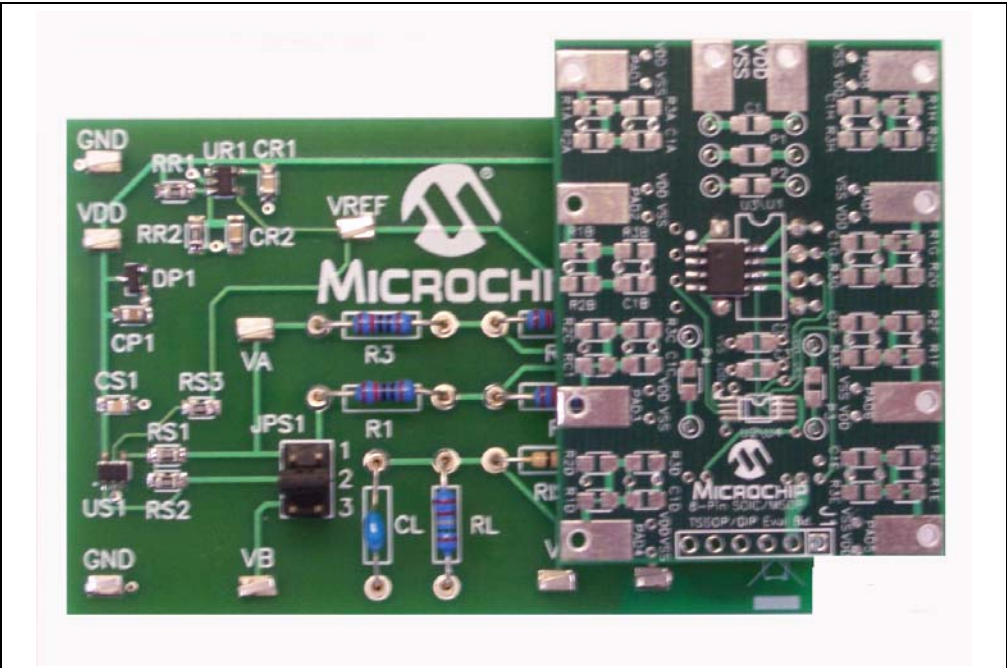


FIGURE 2-20: Connecting Adaptor Board onto MCP6XXX Amplifier Evaluation Board 3.



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Appendix A. Schematic and Layouts

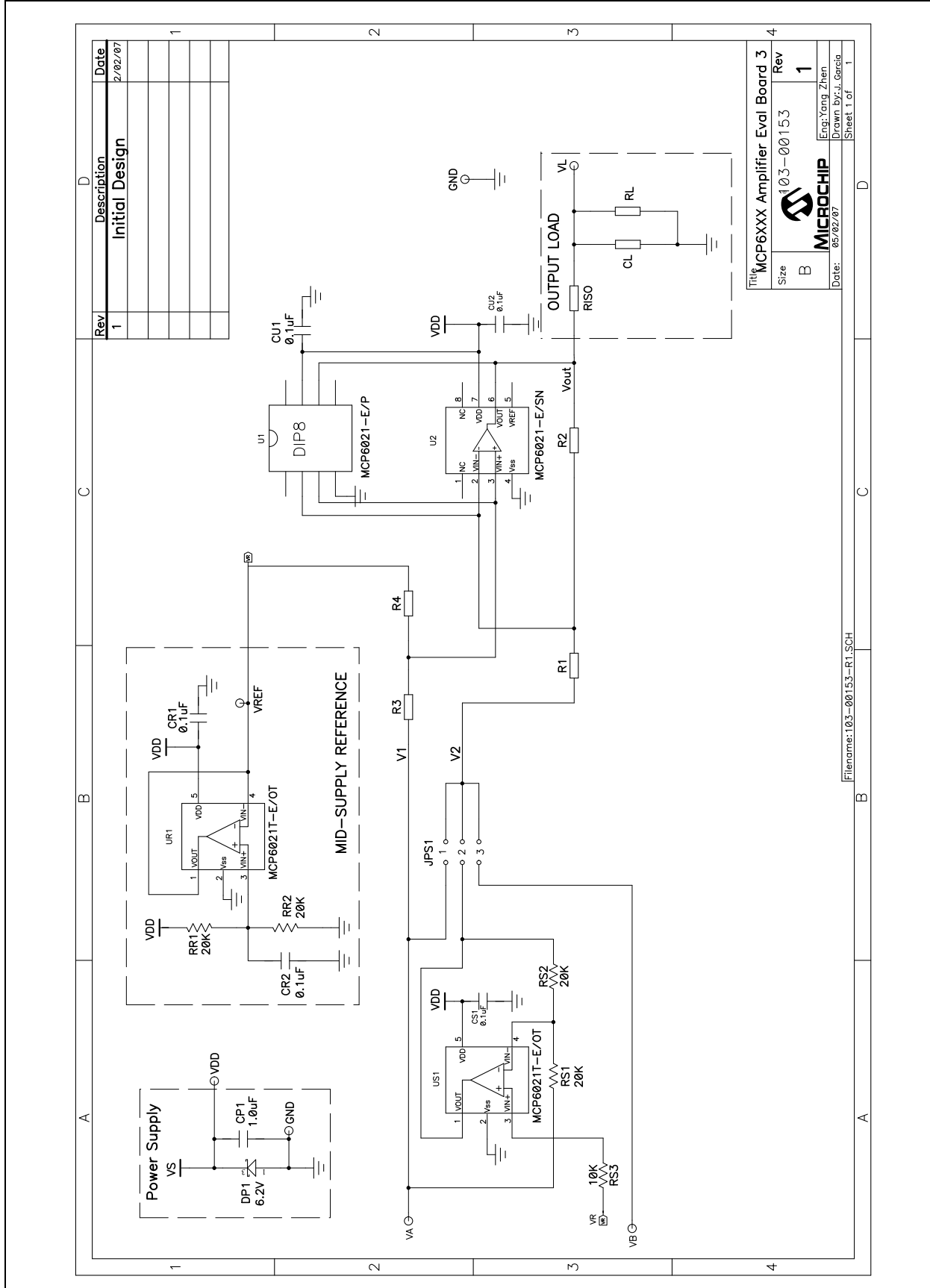
A.1 INTRODUCTION

This appendix contains the following schematics and layouts for the MCP6XXX Amplifier Evaluation Board 3:

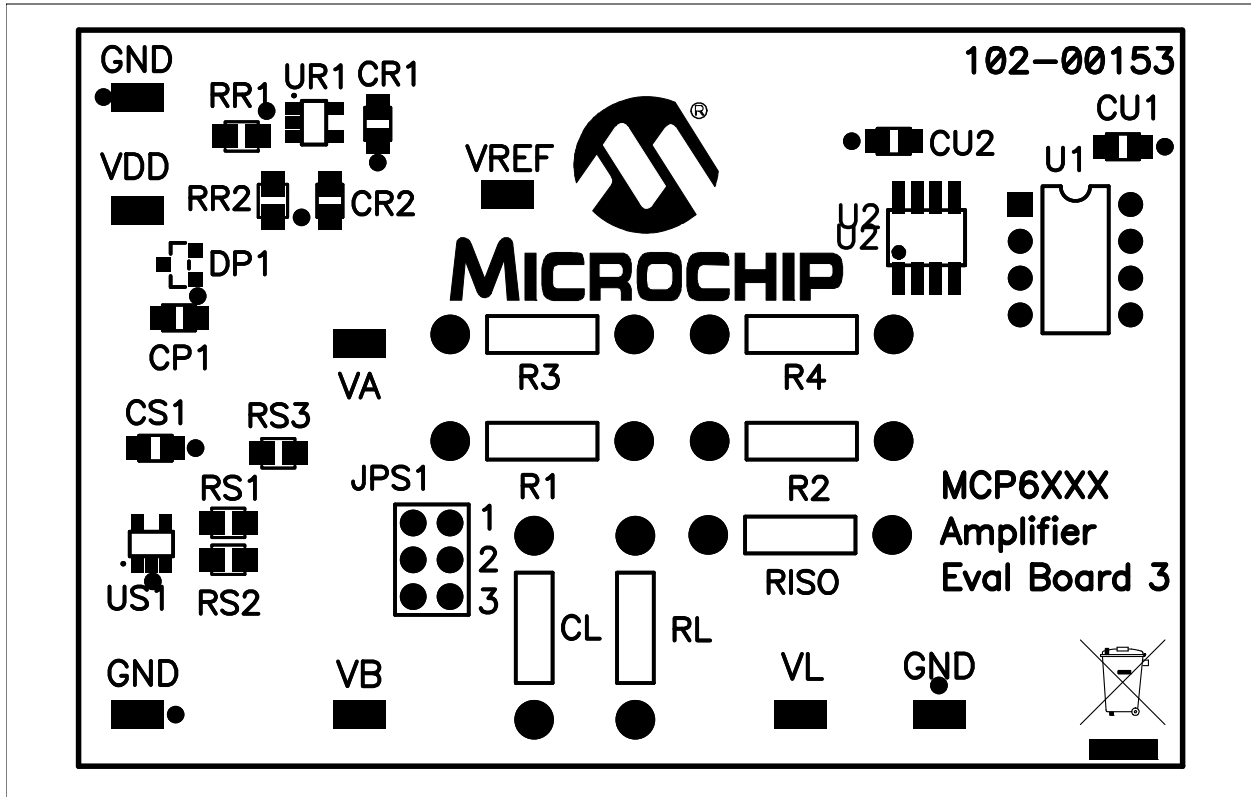
- Board – Schematic
- Board – Top Silk Layer
- Board – Top Trace and Silk Layer
- Board – Bottom Layer

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A.2 BOARD - SCHEMATIC

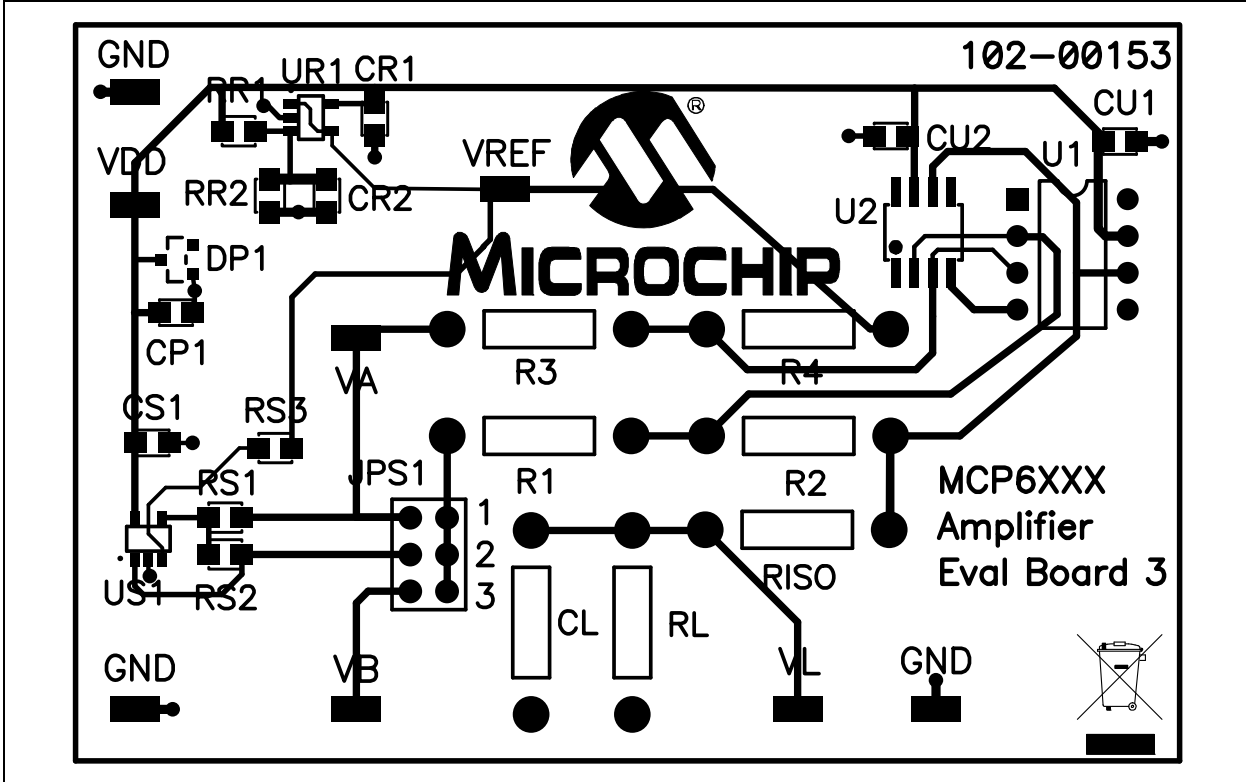


A.3 BOARD - TOP SILK LAYER

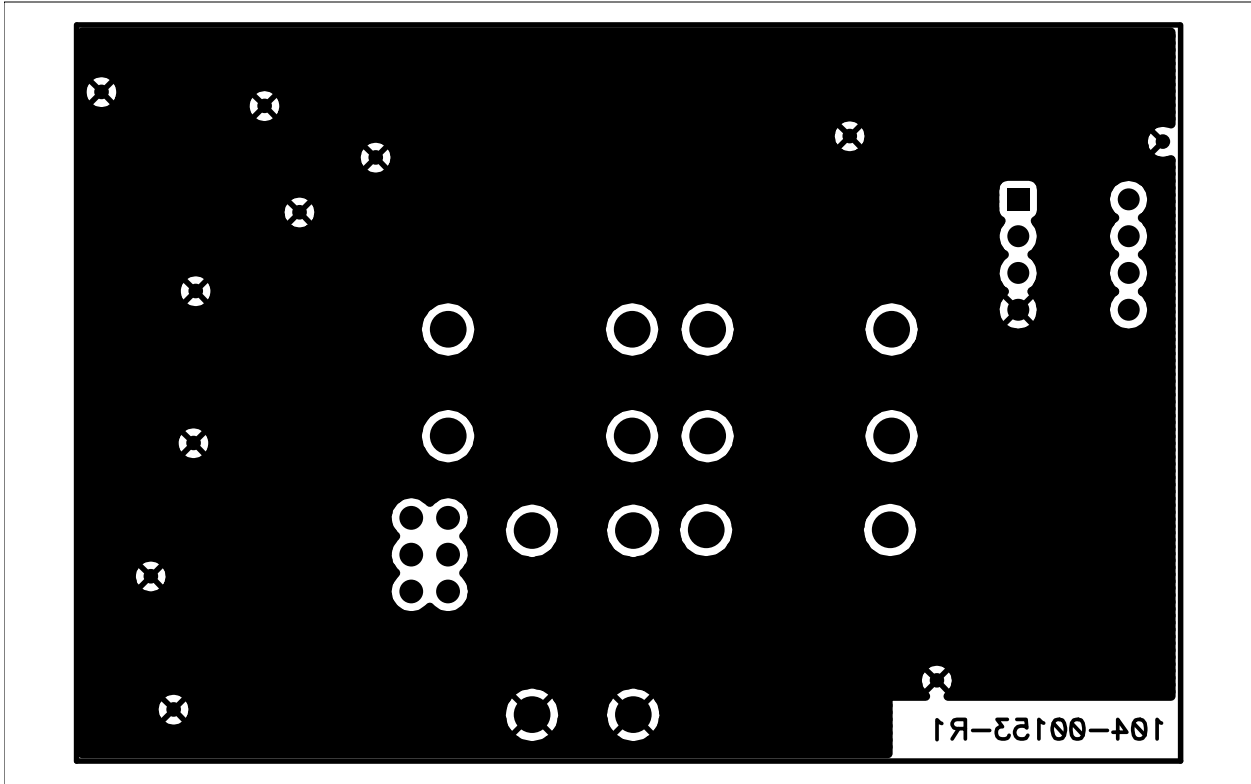


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A.4 BOARD - TOP TRACE AND SILK



A.5 BOARD - BOTTOM LAYER



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NOTES:



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Appendix B. Bill of Materials (BOM)

B.1 MCP6XXX AMPLIFIER EVALUATION BOARD 3 BOM

The Bill of Materials (BOM) in Table B-1 corresponds to Figure 2-1 and Figure 2-2. Unpopulated parts are in Table B-2.

TABLE B-1: BILL OF MATERIALS (102-00153R1) (NOTE 1)

Qty	Reference	Description	Manufacturer	Part Number
1	CP1	CAP CERAMIC 1UF 10% 25V X5R 0805	Panasonic® - ECG	ECJ-2FB1E105K
5	CR1,CR2 CS1 CU1,CU2	CAP CERAMIC .1UF 10% 25V X7R 0805	Panasonic - ECG	ECJ-2VB1E104K
4	EA Corner	BUMPER CLEAR .375X.15"DOME	Richco Plastic Co	RBS-12
1	JPS1	CONN HEADR BRKWAY .100 06POS STR	Tyco® Electronics/Amp	4-103327-0-06
1	PCB	RoHS Compliant Bare PCB	Microchip Technology Inc.	104-00153
14	Pin Socket	PIN RECPT .015/.025 DIA 0667 SER	Mill-Max®	0667-0-15-01-30-27-10-0
4	RR1,RR2 RS1,RS2	RES 20.0K OHM 1/8W 1% 0805 SMD	Panasonic - ECG	ERJ-6ENF2002V
1	RS3	RES 10.0K OHM 1/8W 1% 0805 SMD	Panasonic - ECG	ERJ-6ENF1002V
1	Shunt for JPS1	SOCKET,SHORT BLKS W TAB BLK	JAMECO VALUEPRO	2012JH-R
8	Test Points	PC TEST POINT COMPACT SMT	Keystone Electronics®	5016
2	UR1,US1	MCP6021 SOT-23-5 Single OpAmp	Microchip Technology Inc.	MCP6021T-E/OT
1	For U1	CONN IC SOCKET 8POS DIP TIN	Tyco Electronics/Amp	2-641260-1

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.

Bill of Materials (BOM)

TABLE B-2: BILL OF MATERIALS – UNPOPULATED PARTS (102-00153R1)

Qty	Reference	Description	Manufacturer	Part Number
1	U1	MCP6021 PDIP-8, Single Op Amp	Microchip Technology Inc	MCP6021T-E/P
1	U2	MCP6021 SOIC-8, Single Op Amp	Microchip Technology Inc	MCP6021T-E/SN
7	R1-R4, RISO, RL, CL	Not Populated when shipped to customer	—	—

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.

The BOM in Table B-3 corresponds to the collection of resistors, capacitors, jumpers and MCP6021 op amps that come in the Accessory Bag which is shipped in the MCP6XXX Amplifier Evaluation Board 3 Kit. These components are placed in an separate ESD bag. They support the circuit in **Section 2.4.1 “Building the Amplifier”**. Customers need to provide the resistors and capacitors for more amplifier circuits.

TABLE B-3: BILL OF MATERIALS – ACCESSORY BAG PARTS (102-00153R1)

Qty	Reference	Description	Manufacturer	Part Number
1	Accessory Bag	CAP CER 56PF 50V C0G RADIAL	Murata Electronics®	RPE5C1H560J2P1Z03B
1	Accessory Bag	JUMPER ZERO OHM 1/8W	Yageo® Corporation	ZOR-12-B-52
5	Accessory Bag	RES 1.96K OHM 1/4W 1% METAL FILM	Yageo Corporation	MFR-25FBF-1K96
1	ESD Sample Box	MCP6021 Single OpAmp PDIP-8	Microchip Technology Inc	MCP6021-E/P

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.

Bill of Materials (BOM)

NOTES:



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