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Active Filter Demo Board Kit User's Guide

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ACTIVE FILTER DEMO BOARD KIT USER'S GUIDE

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ACTIVE FILTER DEMO BOARD KIT 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 Active Filter Demo Board Kit. 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 Active Filter Demo Board Kit. The manual layout is as follows:

- **Chapter 1. "Product Overview"** - Important information about the Active Filter Demo Board Kit.
- **Chapter 2. "Setup and Installation"** – Covers the initial set-up of the Active Filter Demo Board Kit. It lists the required tools, shows how to connect the boards and demonstrates how to verify the set-up.
- **Chapter 3. "Building the Filter Supplied in the Kit"** – Discusses the filter supplied in the kit (loose parts in a separate bag). Its design, component placement, and testing are discussed.
- **Chapter 4. "Common Filter Modifications"** – Covers modifications that are easy to do with these boards. It also discusses common filter limitations.
- **Appendix A. "Schematics and Layouts"** – Shows the schematic and board layouts for the Active Filter Demo Board Kit.
- **Appendix B. "Bill Of Materials (BOM)"** – Lists the parts used to build the sub-assemblies in the Active Filter Demo Board Kit.

CONVENTIONS USED IN THIS GUIDE

This manual uses the following documentation conventions:

DOCUMENTATION CONVENTIONS

Description	Represents	Examples
Arial font:		
Italic characters	Referenced books	*MPLAB® IDE User's Guide*
	Emphasized text	...is the *only* compiler...
Initial caps	A window	the Output window
	A dialog	the Settings dialog
	A menu selection	select Enable Programmer
Quotes	A field name in a window or dialog	"Save project before build"
Underlined, italic text with right angle bracket	A menu path	*File>Save*
Bold characters	A dialog button	Click **OK**
	A tab	Click the **Power** tab
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	*`file`*`.o`, where *`file`* can be any valid filename
Square brackets [ ]	Optional arguments	`mcc18 [options]` *`file`* `[options]`
Curly brackets and pipe character: { | }	Choice of mutually exclusive arguments; an OR selection	`errorlevel {0|1}`
Ellipses...	Replaces repeated text	`var_name [, var_name...]`
	Represents code supplied by user	`void main (void) { ... }`

RECOMMENDED READING

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

MCP6271 Data Sheet (DS21810)

Gives detailed information on the op amps that are included in the Active Filter Demo Board Kit Accessory Bag.

FilterLab® 2.0 User's Guide (DS51419)

Covers the functionality of Microchip's active filter design software. The appendices include information on filter terminology, design parameters, selecting an op amp, and selected references to the analog filter literature.

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 (June 2006)

- Initial Release of this Document.

NOTES:

Chapter 1. Product Overview

1.1 INTRODUCTION

The Active Filter Demo Board Kit is described by the following:

- Assembly # : 114-00097R1
- Order # : MCP6XXXDM-FLTR
- Name: Active Filter Demo Board Kit

Items discussed in this chapter include:

- Kit Contents
- Intended Use of the Active Filter Demo Board Kit
- Active Filter Demo Board Kit Description
- Sub-Assemblies
- Associated Tools

1.2 KIT CONTENTS

- V_{DD}/2 Filter Section Board - One partially assembled board
- Active Filter Section – Four partially assembled boards
- Important Information "Read First"
- Accessory Bag - contains loose parts for populating sockets on boards
- Analog and Interface Products Demonstration Boards CD-ROM (DS21912) – This CD-ROM contains the files and literature mentioned in this user's guide

FIGURE 1-1: *Active Filter Demo Board Kit Contents.*

1.3 INTENDED USE OF THE ACTIVE FILTER DEMO BOARD KIT

This kit is intended to support active filters designed by FilterLab® V2.0 (see **Section 1.6 "Associated Tools"**). These filters are all pole and are built by cascading first and second order sections.

Higher frequency filters (e.g., a low-pass filter with cutoff at 1 MHz) can have their design initially verified on these boards; see **Section 4.5 "Higher Frequency Filters"**.

1.4 ACTIVE FILTER DEMO BOARD KIT DESCRIPTION

The Printed Circuit Boards (PCB) in the Active Filter Demo Board Kit have the following features:

- All filter resistors and capacitors are socketed
- Supports all Microchip single op amps
  - PDIP-8 package (e.g., MCP6271) are socketed
  - SOIC-8 package can be accomodated; see **Section 4.6 "Using 8-Pin SOIC Op Amps"**
- Test points for connecting lab equipment
- Single supply configuration
- Modularized connection scheme

1.5 SUB-ASSEMBLIES

The Active Filter Demo Board Kit is comprised of three sub-assemblies:

- $V_{DD}/2$ Filter Section
  - Sub-Assembly # : 102-00098R1
  - One PCB designed to provide mid-supply biasing to the other PCBs
  - Provides power supply test points for a lab power supply
  - Provides input test points for a lab signal generator
- Active Filter Sections
  - Sub-Assembly # : 102-00097R1
  - Four PCBs designed to be cascaded
  - Support filter orders between n = 1 and n = 8
  - Provide output test points for lab equipment
- Accessory Bag
  - Sub-Assembly # : 110-00097R1
  - Kit of resistors, capacitors, and op amps that can be used to build the filter circuit in Figure 2-8

Figure 1-2 shows the Active Filter Demo Board Kit's five PCBs; one $V_{DD}/2$ Filter Section PCB and four Active Filter Section PCB's. It shows how these boards are cascaded (using board connectors), and how lab equipment can be attached (via test points) to measure the filter response.

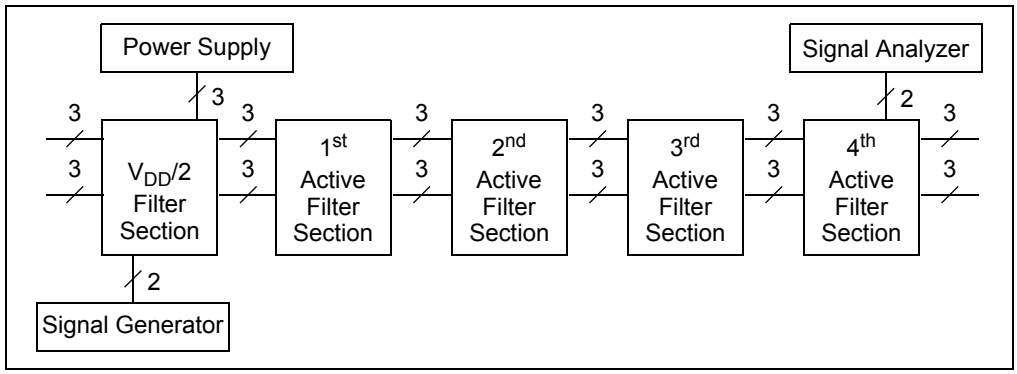

FIGURE 1-2: *Measurement Setup Block Diagram.*

Figure 1-3 shows the block diagram of the $V_{DD}/2$ Filter Section, and Figure 1-4 shows the block diagram of the Active Filter Sections.

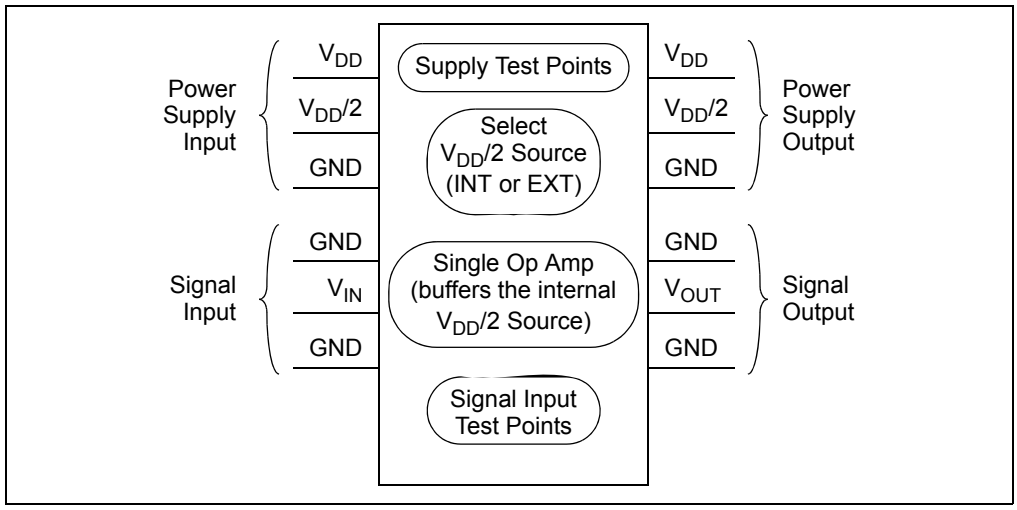

FIGURE 1-3: *$V_{DD}/2$ Filter Section Block Diagram.*

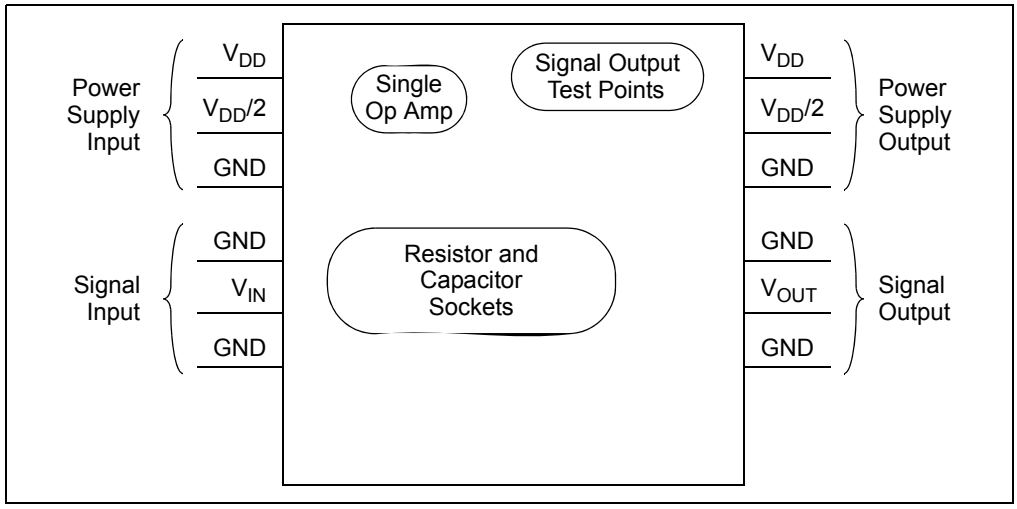

FIGURE 1-4: *Active Filter Section (4 each) Block Diagram.*

1.6 ASSOCIATED TOOLS

FilterLab 2.0® is an innovative software tool that simplifies active (op amp) filter design. Available at no cost from Microchip's web site (www.microchip.com), the FilterLab 2.0 active filter software design tool provides full schematic diagrams of the filter circuit with component values, displays the frequency response, and gives a SPICE listing for further simulations. Users can select a low-pass, band-pass or high-pass response. Available functions are Bessel, Butterworth, and Chebyshev, with order between n = 1 and 8.

Chapter 2. Setup and Installation

2.1 INTRODUCTION

This chapter shows how to set up the Active Filter Demo Board Kit. Items discussed in this chapter include:

- Required Tools
- Connecting the PCBs
- $V_{DD}/2$ Filter Section Set-up
- Active Filter Section Set-up
- Set-up Verification

2.2 REQUIRED TOOLS

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

2.3 CONNECTING THE PCBs

This section discusses the primary method for setting up the Active Filter Demo Board Kit. An exploded view of how the different boards connect is shown in Figure 2-1 (see also Figure 1-2).

The filter order will determine how many of the Active Filter Section boards need to be cascaded (one board when n = 1 or 2, two boards when n = 3 or 4, …).

The board edge connectors are slid together to make good electrical connection between boards.

The (surface mount) test points allow lab equipment to be connected to these boards. The user provides the input signal and power to the $V_{DD}/2$ Filter Section, and measures the output signal at the last Active Filter Section.

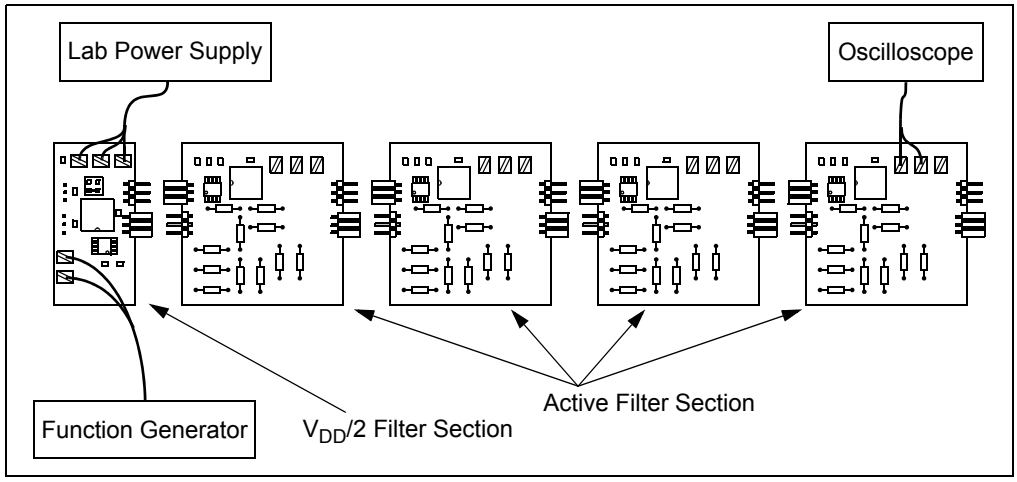

FIGURE 2-1: *Board Connections for the Active Filter Demo Board Kit.*

The user provides the supply voltages, which need 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; higher voltage parts can be accommodated (see **Section 4.2 "Power Supplies"**). Five MCP6271 op amps are included in the accessory bag for convenience.

The power lines are bypassed by 1.0 µF capacitors at each board input. The op amps also have 0.1 µF local bypass capacitors.

2.4 V_{DD}/2 FILTER SECTION SET-UP

Figure 2-2 gives the circuit diagram for the V_{DD}/2 Filter Section. It allows the mid-supply voltage (V_{DD}/2) to be set by an external power supply (JP_1 at EXT), or internally (JP_1 at INT) by the on-board op amp (U_1). The headers and test points allow the user flexibility in setting up a filter circuit.

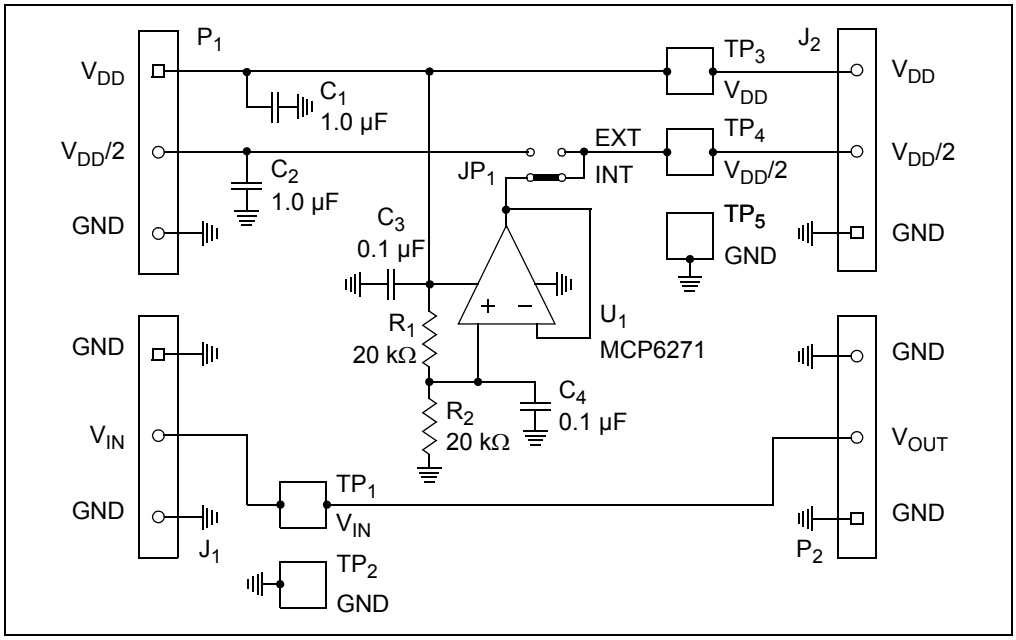

FIGURE 2-2: *V_{DD}/2 Filter Section Circuit.*

The V_{DD}/2 Filter Section PCB is shown in Figure 2-3. 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 above the U1 label
- SOIC-8 packages can be accommodated; see **Section 4.6 "Using 8-Pin SOIC Op Amps"**
- Only one op amp can be connected at a time

Select the mid-supply power source by setting jumper JP1 to (see Figure 2-3):

- Internal V_{DD}/2 (INT on bottom)
  - Op amp U1 drives the V_{DD}/2 line on all of the PCBs
  - The V_{DD}/2 line must be disconnected from any power supply (at P1 or TP4)
- External V_{DD}/2 (EXT on top, as shown)
  - Op amp U1 has no load
  - The V_{DD}/2 line must be connected to an external supply voltage (at P1 or TP4)

The headers P1 and J1 on the left of the board are unpopulated (see Figure 2-3):

- The test points TP1 through TP5 provide connections for the same voltages
- P1 and J1 can be populated by the user, if desired, to connect to another (user provided) board on the left

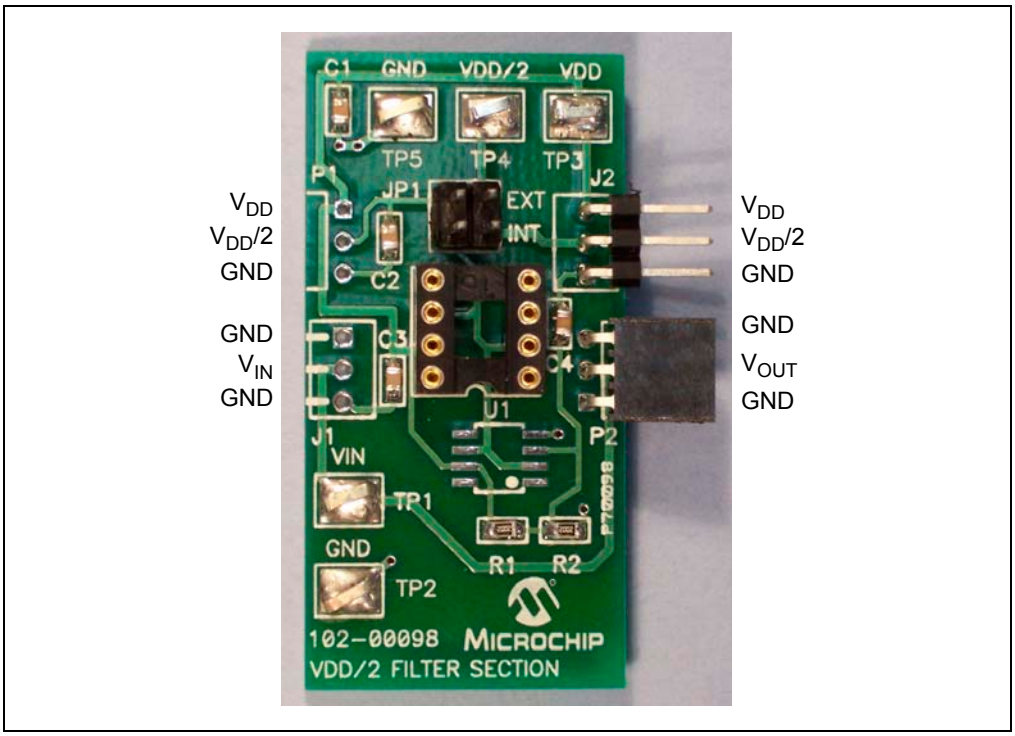

FIGURE 2-3: *V_{DD}/2 Filter Section Top View.*

2.5 ACTIVE FILTER SECTION SET-UP

The filter sections designed by FilterLab V2.0 have several topologies. This section details the conversion of these topologies to the Active Filter Demo Board Kit. Figure 2-4 shows the circuit diagram for the Active Filter Section.

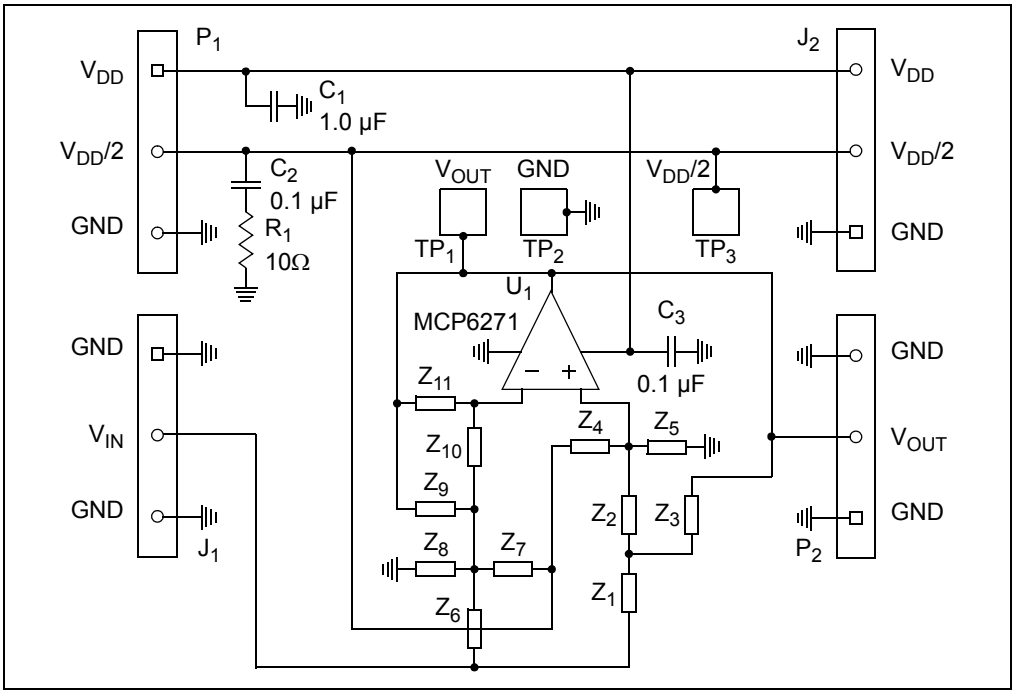

FIGURE 2-4: *Active Filter Section Circuit.*

The Active Filter Section is shown in Figure 2-5. 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 4.6 "Using 8-Pin SOIC Op Amps"**

The resistors and capacitors that are part of a filter section are placed in pin sockets (see Figure 2-5):

- The socket pairs are labeled Z1 through Z12
- The following sub-sections detail how the resistors and capacitors are chosen and populated

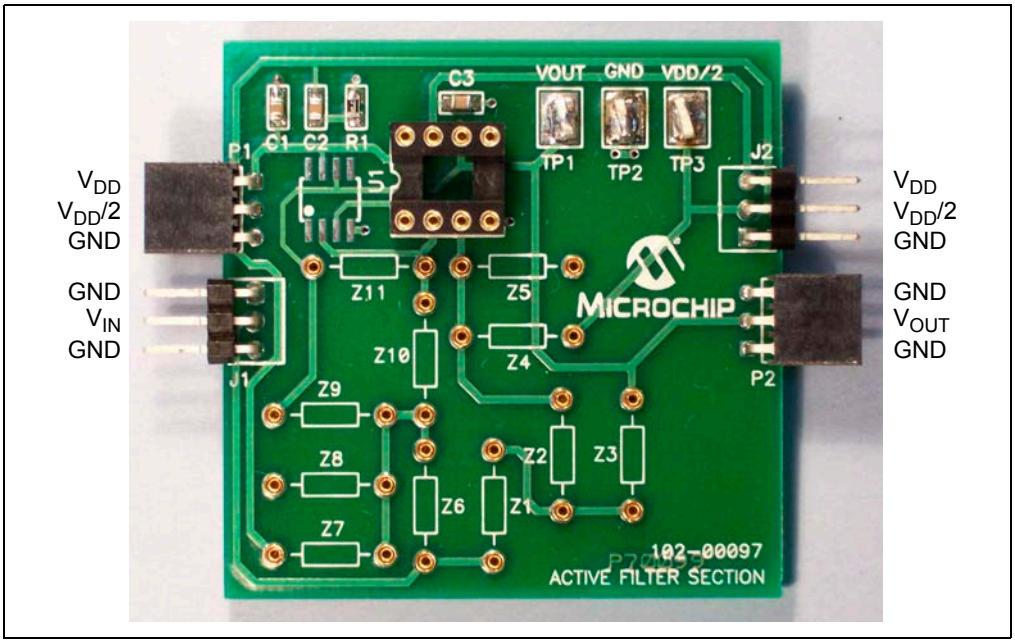

FIGURE 2-5: *Active Filter Section Top View.*

2.5.1 FilterLab Circuit Topology vs. PCB Reference Designators

FilterLab V2.0 labels the capacitors and resistors in its circuit diagram as follows:

- R12 = Resistor, Section # 1, Resistor # 2 in that section
- C31 = Capacitor, Section # 3, Capacitor # 1 in that section
- Ra = Gain setting resistor for op amp in Sallen-Key Section # 1 (open, and not labeled, when in unity gain)
- Rb = Feedback resistor for op amp in Sallen-Key Section # 1 (0Ω, and not labeled, when in unity gain)

The resistor and capacitor reference designators on the Active Filter Section board (Z1 - Z11) need to be filled according to FilterLab's design. The following sub-sections show how to convert from FilterLab's circuit diagram to the PCB.

In the following, the PCBs are given section numbers 0 to 4:

- Section # 0 – for $V_{DD}/2$ Filter Section
- Section # 1 to # 4 – for cascaded Active Filter Section

The different circuit topologies referred to in **Section 2.5.2 "Sallen-Key, Low-pass Filter Sections"**, **Section 2.5.3 "Sallen-Key, High-pass Filter Sections"**, and **Section 2.5.4 "Multiple Feedback, Low-pass and Band-pass Filter Sections"** will be labeled as shown in Figure 2-6.

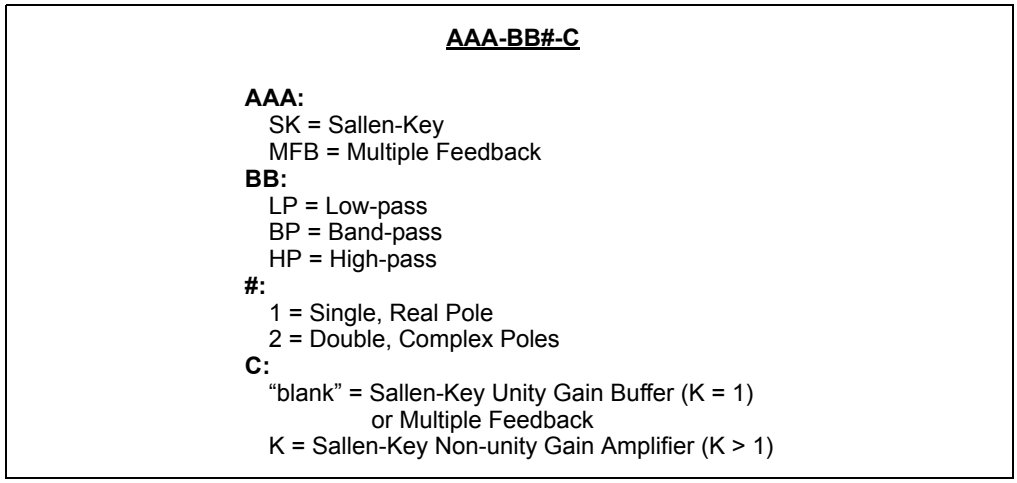

FIGURE 2-6: *Filter Section Labels.*

2.5.2 Sallen-Key, Low-pass Filter Sections

TABLE 2-1: IMPEDANCES FOR SALLEN-KEY, LOW-PASS FILTER SECTIONS

Topology	SK-LP1	SK-LP2	SK-LP1-K	SK-LP2-K
Z_1	0Ω	R11	0Ω	R11
Z_2	R11	R12	R11	R12
Z_3	—	C11	—	C11
Z_4	—	—	—	—
Z_5	C11	C12	C11	C12
Z_6	—	—	—	—
Z_7	—	—	0Ω	0Ω
Z_8	—	—	—	—
Z_9	—	—	—	—
Z_{10}	—	—	Ra	Ra
Z_{11}	0Ω	0Ω	Rb	Rb

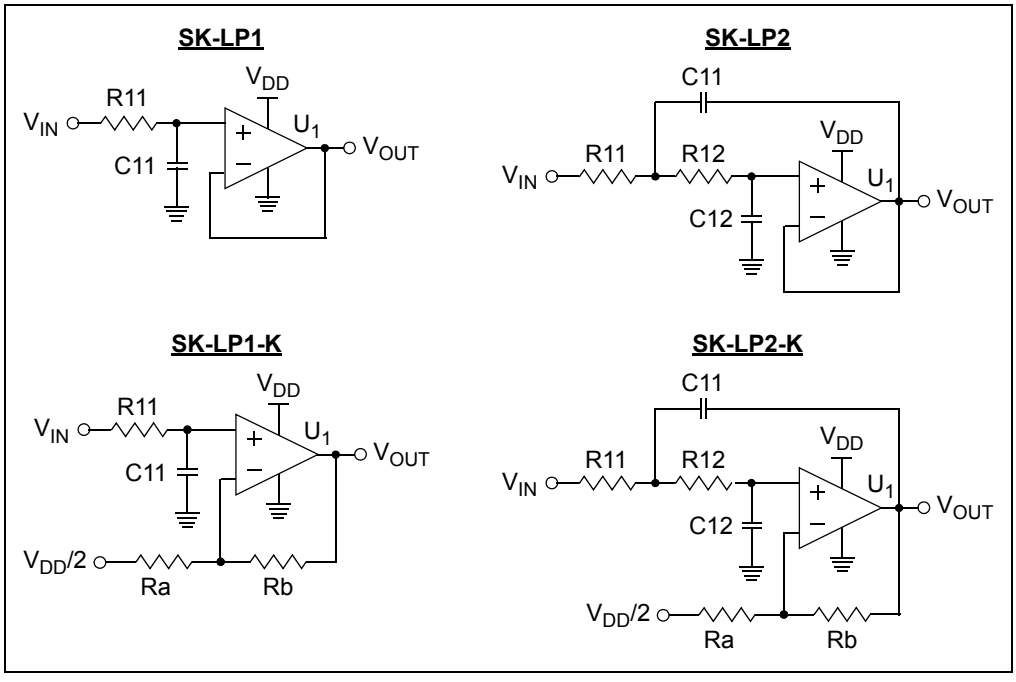

FIGURE 2-7: *Sallen-Key, Low-pass (modified) Filter Topologies.*

2.5.3 Sallen-Key, High-pass Filter Sections

TABLE 2-2: IMPEDANCES FOR SALLEN-KEY, HIGH-PASS FILTER SECTIONS

Topology	SK-HP1	SK-HP2	SK-HP1-K	SK-HP2-K
Z_1	0Ω	C11	0Ω	C11
Z_2	C11	C12	C11	C12
Z_3	—	R11	—	R11
Z_4	R11	R12	R11	R12
Z_5	—	—	—	—
Z_6	—	—	—	—
Z_7	—	—	0Ω	0Ω
Z_8	—	—	—	—
Z_9	—	—	—	—
Z_{10}	—	—	Ra	Ra
Z_{11}	0Ω	0Ω	Rb	Rb

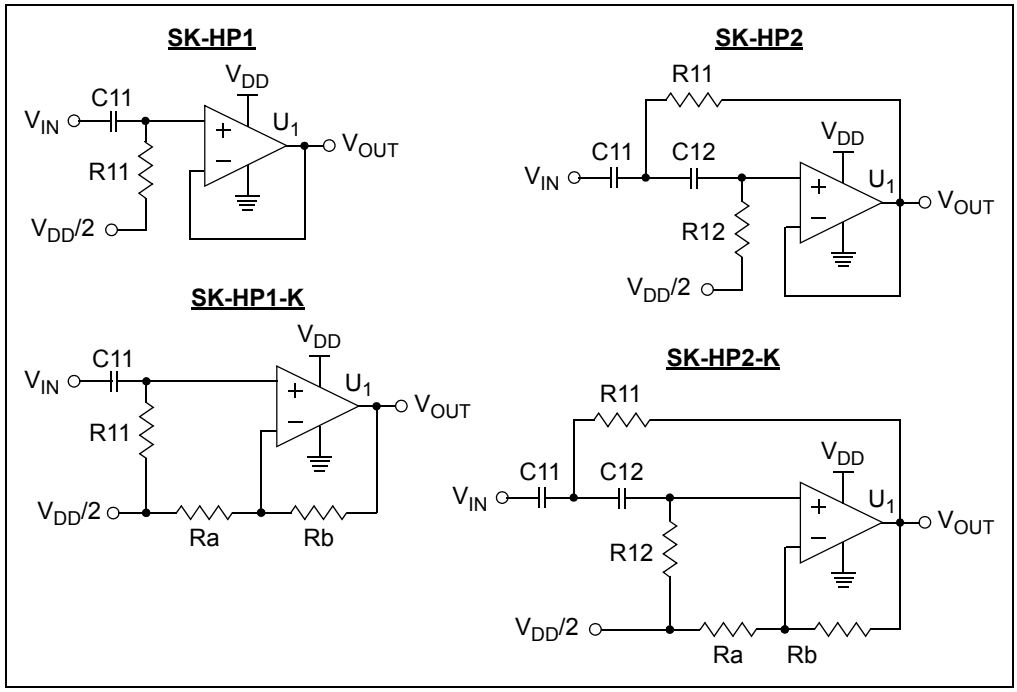

FIGURE 2-8: *Sallen-Key, High-pass (modified) Filter Topologies.*

2.5.4 Multiple Feedback, Low-pass and Band-pass Filter Sections

TABLE 2-3: IMPEDANCES FOR MULTIPLE FEEDBACK, LOW-PASS AND BAND-PASS FILTER SECTIONS

Topology	MFB-LP1	MFB-LP2	MFB-BP2
Z_1	—	—	—
Z_2	—	—	—
Z_3	—	—	—
Z_4	0Ω	0Ω	0Ω
Z_5	—	—	—
Z_6	R11	R11	R11
Z_7	—	—	R12
Z_8	—	C12	—
Z_9	R12	R12	C11
Z_{10}	0Ω	R13	C12
Z_{11}	C11	C11	R13

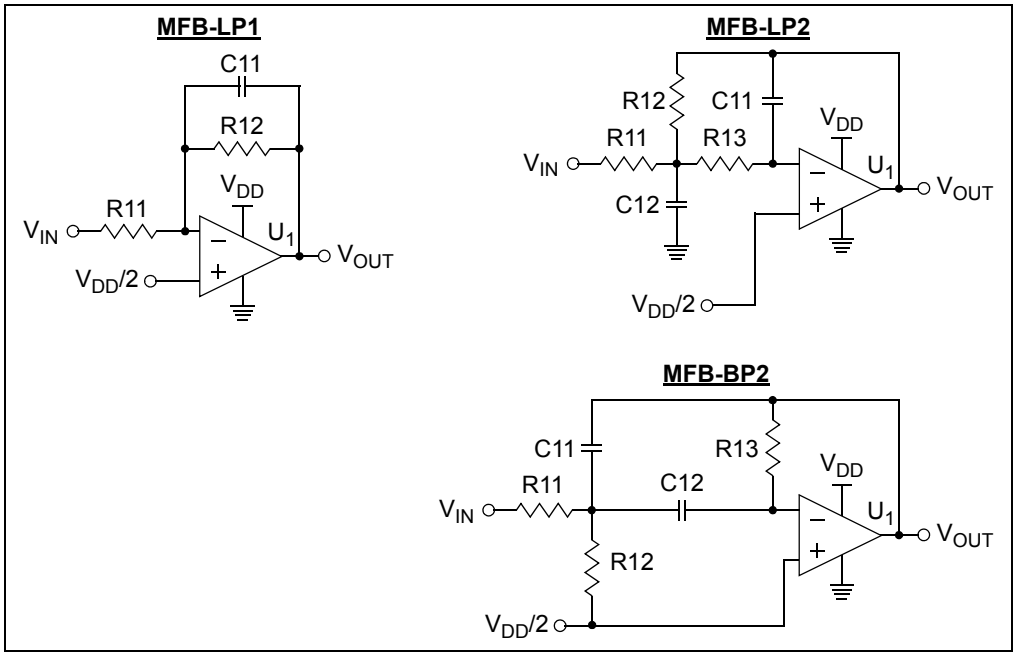

FIGURE 2-9: *Multiple Feedback, Low-pass and Band-pass (modified) Filter Topologies.*

2.6 SET-UP VERIFICATION

1. Install components (resistors, capacitors, and op amps) for a filter design (e.g., the filter described in **Section 3.2 “The Filter Design”** and **Section 3.3 “Putting the Filter Together”**).
2. Verify the power supply voltages, including $V_{DD}/2$, for all of the boards.
3. Test the filter response as described in **Section 3.4 “Testing the Filter”**.

NOTES:

Chapter 3. Building the Filter Supplied in the Kit

3.1 INTRODUCTION

The accessory bag that comes with this kit makes it quick and easy to evaluate the filter described below; it was designed in FilterLab V2.0. Items discussed in this chapter include:

- The Filter Design
- Putting the Filter Together
- Testing the Filter

3.2 THE FILTER DESIGN

See Figure 3-1 for the circuit diagram supported by the accessory bag. This filter is described as follows:

- Bessel Low-pass
- n = 5, (filter order)
- f_C = 100 Hz, (cut-off frequency)
- Gain = 1 V/V
- Sallen-Key sections
- Single Supply

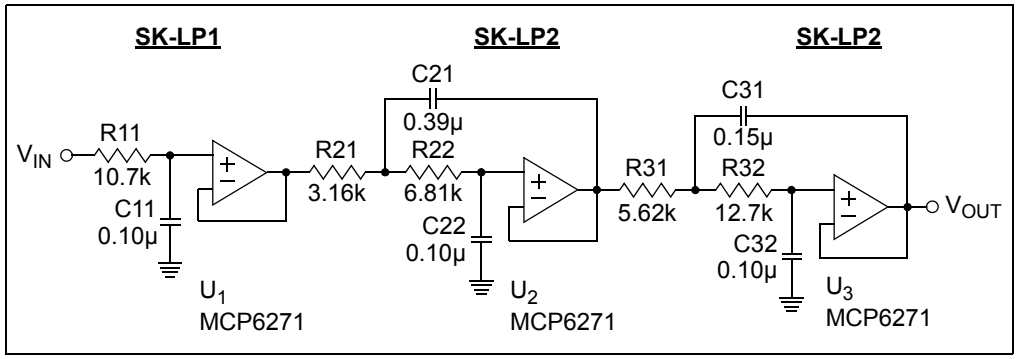

FIGURE 3-1: *5th Order, Bessel, Low-pass Filter Supported by the Active Filter Demo Board Kit.*

This filter was built, and its frequency response was measured; the result is shown in Figure 3-2. MCP601 op amps were used, instead of MCP6271 op amps, because they are slower. Notice how close the measured and simulated data are; this happened because the MCP601 op amp is much faster than the filter, and because 1% resistors and 5% capacitors were used.

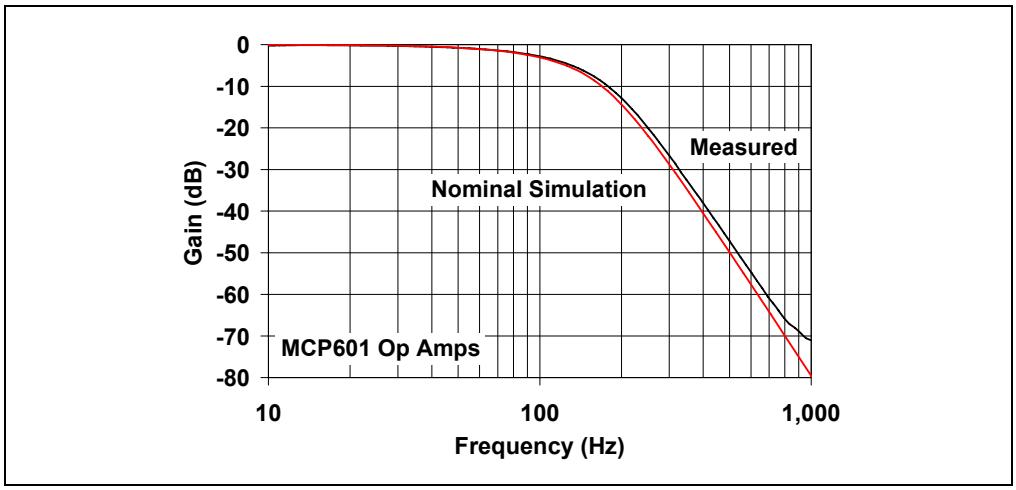

FIGURE 3-2: *Filter Frequency Response.*

3.3 PUTTING THE FILTER TOGETHER

Each of the components in Figure 3-1 that needs to be inserted in a socket is listed in Table 3-1 (see Table B-5). This table gives the section number (see **Section 2.5 "Active Filter Section Set-up"**) and the PCB reference designators (e.g., Z5). Since this design is of 5th order, there are no components for Section # 4.

TABLE 3-1: ACCESSORY BAG PARTS LIST

Component Values	Qty	Section	Reference	PCB Label
100 nF	1	1	C11	Z5
	1	2	C22	Z5
	1	3	C32	Z5
150 nF	1	3	C31	Z3
390 nF	1	2	C21	Z3
Jumper Wire (0Ω) **(Note 1)**	2	1	—	Z1, Z11
	1	2	—	Z11
	1	3	—	Z11
3.16 kΩ	1	2	R21	Z1
5.62 kΩ	1	3	R31	Z1
6.81 kΩ	1	2	R22	Z2
10.7 kΩ	1	1	R11	Z2
12.7 kΩ	1	3	R32	Z2
MCP6271, Single Op Amp, 2 MHz, PDIP-8, Microchip Technology Inc. **(Note 1)**	1	0	U_1	U1
	1	1	U_1	U1
	1	2	U_2	U1
	1	3	U_3	U1

Note 1: The other 6 jumpers and 1 op amp in the accessory bag are for convenience in building other filters.

Figure 3-3 is a picture of the fully assembled filter shown in Figure 3-1. Note that the board on the left ($V_{DD}/2$ Filter Section) provides an easy way to connect the input signal source and power supply to the filter. JP1 on this board may be connected to INT or EXT in this case.

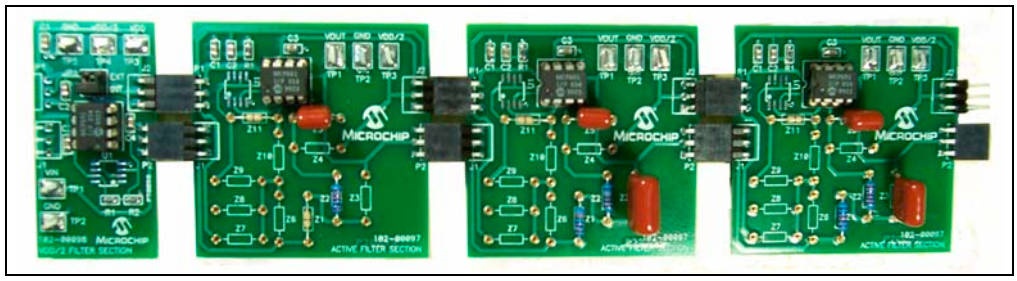

FIGURE 3-3: *Picture of the Filter Supported by the Active Filter Demo Board Kit.*

3.4 TESTING THE FILTER

3.4.1 DC Bias

Figure 3-4 shows the most important DC bias voltages to check.

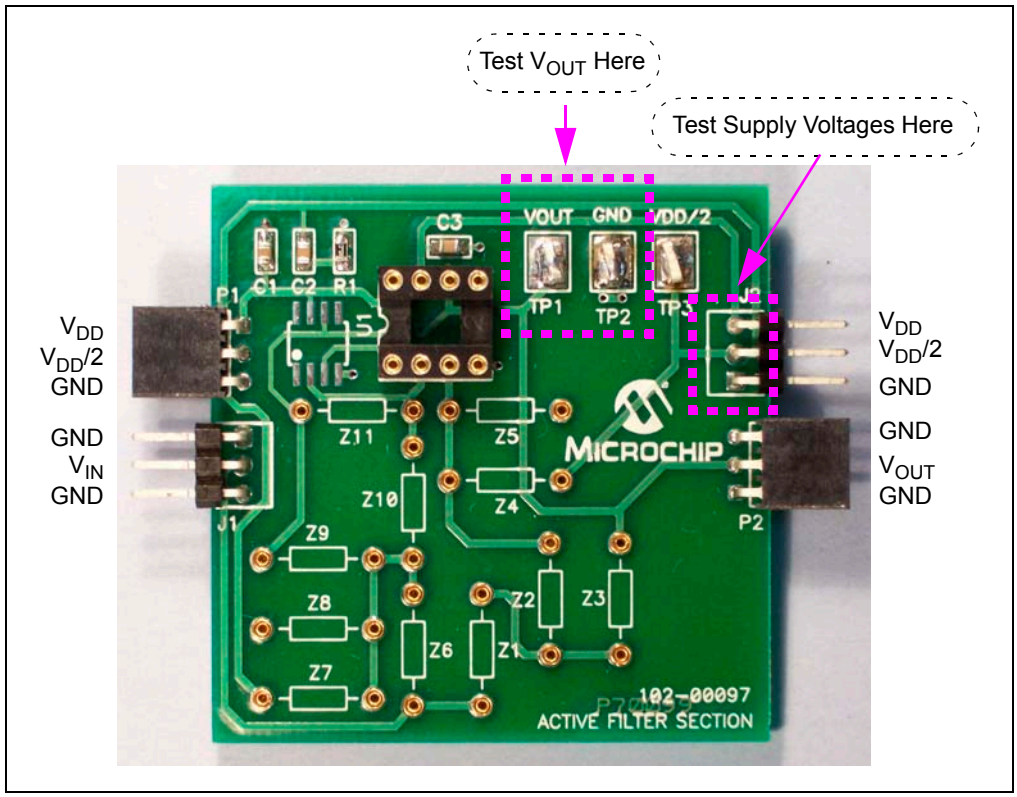

FIGURE 3-4: *Points to check DC Bias.*

3.4.2 Response Variability

Resistors and capacitors with tighter tolerances will reduce the variability of the filters response over process and, sometimes, temperature. Figure 3-5 shows the simulated ±3.3 sigma gain error (in dB) for each frequency (based on a uniform random distribution). Figure 3-6 shows a histogram of the pass-band frequency (f_P) from the same simulation.