Active Filter Demo Board Kit User's Guide

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

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

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

Information contained in this publication regarding device applications and the like is provided only for your convenience and may be superseded by updates. It is your responsibility to ensure that your application meets with your specifications. MICROCHIP MAKES NO REPRESENTATIONS OR WARRANTIES OF ANY KIND WHETHER EXPRESS OR IMPLIED, WRITTEN OR ORAL, STATUTORY OR OTHERWISE, RELATED TO THE INFORMATION, INCLUDING BUT NOT LIMITED TO ITS CONDITION, QUALITY, PERFORMANCE, MERCHANTABILITY OR FITNESS FOR PURPOSE**.** Microchip disclaims all liability arising from this information and its use. Use of Microchip devices in life support and/or safety applications is entirely at the buyer's risk, and the buyer agrees to defend, indemnify and hold harmless Microchip from any and all damages, claims, suits, or expenses resulting from such use. No licenses are conveyed, implicitly or otherwise, under any Microchip intellectual property rights.

Trademarks

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

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

Analog-for-the-Digital Age, Application Maestro, dsPICDEM, dsPICDEM.net, dsPICworks, ECAN, ECONOMONITOR, FanSense, FlexROM, fuzzyLAB, In-Circuit Serial Programming, ICSP, ICEPIC, Linear Active Thermistor, Mindi, MiWi, MPASM, MPLIB, MPLINK, PICkit, PICDEM, PICDEM.net, PICLAB, PICtail, PowerCal, PowerInfo, PowerMate, PowerTool, REAL ICE, rfLAB, rfPICDEM, Select Mode, Smart Serial, SmartTel, Total Endurance, UNI/O, WiperLock and ZENA are trademarks of Microchip Technology Incorporated in the U.S.A. and other countries.

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

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

© 2006, Microchip Technology Incorporated, Printed in the U.S.A., All Rights Reserved.

Printed on recycled paper.

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

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

Table of Contents

Preface 1
Introduction 1
Document Layout 1
Conventions Used in this Guide 2
Recommended Reading 3
The Microchip Web Site 3
Customer Support 3
Document Revision History 3
Chapter 1. Product Overview 5
1.1 Introduction 5
1.2 Kit Contents 5
1.3 Intended Use of the Active Filter Demo Board Kit 6
1.4 Active Filter Demo Board Kit Description 6
1.5 Sub-assemblies 6
1.6 Associated Tools 8
Chapter 2. Setup and Installation 9
2.1 Introduction 9
2.2 Required Tools 9
2.3 Connecting the PCBs 9
2.4 V_{DD}/2 Filter Section Set-up 10
2.5 Active Filter Section Set-up 11
2.6 Set-up Verification 17
Chapter 3. Building the Filter Supplied in the Kit 19
3.1 Introduction 19
3.2 The Filter Design 19
3.3 Putting the Filter Together 20
3.4 Testing the Filter 21
Chapter 4. Common Filter Modifications 25
4.1 Introduction 25
4.2 Power Supplies 25
4.3 Filter Section Ordering for Noise and Headroom 27
4.4 Combining Low-pass and High-pass Sections 27
4.5 Higher Frequency Filters 27
4.6 Using 8-Pin SOIC Op Amps 28

Appendix A. Schematics and Layouts 31
A.1 Introduction 31
A.2 V_{DD}/2 Filter Section (Sub-Assembly #: 102-00098R1) 31
A.3 Active Filter Section (Sub-Assembly #: 102-00097R1) 34
A.4 Accessory Bag (Sub-Assembly #: 110-00097R1) 37
Appendix B. Bill Of Materials (BOM) 39
B.1 V_{DD}/2 Filter Section BOMs 39
B.2 Active Filter Section BOM 40
B.3 Accessory Bag BOM 41
Worldwide Sales and Service 42

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	<u>*File>Save*</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	*`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

CUSTOMER SUPPORT

Users of Microchip products can receive assistance through several channels:

- 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

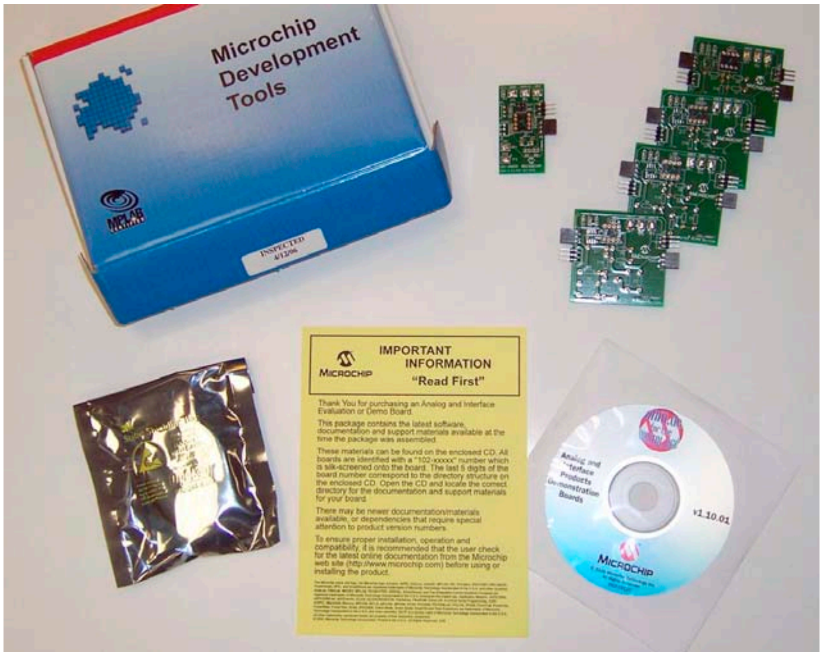

Microchip Development Tools
INSPECTED
IMPORTANT INFORMATION "Read First"
MICROCHIP
v1.10.01

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.

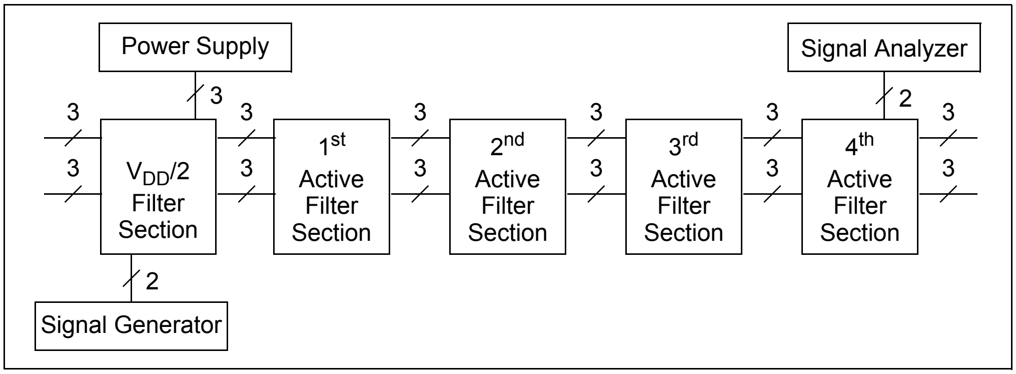

Power Supply
Signal Analyzer
3
2
VDD/2 Filter Section
1st Active Filter Section
2nd Active Filter Section
3rd Active Filter Section
4th Active Filter Section
Signal Generator

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.

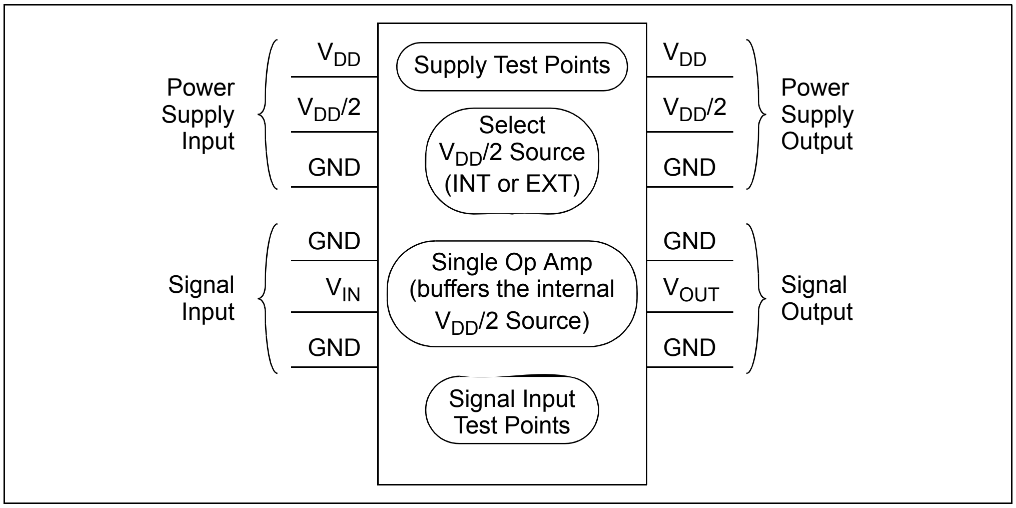

Power Supply Input
VDD
VDD/2
GND
Signal Input
GND
VIN
GND
Supply Test Points
Select VDD/2 Source (INT or EXT)
Single Op Amp (buffers the internal VDD/2 Source)
Signal Input Test Points
VDD
VDD/2
GND
Power Supply Output
GND
VOUT
GND
Signal Output

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

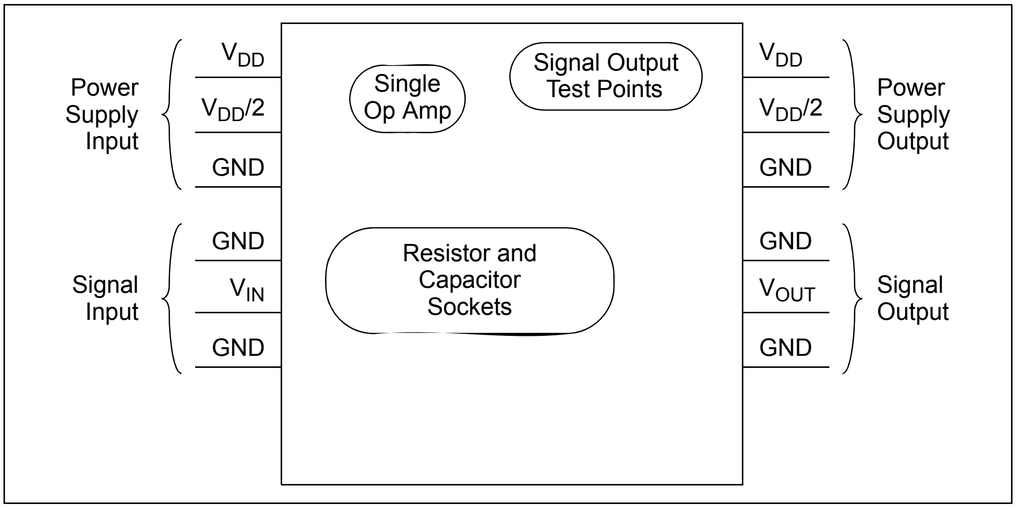

Power Supply Input
VDD
VDD/2
GND
Signal Input
GND
VIN
GND
Single Op Amp
Signal Output Test Points
Resistor and Capacitor Sockets
VDD
VDD/2
GND
Power Supply Output
GND
VOUT
GND
Signal Output

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.

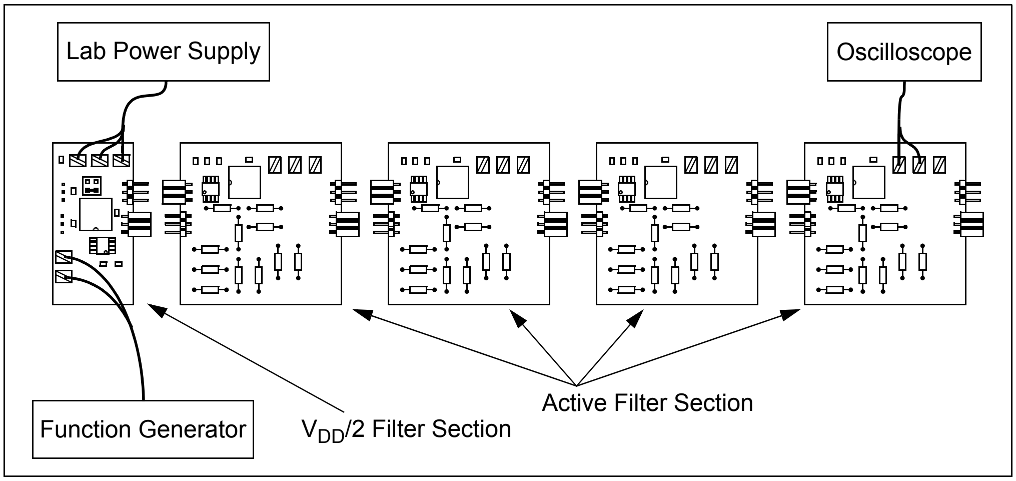


FIGURE 2-1: Board Connections for the Active Filter Demo Board Kit.

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.

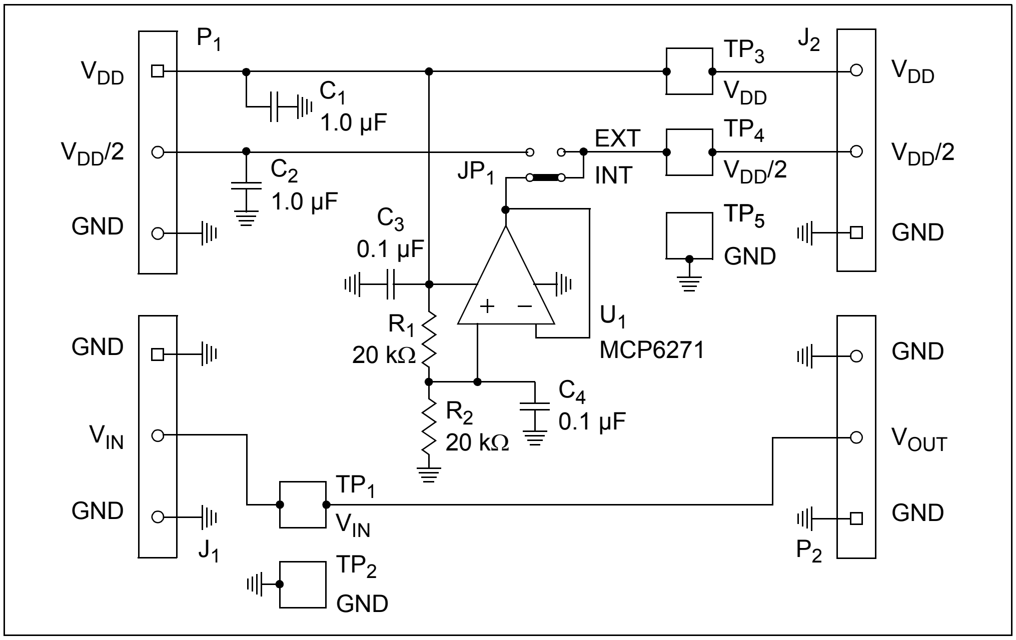


FIGURE 2-2: *V_{DD}/2 Filter Section Circuit.*

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

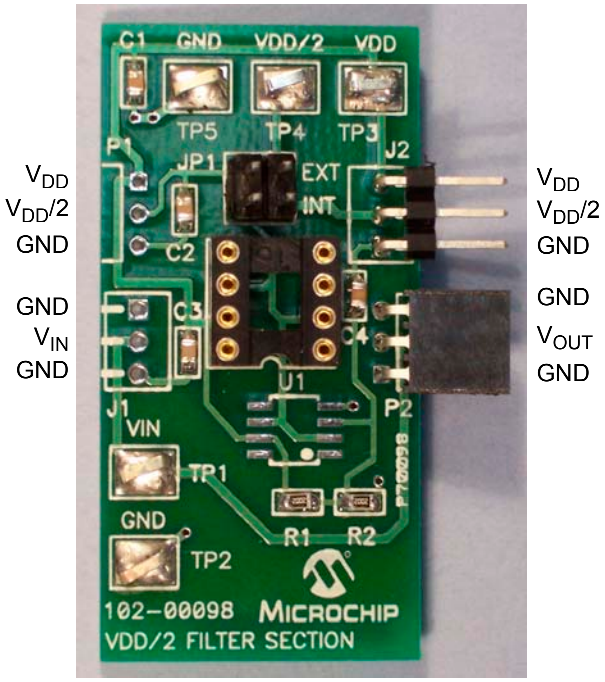

C1
GND
VDD/2
VDD
TP5
TP4
TP3
P1
JP1
EXT
INT
J2
C2
C3
C4
U1
J1
VIN
TP1
GND
TP2
R1
R2
P2
102-00098
MICROCHIP
VDD/2 FILTER SECTION
V_{DD}
$V_{DD}/2$
GND
GND
V_{IN}
GND
V_{DD}
$V_{DD}/2$
GND
GND
V_{OUT}
GND

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.

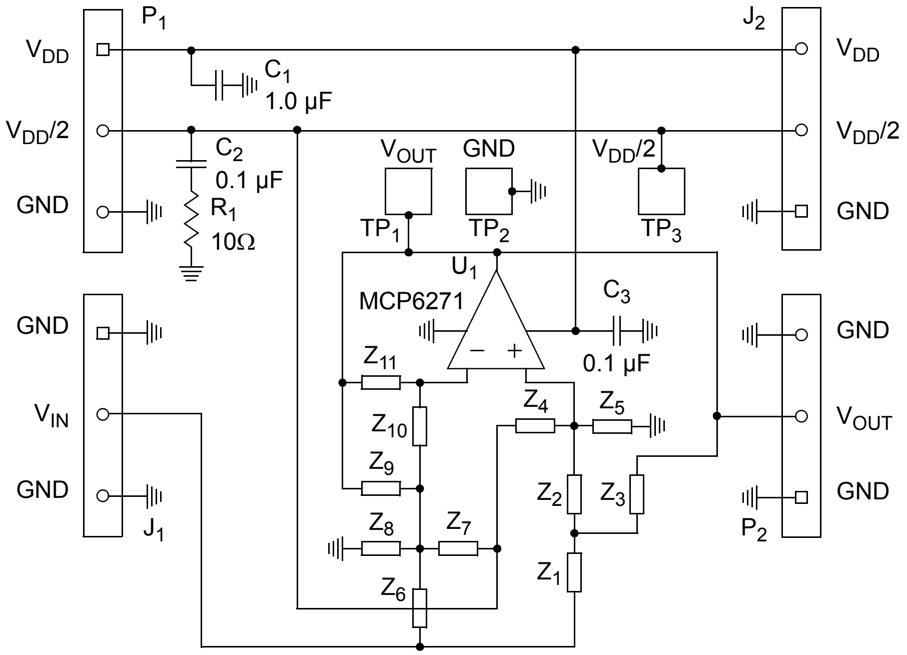

P_1
J_2
V_{DD}
$V_{DD}/2$
GND
C_1
1.0 µF
C_2
0.1 µF
R_1
10Ω
V_{OUT}
GND
$V_{DD}/2$
TP_1
TP_2
TP_3
U_1
MCP6271
C_3
0.1 µF
GND
V_{IN}
GND
J_1
Z_{11}
Z_{10}
Z_9
Z_8
Z_7
Z_6
Z_4
Z_5
Z_2
Z_3
Z_1
V_{DD}
$V_{DD}/2$
GND
GND
V_{OUT}
GND
P_2

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

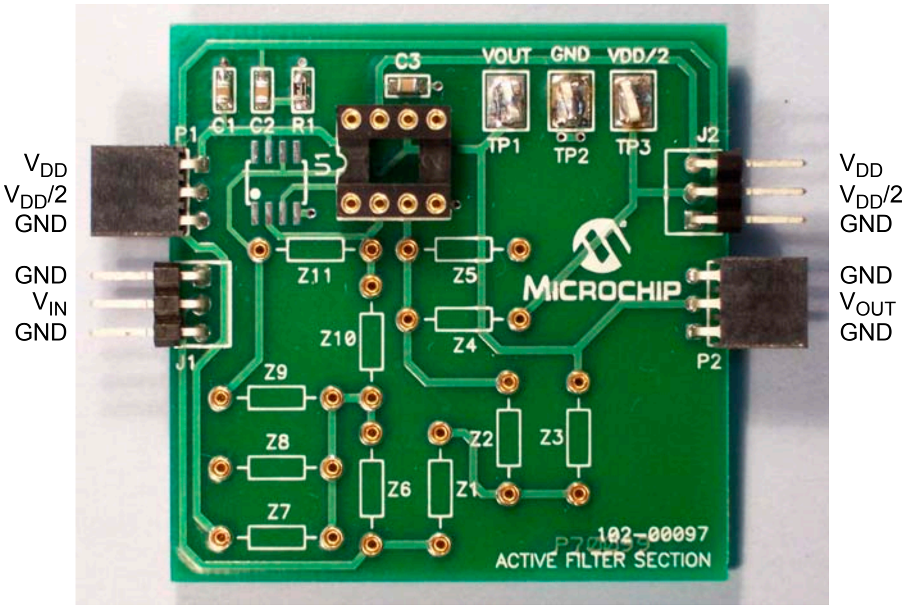

V_{DD}
$V_{DD}/2$
GND
GND
V_{IN}
GND
V_{DD}
$V_{DD}/2$
GND
GND
V_{OUT}
GND
C3
VOUT
GND
VDD/2
C1
C2
R1
P1
TP1
TP2
TP3
J2
Z11
Z5
MICROCHIP
Z10
Z4
J1
P2
Z9
Z8
Z2
Z3
Z6
Z1
Z7
102-00097
ACTIVE FILTER SECTION

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.

AAA-BB#-C

AAA:
SK = Sallen-Key
MFB = Multiple Feedback
BB:
LP = Low-pass
BP = Band-pass
HP = High-pass
#:
1 = Single, Real Pole
2 = Double, Complex Poles
C:
"blank" = Sallen-Key Unity Gain Buffer (K = 1)
or Multiple Feedback
K = Sallen-Key Non-unity Gain Amplifier (K > 1)

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

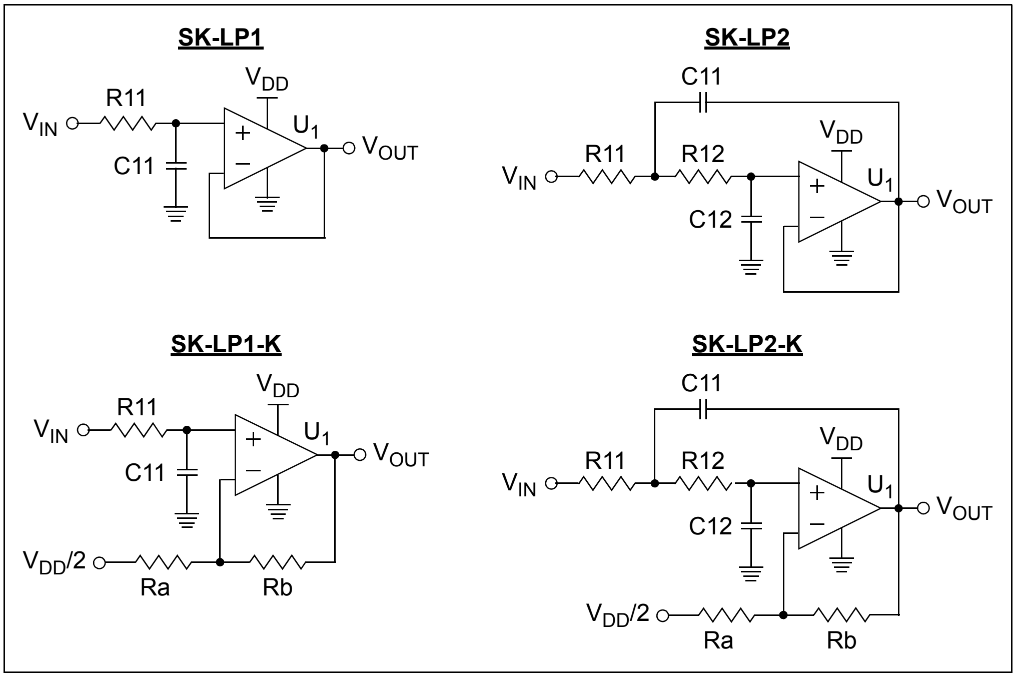

SK-LP1
VIN
R11
VDD
U1
VOUT
C11
SK-LP2
C11
VDD
VIN
R11
R12
U1
VOUT
C12
SK-LP1-K
VDD
VIN
R11
U1
VOUT
C11
VDD/2
Ra
Rb
SK-LP2-K
C11
VDD
VIN
R11
R12
U1
VOUT
C12
VDD/2
Ra
Rb

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

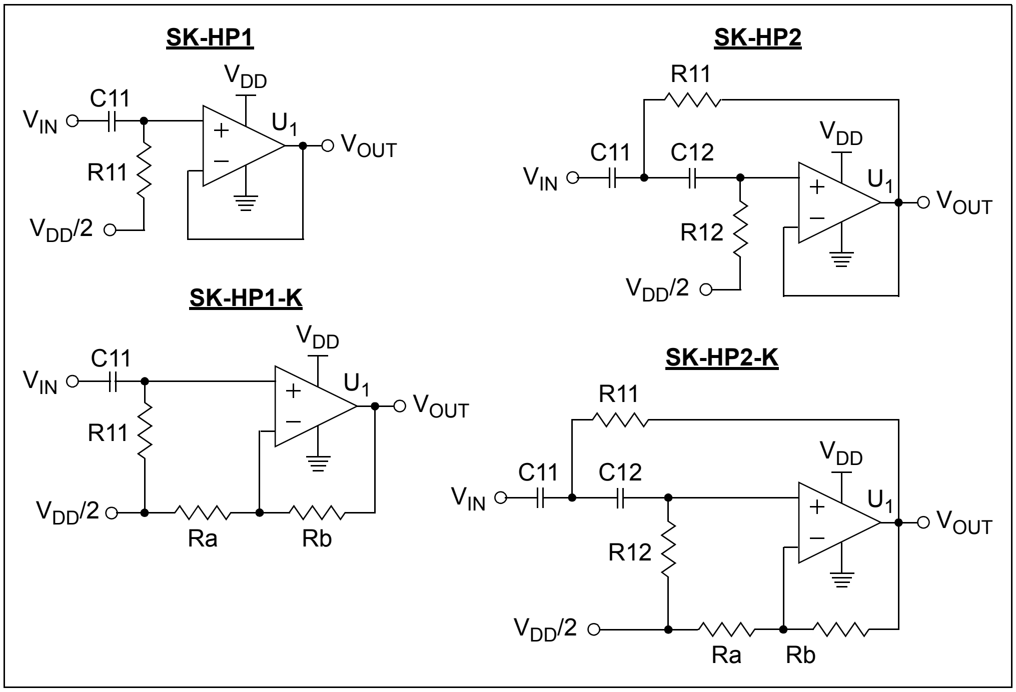

SK-HP1
VDD
C11
VIN
U1
VOUT
R11
VDD/2
SK-HP2
R11
C11
C12
VDD
VIN
U1
VOUT
R12
VDD/2
SK-HP1-K
VDD
C11
VIN
U1
VOUT
R11
VDD/2
Ra
Rb
SK-HP2-K
R11
VDD
C11
C12
VIN
U1
VOUT
R12
VDD/2
Ra
Rb

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

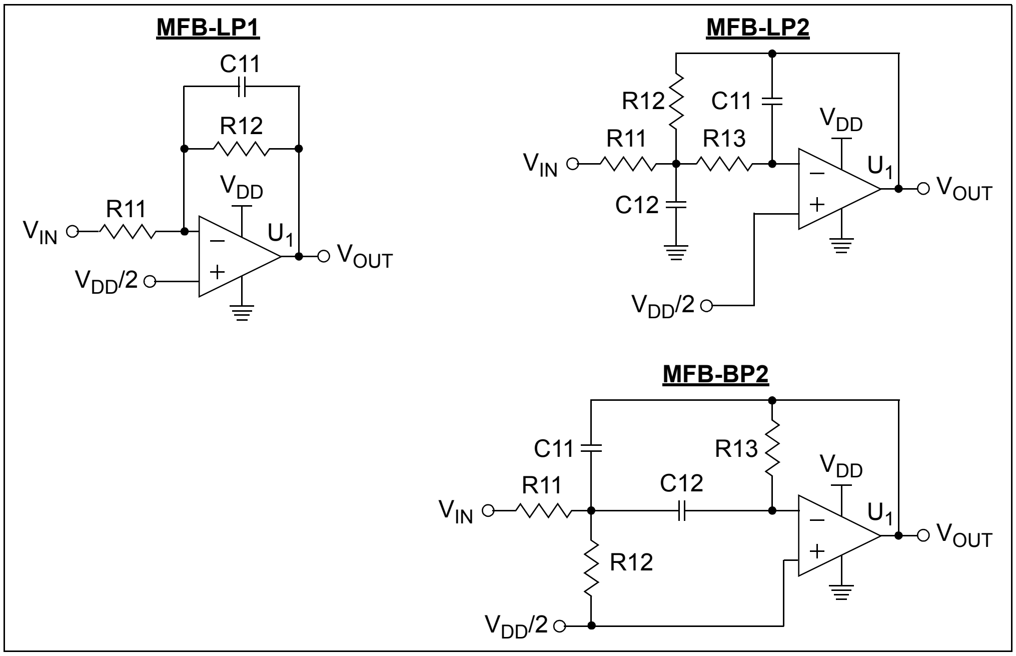

MFB-LP1
C11
R12
V_{DD}
R11
V_{IN}
U_1
V_{OUT}
$V_{DD}/2$
MFB-LP2
R12
C11
V_{DD}
R11
R13
V_{IN}
U_1
V_{OUT}
C12
$V_{DD}/2$
MFB-BP2
C11
R13
V_{DD}
R11
C12
V_{IN}
U_1
V_{OUT}
R12
$V_{DD}/2$

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

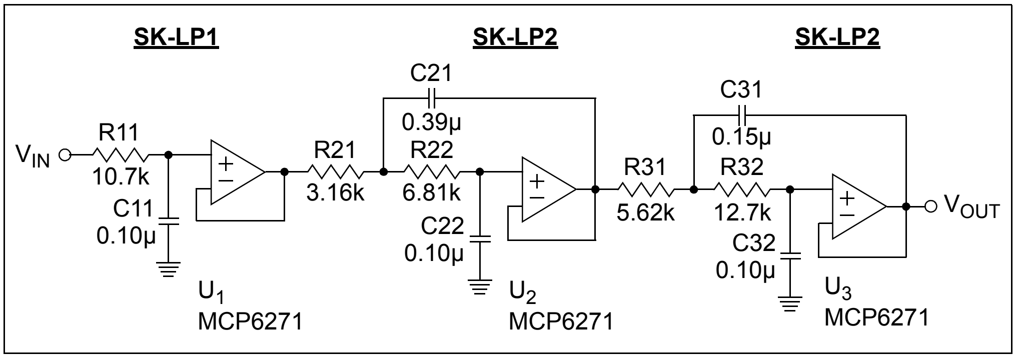

SK-LP1
SK-LP2
SK-LP2
C21
0.39µ
C31
0.15µ
R11
V_{IN}
10.7k
R21
3.16k
R22
6.81k
C11
0.10µ
C22
0.10µ
R31
5.62k
R32
12.7k
C32
0.10µ
V_{OUT}
U_1
MCP6271
U_2
MCP6271
U_3
MCP6271

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.

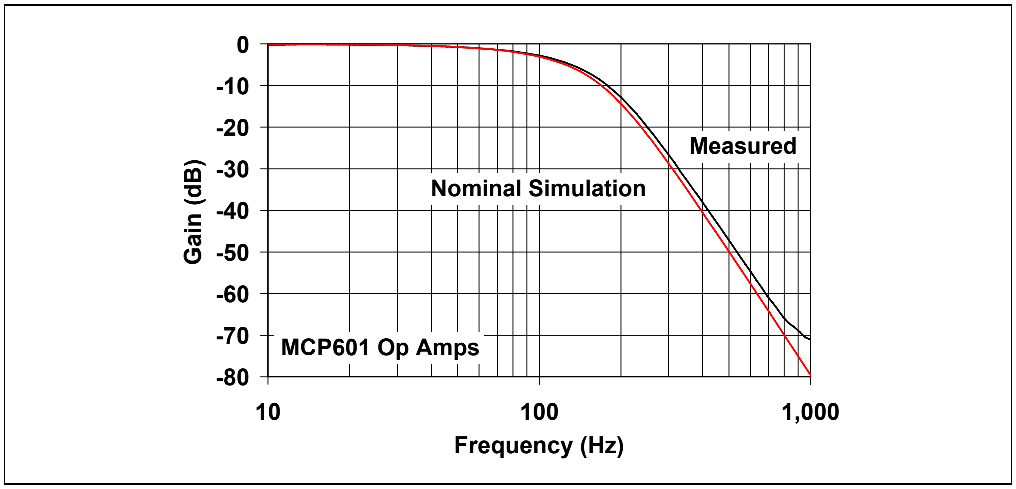


FIGURE 3-2: *Filter Frequency Response.*

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.

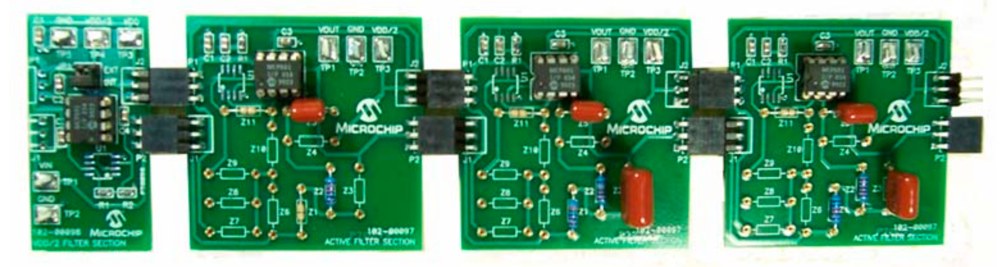


FIGURE 3-3: *Picture of the Filter Supported by the Active Filter Demo Board Kit.*

3.4 TESTING THE FILTER

3.4.1 DC Bias

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

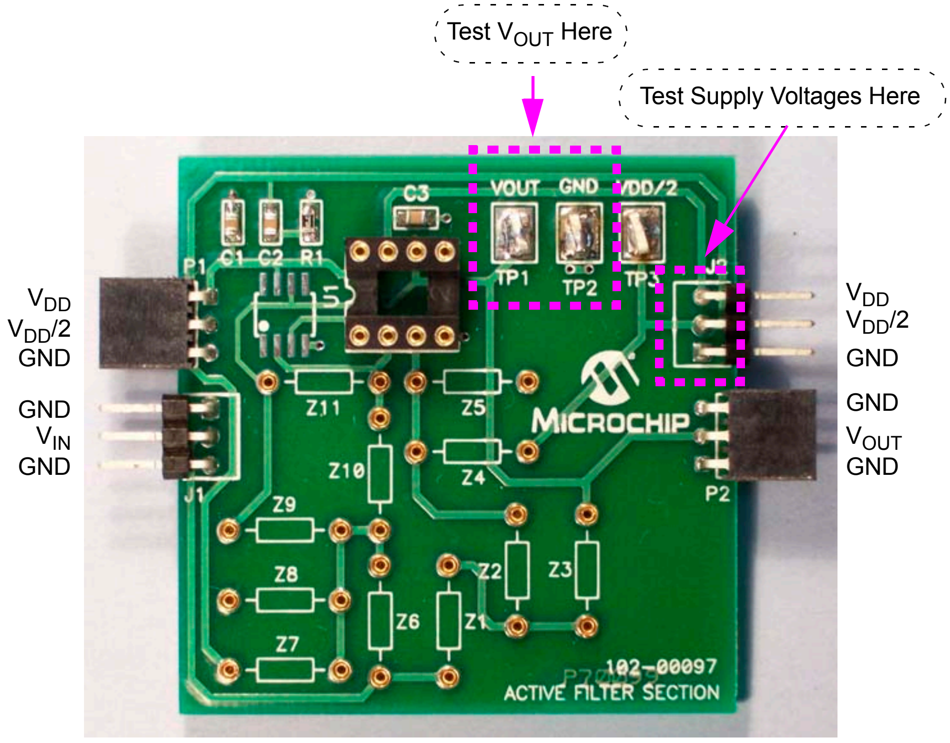

Test V_{OUT} Here
Test Supply Voltages Here
V_{DD}
V_{DD}/2
GND
GND
V_{IN}
GND
V_{DD}
V_{DD}/2
GND
GND
V_{OUT}
GND
VOUT
GND
VDD/2
C3
TP1
TP2
TP3
C1
C2
R1
P1
J1
J2
P2
Z11
Z5
Z10
Z4
Z9
Z8
Z7
Z6
Z1
Z2
Z3
MICROCHIP
102-00097
ACTIVE FILTER SECTION

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.

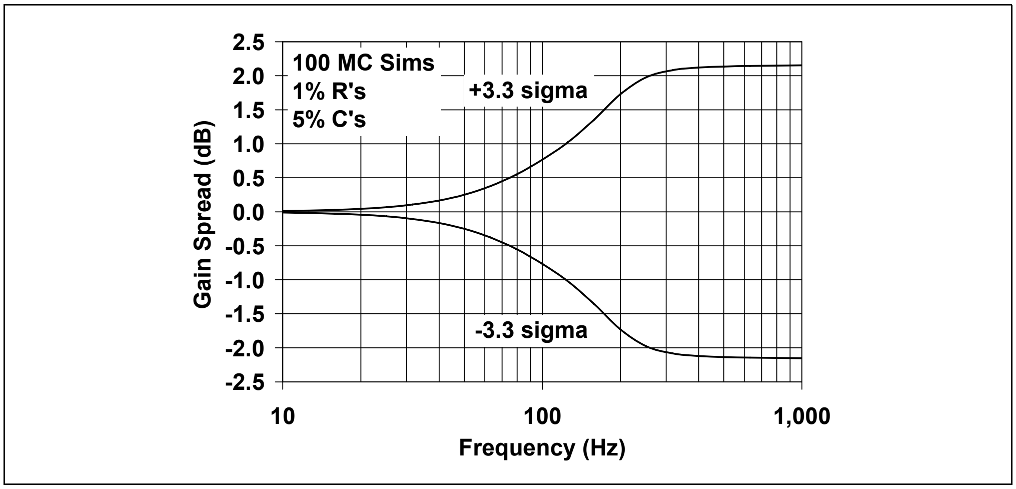


FIGURE 3-5: *Gain Error (Monte Carlo simulation) vs. Frequency.*

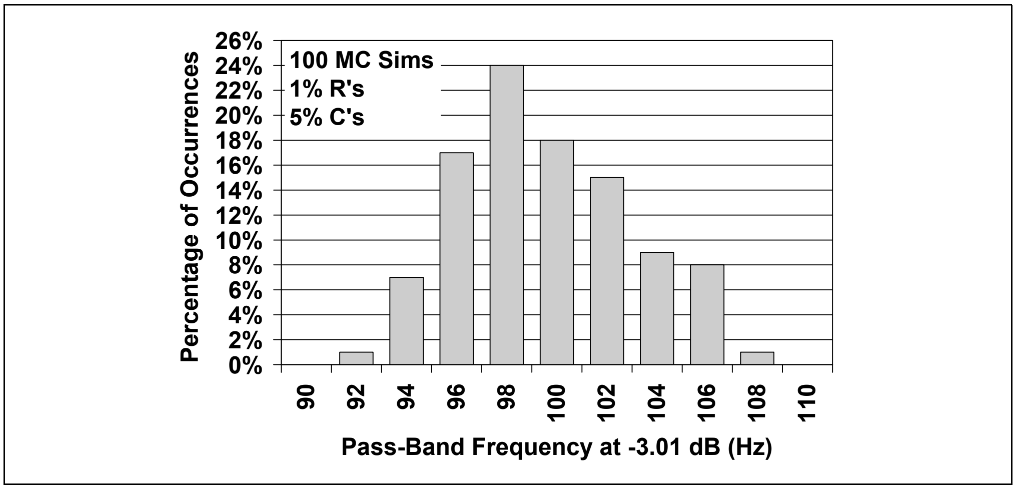


FIGURE 3-6: *Pass-Band Frequency (Monte Carlo simulation) Histogram.*

Using components with tighter tolerances (e.g., 2% capacitors) will improve the variability of the filter response. This is especially important for filters with a sharp cutoff characteristic (i.e., Chebyshev).

3.4.3 Checking Output Headroom

It is also possible to check op amp overdrive issues by testing the output of all of the op amps (every Active Filter Section). The worst-case signal(s) needs to be applied at the first input. Figure 3-7 shows the frequency response of the filter in Figure 3-1. None of the traces goes above 0 dB, so this filter should not have output voltage range issues when the input is a sinewave.

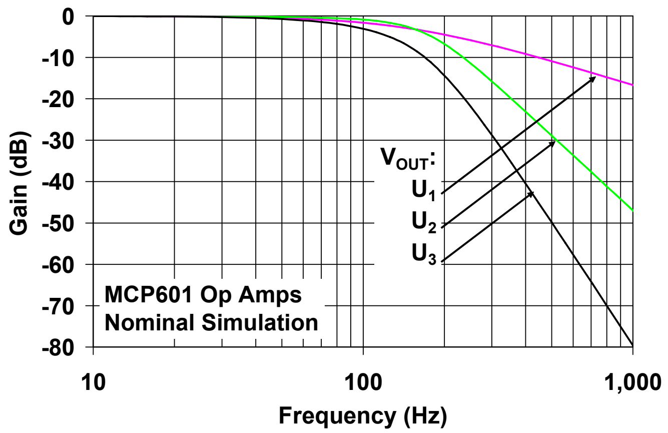


FIGURE 3-7: Frequency Response for All Outputs.

Figure 3-8 shows the step response of the filter in Figure 3-1. The output of U_2 (the second op amp) shows the largest overshoot, so it limits the output voltage range of the filter. The nominal overshoot is 6.1% (0.18V for a 3.0V step).

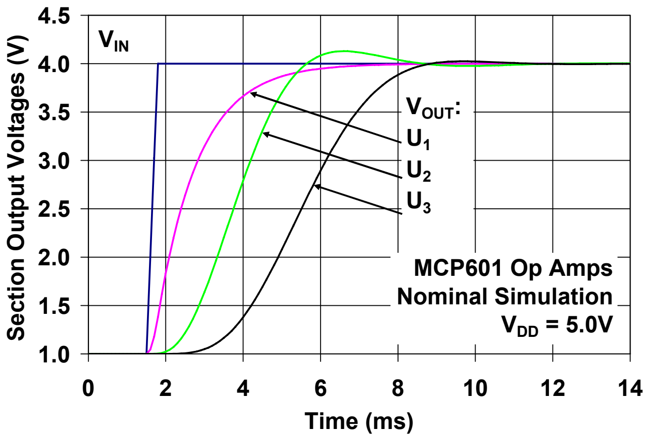


FIGURE 3-8: Step Response for All Outputs.

Many SPICE simulators support Monte Carlo simulations. Using this capability on your design will help determine what tolerances are needed on your design. The same results can be obtained by measuring many filters (i.e., 30 to 10,000), but at a greater cost.

NOTES:

Chapter 4. Common Filter Modifications

4.1 INTRODUCTION

The modifications described in this chapter include:

- Power Supplies
- Filter Section Ordering for Noise and Headroom
- Combining Low-pass and High-pass Sections
- Higher Frequency Filters
- Using 8-Pin SOIC Op Amps

4.2 POWER SUPPLIES

4.2.1 Dual Power Supplies

To implement dual supplies, change the $V_{DD}/2$ Filter Section (see Figure 4-1) setup:

- The boards' bypass capacitors (C1 and C3) need to be removed and replaced
  - Connect one set from –VS (board GND) to GND (board VDD/2)
  - Connect the other set from +VS (board VDD) to GND (board VDD/2).
- Remove R1 and R2, and then replace R2 with a short
- Set JP1 to External $V_{DD}/2$ (EXT, as shown)
- Connect the Lab Power Supply
  - Voltage $+V_S$ to the board's V_{DD} input (TP3)
  - Voltage GND to the $V_{DD}/2$ input (TP4)
  - Voltage $–V_S$ to the board's GND input (TP5)

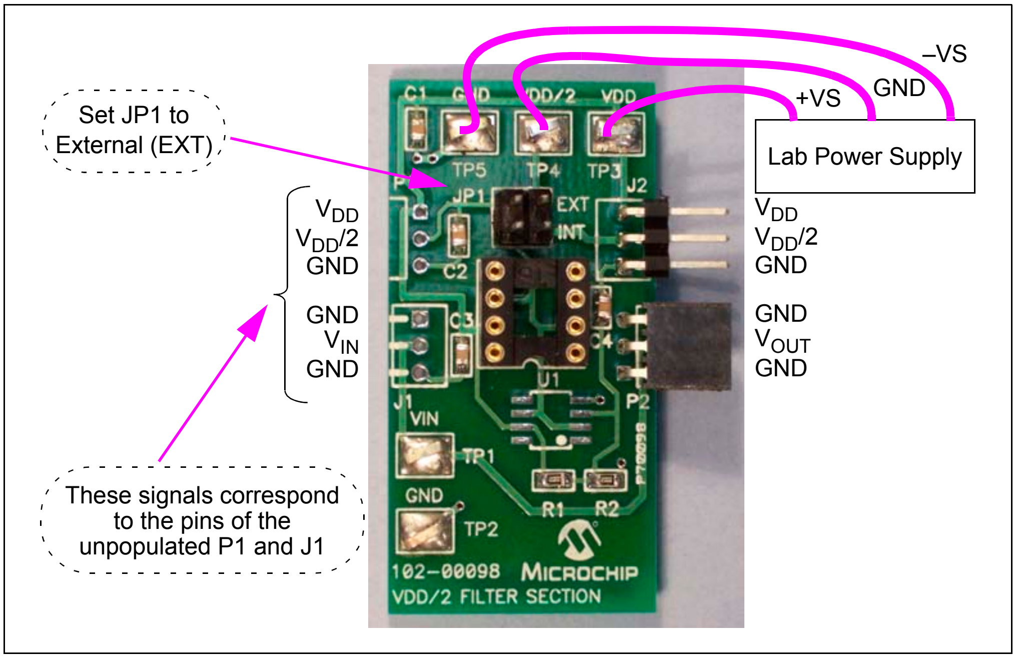

Set JP1 to External (EXT)
–VS
GND
+VS
Lab Power Supply
V_{DD}
$V_{DD}/2$
GND
GND
V_{IN}
GND
V_{DD}
$V_{DD}/2$
GND
GND
V_{OUT}
GND
These signals correspond to the pins of the unpopulated P1 and J1
C1
GND
VDD/2
VDD
TP5
TP4
TP3
JP1
EXT
INT
J2
C2
C3
C4
U1
P2
J1
VIN
TP1
GND
TP2
R1
R2
102-00098 MICROCHIP
VDD/2 FILTER SECTION

FIGURE 4-1: Setting up $V_{DD}/2$ Filter Section for dual supplies.

To implement dual supplies, it is also necessary to change the Active Filter Section (see Figure 4-2) set-up:

- The boards' bypass capacitors (C1 and C3) need to be removed and replaced
  - Connect one set from –VS (board GND) to GND (board VDD/2)
  - Connect the other set from +VS (board VDD) to GND (board VDD/2).
- If desired, R1 and C1 can be removed
- Connect the Oscilloscope as follows
  - Oscilloscope signal probe to VOUT (TP1)
  - Oscilloscope GND probe to VDD/2 (TP3)

Note: Do not connect the oscilloscope GND probe to board GND (TP2) when set up for dual supplies; *this may cause a ground conflict between lab equipment*.

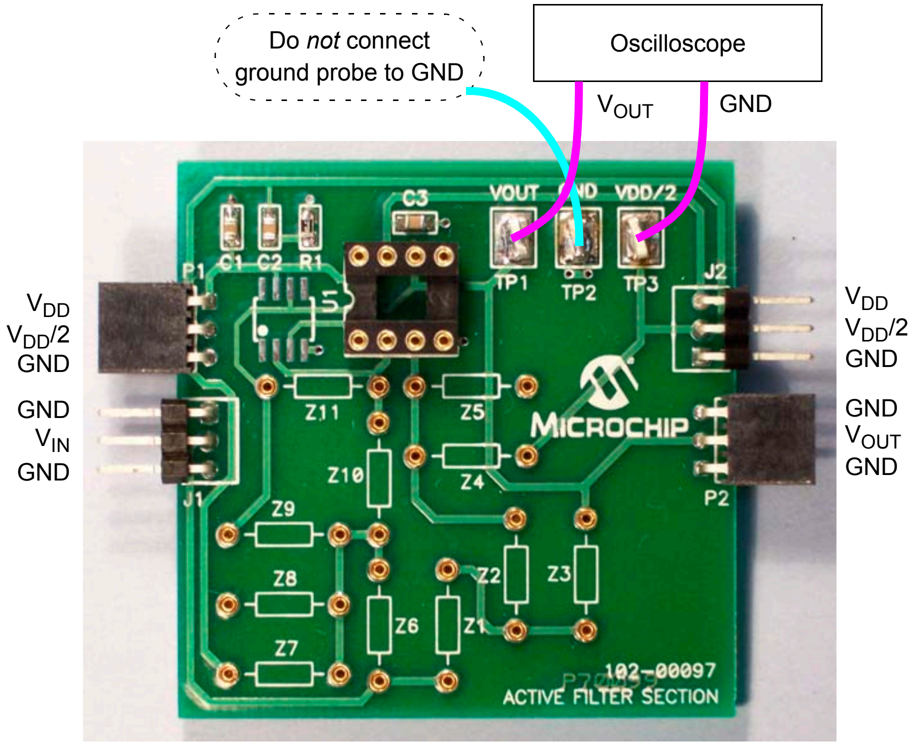

Do *not* connect
ground probe to GND
Oscilloscope
V_{OUT}
GND
V_{DD}
$V_{DD}/2$
GND
GND
V_{IN}
GND
V_{DD}
$V_{DD}/2$
GND
GND
V_{OUT}
GND
C3
VOUT
VDD/2
C1
C2
R1
P1
TP1
TP2
TP3
J2
Z11
Z5
MICROCHIP
Z10
Z4
J1
P2
Z9
Z8
Z2
Z3
Z6
Z1
Z7
102-00097
ACTIVE FILTER SECTION

FIGURE 4-2: *Setting up Active Filter Section" or dual supplies.*

Using dual supplies may not work well for high frequency designs. $-V_S$ will be connected to the ground plane, instead of GND, causing greater radiation of supply noise and more crosstalk.

4.2.2 Increased Power Supply Voltages

The total voltage across the power supplies should not exceed the op amp's specification (5.5V for the MCP6271). The large bypass capacitors on each board are rated at 16V, which also limits the possible supply voltage.

If necessary, op amps with higher supply voltage can be accommodated. The boards' bypass capacitors must be removed and replaced with other bypass capacitors with a higher voltage rating.

4.3 FILTER SECTION ORDERING FOR NOISE AND HEADROOM

FilterLab V2.0 orders the filter sections for good dynamic range performance. Its default selections are:

- Section pole quality factors (Q_P) are ordered from lowest to highest (from Section # 1 to Section # 4)
  - In other words, section damping factors ($\zeta = 0.5/Q_P$) go from highest to lowest (from Section # 1 to Section # 4)
- Gains greater than unity are placed in Section # 1 (for best component sensitivities)

Some applications may need to alter the default section ordering for special requirements. To compare different section orderings:

- Check the output headroom of each section's output (V_{OUT}) using the worst-case input signal; examples include:
  - Minimum and maximum DC levels
  - Swept frequency sine wave with maximum magnitude
  - Voltage step with maximum step size
- Measure the noise performance
  - Measure the output with a DC input signal (i.e., at mid-supply), an oscilloscope, and a high gain low noise amplifier
  - Calculate the standard deviation of the output; this is the integrated noise in V_{RMS}
  - The noise can be improved by scaling the resistors, or by changing the op amps
- Re-connect the sections in a different order
  - Usually it is best to leave the high gain section at the front of the filter
  - Re-check output headroom and noise

4.4 COMBINING LOW-PASS AND HIGH-PASS SECTIONS

Some band-pass and band reject filters can be implemented using cascaded low-pass and high-pass filter sections. These filters have their pass-band frequencies (f_{PL} and f_{PH}) far apart (e.g., $f_{PH}/f_{PL} > 5.8$). The low-pass and high-pass filters are usually designed separately, then cascaded together.

The Active Filter Demo Board Kit allows the user to try out these filters on the bench with little effort. They also help debug this type of design.

4.5 HIGHER FREQUENCY FILTERS

Higher frequency filters (e.g., a low-pass filter with pass band edge at 1 MHz) can have their design initially verified on these boards. Simply scale either the resistors or capacitors to a lower frequency design:

- Increase resistors (or capacitors) by a power of 10
- Choose an op amp that is slower by the same power of 10
- Evaluate response:
  - All frequency parameters are divided by the same power of 10
  - All time parameters are multiplied by the same power of 10

For example, a low-pass filter with a pass-bandfrequency of 1 MHz could be scaled back to 10 kHz.

The final design must be evaluated on a board capable of supporting higher frequency signals.

4.6 USING 8-PIN SOIC OP AMPS

There are two options available when using single op amps in SOIC-8 packages (150 mil wide); soldering onto the $V_{DD}/2$ Filter Section and/or Active Filter Section board(s) 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 4-3 shows a SOIC-8 op amp soldered onto the Active Filter Section Board.

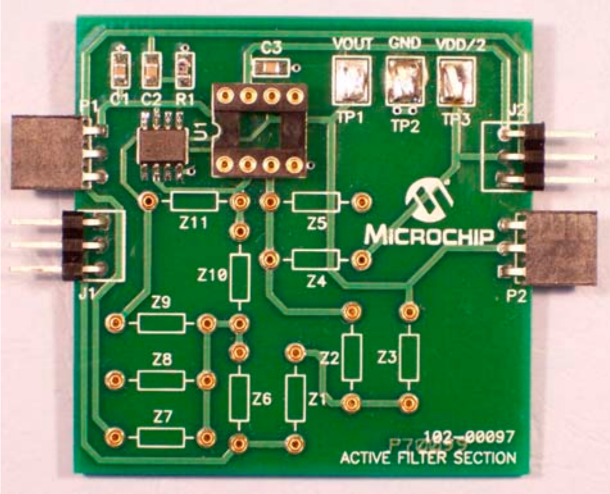
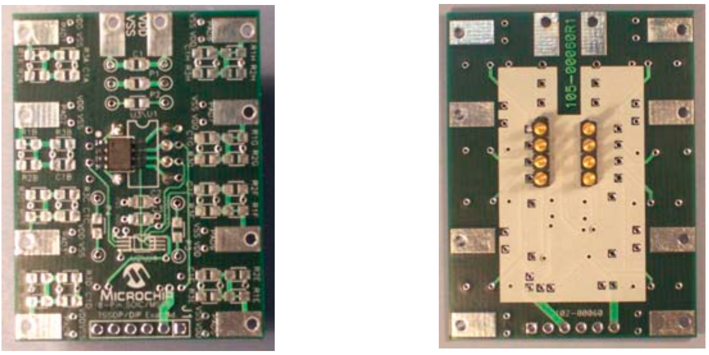


FIGURE 4-3: Op Amp in SOIC-8 package soldered onto Active Filter Section Board.

Figure 4-4 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 4-5 shows this board plugged into the Active Filter Section Board.

Note: Insert the interconnect strips into the DIP-8 socket on the $V_{DD}/2$ Filter Section or Active Filter Section board. 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.



(Front View) (Back View)

FIGURE 4-4: Op Amp in SOIC-8 package soldered to a separate board.

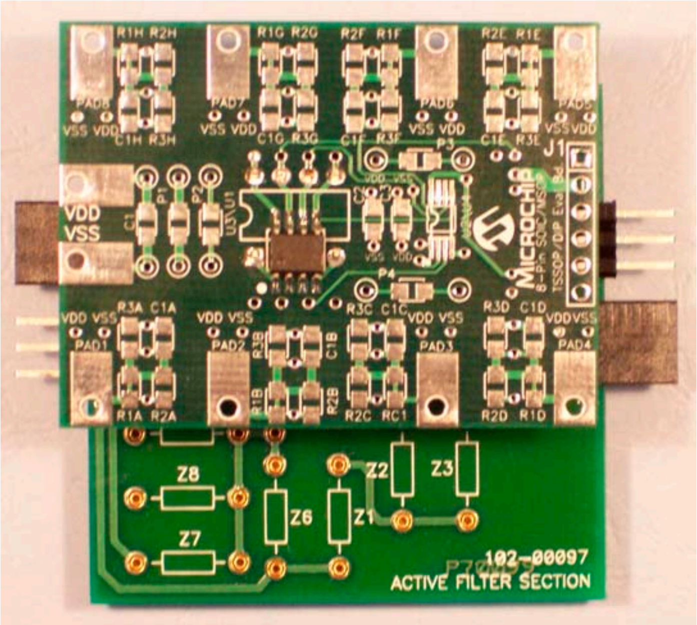

R1H R2H
PAD8
VSS VDD
C1H R3H
R1G R2G
PAD7
VSS VDD
C1G R3G
R2F R1F
C1F R3F
PAD6
VSS VDD
R2E R1E
C1E R3E
PAD5
VSS VDD
J1
VDD
VSS
C1
P1
P2
U1
P3
P4
MICROCHIP
8-Pin SOIC/MSOP/TSSOP/DIP Eval Bd
VDD VSS
PAD1
R3A C1A
R1A R2A
VDD VSS
PAD2
R3B
C1B
R1B
R2B
R3C C1C
R2C RC1
VDD VSS
PAD3
R3D C1D
R2D R1D
VDD VSS
PAD4
Z8
Z7
Z6
Z1
Z2
Z3
102-00097
ACTIVE FILTER SECTION

FIGURE 4-5: *Connecting Adaptor Board onto Active Filter Section.*

NOTES:

Appendix A. Schematics and Layouts

A.1 INTRODUCTION

This appendix contains the schematics and layouts for the different pieces of the Active Filter Demo Board Kit Sub-assemblies:

- $V_{DD}/2$ Filter Section (Sub-Assembly # : 102-00098R1)
- Active Filter Section (Sub-Assembly # : 102-00097R1)
- Accessory Bag (Sub-Assembly # : 110-00097R1)

A.2 $V_{DD}/2$ FILTER SECTION (SUB-ASSEMBLY #: 102-00098R1)

A.2.1 Circuit

See Figure A-1 for the $V_{DD}/2$ Filter Section circuit diagram. The input and output headers (J1, J2, P1, and P2) allow the PCBs to be cascaded as needed. The filter order will determine how many of the Active Filter Section boards need to be cascaded.

R1, R2, and C3 produce a $V_{DD}/2$ reference voltage. The op amp U1 buffers this reference voltage, and is set to unity gain. U1 must drive the impedances connected to it on all of the Active Filter Section. Op amp U1 is usually a single, PDIP-8 part inserted into the DIP-8 socket; it can be a SOIC-8 that is soldered to the board (see U1A in Figure A-1).

C1 and C2 are bypass capacitors for V_{DD}.

The demonstration board includes five test points for convenience on the bench. TP1 and TP2 make it possible to connect a function generator to the filter input; this signal is passed on to the other boards. TP3 through TP5 provide connections for external power supplies, which are also passed on to the other boards.

JP1 allows the user to choose the $V_{DD}/2$ reference voltage source:

- A lab supply (EXT = External $V_{DD}/2$ source)
- Op amp U1's output (INT = Internal $V_{DD}/2$ source)

See **Section B.1 "$V_{DD}/2$ Filter Section BOMs"** for the Bill of Material for this kit.

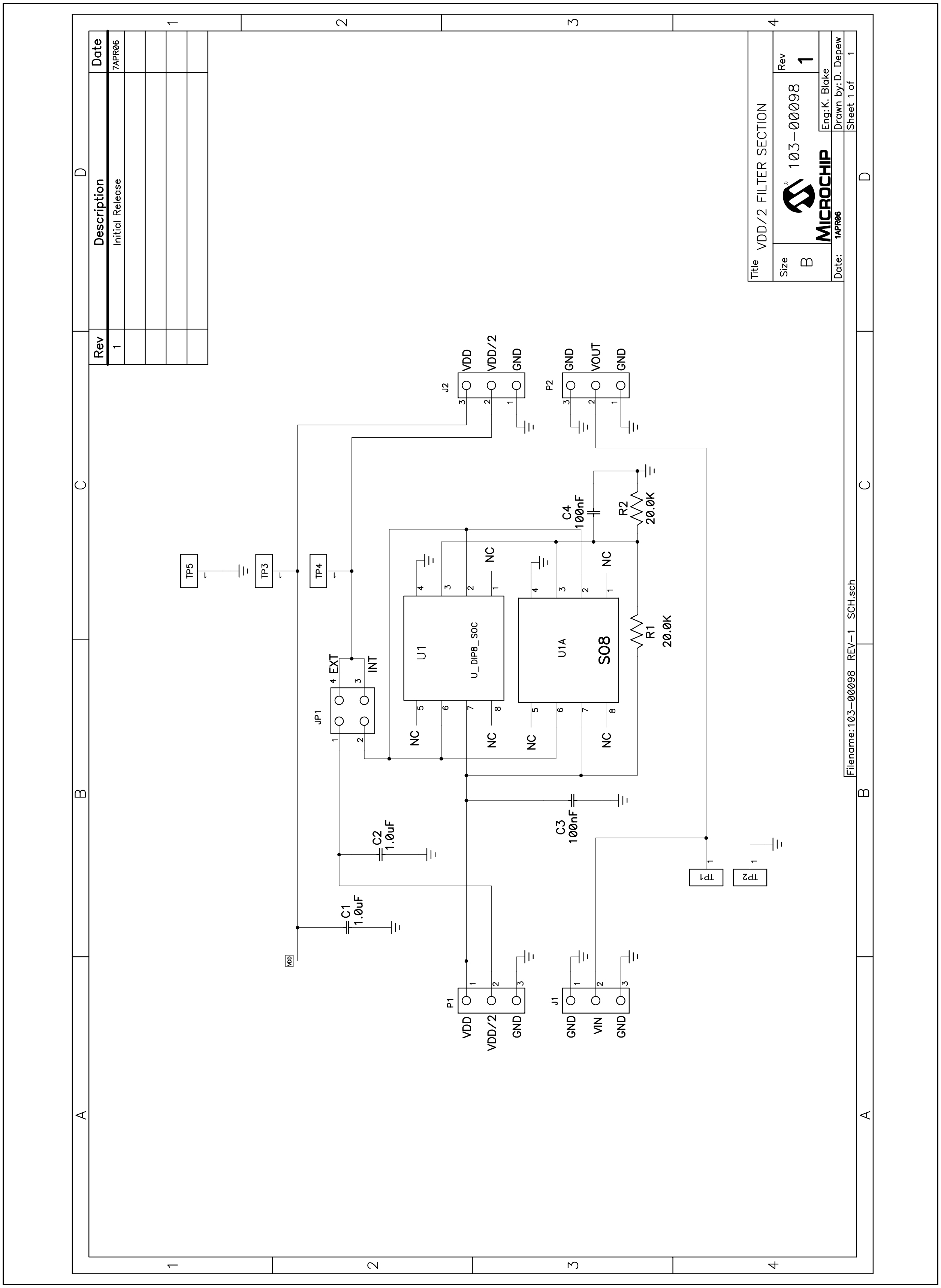

Rev
Description
Date
1
Initial Release
7APR06
Title VDD/2 FILTER SECTION
Size B
103-00098
Rev 1
MICROCHIP
Date: 1APR06
Eng: K. Blake
Drawn by: D. Depew
Sheet 1 of 1
Filename: 103-00098 REV-1 SCH.sch
J2
VDD
VDD/2
GND
P2
GND
VOUT
GND
C4 100nF
R2 20.0K
R1 20.0K
TP5
TP3
TP4
U1
U_DIP8_SOC
U1A
SO8
NC
JP1
EXT
INT
C3 100nF
C2 1.0uF
C1 1.0uF
TP1
TP2
VDD
P1
VDD
VDD/2
GND
J1
GND
VIN
GND
1
2
3
4
A
B
C
D

FIGURE A-1: V_{DD}/2 Filter Section – Schematic.

A.2.2 Board Plots

The Gerber files for this board are available on the Microchip website (www.microchip.com) and are contained in the zip file “`00098R1 Gerbers.zip`”.

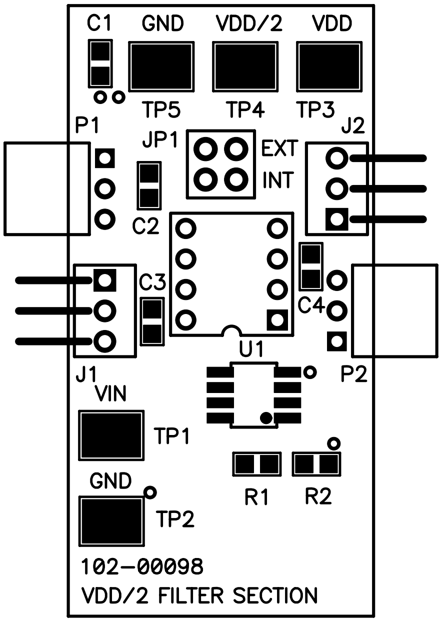

C1
GND
VDD/2
VDD
TP5
TP4
TP3
P1
JP1
J2
EXT
INT
C2
C3
C4
U1
J1
P2
VIN
TP1
GND
R1
R2
TP2
102-00098
VDD/2 FILTER SECTION

FIGURE A-2: *V_{DD}/2 Filter Section – Top Silk Screen.*

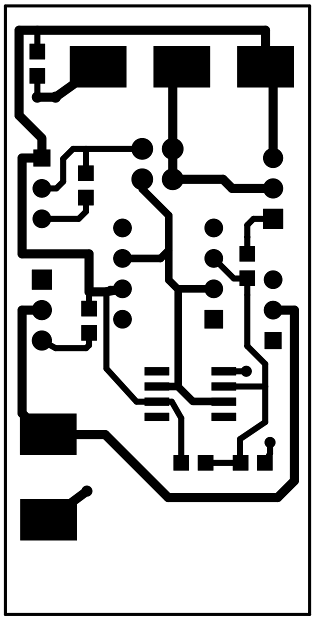


FIGURE A-3: *V_{DD}/2 Filter Section – Top Metal Layer.*

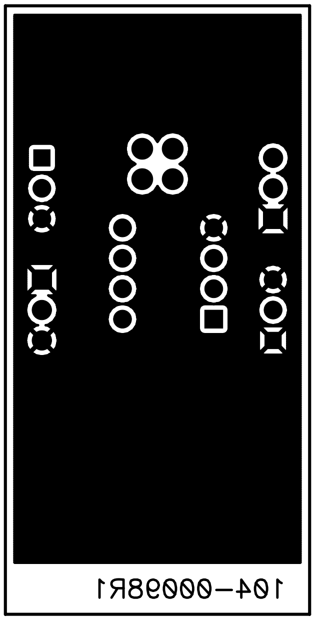


FIGURE A-4: V_{DD}/2 Filter Section – Bottom Metal Layer.

A.3 ACTIVE FILTER SECTION (SUB-ASSEMBLY #: 102-00097R1)

A.3.1 Circuit

See Figure A-5 for the V_{DD}/2 Filter Sections circuit diagram. The input and output headers (J1, J2, P1, and P2) allow the PCBs to be cascaded as needed. The filter order will determine how many of these boards need to be cascaded.

The impedances Z1 to Z11 are realized as resistors, capacitors, shorts or open circuits, depending on the section topology. These components are placed in pin sockets.

Op amp U1 interacts with the impedances Z1 to Z11 to form an active filter section (one or two pole). Op amp U1 is usually a single, PDIP-8 part inserted into the DIP-8 socket; it can be a SOIC-8 that is soldered to the board (see U1A in Figure A-5).

C1 and C3 are bypass capacitors for V_{DD}. C2 is a bypass capacitor for V_{DD}/2, and R1 is a snubber resistor that helps prevent capacitive loading problems for the op amp on the V_{DD}/2 Filter Section.

The demonstration board includes test points for convenience on the bench. TP1 through TP3 make it possible to measure the output voltage of each filter section.

See **Section B.1 "V_{DD}/2 Filter Section BOMs"** for the Bill of Material for this kit.

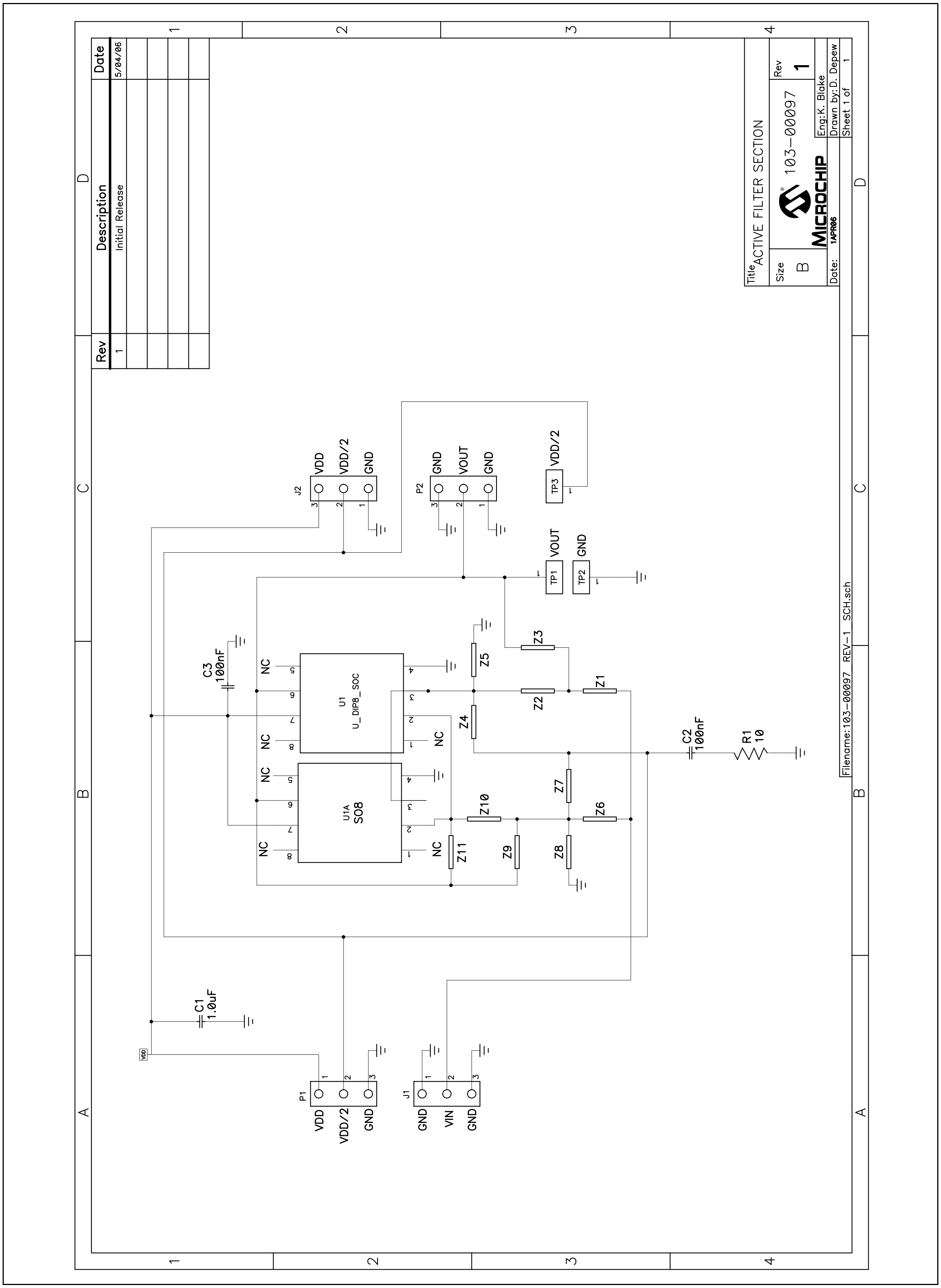

Rev
1
Description
Initial Release
Date
5/04/06
Title ACTIVE FILTER SECTION
Size
B
103-00097
Rev
1
MICROCHIP
Date: 1APR06
Eng: K. Blake
Drawn by: D. Depew
Sheet 1 of 1
Filename:103-00097 REV-1 SCH.sch
J2
VDD
VDD/2
GND
P2
GND
VOUT
GND
TP3
VDD/2
TP1
VOUT
TP2
GND
U1
U_DIP8_SOC
U1A
SO8
NC
C3
100nF
C2
100nF
R1
10
C1
1.0uF
Z1
Z2
Z3
Z4
Z5
Z6
Z7
Z8
Z9
Z10
Z11
VDD
P1
VDD
VDD/2
GND
J1
GND
VIN
GND
1
2
3
4
A
B
C
D

FIGURE A-5: *Active Filter Section – Schematic.*

A.3.2 Board Plots

The Gerber files for this board are available on the Microchip website (www.microchip.com) and are contained in the zip file “`00097R1 Gerbers.zip`”.

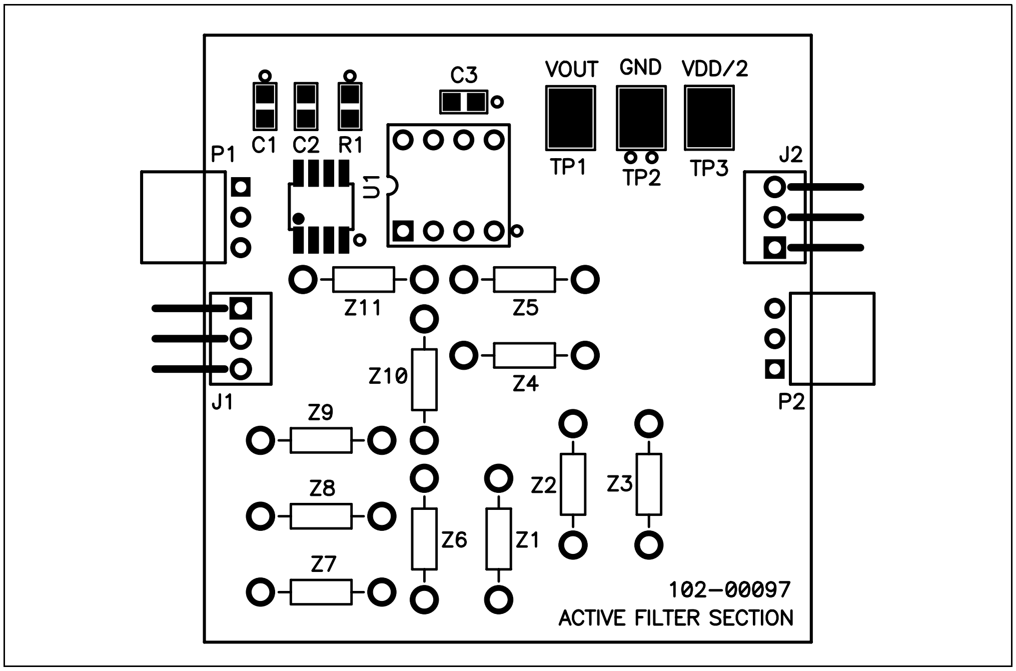

C3
VOUT
GND
VDD/2
C1
C2
R1
P1
U1
TP1
TP2
TP3
J2
Z11
Z5
Z10
Z4
J1
P2
Z9
Z8
Z2
Z3
Z6
Z1
Z7
102–00097
ACTIVE FILTER SECTION

FIGURE A-6: *Active Filter Section – Top Silk-Screen.*

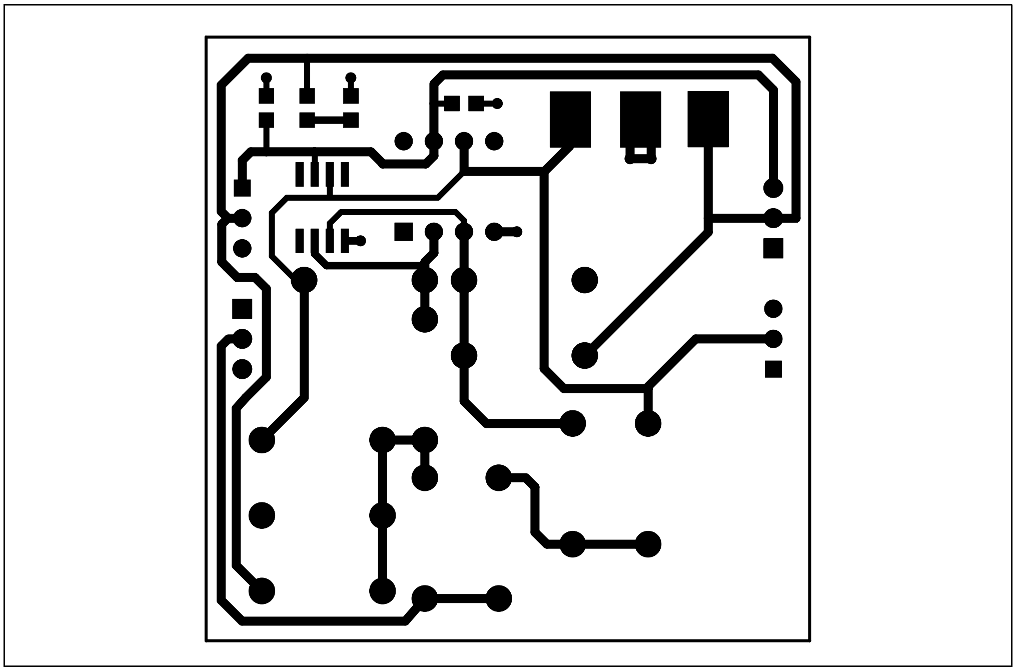


FIGURE A-7: *Active Filter Section – Top Metal Layer.*

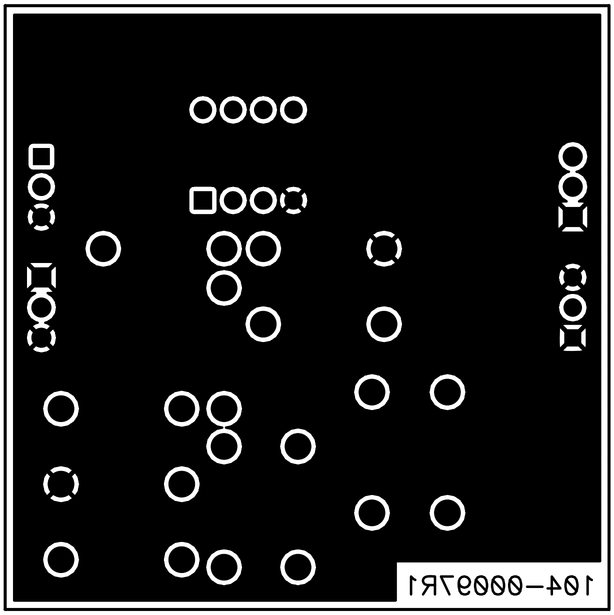


FIGURE A-8: Active Filter Section – Bottom Metal Layer.

A.4 ACCESSORY BAG (SUB-ASSEMBLY #: 110-00097R1)

See Figure 3-1 for the circuit diagram supported by this Accessory Bag. This filter is a Bessel low-pass with n = 5, f_C = 100 Hz, and Gain = 1 V/V. It uses single supply, Sallen-Key sections.

See **Section B.3 “Accessory Bag BOM”** for the Bill of Material for this filter. These components are placed in an ESD separate ESD bag. The Accessory Bag includes more MCP6271 op amps than needed for Figure 3-1; there are enough to populate all of the DIP-8 sockets in the Active Filter Demo Board Kit. These op amps are included in the accessory bag for ESD protection.

NOTES:

Appendix B. Bill Of Materials (BOM)

B.1 V_{DD}/2 FILTER SECTION BOMS

The BOM in Table B-1 corresponds to Figure 2-2. Unpopulated parts are in Table B-2.

TABLE B-1: BILL OF MATERIALS (102-00098R1)

Qty	Reference	Description	Manufacturer	Part Number
2	C_3, C_4	100 nF, 50V, 10%, X7R, 0805 SMD, Ceramic	Kemet® Electronics	C0805C104K5RACTU
2	C_1, C_2	1.0 µF, 16V, 10%, X7R, 0805 SMD, Ceramic	Kemet Electronics	C0805C105K4RACTU
1	JP_1	Header, 2 × 2, 0.100" Pitch, Vertical, Gold	Amp®/Tyco® Electronics	87227-2
1	(for JP_1)	Shunt, 1 × 2, With Handle, Gold	AMP/Tyco Electronics	881545-2
1	J_2	Header, Male, 1 × 3, 0.100", R/A, Tin	AMP/Tyco Electronics	640453-3
1	P_2	Header, Female, 1 × 3, 0.100", R/A, Tin	Mill-Max®	801-44-003-20-001000
2	R_1, R_2	20.0 kΩ, 1/8W, 1%, 0805 SMD	Yageo® America	RC0805FR-0720KL
5	TP_1 – TP_5	PC Test Point, Compact, Surface Mount	Keystone Electronics	5016
1	(for U_1)	IC Socket, 8-pin DIP, Tin, 0.300"	AMP/Tyco Electronics	2-641260-1
1	PCB	RoHS Compliant Bare PCB, V_{DD}/2 Filter Section (1.0 in × 2.0 in)	—	104-00098R1

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.

TABLE B-2: BILL OF MATERIALS – UNPOPULATED PARTS (102-00098R1)

Reference	Description	Manufacturer	Part Number
J_1	Header, Male, 1 × 3, 0.100", R/A, Tin **(Note 1)**	AMP/Tyco Electronics	640453-3
P_1	Header, Female, 1 × 3, 0.100", R/A, Tin **(Note 1)**	Mill-Max®	801-44-003-20-001000
U_1	MCP6271, Single Op Amp, 2 MHz, PDIP-8 **(Note 2)**	Microchip Technology Inc	MCP6271-E/P
	SOIC-8 **(Note 3)**	Microchip Technology Inc	MCP6271-E/SN

Note 1: These parts are supplied by the user, if desired.

2: This op amp is supplied by Microchip; it is found in the Accessory Bag described in Table B-5. Any other op amp is supplied by the user.

3: Op amps in SOIC-8 package are supplied by the user, if desired. See **"4.6 "Using 8-Pin SOIC Op Amps"** for information on using op amps in these packages (150 mil wide).

B.2 ACTIVE FILTER SECTION BOM

The BOM in Table B-3 corresponds to the circuit in Figure 2-4, which is repeated four times. Unpopulated parts are in Table B-4.

TABLE B-3: BILL OF MATERIALS (102-00097R1) (NOTE 3)

Qty (Note 1)	Reference	Description	Manufacturer	Part Number
8	C_2, C_3	100 nF, 50V, 10%, X7R, 0805 SMD, Ceramic	Kemet Electronics	C0805C104K5RACTU
4	C_1	1.0 µF, 16V, 10%, X7R, 0805 SMD, Ceramic	Kemet Electronics	C0805C105K4RACTU
8	J_1, J_2	Header, Male, 1 × 3, 0.100", R/A, Tin	AMP/Tyco Electronics	640453-3
8	P_1, P_2	Header, Female, 1 × 3, 0.100", R/A, Tin	Mill-Max®	801-44-003-20-001000
4	R_1	10.0Ω, 1/8W, 1%, 0805 SMD	Yageo America	RC0805FR-0710RL
12	TP_1 – TP_3	PC Test Point, Compact, Surface Mount	Keystone Electronics	5016
4	(for U_1)	IC Socket, 8-pin DIP, Tin, 0.300"	AMP/Tyco-Electronics	2-641260-1
88	(for Z_1 to Z_{11})	Pin Recepticle, 0.015” to 0.025” dia., 0.057” hole dia.	Mill-Max® **(Note 2)**	0252-0-15-15-30-27-10-0
4	PCB	RoHS Compliant Bare PCB, Active Filter Section (2.0 in × 2.0 in)	—	104-00097R1

Note 1: The quantities per board all have been multiplied by 4 because there are four Active Filter Section PCB’s (sub-assembly) in the Active Filter Demo Board Kit (assembly).

2: This part is also found at Digi-Key (ED90069-ND).

3: 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.

TABLE B-4: BILL OF MATERIALS – UNPOPULATED PARTS (102-00097R1)

Reference	Description	Manufacturer	Part Number
U_1	MCP6271, Single Op Amp, 2 MHz, PDIP-8 **(Note 1)**	Microchip Technology Inc	MCP6271-E/P
	SOIC-8 **(Note 2)**	Microchip Technology Inc	MCP6271-E/SN
Z_1 – Z_{11}	Impedances (resistors and capacitors) **(Note 3)**	—	—

Note 1: These op amps are supplied by Microchip; they are found in the Accessory Bag described in Table B-5. Other op amps are supplied by the user.

2: Op amps in SOIC-8 package are supplied by the user, if desired. See **”4.6 “Using 8-Pin SOIC Op Amps”** for information on using op amps in these packages (150 mil wide).

3: The resistors and capacitors represented by Z_1 to Z_{11} are provided by the customer. Not all of these will be populated for any given filter. The Accessory Bag described in Table B-5 includes 10 jumpers that can be used to configure different filter circuits.

B.3 ACCESSORY BAG BOM

The BOM in Table B-5 corresponds to the collection of resistors, capacitors, and MCP6271 op amps that comes in the Accessory Bag which is shipped in the Active Filter Demo Board Kit. It includes enough op amps and jumpers to support any reasonable filter design. It also supports the circuit in **"Chapter 3. "Building the Filter Supplied in the Kit"**. Other filters may need tighter tolerance resistors and capacitors (i.e., 1% or 2%). The customer provides the resistors and capacitors for any other filter circuit.

TABLE B-5: BILL OF MATERIALS (110-00097R1)

Qty	Reference	Description	Manufacturer	Part Number
3	C11, C22, C32	100 nF, 50V, 5%, Radial, Polyester Film	Panasonic	ECQ-B1H104JF
1	C31	150 nF, 50V, 5%, Radial, Polyester Film	Panasonic	ECQ-B1H154JF
1	C21	390 nF, 50V, 5%, Radial, Polyester Film	Panasonic	ECQ-B1H394JF
10	—	Jumper Wire, 0Ω, Axial 1/8W Resistor" **(Note 1)**	Yageo America	ZOR-12-B-52
1	R21	3.16 kΩ, 1/4W, 1%, Axial, Metal Film	Yageo America	MFR-25FBF-3K16
1	R31	5.62 kΩ, 1/4W, 1%, Axial, Metal Film	Yageo America	MFR-25FBF-5K62
1	R22	6.81 kΩ, 1/4W, 1%, Axial, Metal Film	Yageo America	MFR-25FBF-6K81
1	R11	10.7 kΩ, 1/4W, 1%, Axial, Metal Film	Yageo America	MFR-25FBF-10K7
1	R32	12.7 kΩ, 1/4W, 1%, Axial, Metal Film	Yageo America	MFR-25FBF-12K7
5	U_1	MCP6271, Single Op Amp, 2 MHz, PDIP-8 **(Note 2)**	Microchip Technology Inc	MCP6271-E/P

Note 1: Four of these "resistors" (jumpers) are used for shorting the feedback resistors (Z_1 on 3 PCBs), and for shorting Z_{11} on the SK-LP1 stage (see Table 3-1), for the filter in **"Chapter 3. "Building the Filter Supplied in the Kit"**. A total of ten is included because this is the maximum that might be needed for any FilterLab design, plus two spares.

2: These five op amps are placed in ESD protective "clam shells," which are then put into an ESD protective bag with the resistors and capacitors.

MICROCHIP

WORLDWIDE SALES AND SERVICE

AMERICAS

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

Asia Pacific Office
Suites 3707-14, 37th Floor
Tower 6, The Gateway
Habour City, Kowloon
Hong Kong
Tel: 852-2401-1200
Fax: 852-2401-3431

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

Boston
Westborough, MA
Tel: 774-760-0087
Fax: 774-760-0088

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

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

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

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

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

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

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

ASIA/PACIFIC

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

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

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

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

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

China - Qingdao
Tel: 86-532-8502-7355
Fax: 86-532-8502-7205

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

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

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

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

China - Wuhan
Tel: 86-27-5980-5300
Fax: 86-27-5980-5118

China - Xian
Tel: 86-29-8833-7250
Fax: 86-29-8833-7256

ASIA/PACIFIC

India - Bangalore
Tel: 91-80-4182-8400
Fax: 91-80-4182-8422

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

India - Pune
Tel: 91-20-2566-1512
Fax: 91-20-2566-1513

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

Korea - Gumi
Tel: 82-54-473-4301
Fax: 82-54-473-4302

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

Malaysia - Penang
Tel: 60-4-646-8870
Fax: 60-4-646-5086

Philippines - Manila
Tel: 63-2-634-9065
Fax: 63-2-634-9069

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

Taiwan - Hsin Chu
Tel: 886-3-572-9526
Fax: 886-3-572-6459

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

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

Thailand - Bangkok
Tel: 66-2-694-1351
Fax: 66-2-694-1350

EUROPE

Austria - Wels
Tel: 43-7242-2244-3910
Fax: 43-7242-2244-393

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

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

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

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

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

Spain - Madrid
Tel: 34-91-708-08-90
Fax: 34-91-708-08-91

UK - Wokingham
Tel: 44-118-921-5869
Fax: 44-118-921-5820

06/08/06