

Schmartboard Active Filter Board

Part # 710-0013-01

The Active filter Board is configured as a two pole active filter followed by a third passive pole if desired. The op amp circuitry forms the two pole filter while the RC network at the output of the operational amplifier forms the third passive pole.

The general filter type is MFB, or multi-feedback, allowing relatively easy implementation of active filters.

Applications for the Active Filter Board include being used as an anti-aliasing filter for A/D conversion or as a reconstruction filter after D/A conversion.

Component values for Butterworth, Bessel, and 3-dB Chebyshev type low pass filters are shown along with how to easily calculate new corner frequency values. Using this information it is easy to make active anti-aliasing and reconstruction filters.

The operational amplifier used for this board is the Texas Instrument's OPA172 whose main features make it very suitable for experimenting.

These features are,

- Wide Supply Range: +4.5 V to +36 V, ± 2.25 V to ± 18 V
- Low Offset Voltage: ± 0.2 mV
- Gain Bandwidth: 10 MHz
- Input Range Includes the Negative Supply
- Input Range Operates to Positive Supply
- Rail-to-Rail Output
- Low Noise: 7 nV/VHz
- High Common-Mode Rejection: 120 dB
- Low Input Bias Current: ± 8 pA
- Low Quiescent Current: 1.6mA per Amplifier

The OPAMP Board can be operated with single or dual power supplies and the 10MHz bandwidth makes is sufficient for most experimenter's circuits.

The applications in this app note all use ± 12 V power supplies but other voltages could be used as long as they are sufficiently high so as to not clip the output signal.

The OPA172 data sheet can be downloaded from the SchmartBOARD website.

In the examples, R1 is used to balance the voltage drop across the resistors connected to the positive input of the op-amp with the voltage drop across the resistors connected to the negative input to the op-amp. The OPA172 input bias currents are relatively low so any imbalance between the voltage drops

at the negative and positive inputs are minimal. A different resistor, a zero ohm resistor, or a wire could be instead of a resistor without much output offset error due to this imbalance.

Resources for designing MFB active filters

There are multiple resources for designing MFB active filters.

Following are a few.

A Beginner's Guide to Filter Topologies from Maxim Integrated at

www.maximintegrated.com/en/app-notes/index.mvp/id/1762

Active Low-Pass Filter Design from Texas Instruments at

www.ti.com/lit/an/sloa049b/sloa049b.pdf

FilterPro™ active filter design tool from Texas Instruments at

www.ti.com/analog/docs/litabsmultiplefilelist.tsp?literatureNumber=sbfa001c&docCategoryId=1&familyId=57

Circuit Simulation using LTspiceIV

The example presented in this app note is a Bessell type filter. There are LTspiceIV simulation files on the SchmartBOARD website. These use LTspiceIV which can be downloaded for free from the Linear Technology website. The following describe the setup necessary to run these files.

There are two types of simulation used in this app note.

- 1) Transient analysis.

This calculates the circuit response to various transient waveforms such as a pulse, pulses, square waves, triangle waves etc. The output is similar to what would be seen when observing the various points in the circuit when using an oscilloscope.

- 2) Frequency analysis.

This calculates the general frequency response of the circuit. The output is a BODE plot as would be seen when using a spectrum analyzer. It shows the gain and phase response to a swept frequency sine wave input.

Due to a limitation of the OPA172.LIB circuit description, two different models used for these simulations.

- 1) OPA172.LIB

The OPA172.LIB model is used for transient simulations. When using this model, the transient simulation results fit actual real world transient results of the OPA172. Its limitation is that it

does not work correctly for AC analysis. It will seem to do AC simulations but the results are not correct

2) LTspiceIV's internal UniversalOpamp2.asy.

After modifying some parameters of this model, the AC simulations will be very close to what would be measured using an actual spectrum analyzer.

It can be used for transient simulations but it will not show non-ideal real world responses of the OPA172 such as overshoot when a fast rise and/or fall time transient signal is applied.

Installing and Running LTspiceIV

First download the LTspiceIV from <http://www.linear.com/solutions/ltspice>

Install LTspiceIV by double clicking on the downloaded .exe file

Once it is installed, it will ask if you want to update it. Answer Yes.

Download OPA172.LIB from the SchmartBOARD website.

Put OPA172.LIB file in the C:\Program Files (x86)\LTC\LTspiceIV\lib\sub directory.

The simulation files included with this app note can then be run either by opening the .asc simulation file or by opening it from within LTspice.

Once the simulation file is opened, select **Run** in the **Simulate** menu.

After the simulation is finished, an oscilloscope looking screen will pop up if a transient analysis is run or a spectrum analyzer type window will open if it is an AC analysis is run. In either case, click the cursor on the point in the circuit that you want to see. That waveform results at that point in the circuit will show up in the appropriate window.

There will be one or two type of simulation files for each application. For transient simulation, the last four characters in the filename will be TRAN and for AC simulation the last two characters in the filename will be AC.

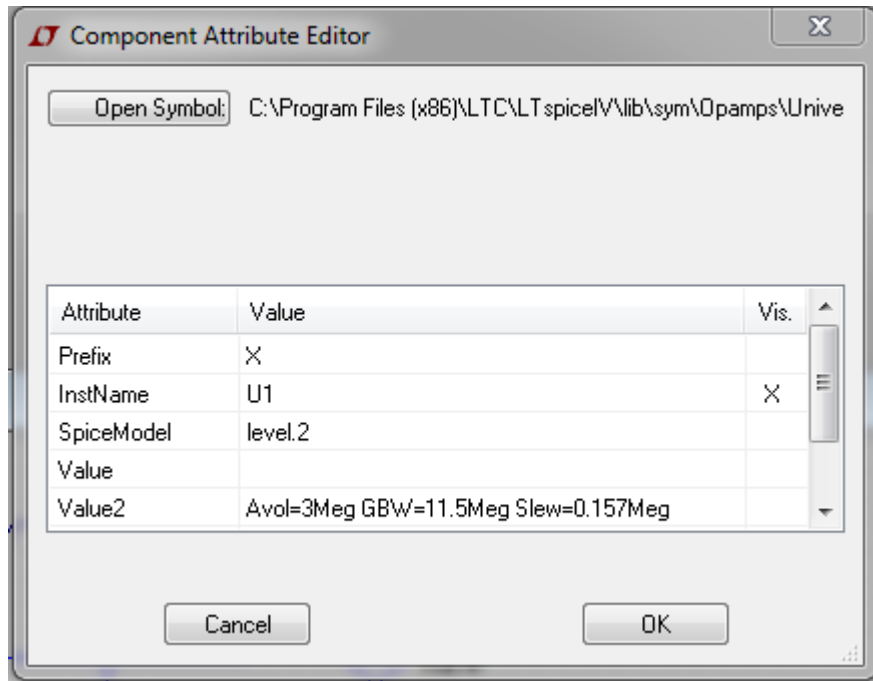
For example,

MFB_Bessel_1KHz_LowPassTRAN.asc is a simulation file for a transient simulation,

MFB_Bessel_1KHz_LowPassAC.asc is a simulation file for AC analysis.

The appropriate model is already included in the files for this app note. If you are generating your own AC analysis circuits using the OPA172 the UniversalOpamp2.asy parameters must be changed. These parameters have been changed for the files used here.

The parameters that should be changed when generating your own AC simulation circuits are,



The line,
Avol=1Meg GBW=10Meg Slew=10Meg should be changed to,
Avol=3Meg GBW=11.5Meg Slew=0.157Meg.
These can be accessed by double clicking on the on the op amp symbol.

Example of MFB Low Pass Filter Application

The following are derived from page 7 and page 11 of sloa049b.pdf from Texas Instruments.

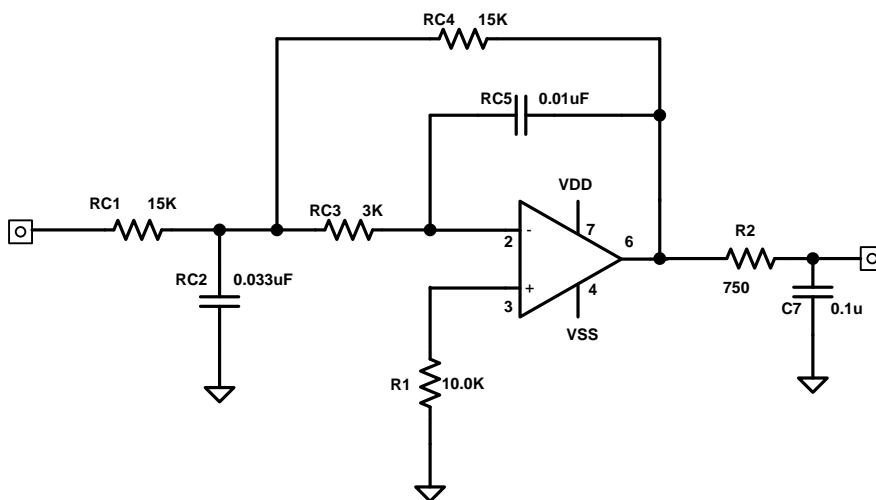


Figure 1, 1KHz Bessel Type Low Pass Filter with third pole at op-amp output

MFB LowPass Filter

Filter Type	RC5	RC2	RC1 & RC4	RC3
Butterworth	0.01 uF	0.047 uF	15.4K	3.48K
Bessel	0.01 uF	0.033 uF	15.4K	3.01K
3-dB Chebyshev	0.01 uF	0.15 uF	9.53K	2.55K

Table 1. Component Values for Low Pass Filters

The -3dB corner frequency, f_0 , of these low pass filters are set for approximately 1KHz. The corner frequency can easily be changed by using the ratio of,

$$\text{CapacitorValues} \times \frac{f_0}{f_{new}}$$

where f_{new} is the desired -3dB corner frequency,

CapacitorValues are the values of all the capacitors in the filter circuit.

For example, if a corner frequency of 100Hz is desired for the filter in figure 1,

$$RC2 = .033\mu\text{F} \times \frac{1\text{KHz}}{100\text{Hz}} = 0.33\mu\text{F}, RC5 = .01\mu\text{F} \times \frac{1\text{KHz}}{100\text{Hz}} = 0.1\mu\text{F}, C7 = .1\mu\text{F} \times \frac{1\text{KHz}}{100\text{Hz}} = 1.0\mu\text{F}$$

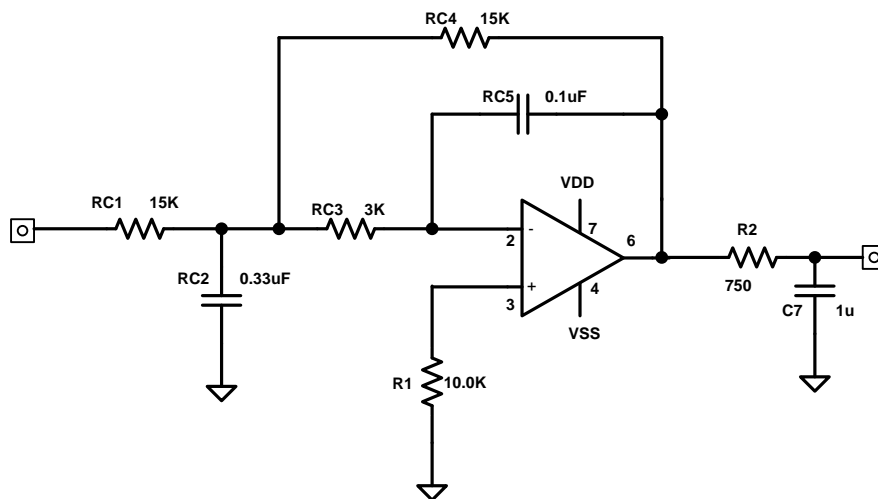
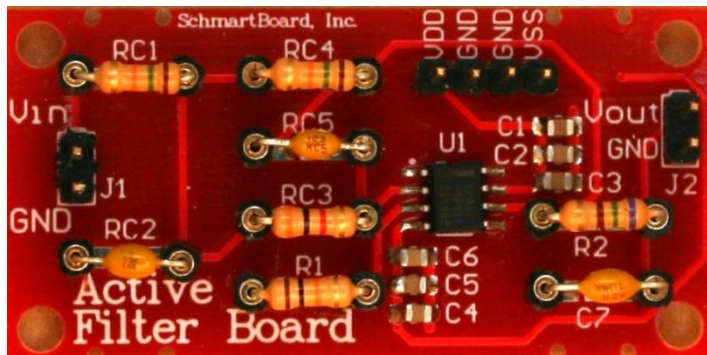


Figure 2, 100Hz Bessel Type Low Pass Filter with third pole at op-amp output

SPICE simulation files for 1KHz Bessel type filter from figure 1,
MFB_Bessel_1KHz_LowPassAC.asc
MFB_Bessel_1KHz_LowPassTRAN.asc

SPICE simulation files for 100Hz Bessel type filter in figure 2,
MFB_Bessel_100Hz_LowPassAC.asc
MFB_Bessel_100Hz_LowPassTRAN.asc

If there are problems running TRAN simulations, verify the OPA172.LIB file is in the C:\Program Files (x86)\LTC\LTspiceIV\lib\sub directory.



1KHz Active Filter Board with components.



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