



EENG 385 - Electronic Devices and Circuits
Frequency Domain: Active Filters
Lab Handout

Outcome and Objectives

The outcome of this lab is to design, implement and analyze a variety of filters on the audio board. Through this process you will achieve the following learning objectives:

- Analyze and design a circuit containing resistors and op amps.
- Analyze and design a circuit consisting of several building blocks.
- Use a Bode plot to predict circuit behavior.
- Produce a Bode plot for a circuit using a simulator and test and measurement equipment.
- Use a software tool to design electronic circuits.
- Assemble a circuit on a PCB using the equipment in the laboratory.
- Use laboratory test and measurement equipment to analyze electronic circuits.

Filter Background

An ideal filter allows a range of frequencies to pass through the filter unchanged in amplitude and phase. This range of frequencies is called the passband. Frequencies outside the passband cannot pass through the filter. Thus, a filter is an electronic device whose output depends on the frequency of the input signal.

In the real world, ideal filters do not exist. Instead, real filters reduce, but do not eliminate, signals outside the passband. The reduction of a signal's amplitude from input to output is called attenuation and is measured in units of decibels.

- A positive decibel value means the amplitude of the output is larger than the input.
- A decibel value of 0 means the output has the same amplitude as the input.
- Negative decibels means that the amplitude of the output is smaller than the input.

The goal of this lab is to design, simulate, assemble and test filters three filters and level-shifter shown in Figure 1 to achieve specific performance goals measured in decibels.

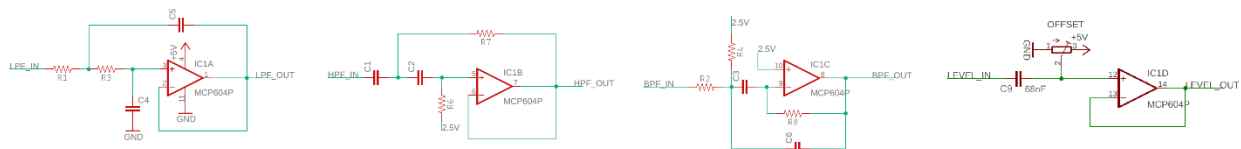


Figure 1: The Audio board comes setup with three filters. From left to right, low pass, high pass, band pass, and level-shifter. Your task in this lab is to select component value to achieve specific performance goals.

Audio Board Interface

In order to experiment with the filters on the Audio Board, you need access to their inputs and outputs. This is done through the 8 header pins shown in Figure 2. The inputs to the four circuits in Figure 1 are available on the four header pins adjacent to the white text “INPUT” in Figure 2. Not surprisingly, the outputs from the four circuits in Figure 1 are available on the four header pins adjacent to the white text “OUTPUT” in Figure 2.

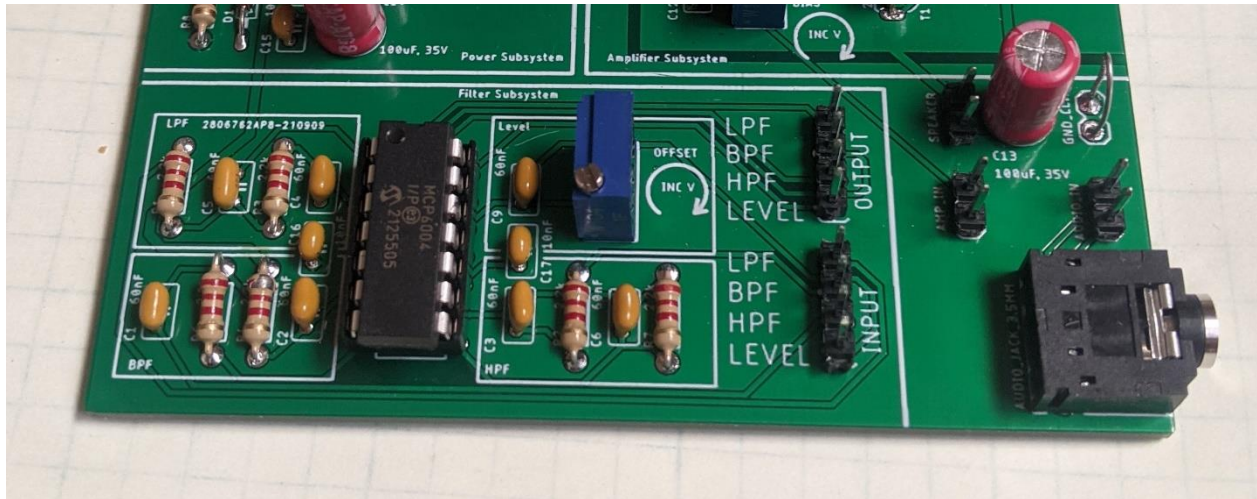


Figure 2: The Audio board interface consists of the headers shown here. The headers labeled INPUT and OUTPUT are connected to the inputs and outputs of the circuits shown in Figure 1. Take a moment to make sense of this.

On the right side of the audio board shown in Figure 2 is a collection of three 2-pin headers and a 3.5mm stereo audio jack. The left and right channels of the audio jack are each sent to one of the two pins of the header labeled AUDIO_IN. You can send signals into the audio amplifier using either of the 2-pin labeled AMP_IN. An external speaker is connected across the 2-pin header labeled SPEAKER.

This layout allows a high degree of flexibility with the circuit configurations. For example, you can use some jumper wires to connect the level-shifter, in series, to the low pass filter as shown in Figure 3.

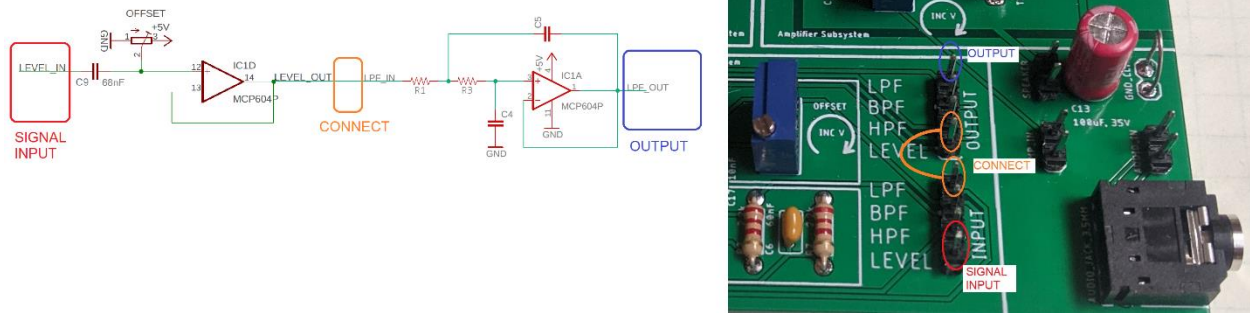


Figure 3: (left) A series arrangement of level shifter and low pass filter. (right) The connections that you would need to make this circuit on the audio board. Note the red, orange, blue colors in the left and right images are correlated.

Going even further with the example in Figure 3:

- How could you connect a signal coming in from the 3.5mm audio jack (either channel) to the input of the level shifter?
- How could you connect the output of the LPF to the input of the audio amplifier?

With this information, you are ready to go. To complete this lab, use the How To documents posted on our class Canvas page. I'd suggest completing the work in the order listed in the **Turn In** section.

Turn in:

Make a record of your response to numbered items below and turn them in a single copy as your team's solution on Canvas using the instructions posted there. Include the names of both team members at the top of your solutions. Use complete English sentences to introduce what each of the following listed items (below) is and how it was derived.

The Level Shifter

Since we will be using the level-shifter as a front-end for FRA of the three filters, we need to make sure that it does not introduce any unwanted attenuation of the input signal. Do this by measuring the frequency response of the level-shifter using the oscilloscopes.

Complete the following:

- **Construct your level shifter filter on your Audio board**
 - **Instructions in:** *freqDomain howTo04 ConstructFilter*
- **Make a Bode plot of your level shifter**
 - **Instructions in:** *freqDomain howTo00 LevelShifter.pdf*
 - **Instructions in:** *freqDomain howTo06 Measure FreqSweep.pdf*

Design a Low Pass Filter:

Design a low pass filter with the following requirements using the instructions in *freqDomain howTo01 DesignFilter.pdf*

Requirements:

Passband:

- * Gain 0dB
- * dB at Hz -3dB @ 220Hz

Stopband:

* dB at Hz -40dB @ 2.2kHz

Filter response: Set passband ripple to 1dB

Use: +Vs=5V -Vs=0V

Use: E6 resistor and capacitors with 5% tolerances

Complete the following:

- **Simulation Bode Plot – Point by Point**
 - **Instructions in:** *freqDomain howTo02 Simulate PointByPoint.pdf*
- **Simulation Bode Plot – Frequency Sweep**
 - **Instructions in:** *freqDomain howTo03 Simulate FreqSweep.pdf*
- **Construct your low pass filter on your Audio board**
 - **Instructions in:** *freqDomain howTo04 ConstructFilter*
- **Circuit Bode Plot – Point by Point**
 - **Instructions in:** *freqDomain howTo05 Measure PointByPoint.pdf*
- **Circuit Bode Plot – Frequency Sweep using FRA**
 - **Instructions in:** *freqDomain howTo06 Measure FreqSweep.pdf*

Design a High Pass Filter:

Design a high filter with the following requirements. Use the Analog Design Wizard to determine the component values.

Requirements:

Passband:

* Gain 0dB

* dB at Hz -3dB @ 880Hz

Stopband:

* dB at Hz -40dB @ 88Hz

Filter response: Set passband ripple to 2dB

Use: +Vs=5V -Vs=0V

Use: E6 resistor and capacitors with 5% tolerances

Ignore the mid-supply voltage reference circuit suggested by the Filter Wizard. Our PCB circuit uses the 2.5V Zener as the REF signal.

Complete the following:

- **Simulation Bode Plot – Frequency Sweep**
 - **Instructions in:** *freqDomain howTo03 Simulate FreqSweep.pdf*
- **Construct you high pass filter on your Audio board**
 - **Instructions in:** *freqDomain howTo04 ConstructFilter*
- **Circuit Bode Plot – Frequency Sweep using FRA**
 - **Instructions in:** *freqDomain howTo06 Measure FreqSweep.pdf*

Design a Band Pass Filter:

Design a band pass filter with the following requirements. Use the Analog Design Wizard to determine the component values.

Requirements:

Passband:

Frequency Domain: Theory and Practice of Filter Design

* Gain 0dB
* dB at Hz -3dB @ 200Hz
Stopband:
* dB at Hz -20dB @ 2kHz
Center Frequency: 440Hz
Filter response: 2nd order Butterworth
Use: +Vs=5V -Vs=0V
Use: E6 resistor and capacitors with 5% tolerances
Ignore the mid-supply voltage reference circuit suggested by the Filter Wizard. Our PCB circuit uses the 2.5V Zener as the REF signal.

Complete the following:

- **Simulation Bode Plot – Frequency Sweep**
 - **Instructions in:** *freqDomain howTo03 Simulate FreqSweep.pdf*
- **Construct you band pass filter on your Audio board**
 - **Instructions in:** *freqDomain howTo04 ConstructFilter*
- **Circuit Bode Plot – Frequency Sweep using FRA**
 - **Instructions in:** *freqDomain howTo06 Measure FreqSweep.pdf*

Demo:

- Connect an audio source into the audio jack (Husker Scope).
- Use jumper wire to connect the LEFT audio header pin to the LEVEL input header pin.
- Use jumper wire to connect the LEVEL output header pin to the LPF input header pin.
- Use jumper wire to connect the LPF output header pin to the AMPIN input header pin.
- Connect a speaker to the SPEAKER+ and SPEAKER- pins.
- Adjust the signal frequency to hear the audio output produced. Note the frequency where the volume starts to drop off – this should correspond to the corner frequency of the LPF filter.
- Try replacing the LPF with the BPF and HPF to hear the effect produced and note the frequency where the volume starts to change.