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ECEN 457 Section 503

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Due date: 17 October 2025

Lab 3: Active Filter Synthesis, designing a Simple Graphic Equalizer Filter

Overview:

The objective of the lab is to create an equalizer and reinforce all the techniques that have been taught throughout the semester.

Equalization is the process of adjusting the balance between frequency components within an electronic signal. Equalizers are used in many different applications, audio systems being the most commonly known. Where the main purpose of the equalizer is to adjust the output sound to the desire of the user. The simplest type of equalizer to construct is the graphic equalizer, which consists of a bank of filters with different bandwidths, with each filter's gain adjustable by a control knob. The output of the equalizer is generated by combining each of the filter's outputs, essentially adjusting the magnitude of the different frequency components of its input according to the equalizer configuration. Graphic equalizers for audio can have between 5 to 30 or more different frequency bands depending on the application. Fig. 1 depicts a simple example of Graphic Equalizer which uses two BPF in parallel and adds the individual outputs to generate a single output.

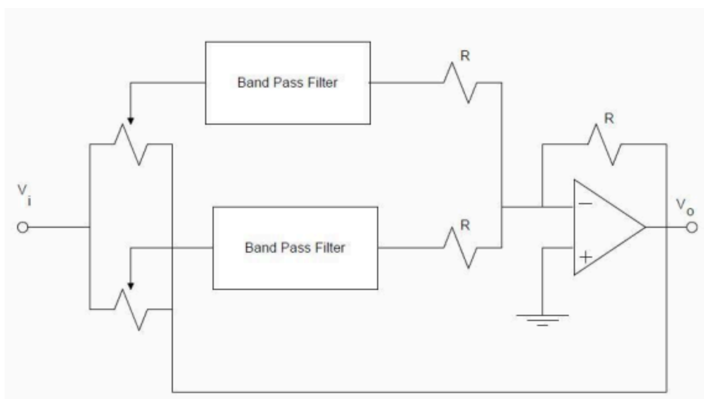
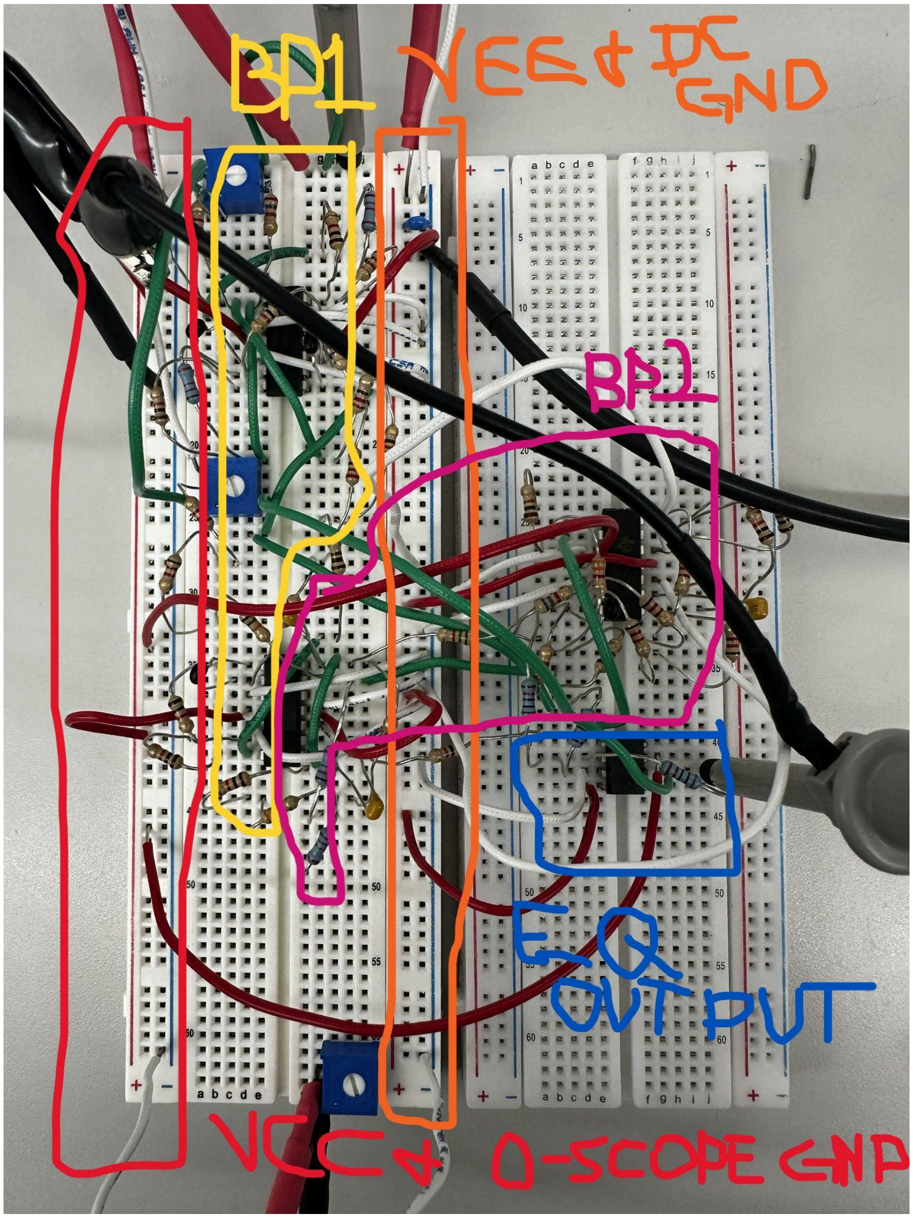


Fig. 1 – Simple Graphic Equalizer circuit

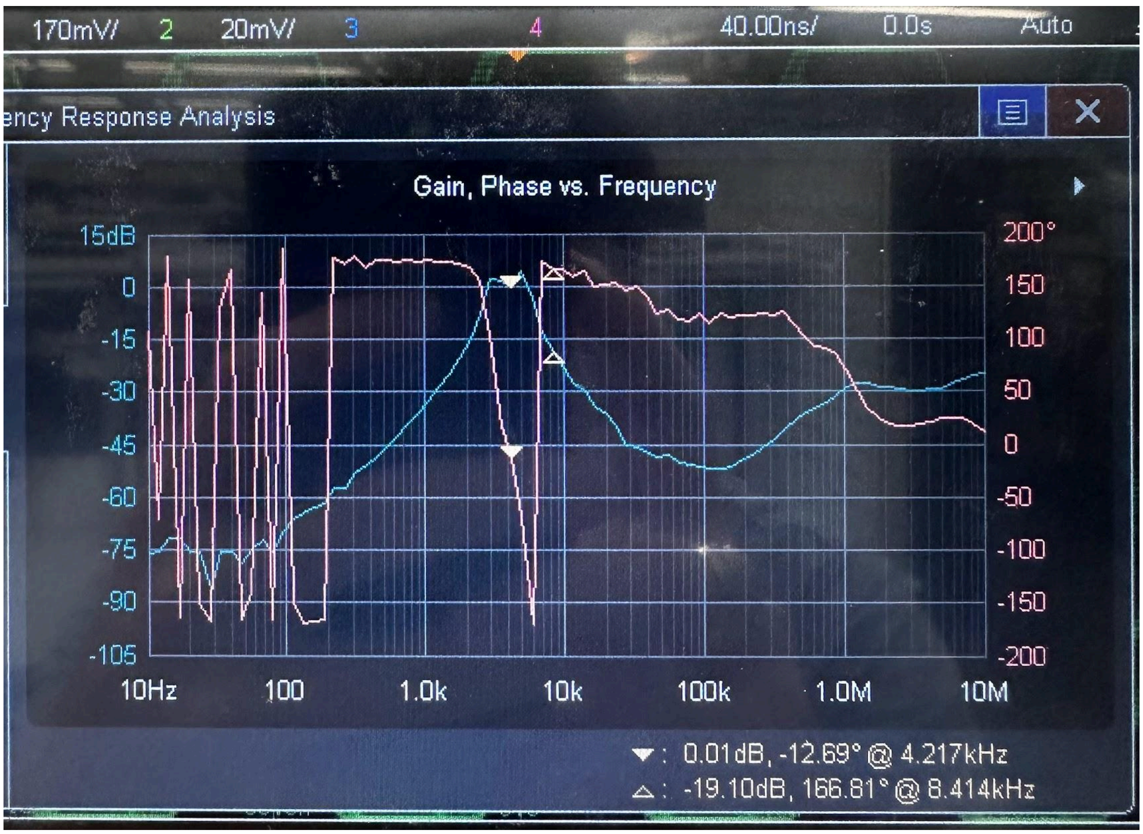
Procedure:

I started the lab by implementing each Biquad filter on two breadboards and obtained their frequency response using an AC analysis with the oscilloscope. Below is a picture of the breadboard implementation.



Since this circuit has multiple stages and each filter is a 4th order filter, it was especially important to ensure I was grounding correctly and to use decoupling capacitors to reduce as much noise as possible. The red section is where I connected V_{CC} (+5V) and the ground for the AC/oscilloscope signal/probes. The orange section is where I connected V_{EE} (-5V) and the ground for the DC power supply. I then used a wire to connect the two ground planes towards the bottom of the circuit. As for the placement of the filters and equalizer output, I built the first biquad towards the top highlighted in yellow, and then built the second biquad below the first and also with another breadboard which is highlighted in pink. Before connecting the two filters to implement the equalizer, I measured the AC response for both filters using the oscilloscope to verify consistent results with the simulations. Once verifying the results, I then moved on to implementing the equalizer circuit using Figure 1 in the lab manual as a reference. I then varied the potentiometers for both filters from 1k-9k in steps of 2k and measured the AC response for each step using the oscilloscope. I then set the first potentiometer for the first biquad filter and varied the second one from 1k-9k in steps of 2k and re-measured the AC response. Below are the measured results from the oscilloscope starting with the individual AC responses for each filter.

Biquad #1 AC response:



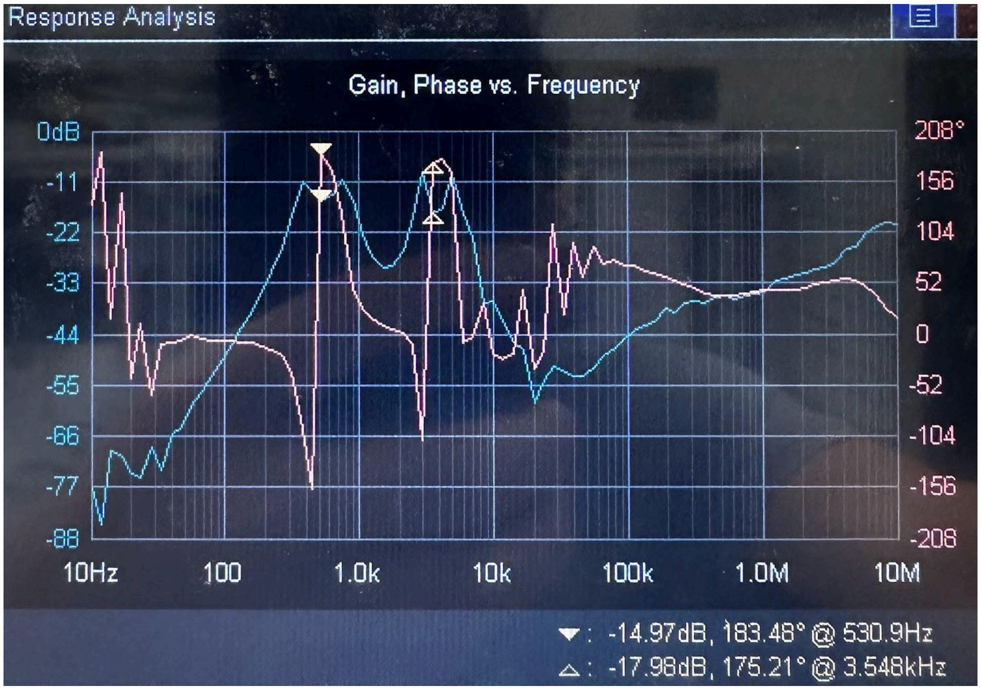
This result is consistent with the specifications and simulated result with a f_0 at around 3.75kHz and a stopband attenuation of -19.1dB at 8.41kHz.

Biquad #2 AC response:

This result is also consistent with the specifications and simulated result with a f_0 at around 500Hz and a stopband attenuation of -18.52dB at 1.26kHz

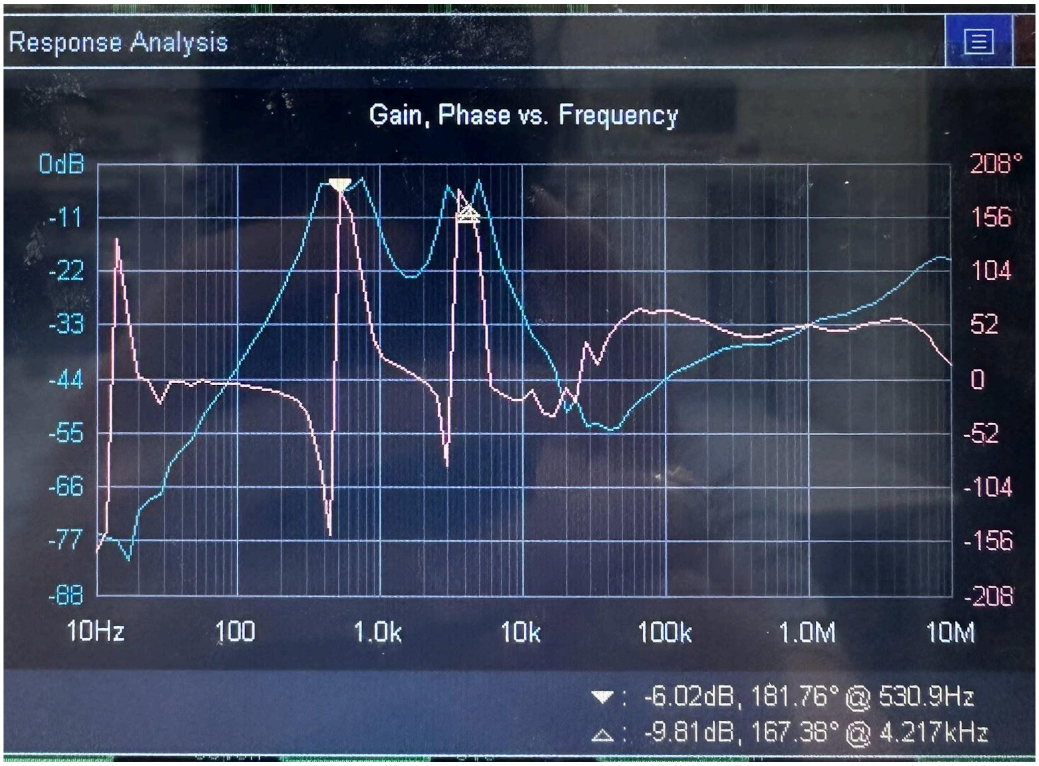
Equalizer with both pots @ 1kΩ:

Equalizer with both pots @ 3kΩ:



Equalizer with both pots @ 5kΩ:

Equalizer with both pots @ 7kΩ:



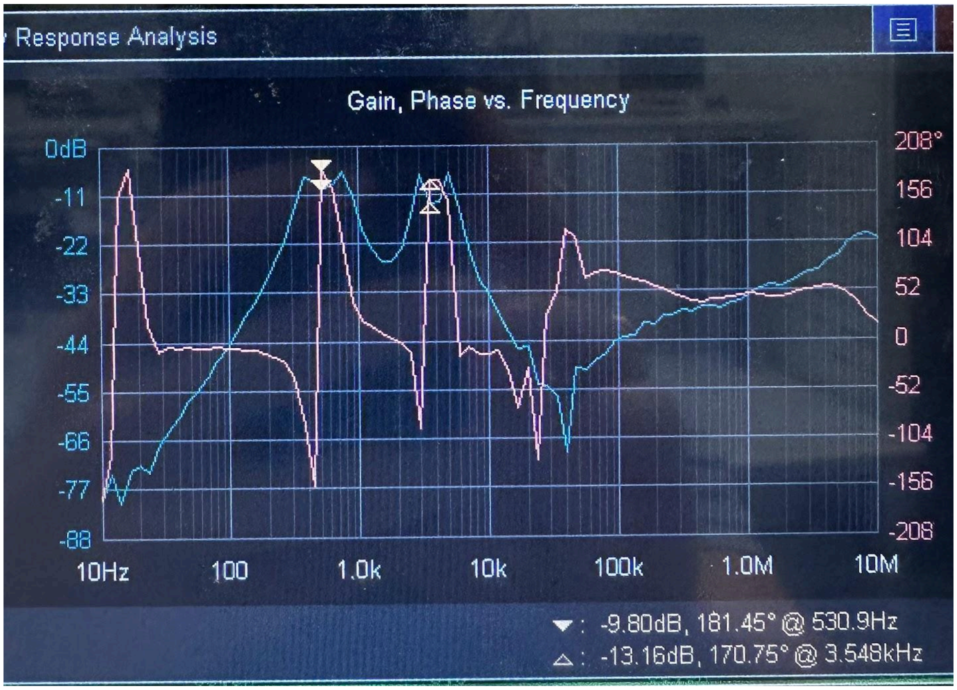
Equalizer with both pots @ 9kΩ:

We can see that the peaks of the equalizer are measured at around -20dB to start and increase after each step up to around -2dB.

Equalizer with pot 1 @ 5kΩ, pot 2 @ 1kΩ:

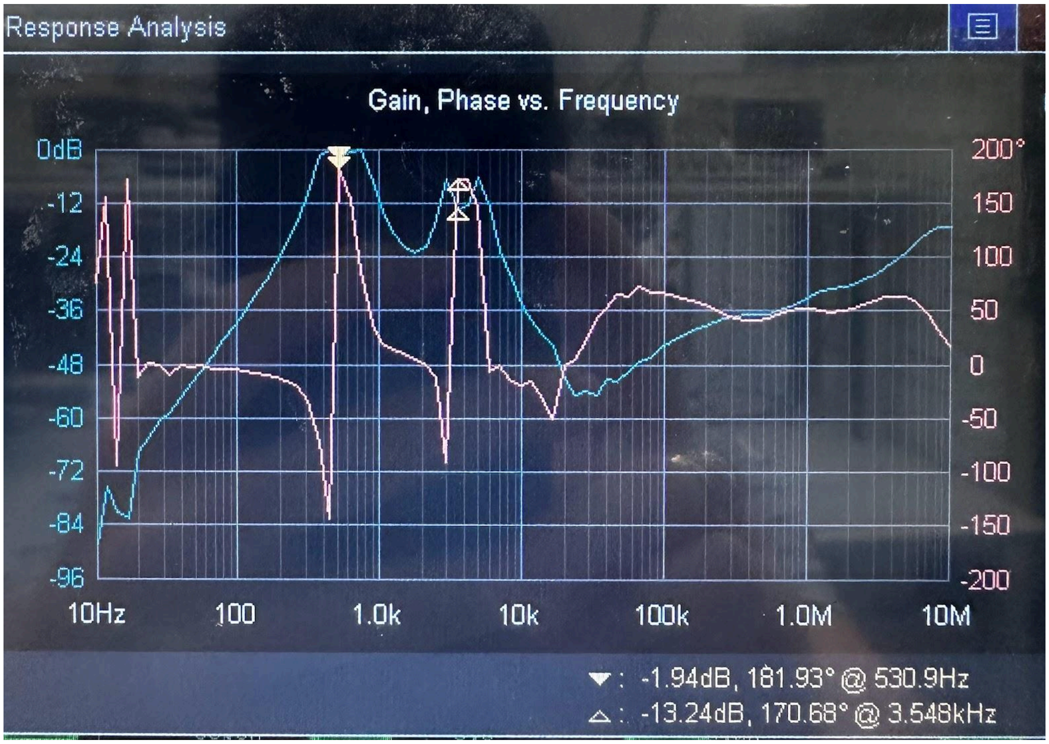
Equalizer with pot 1 @ 5kΩ, pot 2 @ 3kΩ:

Equalizer with pot 1 @ 5kΩ, pot 2 @ 5kΩ:



Equalizer with pot 1 @ 5kΩ, pot 2 @ 7kΩ:

Equalizer with pot 1 @ 5kΩ, pot 2 @ 9kΩ:

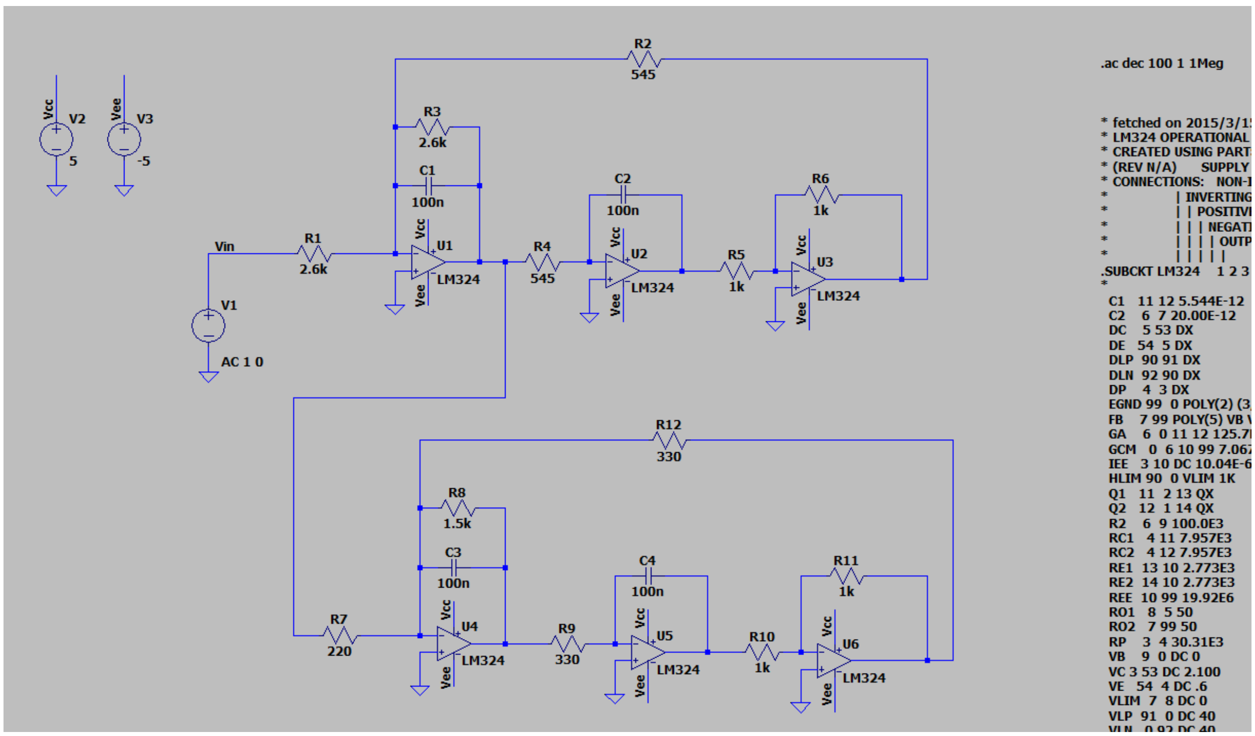


We can see from the pictures that the response of the first biquad with f_0 @ around 3.75kHz remains the same after each step, but the magnitude of the second biquad with f_0 @ around 500Hz increases starting from around -26dB and ending at around -2dB. This makes sense since I was varying the second pot while keeping the first pot at 5kΩ.

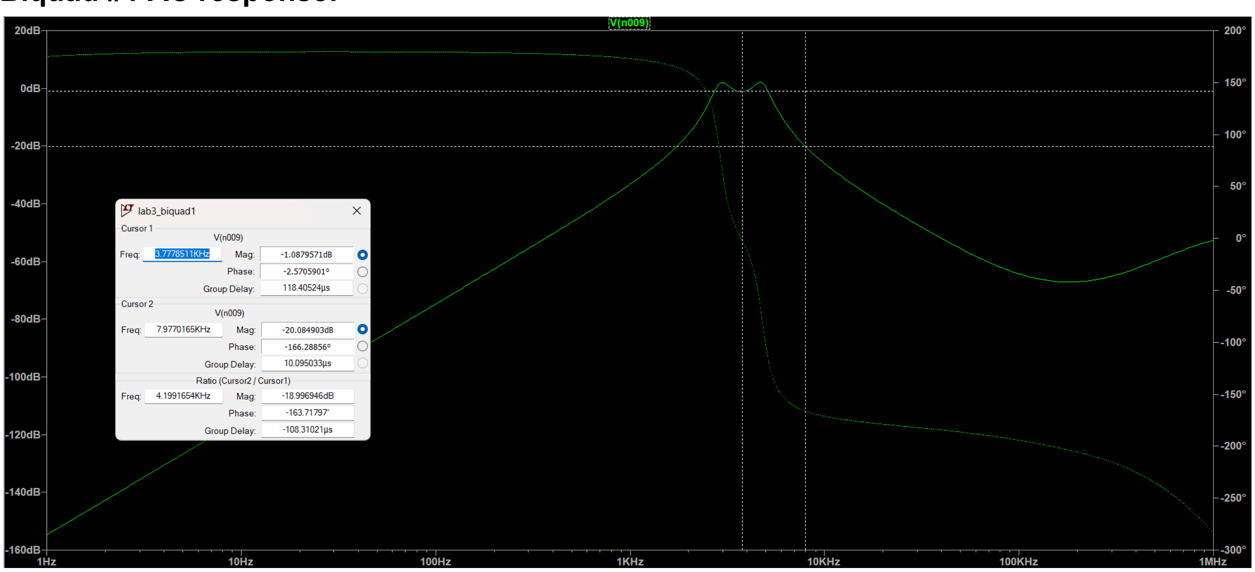
Corrections for the Pre-lab Simulations:

Since I was unable to meet the required specifications for the biquad filters using 2nd order MFB filters, I redid the process using 4th order MFB filters to calculate for each of the biquad filters. Below are the schematics and simulated AC responses for each filter, as well as the final equalizer schematic and AC response.

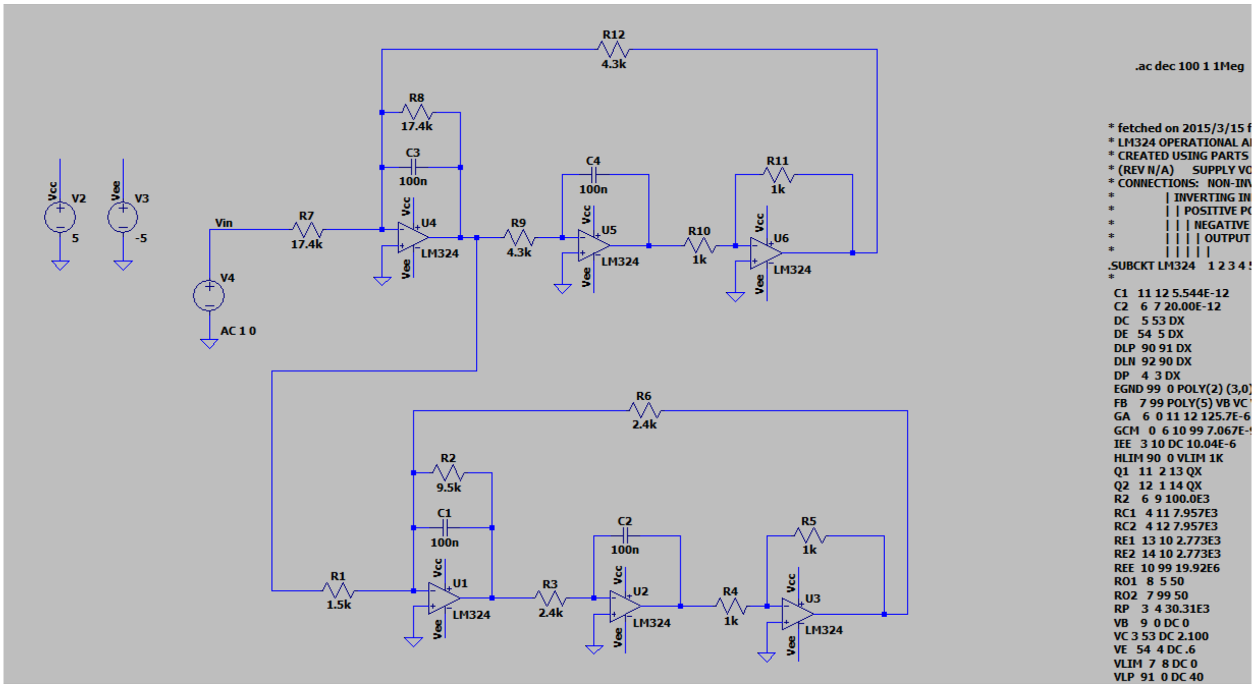
Biquad #1 Schematic:



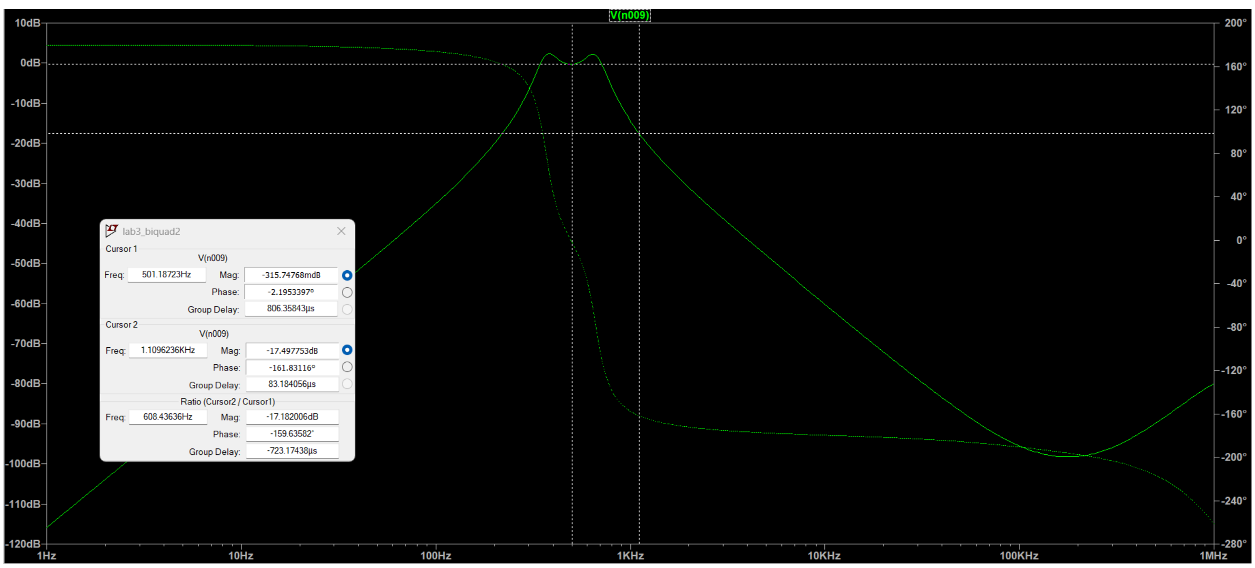
Biquad #1 AC response:



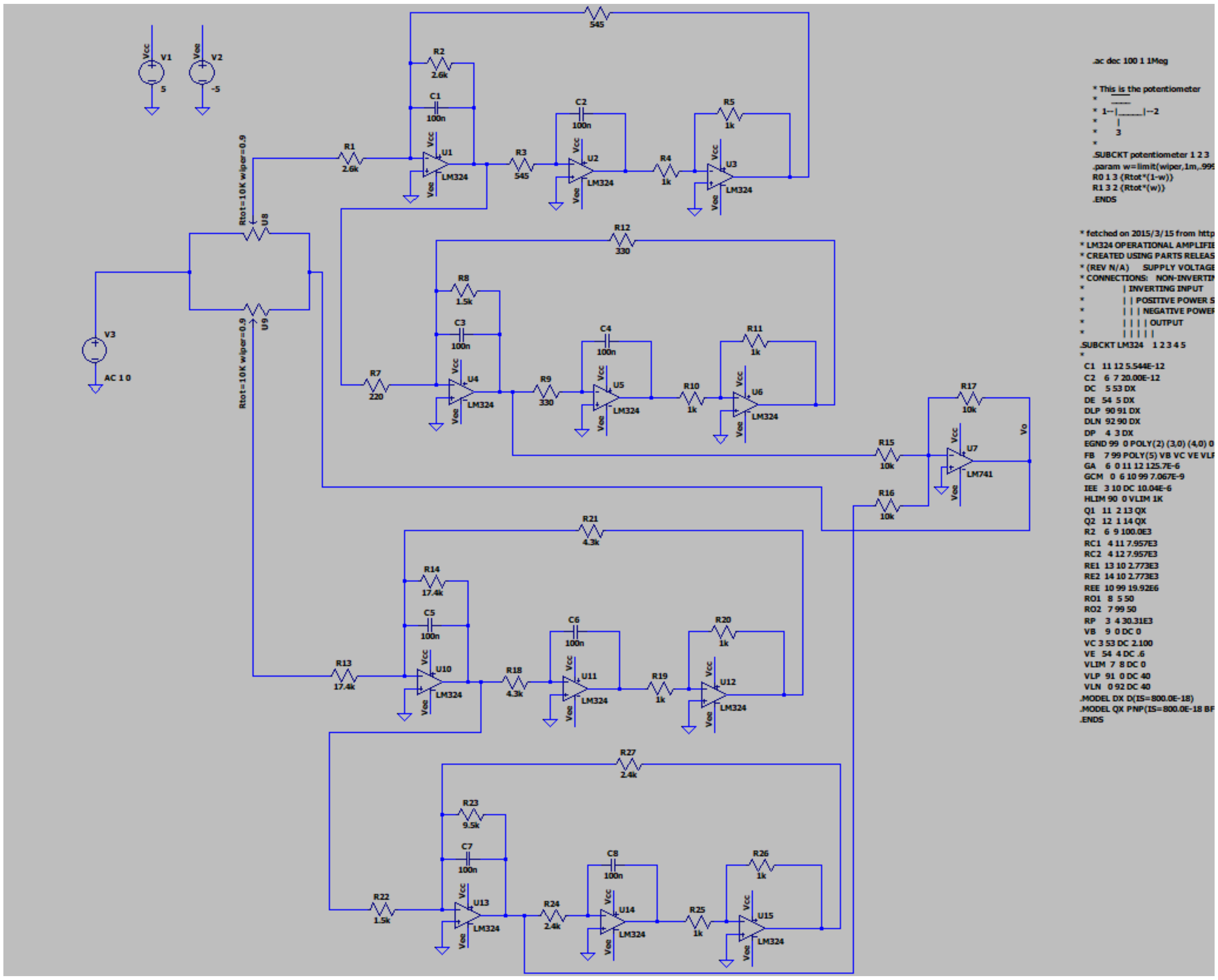
Biquad #2 Schematic:



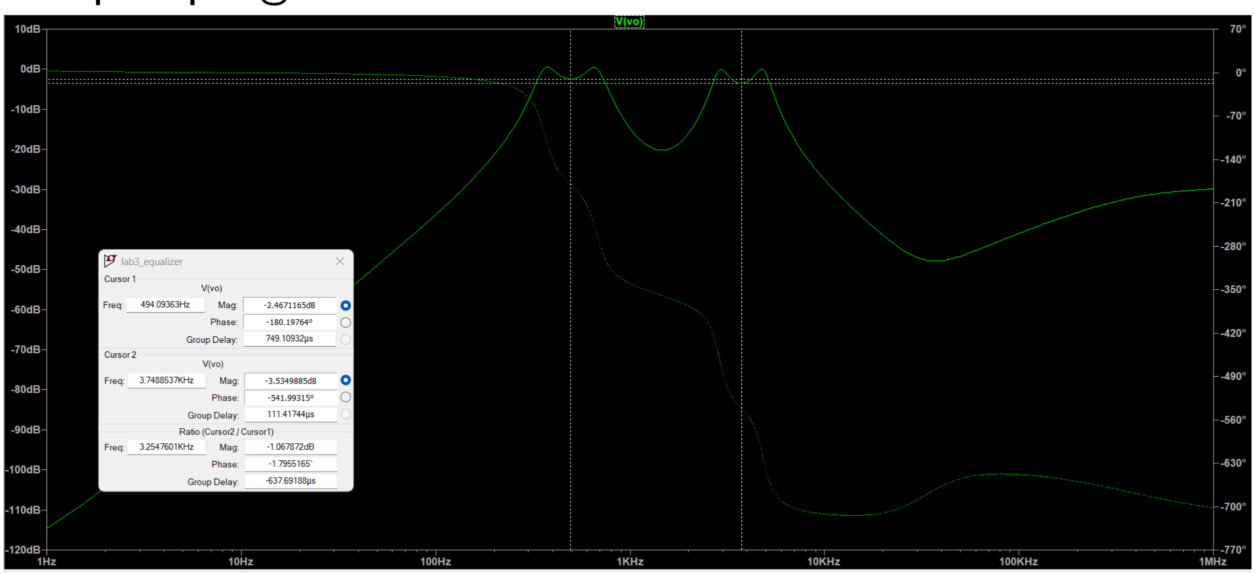
Biquad #2 AC response:



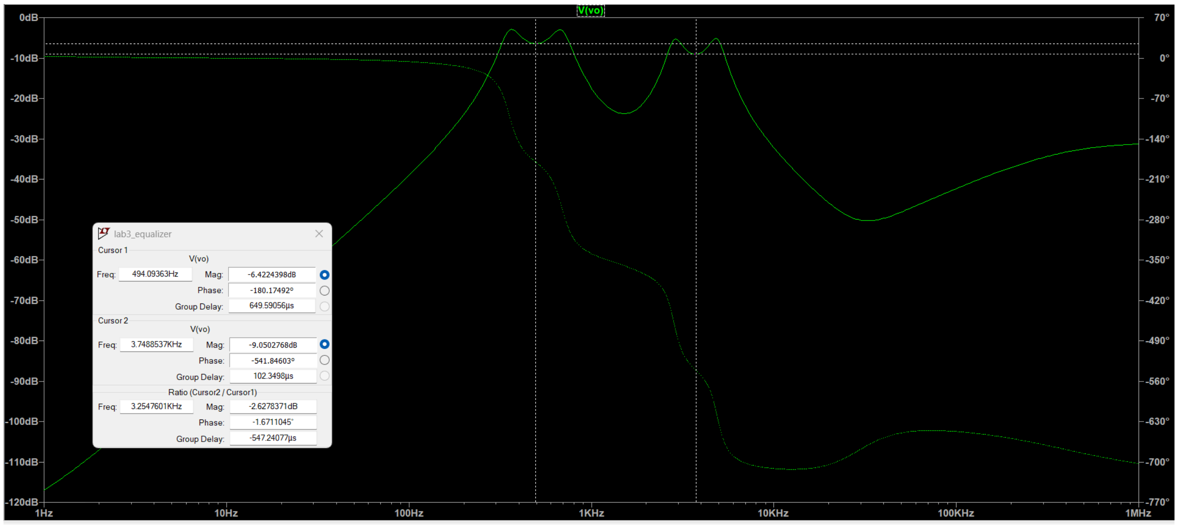
Equalizer schematic:



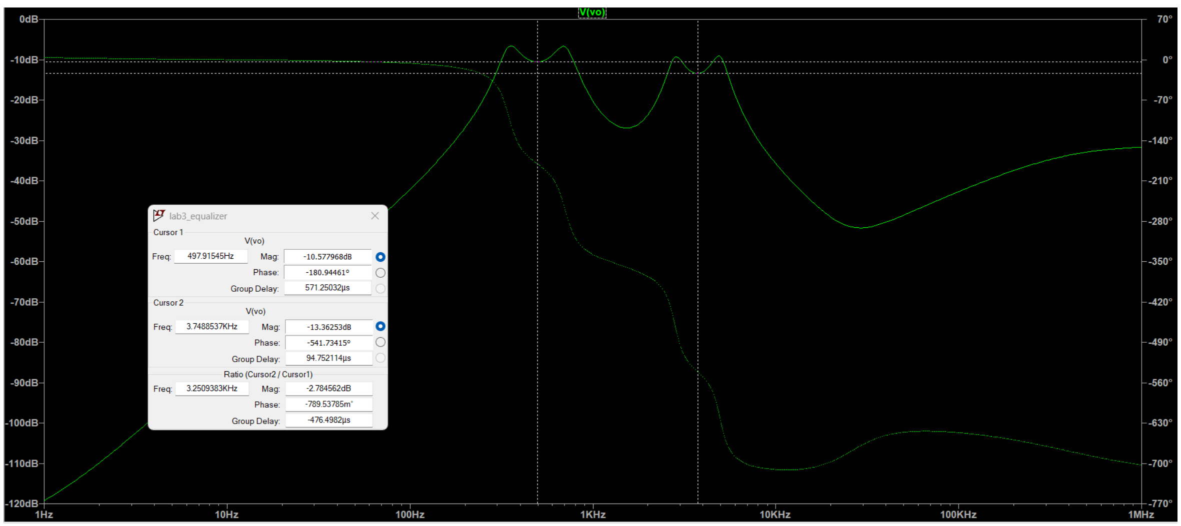
AC response pots @ 1kΩ:



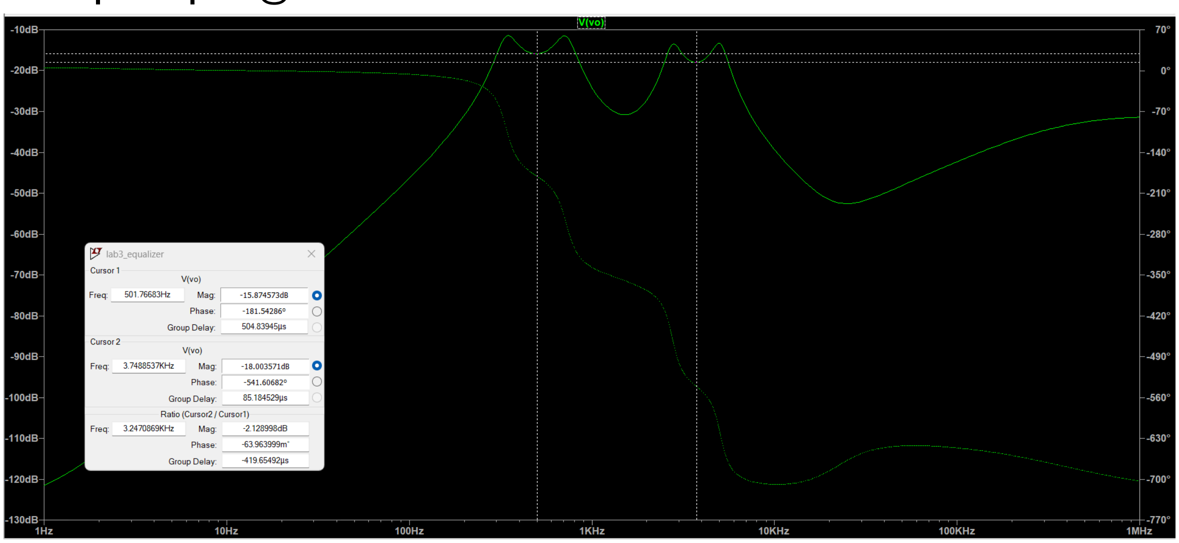
AC response pots @ 3kΩ:



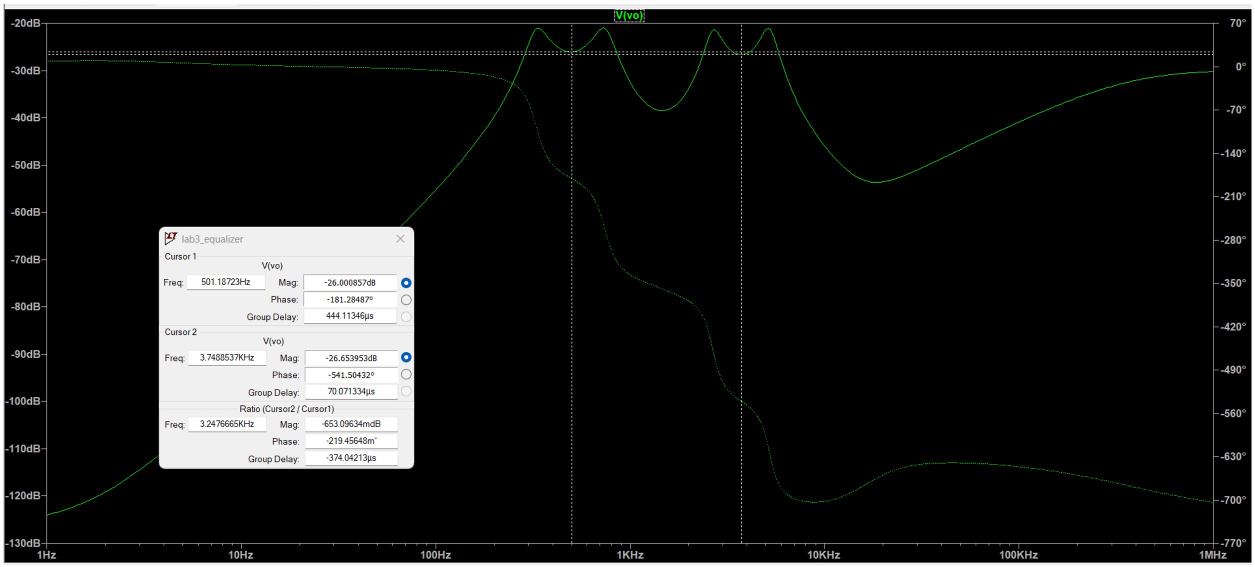
AC response pots @ 5kΩ:



AC response pots @ 7kΩ:



AC response pots @ 9kΩ:



The simulated result is slightly different since I had the potentiometers flipped, but the overall response is the same as the measured result. Since the potentiometers were flipped the actual values for the pots began at 9k and ended at 1k.