Laboratory 4: Audio Mixer

Lab Section AA

Travis Kee, Ethan Diep, Junhan Jiao

EE233 Circuit Theory

Department of Electrical Engineering, University of Washington, Seattle, WA, 98195

Abstract — In this lab, given topology and specifications were considered in the construction of three different filters combined into an equalizer system. Further construction of previous lab circuits was utilized in the final construction of the audio mixing console. Further usage of lab equipment for testing/analyzing circuits was conducted. This lab effectively demonstrated the culmination of filters and other circuit elements for the overall project of making an audio mixer.

I. Introduction

In this lab, students will explore filter designs given various topologies and specifications in their role for the equalizer system. These three filters serve as the last key step in the construction of the audio mixer. The lab's focus is on filter designs, ensuring that each filter meets the specified requirements for functional use. The fully constructed equalizer system: including the three filters, a voltage follower, and a summing amplifier are used to adjust the frequency response of the audio system, as well as adjusting the amplitudes of audio signals at various frequencies. Through the previous labs, building up the audio mixer in "chunks," allows the student to better understand every aspect of the project and see the full culmination of each lab's objectives.

II. Lab Procedure

The equipment to construct the different circuits for this lab included a breadboard, LM348N Operational-Amplifiers, 240kΩ resistors, 2.4kΩ resistor, 100kΩ potentiometers, a 560pF capacitor, a 0.1µF capacitor, a 0.0056µF capacitor, a 0.0022µF capacitor, a 0.022µF capacitor, a 22pF capacitor, a speaker, audio-jacks for external sound input, and jumper wires to connect the components.

The function generator was used to produce different sine waves throughout this lab. For the sine wave, the function generator was set to a sine wave with a range of frequencies: 250Hz, 1kHz, 4kHz, and 10Hz-50kHz (in 1-2-5 sweep order). The amplitude of the given sine wave remained at 200mV peak-to-peak.

The oscilloscope was used to measure output and input voltage of the whole circuit, displaying those voltages on the display. The measurement functions of the oscilloscope were used to determine the amplitude of the output signals. Two main channels were used from the oscilloscope: Channel 1 and 2. Those channels were connected to the input signal voltages that were supplied by the waveform generator and the various output signal voltages measured across the different filters/equalizer system respectively.

III. Experimental Procedure and Analysis[https://www.xiaoyuzhoufm.com/podcast/655ac689b95673db211562f9https://www.xiaoyuzhoufm.com/podcast/655ac689b95673db211562f9https://www.xiaoyuzhoufm.com/podcast/655ac689b95673db211562f9https://www.xiaoyuzhoufm.com/podcast/655ac689b95673db211562f9]

First the filter circuit shown in Figure 1 was built, with power supplies V_{CC} = 12V, V_{EE} = -12V. R1 and R2 was set to 240kΩ, R3 and R4 was set to 2.4kΩ, R5 was set to a 100kΩ potentiometer. The capacitor C1 was chosen to be 0.022µF. The capacitor C2 was chosen to be 0.0022µF. This combination of capacitors was for a center frequency of 1 kHz.

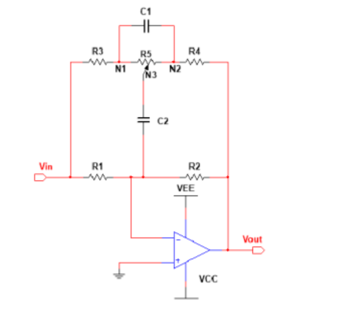

Figure 1. Filter Circuit

1. For R1 and R2, the 240kΩ resistors were used, for R3 and R4, the 2.4kΩ resistors were used, and lastly for R5, a 100kΩ potentiometer was used. These R1-R5 resistances were used for the construction of all three types of filters. As for the capacitor's values, to get a center frequency of around 1000 Hz, C1 was 0.022µF while C2 was 0.0022µF.

The gain of the filter was plotted between 10 Hz and 50 kHz by setting the potentiometer to 25%, 50%, and 75%. To generate the points, the waveform generator was set to a sine wave with 200 mV peak to peak amplitude. The frequency was swept using the 1-2-5 sequence starting from 10 Hz up to 50 kHz. The gain of the circuit was measured by V_{out}/V_{in}.

2. Figure 2 shows the input and output waveform for the filter built for a center frequency of 1 kHz. The maximum gain was determined from the measurements laid out in the table. For the potentiometer set to 25%, the maximum gain was 2, while the potentiometer set to 50% had a maximum gain of 1, and lastly the potentiometer set to 75% had a maximum gain of around 1.62.

   To determine the 3-dB frequencies, the students multiplied the maximum gain by $1/\sqrt{2}$ to get the gain to 3-dB equivalent. Then the frequencies that aligned closest to that equivalent were determined. For 25%, the 3-dB frequencies are around 350 and 2000 Hz. For 50%, since through the entire range the gain was 1, the 3-dB frequency was never shown. As for 75%, the 3-dB frequencies are around 200 and 3000 Hz.

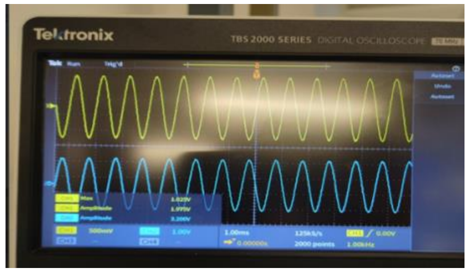

Figure 2. 1 kHz center frequency filter circuit input signal (yellow) and output signal (blue) displayed on oscilloscope. Gain was found by V_{out}/V_{in}.

Center Frequency of 1000Hz	
Frequency	Gain when potentiometer set to 25%
10Hz	2
20Hz	2
50Hz	2
100Hz	2
200Hz	1.67
500Hz	1.17
1000Hz	1.13
2000Hz	1.48
5000Hz	1.87
10000Hz	2
20000Hz	2
50000Hz	2

Center Frequency of 1000Hz	
Frequency	Gain when potentiometer set to 50%
10Hz	1
20Hz	1
50Hz	1
100Hz	1
200Hz	1
500Hz	1
1000Hz	1
2000Hz	1
5000Hz	1
10000Hz	1
20000Hz	1
50000Hz	1

Center Frequency of 1000Hz

Frequency	Gain when potentiometer set to 75%
10Hz	1
20Hz	1
50Hz	1
100Hz	1
200Hz	1.12
500Hz	1.57
1000Hz	1.62
2000Hz	1.27
5000Hz	1.04
10000Hz	1
20000Hz	1
50000Hz	1

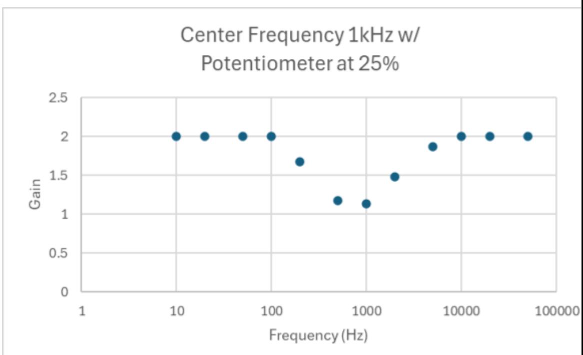

Figure 3. 1 kHz Center Frequency Filter at 25%

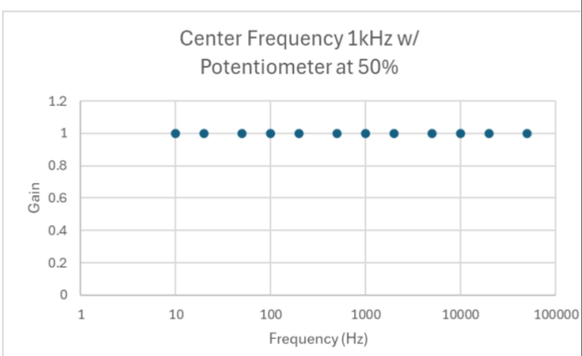

Figure 4. 1 kHz Center Frequency Filter at 50%

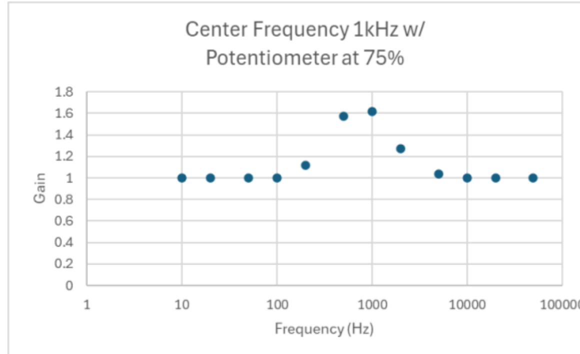

Figure 5. 1 kHz Center Frequency Filter at 75%

Next the other two filters with center frequencies designed at 250 Hz and 4 kHz were built. The same steps were followed as when building the 1 kHz, but the capacitor values were changed. For the 250 Hz center frequency C1 was set to 0.1μF and C2 was set to 0.0056μF. For the 4 kHz center frequency C1 was set to 0.005μF and C2 was set to 560pF.

3. Figures 6 and 7 show the input and output waveform for the filter built for a center frequency of 250 Hz and 4 kHz. As mentioned in question 1, the resistors that were used for the first filter were also used for the construction of the other two filters. As for the capacitors, with the center frequency at around 250 Hz, C1 was 0.1μF and C2 was 0.0056μF. To get a center frequency of around 4kHz, C1 was 0.0056μF and C2 was 560pF.

   Like question 2, the maximum gain was determined from the measurements. The 3-dB frequencies were determined through multiplying the maximum gain by $1/\sqrt{2}$ to get the gain to 3-dB equivalent. Then the frequencies that aligned closest to that equivalent were determined. For the center frequency at 250 Hz, the maximum gain for 25%, 50%, and 75% are around 1, 1, and 1.7 respectively. The 3-dB frequencies for 25%, 50%, and 75% are around [150, 1000 Hz], [N/A (same explanation from the 1000 Hz center frequency)], and [100, 1000 Hz] respectively. The same process was done for the center frequency at 4 kHz. The maximum gain at 25%, 50%, and 75% are around 1, 1, and 1.7 respectively. The 3-dB frequencies at 25%, 50%, and 75% are around [1000, 10000Hz], [N/A (same explanation from the

1000 Hz center frequency)], and [1000, 10000 Hz] respectively.

Figure 6. 250 Hz center frequency filter circuit input signal (yellow) and output signal (blue) displayed on oscilloscope. Gain was found by V_{out}/V_{in}.

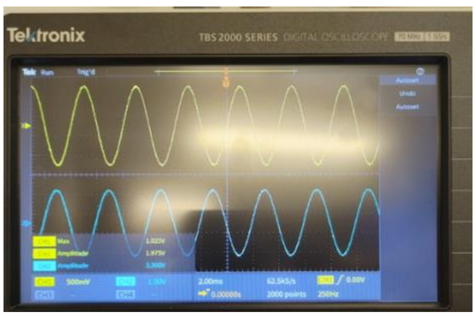

Figure 7. 4 kHz center frequency filter circuit input signal (yellow) and output signal (blue) displayed on oscilloscope. Gain was found by V_{out}/V_{in}.

Center Frequency of 250Hz	
Frequency	Gain when potentiometer set to 25%
10Hz	1
20Hz	1
50Hz	1
100Hz	0.77
200Hz	0.58
500Hz	0.51
1000Hz	0.71
2000Hz	0.89
5000Hz	0.97
10000Hz	1
20000Hz	1
50000Hz	1

Center Frequency of 250Hz	
Frequency	Gain when potentiometer set to 50%
10Hz	1
20Hz	1
50Hz	1
100Hz	1
200Hz	0.96
500Hz	1
1000Hz	1
2000Hz	1
5000Hz	1
10000Hz	1
20000Hz	1
50000Hz	1

Center Frequency of 250Hz	
Frequency	Gain when potentiometer set to 75%
10Hz	1
20Hz	1
50Hz	1.02
100Hz	1.17
200Hz	1.57
500Hz	1.7
1000Hz	1.29
2000Hz	1.07
5000Hz	1
10000Hz	1
20000Hz	1
50000Hz	1

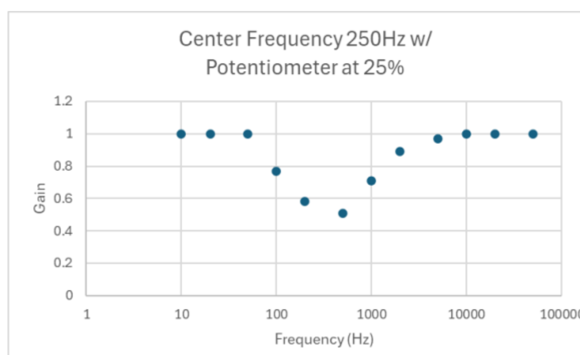

Figure 8. 250 Hz Center Frequency Filter at 25%

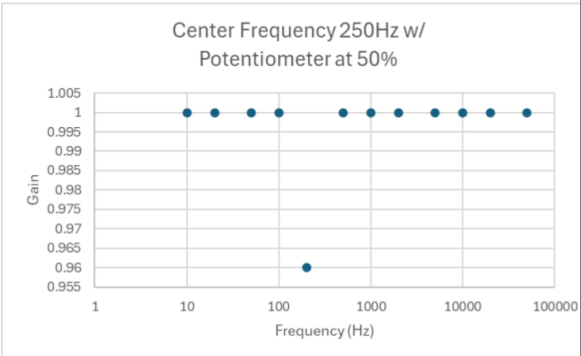

Figure 9. 250 Hz Center Frequency Filter at 50%

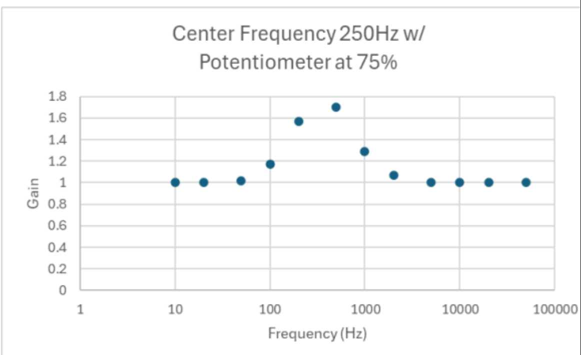

Figure 10. 250 Hz Center Frequency Filter at 75%

Center Frequency of 4000Hz	
Frequency	Gain when potentiometer set to 25%
10Hz	1
20Hz	1
50Hz	1
100Hz	1
200Hz	1
500Hz	0.91
1000Hz	0.79
2000Hz	0.57
5000Hz	0.56
10000Hz	0.75
20000Hz	0.91
50000Hz	1

Center Frequency of 4000Hz	
Frequency	Gain when potentiometer set to 50%
10Hz	1
20Hz	1
50Hz	1
100Hz	1
200Hz	1
500Hz	1
1000Hz	1
2000Hz	1
5000Hz	1
10000Hz	1
20000Hz	1
50000Hz	1

Center Frequency of 4000Hz	
Frequency	Gain when potentiometer set to 75%
10Hz	1
20Hz	1
50Hz	1
100Hz	1
200Hz	1
500Hz	1
1000Hz	1.17
2000Hz	1.55
5000Hz	1.7
10000Hz	1.27
20000Hz	1.04
50000Hz	1

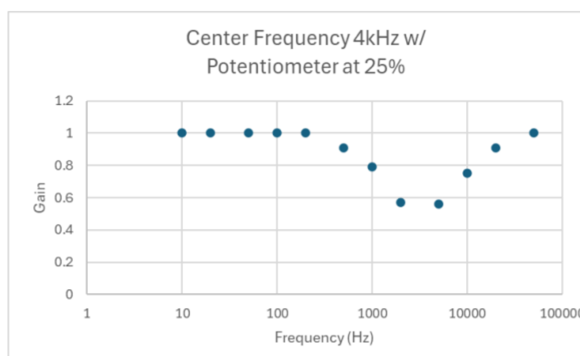

Figure 11. 4 kHz Center Frequency Filter at 25%

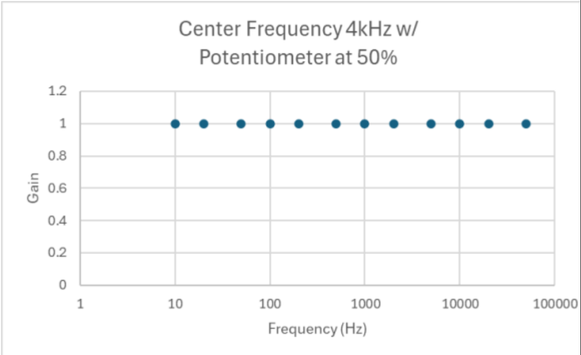

Figure 12. 4 kHz Center Frequency Filter at 50%

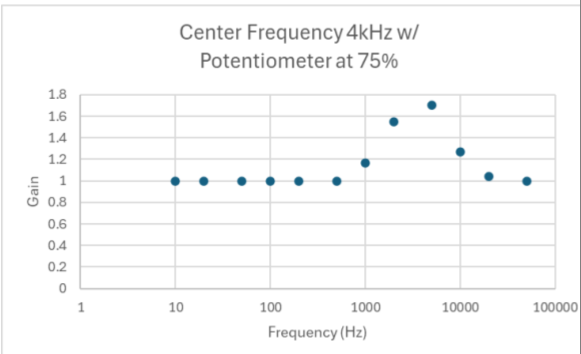

Figure 13. 4 kHz Center Frequency Filter at 75%

In the next part of the lab a whole mixing console was built shown in Figure 14. The circuits that were built for this were the summing amplifier from lab 2 shown in Figure 15 with R1, R2, R3, and Rf all set to 100kΩ potentiometers and C being set to a 22pF capacitor. The voltage follower from lab 2 shown in Figure 16 was built. The 3 filters with center frequencies 250 Hz, 1 kHz, and 4k Hz shown in Figure 1 with the respective capacitors were built. The summing amplifier from lab 3 shown in Figure 17 with R1, R2, R3, and Rf all set to 100kΩ potentiometers and C being set to a 0.1μF capacitor.

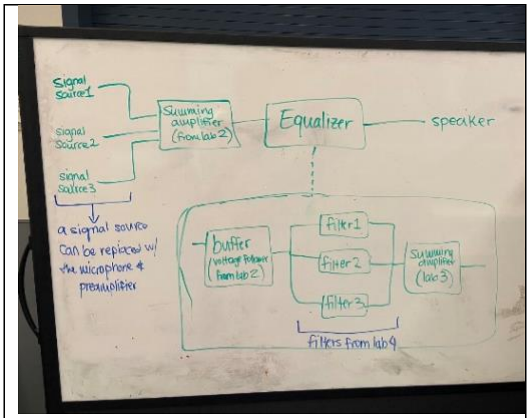

Figure 14. Mixing console

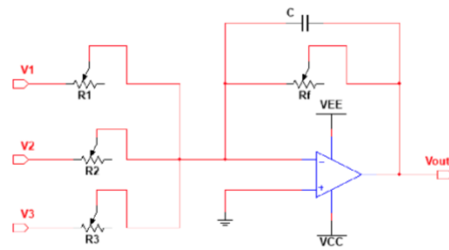

Figure 15. Summing amplifier lab 2

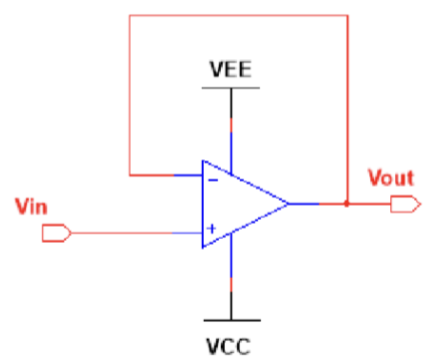

Figure 16. Voltage follower

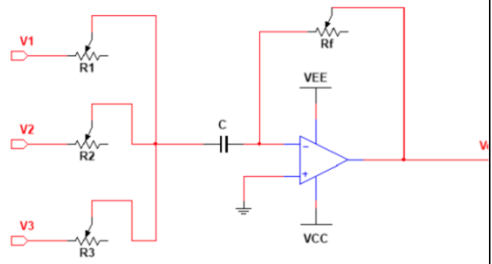

Figure 17. Summing amplifier lab 3

A sine wave with frequency 250 Hz was used with a 200 mV peak to peak voltage amplitude was used as an input to the system.

4. The input and output waveforms for the given sine wave are seen in Figure 18.

Figure 18. Input and Output Waveforms of the Audio Mixer with Frequency at 250 Hz and amplitude at 200 mV peak-to-peak

The potentiometers in the equalizer (filters and summing amplifier) were changed and the output was displayed on the oscilloscope.

5. With the input frequency of the sine wave at 250 Hz, examining the effects of changing the potentiometers for each filter led to the conclusion that the filter with a center frequency of 250 Hz was the filter that affected the amplitude of the output the most. There was a slight change that came from changing the potentiometer for the filter with 1 kHz-center frequency. The oscilloscope readings for 250 Hz can be seen in Figure 19.

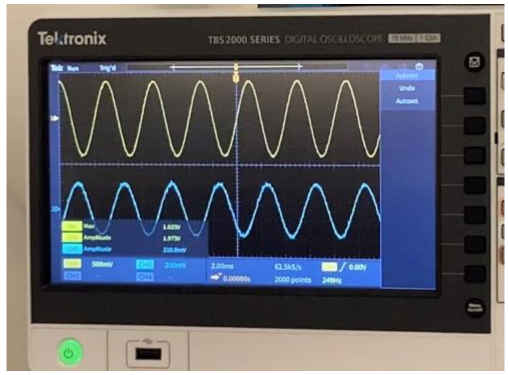

Figure 19. Audio Mixer with an Input Signal at 250Hz Frequency

Next sine waves with frequency 1 kHz and 4 kHz were used and the potentiometers in the equalizer were changed and output displayed on the oscilloscope.

6. For the input signal at 1 kHz, it was discovered that the 1 kHz-center frequency filter affected the amplitude of the output the most. There was some slight change when changing the potentiometer of the 250 Hz-center frequency filter but not as much. As for the input signal at 4 kHz, it was only the 4 kHz-center frequency filter that affected the amplitude of the output. The oscilloscope readings for 1 kHz and 4 kHz can be seen in Figures 20 and 21 respectively.

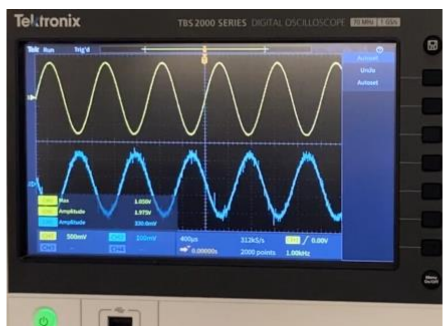

Figure 20. Audio Mixer with an Input Signal at 1 kHz Frequency

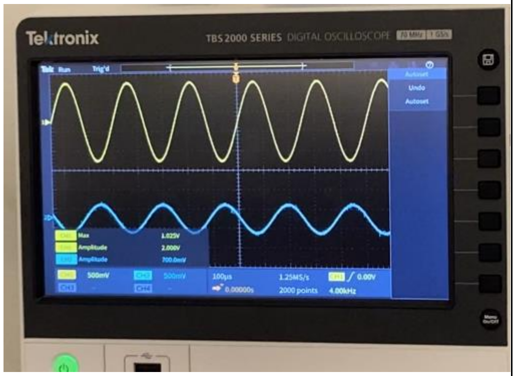

Figure 21. Audio Mixer with an Input Signal at 4 kHz Frequency

The gain of the filter was plotted between 10 Hz and 50 kHz by setting the potentiometer to 25%, 50%, and 75%. To generate the points, the waveform generator was set to a sine wave with 200 mV peak to peak amplitude. The frequency was swept using the 1-2-5 sequence starting from 10 Hz up to 50 kHz. The gain of the circuit was measured by V_{out}/V_{in}.

7. After plotting the measurements for the gain of the audio mixer which can be seen in Figure 22, there is only one big band-pass when all the filters have their R5 potentiometers operating at 100kΩ.

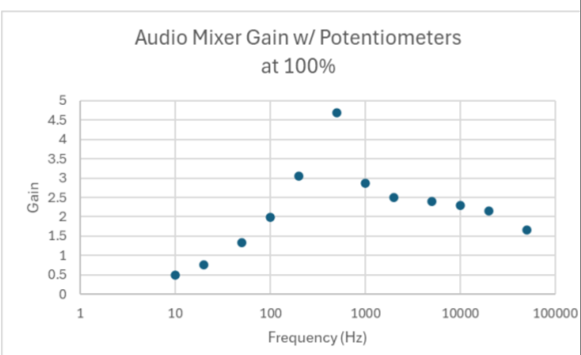

Figure 22. Audio Mixer Gain with Filters' Potentiometers Set to 100% Resistance

For the lab test, three different audio signals were connected from the laptop's headphone jacks to each input of the mixing console. The circuit performed as expected with the equalizer being able to control the filter of different frequencies and potentiometers of the summing amplifier controlling the volume of each individual signal and the overall signal.

Extra Credit (E). In the extra credit portion of the lab the microphone circuit in Lab 3 was already previously built and extra credit was received.
The whole audio mixer system was built in SPICE and the AC analysis of the transfer function of the whole system was simulated.
Question E: The transfer function with only one input track shown in Figure 23 looks like a combination of two band-pass and one band-stop filter. The summing amplifiers that connected to the input signals and were part of the equalizer system were responsible for combining the three signals coming into it and outputting one signal in return. The summing amplifiers both also were able to adjust the amplitude for its specific input channel. The voltage follower that was part of the equalizer system was responsible for taking the output voltage from the summing amplifier from lab 2 and providing it as an ideal input voltage into the filters. Lastly, the three filters that are part of the equalizer system are responsible for amplifying and attenuating the amplitudes of the output signal at certain frequency ranges.

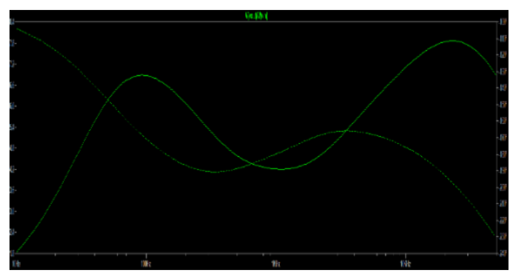

Figure 23. AC analysis SPICE of the mixing console with one input signal.

IV. Conclusions

This laboratory demonstrated the full applications of filter designs and previous circuit components in audio signal processing, specifically within the context of the building an audio mixer. The experiments allowed for a deeper understanding of filter designs and more specifically how they can be applied to the construction of the entire audio mixer system. Key findings from the lab include selecting key capacitors/resistors and ensuring correct placement of those capacitors had a great impact on the center frequency and behavior of a specific filter. These distinct selections and adjustment of the operating ability of a given filter (potentiometer) confirmed the theoretical predictions about filter behavior.

Adjusting the operating ability of the filter (potentiometer) also modified the amplitude of input signals at various frequencies. Each filter had its own effectiveness in altering the output signal depending on what the input frequency is. This illustrates the tunability of these filters through these simple adjustments.

Through these experiments, the students were able to observe more specific behaviors and characteristics of filters in electronic circuits. It provided valuable insight into the last steps in constructing the final audio mixer and for future projects.

Team Roles

Activity	Student(s) Name
Prelab: Circuit Analysis	Ethan, Juhan, Travis
Prelab: Simulations and Graphs	Ethan, Juhan, Travis
Prelab: Questions	Ethan, Juhan, Travis
Lab: Circuit Construction	Ethan, Juhan, Travis
Lab: Data Collection	Ethan, Juhan, Travis
Lab: Data Analysis	Ethan, Juhan, Travis
Report: Procedure	Ethan, Juhan, Travis
Report: Analysis and Graphs	Ethan, Juhan, Travis
Report: Questions	Ethan, Juhan, Travis