Audio Mixer Circuit

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Circuit Theory

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Abstract — **The purpose of this lab is to design and apply the characteristics of filter circuits with a given topology and specifications. Changing the value of two capacitors in the filter circuit shifts the center frequency. Additionally, by adjusting the potentiometer from 25% to 75%, the filter transitions from band-reject to band-pass. An audio mixer circuit was created using a three-channel equalizer, summing amplifiers, and a buffer. The experimental data matched the SPICE simulation and overall performed as expected.**

I. INTRODUCTION

The objectives of this lab are to design and apply filter circuits with given criteria. A filter's output depends on the frequency of the input, giving it the ability to 'filter' out frequencies. For example, a band-pass filter amplifies a specific window of frequencies, while suppressing the rest. This makes them ideal for audio applications which deal with mixed signals and frequencies. In the lab experiments, filter circuits are analyzed by their frequency response, while changing their capacitor and potentiometer values. These circuits are then used in a three-channel amplifier, which is implemented in an audio mixer circuit. The mixer is also constructed in a SPICE simulation to verify the behavior.

II. LAB PROCEDURE

A. Band-Pass Filters

In part A, a Band Filter circuit (AP.1) is constructed using a LM348N chip and power supplies V_{CC} = 12V, V_{EE} = – 12 V. In addition, $R_1 = R_2 = 240k\Omega$, $R_3 = R_4 = 2.4k\Omega$, and potentiometer $R_5 = 100k\Omega$. The amplitude of the input signal is kept at 300mV and generated using a waveform generator. Input and output signals are measured using an oscilloscope.

A.1. Frequency Response

Potentiometer R_5 is set to 25%; the resistance between N1 and N3 is 25% of R_5. Capacitors C1 and C2 are chosen such that the center frequency of the circuit is roughly 1kHz. The gain of the system is recorded, sweeping the frequency from 10Hz to 50kHz using the 1-2-5 sequence.

A.2. Capacitor and Potentiometer Response

A.1 is repeated but with R_5 set to 50%, and then 75%. Then, A.1 is repeated as those three R_5 values but for new C1 and C2 such that the center frequency of the circuit is roughly 250Hz. Lastly, this process is repeated such that the center frequency is roughly 4kHz, for a total of nine times.

B. Audio Mixer

Now that the equalizer has been tested, the audio mixer circuit can be constructed (AP.1 – 6).

B.1. Basic Testing

A sine wave with 0.1V amplitude and 250Hz frequency is inputted into the system, and the input and output waveforms are compared on the oscilloscope display. Then, the potentiometers in the equalizers are tested to determine how they impact the output signal. This process is repeated but for an input wave with 1kHz and then 4kHz, while keeping the amplitude at 0.1V.

B.2. Frequency Response

With an input sine wave of 0.1V, the gain of the system is recorded, sweeping the frequency from 10Hz to 50kHz using the 1-2-5 sequence.

B.3 SPICE Testing

The entire circuit (AP.6) was recreated in LTspice and tested once again for frequency response using AC analysis.

III. Experimental Procedure and Analysis

A. Band-Pass Filters

Questions 1/3:

The filter circuit as shown in AP.1 was built with the following resistor values:

- R1 = R2 = 240kΩ
- R3 = R4 = 2.4kΩ
- R5 (Potentiometer) = 100kΩ

The values of C1 and C2 were dependent on the center frequencies the filter circuit was being built for. Table 1 shows the capacitors used for circuits with center frequencies of 250Hz, 1kHz, and 4kHz.

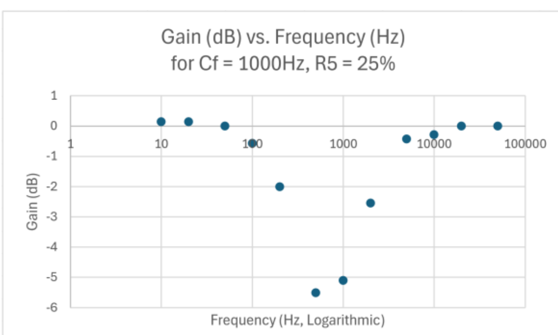
Table 1. C1 and C2 values used to build filter circuits with center frequencies of 250, 1000, and 4000 Hz

	250 Hz	1 kHz	4 kHz
C1 (nF)	100	22	5.6
C2 (nF)	10	2.2	0.56

Question 2:

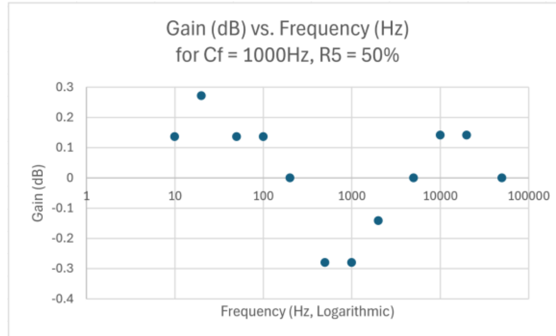
Next, to confirm when the circuit behaves as a band-pass or band-reject filter, the gain of the filter between 10Hz and 50kHz was plotted for when the potentiometer was set to 25%, 50%, and 75%, as explained in the procedure. Graphs 1-3 show the respective graphs plotted from the raw data (AP.7). The gain was calculated using (1).

$$Gain = 20log_{10}\left(\frac{|V_{out}|}{|V_{in}|}\right) \quad (1)$$



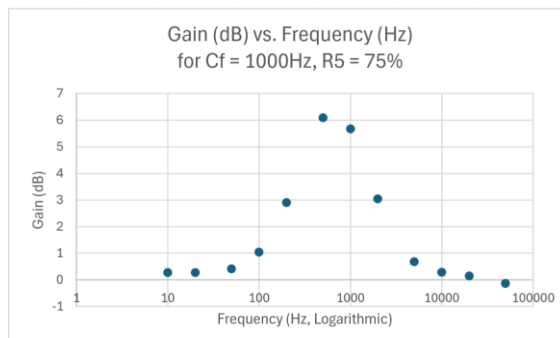
Graph 1. Gain of Filter Circuit at 1000Hz with 25% Potentiometer

Each plot can be characterized as either a band-pass, or band-reject filter. Graph 1 is a band-reject filter, whilst Graph 3 is a band-pass filter. The band-reject filters have a range near the center frequency (1kHz) where the gain is significantly lower than the rest of the plot, whereas the band-pass filter has a range near 1kHz where the gain is significantly



Graph 2. Gain of Filter Circuit at 1000Hz with 50% Potentiometer

higher than the rest of the plot. Graph 2 resembles a band-reject filter, but the range of gain is less than 1dB, making it essentially flat compared to the others. Ideally, the 50% should be completely flat, and adjusting it changes the steepness of the band-pass/band-reject. This error in graph 2 is due to the potentiometers being hand-adjusted.



Graph 3. Gain of Filter Circuit at 1000Hz with 75% Potentiometer

Table 2. Maximum Gains for Filter Circuit at Center Frequency 1kHz

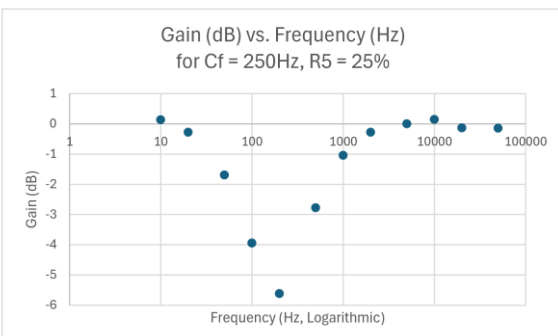
Max Gain (dB)		
25%	50%	75%
0.137	0.271	6.089

Table 3. 3dB Frequencies for Filter Circuit at Center Frequency 1kHz

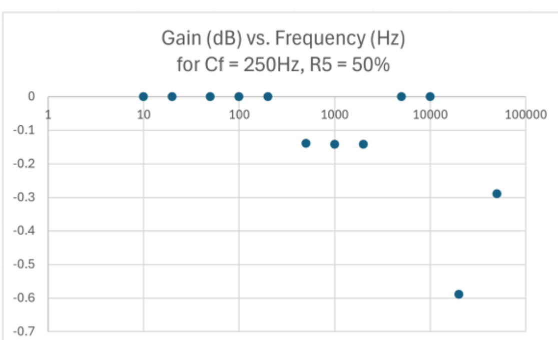
3dB Frequencies (Hz)					
25%		50%		75%	
Lower	Upper	Lower	Upper	Lower	Upper
50	20k	100	10k	50	10k

Table 2 shows the maximum gain for each potentiometer setting, which was taken directly from the raw data and plot. Table 3 shows the 3dB frequencies for each potentiometer setting. The 3dB frequencies also known as the cutoff frequencies, are the points at which the plot enters the frequency range that is passed through or blocked, depending on the type of filter (band-pass or band-reject). These values were approximated by looking at the points which set the bandwidth on each plot.

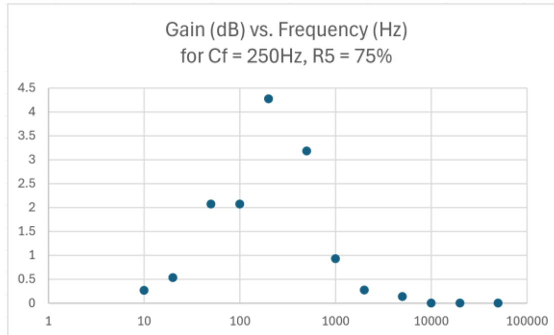
Question 1/3:
The above experiment was repeated for two more circuits: one with a center frequency of 250Hz and another with 4kHz. The same resistors from the 1kHz filter circuit were used. Graphs 4-6 show the behavior of a 250Hz filter circuit and were graphed with the raw data from AP.8. Graphs 4 and 5 are band-reject filters characterized by the downright spike at 250Hz, and Graph 6 is a band-pass filter characterized by the upright spike at 250Hz. Tables 4 and 5 show the maximum gains and 3dB frequencies for the filter circuit with a center frequency of 250Hz.



Graph 4: Gain of Filter Circuit at 250Hz with 25kΩ Potentiometer



Graph 5: Gain of Filter Circuit at 250Hz with 50kΩ Potentiometer



Graph 6: Gain of Filter Circuit at 250Hz with 75kΩ Potentiometer

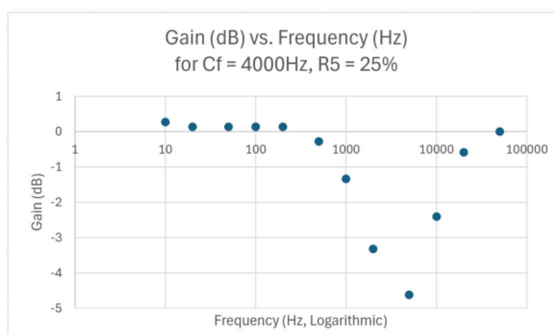
Table 4: Maximum Gains for Filter Circuit at Center Frequency 250Hz

Max Gain (dB)		
25%	50%	75%
0.137	0	5.227

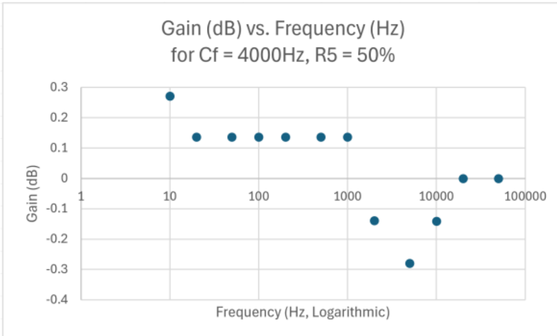
Table 5: 3dB Frequencies for Filter Circuit at Center Frequency 250Hz

3dB Frequencies (Hz)					
25%		50%		75%	
Lower	Upper	Lower	Upper	Lower	Upper
15	5k			15	5k

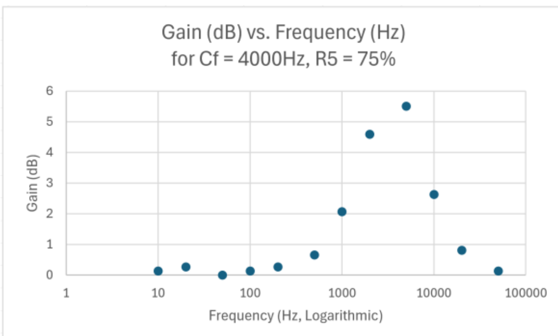
Graphs 7-9 show the behavior of a 4kHz filter circuit and were graphed with the raw data from AP.9. Graphs 7 and 8 are band-reject filters, and Graph 9 is a band-pass filter. Tables 6 and 7 show the maximum gains and 3dB frequencies for the filter circuit with a center frequency of 4kHz.



Graph 7: Gain of Filter Circuit at 4kHz with 25kΩ Potentiometer



Graph 8: Gain of Filter Circuit at 4kHz with 50kΩ Potentiometer



Graph 9: Gain of Filter Circuit at 4kHz with 75kΩ Potentiometer

Table 6: Maximum Gains for Filter Circuit at Center Frequency 250Hz

Max Gain (dB)		
25%	50%	75%
0.271	0.271	5.516

Table 7: 3dB Frequencies for Filter Circuit at Center Frequency 250Hz

3dB Frequencies (Hz)					
25%		50%		75%	
Lower	Upper	Lower	Upper	Lower	Upper
200	50k	1k	20k	200	50k

B. Basic Testing

Question 4:

In this section, the entire audio mixer circuit was built, as shown in AP.6. AP.1-4 show each component within the overall system, and AP.5 shows the equalizer circuit. Filter 1 = 250Hz, Filter 2 = 1kHz, and Filter 3 = 4kHz in the equalizer circuit. The result of the circuit system testing is shown in Figure 1.

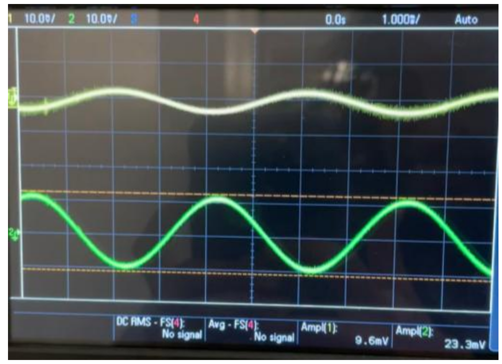


Figure 1: Input (Yellow) and Output (Green) Waveforms of Audio Mixer Circuit

The potentiometer in Filter 1, 250Hz controls the amplitude of the output filter, as shown in Figure 2 and 3. The output amplitude decreased when the potentiometer in filter 2 was set to a lower value, whilst the amplitude increased when the potentiometer was at a higher value.

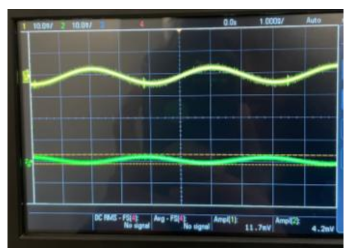


Figure 2: Output Waveform (Green) with low potentiometer in Filter 1

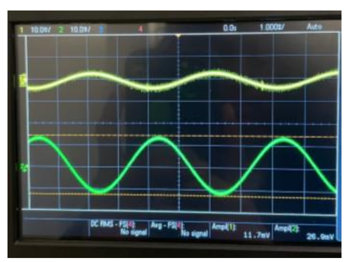


Figure 3: Output Waveform (Green) with high potentiometer in Filter 1

Question 6:

For the 1kHz and 4kHz inputs, the potentiometers in the filter circuits with equal center frequencies as the input controlled the output amplitudes. Figures 4 and 5 show the outputs for 1kHz being controlled by Filter 2's potentiometer, and Figures 6 and 7 show the outputs for 4kHz being controlled by Filter 3's potentiometer.

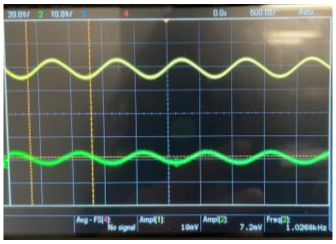


Figure 4: Output Waveform (Green) with low potentiometer in Filter 2

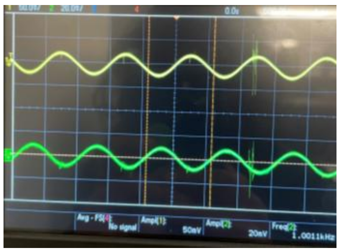


Figure 5: Output Waveform (Green) with high potentiometer in Filter 2

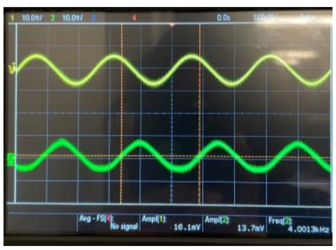


Figure 6: Output Waveform (Green) with low potentiometer in Filter 3

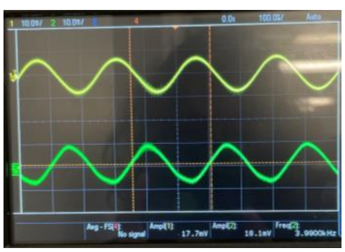
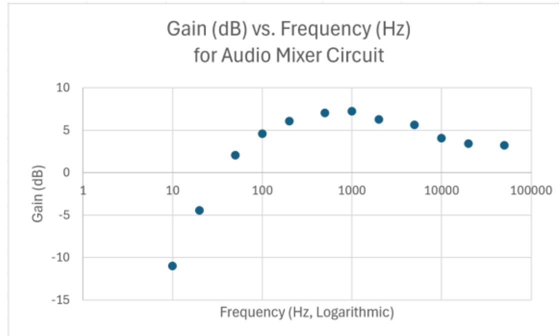


Figure 7: Output Waveform (Green) with high potentiometer in Filter 3

As shown, the potentiometer in filter 1 had the most drastic impact on the output amplitude and the potentiometer in filter 3 had the least drastic impact.

Question 7:
Finally, all of the potentiometers in each of the filters of the equalizer were set to 75% (75kΩ) to observe the gain. Raw data from AP.10 was used to produce Graph 10.
The gain starts low at low frequencies and increases steadily. The peak of the gain is 7.2 dB at 1000 Hz seen in Graph 10, and the gain starts decreasing again in higher frequencies. Only one band is clearly seen in this audio mixer filter, so this audio mixer is a single band-pass filter. The center frequency is around 1000 Hz and the passband spans from 100 Hz to 10000 Hz.



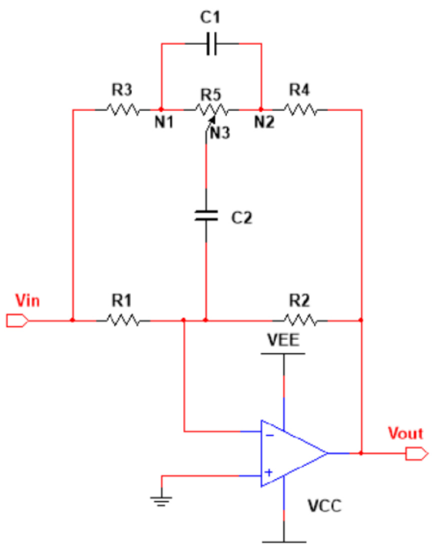
Graph 10: Gain of Audio Mixer with 75kΩ Potentiometers

IV. Conclusions

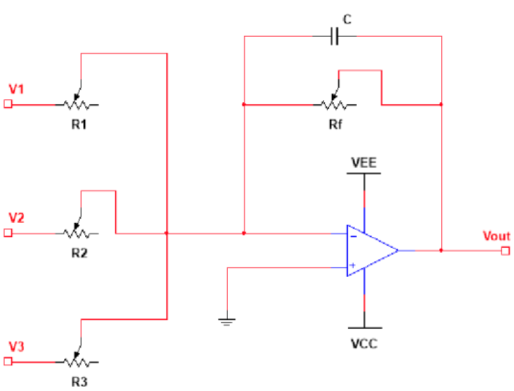
In this lab, filter circuits were characterized by their frequency responses were analyzed. In Part A, three band-filter circuits with different center frequencies are constructed with specific capacitors, and the responses of the filter to frequency and potentiometer is observed. All circuits demonstrated the characteristics of the band-reject circuit with lower potentiometer values of 25% and showed the band-pass filter at 75%. At 50%, the graphs resembled a flatter band-reject, with the errors due to hand-adjusting the potentiometers.

In Part B, the audio mixer system was constructed using the filter circuits as a three-channel equalizer. It is confirmed that the potentiometer of each band filter circuit can control the output waveform with its respective center frequency. The gain of the entire system peaks from 250 – 4kHz, which reflects the three filter circuits used.

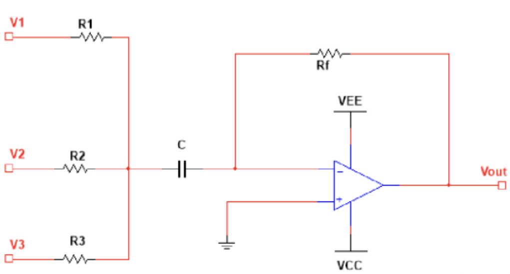
V. APPENDIX



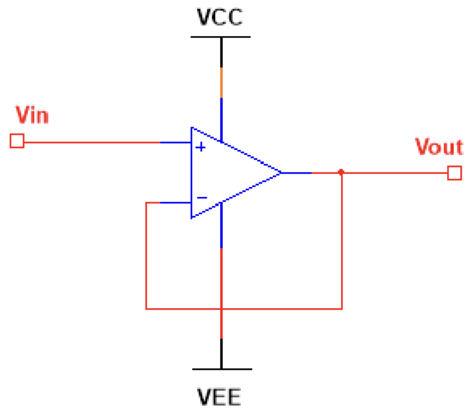
AP.1 Filter Circuit



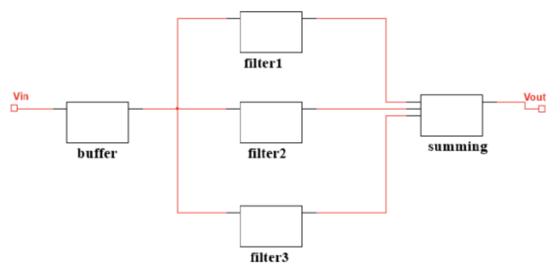
AP.2 Summing Amplifier



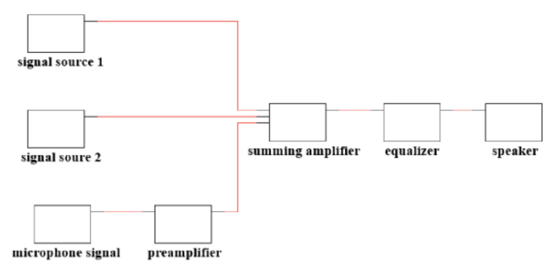
AP.3 Summing Amplifier in Equalizer



AP.4 Buffer Circuit



AP.5 Equalizer Block Diagram



AP.6 Audio Mixer Block Diagram

	25%		50%		75%	
Frequency (Hz)	Input Magnitude (mV)	Output Magnitude (mV)	Input Magnitude (mV)	Output Magnitude (mV)	Input Magnitude (mV)	Output Magnitude (mV)
10	630	640	630	640	630	650
20	630	640	630	650	630	650
50	630	630	630	640	630	660
100	630	590	630	640	630	710
200	630	500	630	630	630	880
500	630	334	630	610	630	1270
1000	630	350	630	610	620	1190
2000	630	470	620	610	620	880
5000	620	590	620	620	620	670
10000	620	600	610	620	610	630
20000	610	610	610	620	610	620
50000	610	610	610	610	630	620

AP.7 Raw Data of Filter Circuit at 1kHz Frequency

	25%		50%		75%	
Frequency (Hz)	Input Magnitude (mV)	Output Magnitude (mV)	Input Magnitude (mV)	Output Magnitude (mV)	Input Magnitude (mV)	Output Magnitude (mV)
10	630	640	630	630	630	650
20	630	610	630	630	630	670
50	620	510	630	630	630	800
100	630	400	630	630	630	1030
200	630	330	630	630	610	1150
500	620	450	630	620	620	880
1000	620	550	620	610	620	690
2000	620	600	620	610	620	640
5000	620	620	610	610	620	630
10000	610	620	610	610	620	620
20000	630	620	610	570	610	610
50000	620	610	610	590	610	610

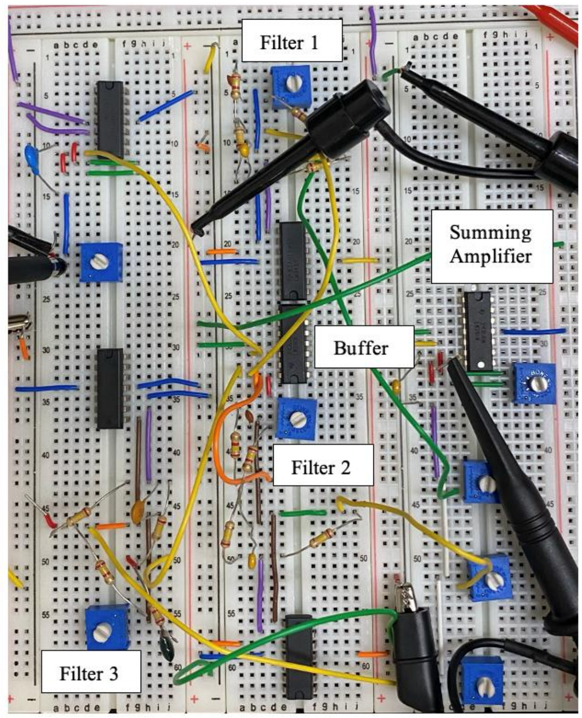
AP.8 Raw Data of Filter Circuit at 250Hz Frequency

	25%		50%		75%	
Frequency (Hz)	Input Magnitude (mV)	Output Magnitude (mV)	Input Magnitude (mV)	Output Magnitude (mV)	Input Magnitude (mV)	Output Magnitude (mV)
10	630	650	630	650	630	640
20	630	640	630	640	620	640
50	630	640	630	640	630	640
100	630	640	630	640	630	640
200	630	640	630	640	630	650
500	630	610	630	640	630	680
1000	630	540	630	640	630	800
2000	630	430	630	620	630	1070
5000	630	370	630	610	620	1170
10000	620	470	620	610	620	840
20000	610	570	610	610	610	670
50000	610	610	610	610	630	620

AP.9 Raw Data of Filter Circuit at 250Hz Frequency

Frequency (Hz)	Input Magnitude (mV)	Output Magnitude (mV)
10	209	59
20	209	125
50	209	265
100	209	354
200	209	420
500	209	470
1000	209	480
2000	209	430
5000	209	400
10000	209	334
20000	209	310
50000	209	302

AP.10: Audio Mixer Gain Raw Data



AP.3 Physical Equalizer Circuit