Technical Report: Lab 14: Basic Audio Equalizer

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Abstract

Equalizers are found in most audio systems, as they enable the ability to adjust and manage how loud each individual frequency bands should be to match the listener's auditory desire. A simple, basic audio equalizer contains of three frequency bands for mid, treble and bass, each of which is able to control the amounts of aforementioned bands using the appropriate filters that are included in each of them. Moreover, for a basic audio equalizer to work, there should also be a volume control and a power amplifier included. In order to construct a simple audio amplifier, this report is conducted based on a common topology of an amplifier circuit and some different experiments to explore and verify the effectiveness of each of the components of this to-be-made amplifier.

1. Objectives

This report has two main objectives. Firstly, it is to create a topology, and verify that topology subsequently. Secondly, it is to construct the basic audio equalizer circuit based on the topology.

1.1. Topology Verification for Filters

This experiment's procedure's objective is to verify the topology that is created for this basic audio amplifier. This experiment is intended to test the validity of the filters in each frequency band: mid, bass, treble. Each of these bands has their own technical constraints: at the -3dB cutoff point, the frequency should be at 320Hz; at 320Hz and 3.2kHz; at 3.2kHz, for the bass filter, mid filter, and treble filter, respectively.

1.2. Audio Equalizer Circuit Verification

This experiment's goal is to eventually construct the basic audio equalizer circuit. This experiment is intended to integrate all subsystems (the filters, volume control systems, and amplifier). This task makes use of the LM324 operational amplifiers incorporated into each of the filters, as well as the summing amplifier, to control the gain to amplify the output signal. This experiment will anticipate how the demonstration of the circuit works with a speaker (ripple ratio, adder, volume control with equalizer adjusted to max) to verify the efficiency and reliability of the circuit.

2. Theory

Figure 1 shows the topology of the basic audio equalizer that is used and verified during this report:

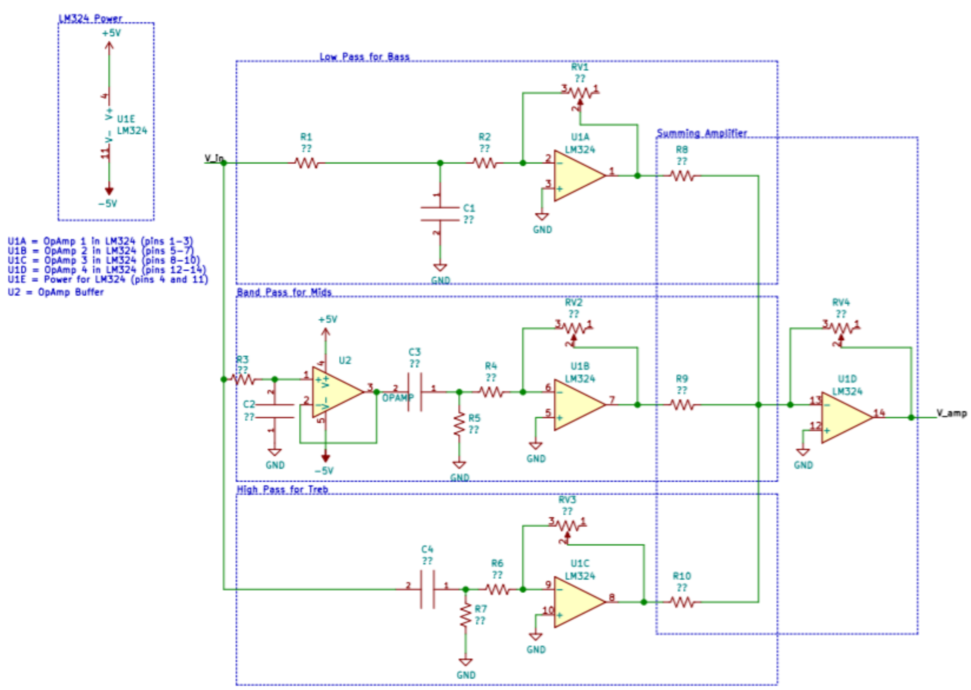

Figure 1: Circuit Topology.

This report relies on the calculations of RMS voltage value of a sinusoidal waveform input using Equation 1., the frequency equation in an RC circuit using Equation 2., gain calculation using Equation 3, which is illustrated by Figure 2, and the LM324N operational amplifier with the pinouts as shown in Figure 3:

$$V_{RMS} = \frac{V_{Peak}}{\sqrt{2}} = \frac{V_{Peak\ to\ peak}}{\sqrt{2}} \tag{1}$$

$$f = \frac{1}{2\pi RC} \leftrightarrow RC = \frac{1}{2\pi} \tag{2}$$

$$G = \frac{R1}{R2} \tag{3}$$

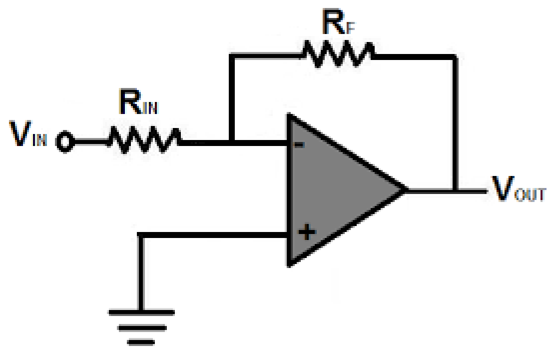

Figure 2: Inverting Op Amp Gain

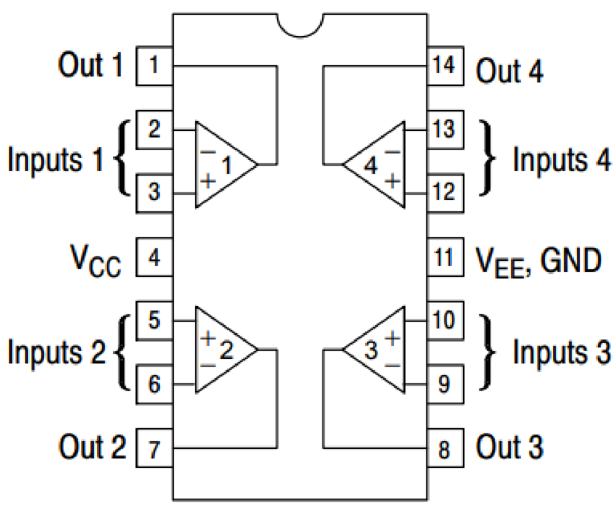

Figure 3: LM324N Op Amp Pinout.

Also, this report utilizes a LM386N-4 op amp to construct a power amplifier. Figure 4 shows the pinout of this op amp, and Figure 5 shows the simple audio amplifier circuit with the two speakers and LM386N-4.

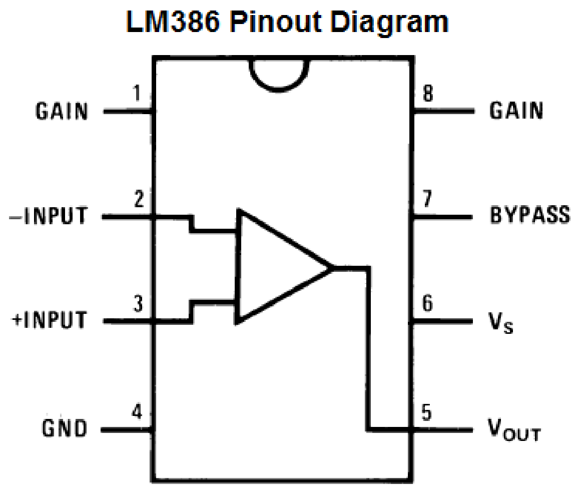

Figure 4: LM386N-4 Pinout

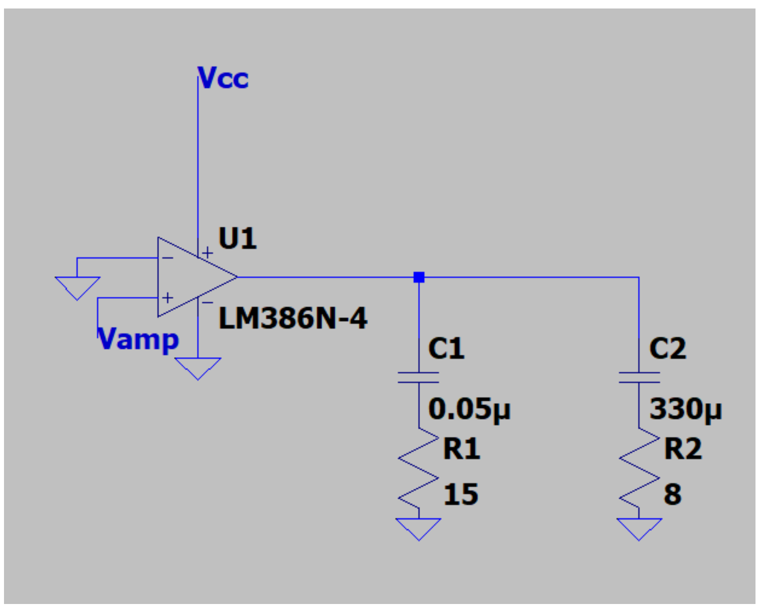

Figure 5: Simple Audio Amplifier Circuit with LM386N-4

Figures 6, and 7 show the simple filter circuits of the low and high pass filters that will be applied for this audio equalizer circuit.

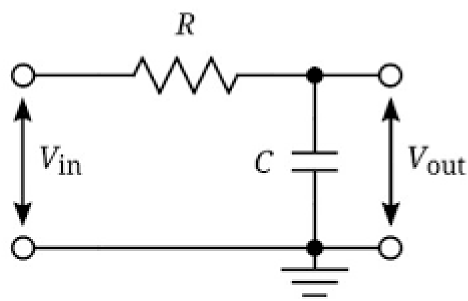

Figure 6: Low Pass Filter Circuit

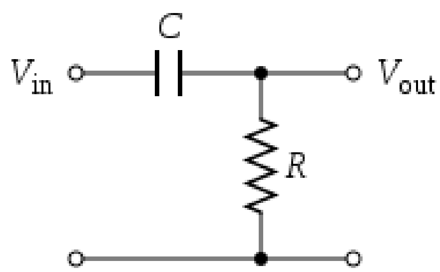

Figure 7: High Pass Filter Circuit

This experiment should show the consistency of the measured results of the filters output, the ripple ratio, as well as the voltage and power output of the amplifiers to the speakers while all equalizers' knobs turned to specific settings compared to the calculated results of those components.

3. Procedure

Table 1: Components values for topology circuit in Figure 1

Component	Task 1	Task 2
R1	470ohm	N/A
R2	5000ohm	N/A
R3	470ohm	N/A
R4	5000ohm	N/A
R5	560ohm	N/A
R6	5000ohm	N/A
R7	560ohm	N/A
R8	N/A	33000ohm
R9	N/A	33000ohm
R10	N/A	33000ohm
C1	1microF	N/A
C2	0.1microF	N/A
C3	1microF	N/A
C4	0.1microF	N/A
RV1	5000ohm	N/A
RV2	5000ohm	N/A

RV3	5000ohm	N/A
Vin	N/A	10000ohm
U1, U2	LM324N	LM324N

3.1. Topology Verification for Filters

Using Equation 2 in the circuit topology in Figure 1, applying Figures 6 and 7 for the filters, with the desired low pass frequency of 320Hz (10% error) and a high pass frequency of 3200Hz (10% error), we can calculate that, resistors R1 and R7 are around 500Ω (which are 470Ω and 560Ω, respectively, as shown in Table 1), and capacitors C1 and C4 are 1µF and 0.1µF, respectively, as shown in Table 1.

Using Equation 3, setting potentiometers RV1, RV2, RV3 in Figure 1 as 5000Ω, to get a gain of 1, resistors R2, R4, and R6 are calculated as 5000Ω each. Connect them to LM324N op amps.

With all these calculations made, the high pass and low pass filters are constructed as shown in Figures 8 and 9:

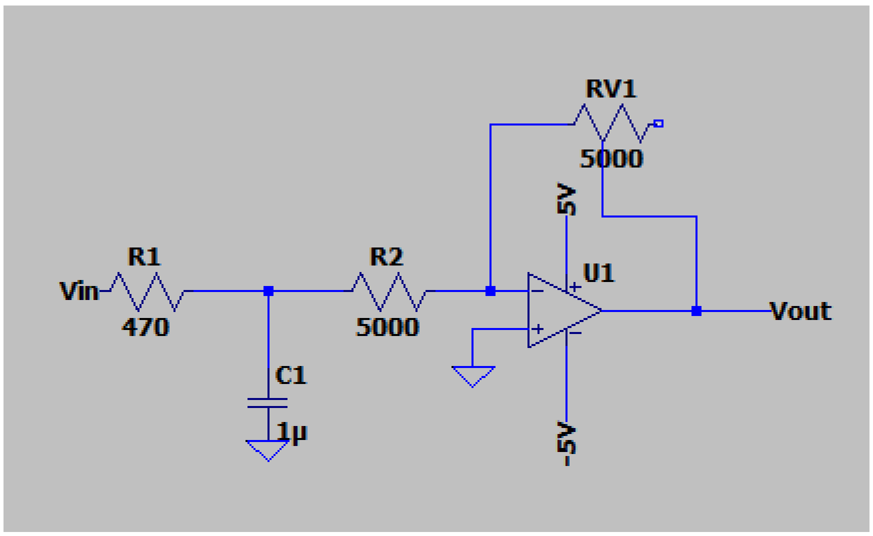

Figure 8: Low Pass Filter with LM324N Op Amp

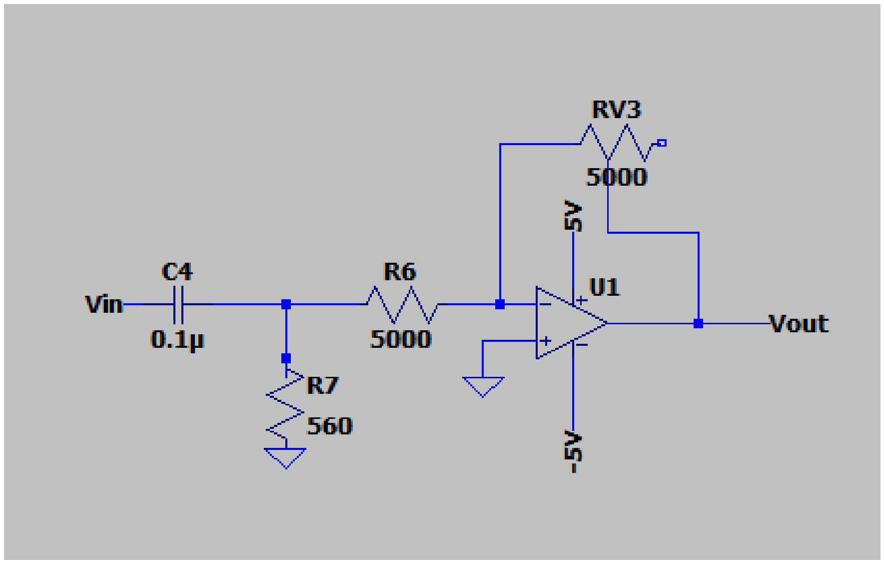

Figure 9: High Pass Filter with LM324N Op Amp

For the Mid filter, construct a band pass as shown in Figure 1. Using Equation 2 applied to the low pass circuit in Figure 6, we calculate the first part of the band pass with resistor R3 as 470ohm and capacitor C2 as 0.1microF. Connect the components to a LM324N, we have the first part of the mid filter.

Repeat the procedure of the first part for the second one but applying that to the high pass circuit in Figure 7, we have capacitor C3 as 1microF, and resistor R5 as 560ohm. Connect the first and second parts of the mid filter to a LM324N op amp and the gain resistors, we construct the mid filter band pass as shown in Figure 10:

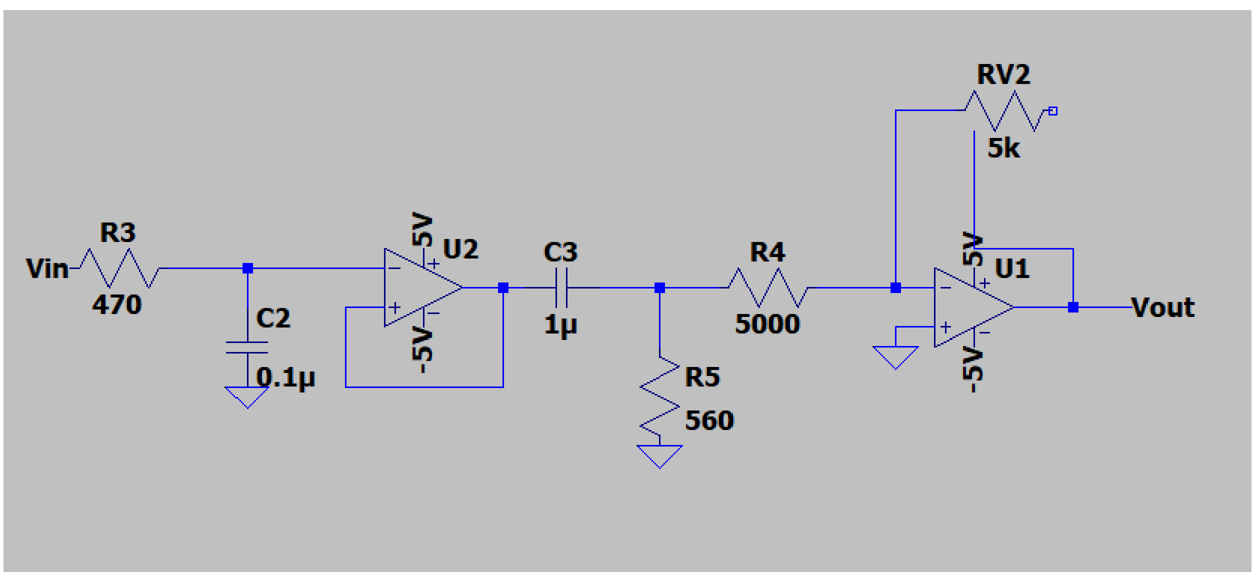

Figure 10: Band Pass Filter for Mid

Measure and plot the gain, phase versus frequency for each filter.

3.2. Audio Equalizer Circuit Verification

Using Equation 1 and Equation 3, to achieve a desired gain that can output the amplified output of 100mVrms, applied to the input signal of 1 V_{pp} sine wave, we calculated that R8, R9 and R10 to be around 30000ohm each (which is 33000ohm, as shown in Table 1) while RV4 is set to maximum at 10000ohm. The summing amplifier is constructed as shown in Figure 11:

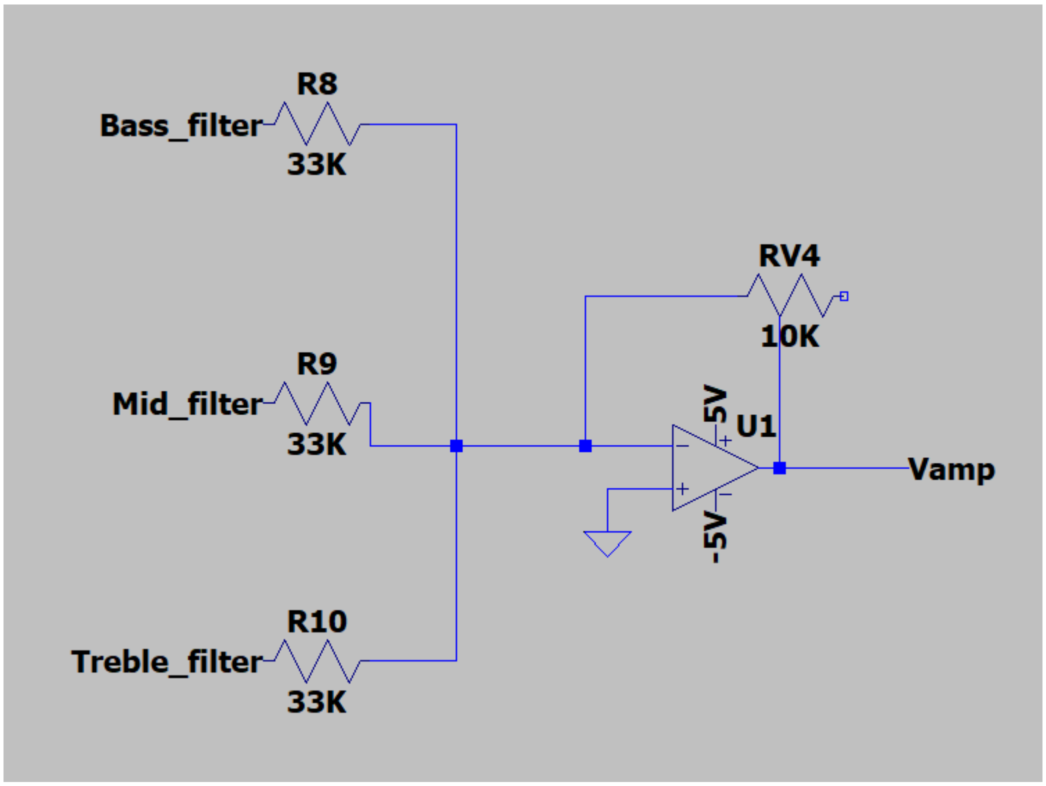

Figure 11: Summing Amplifier Circuit

Connect the summing amplifier to the filters, as shown in Figure 1 topology.

Turn all knobs to minimum settings and measure Vamp at 3 specific frequencies: 200Hz, 2kHz and 10kHz. Repeat the procedure but turn all knobs to maximum settings.

4. Results

4.1. Topology Verification for Filters

After constructing the filters as shown in Figures 8, 9 and 10 and applying a signal of 1 V_{pp} sine wave, we measure that the output voltages for each of the filters as shown in Figures 12, 13 and 14:

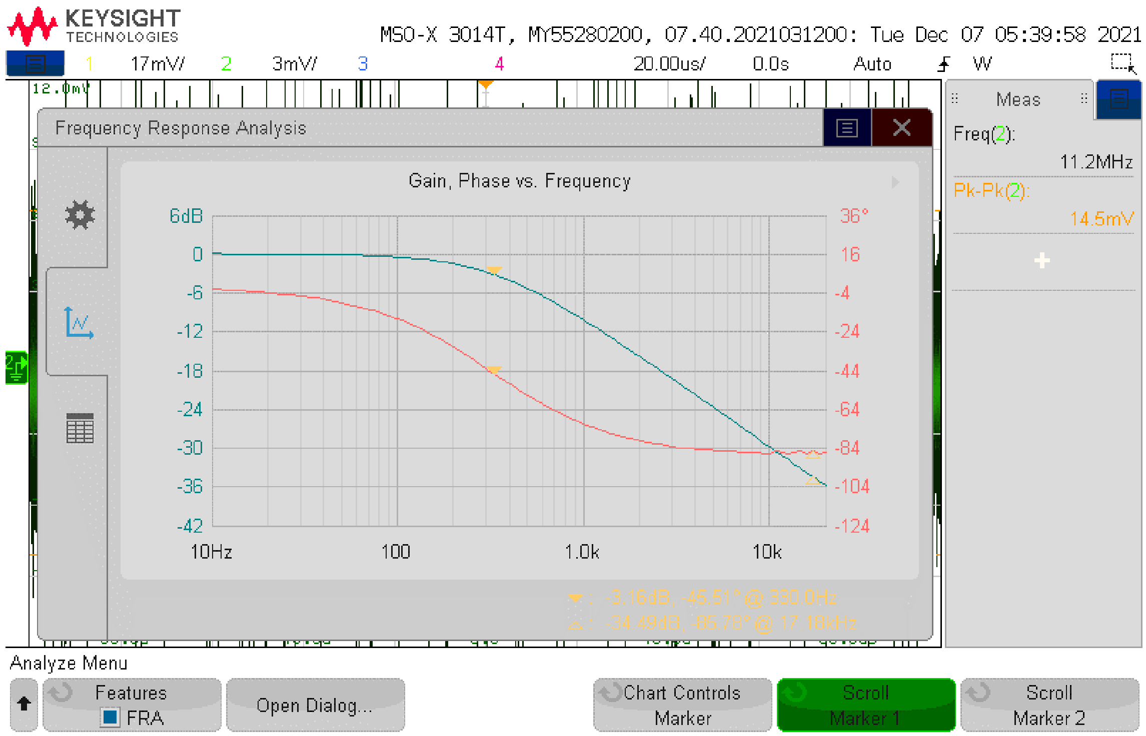

Figure 12: Low Pass Filter Gain and Phase versus Frequency

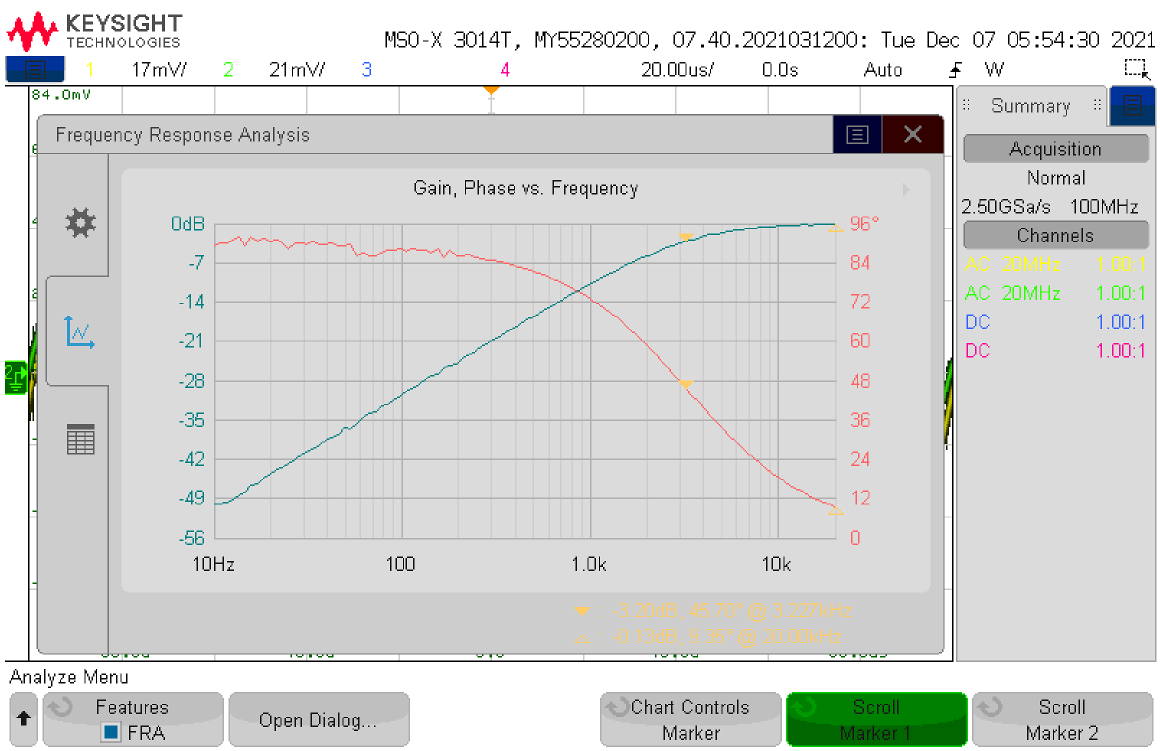

Figure 13: High Pass Filter Gain and Phase versus Frequency

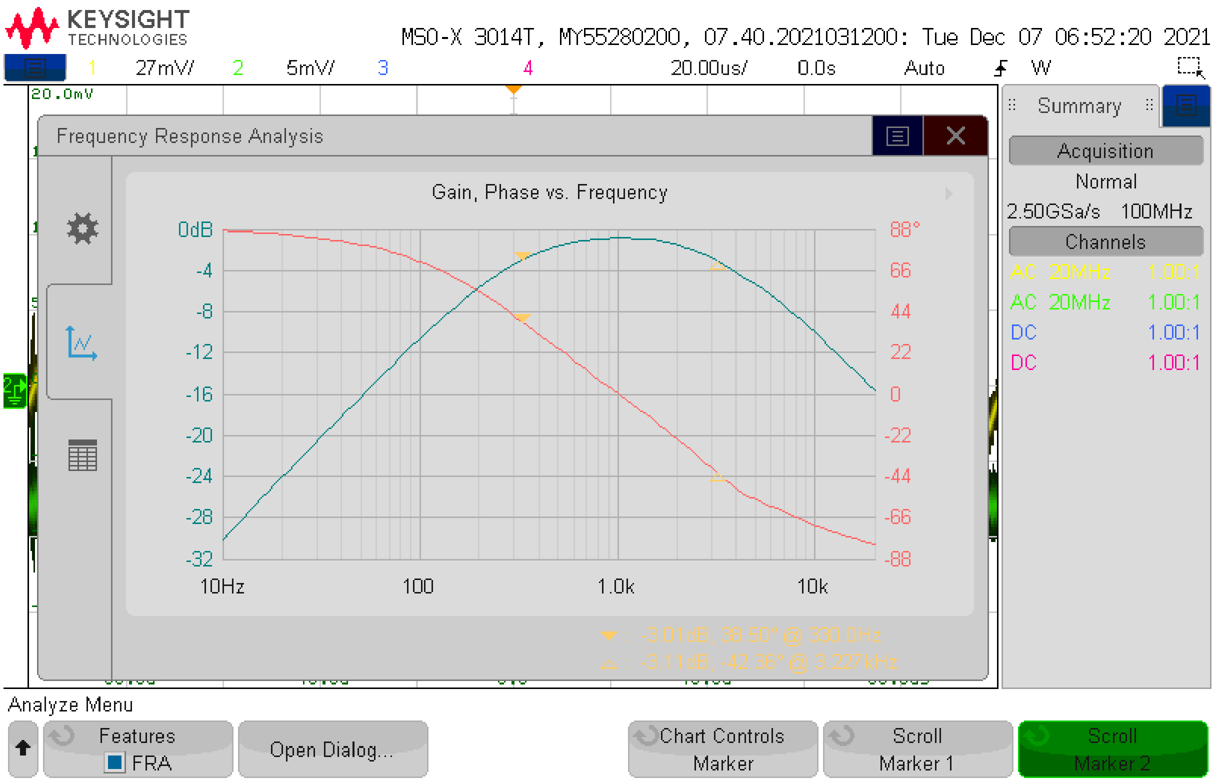

Figure 14: Band Pass Filter Gain and Phase versus Frequency

From there, as shown in each figure, we can record the -3dB cutoff frequency point and have Table 2:

Table 2: -3dB cutoff Frequencies Points

-3dB Cutoff	Measured (Hz)	Theory (Hz)	Error Percentage
Low pass	330	320	3.125%
High pass	3227	3200	0.84375%
Band pass (former)	330	320	3.125%
Band pass (Latter)	3227	3200	0.84375%

4.2. Audio Equalizer Circuit Verification

After connecting the filters to the summing amplifier (Figure 11), by turning the knob to minimum settings, we recorded the amplified voltage output at 3 frequencies (200Hz, 2000Hz, and 10000Hz) and generated the figures (with green as Vamp):

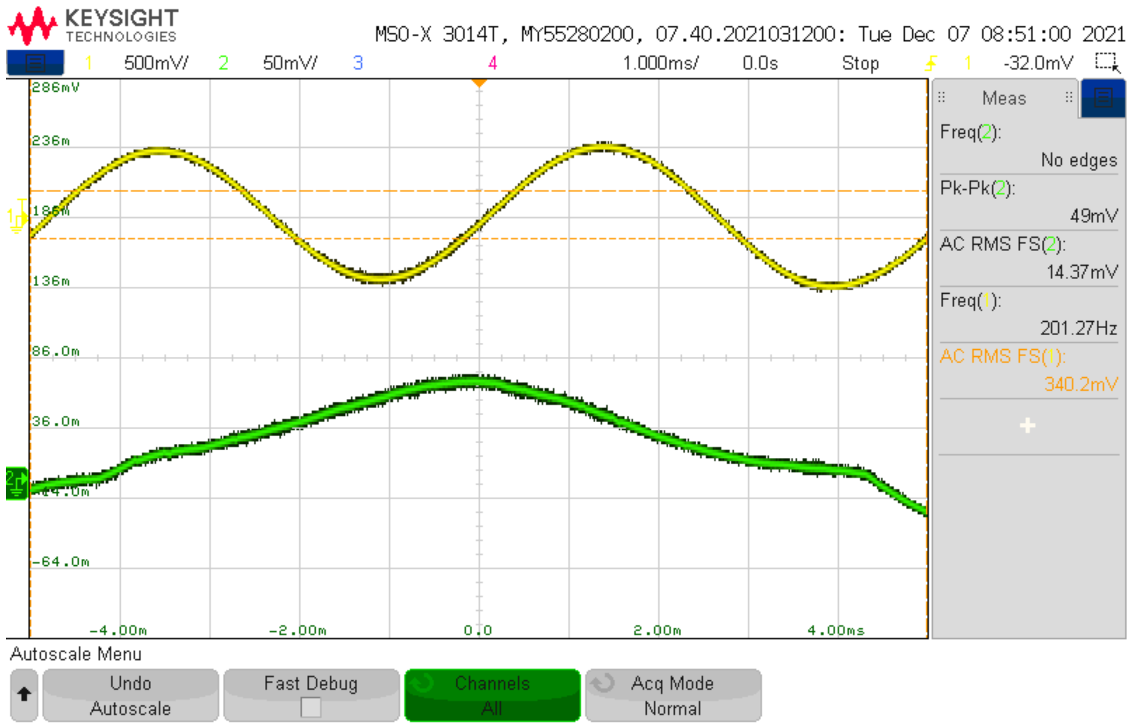

Figure 15: Amplified Voltage Output at 200Hz with All Knobs to Minimum

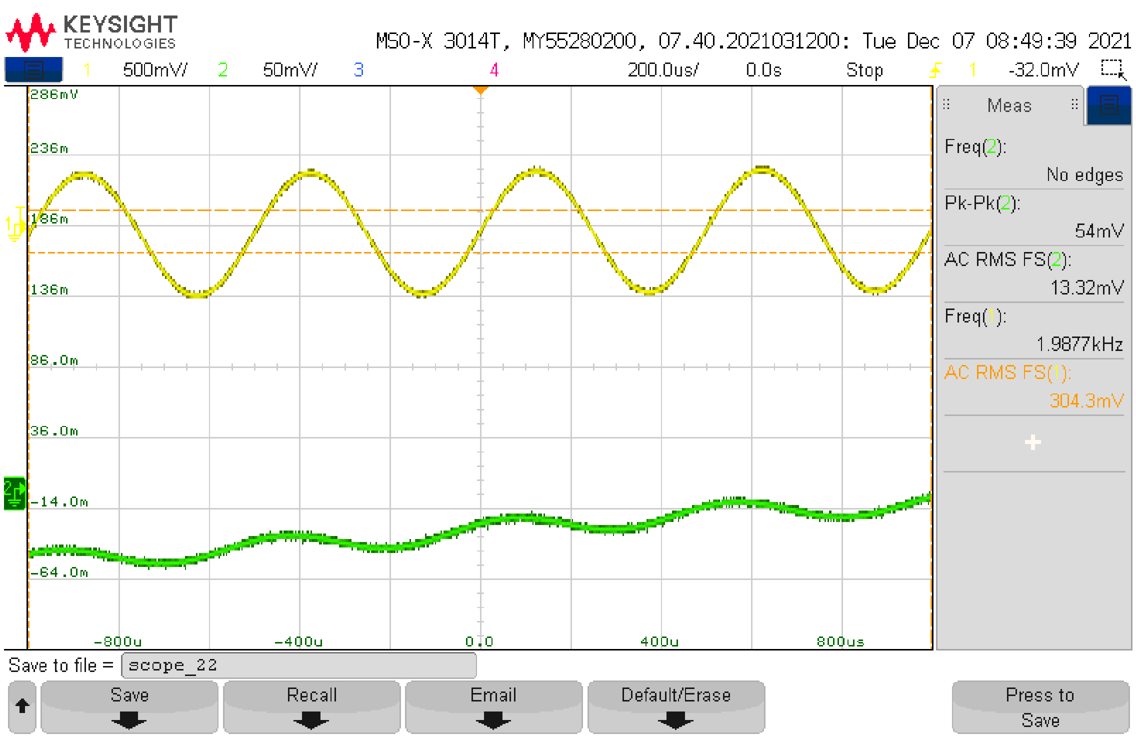

Figure 16: Amplified Voltage Output at 2000Hz with All Knobs to Minimum

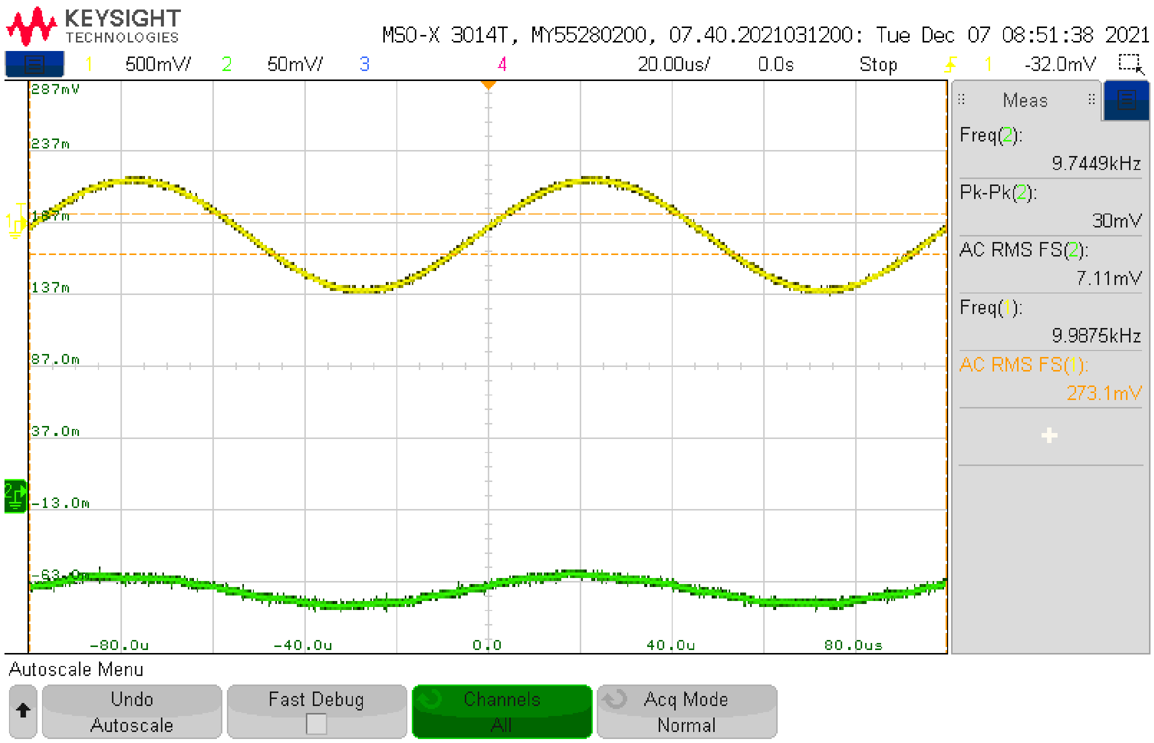

Figure 17: Amplified Voltage Output at 10000Hz with All Knobs to Minimum

When adjusting the knobs to maximum settings, we record the plots for amplified voltage output at the same frequencies:

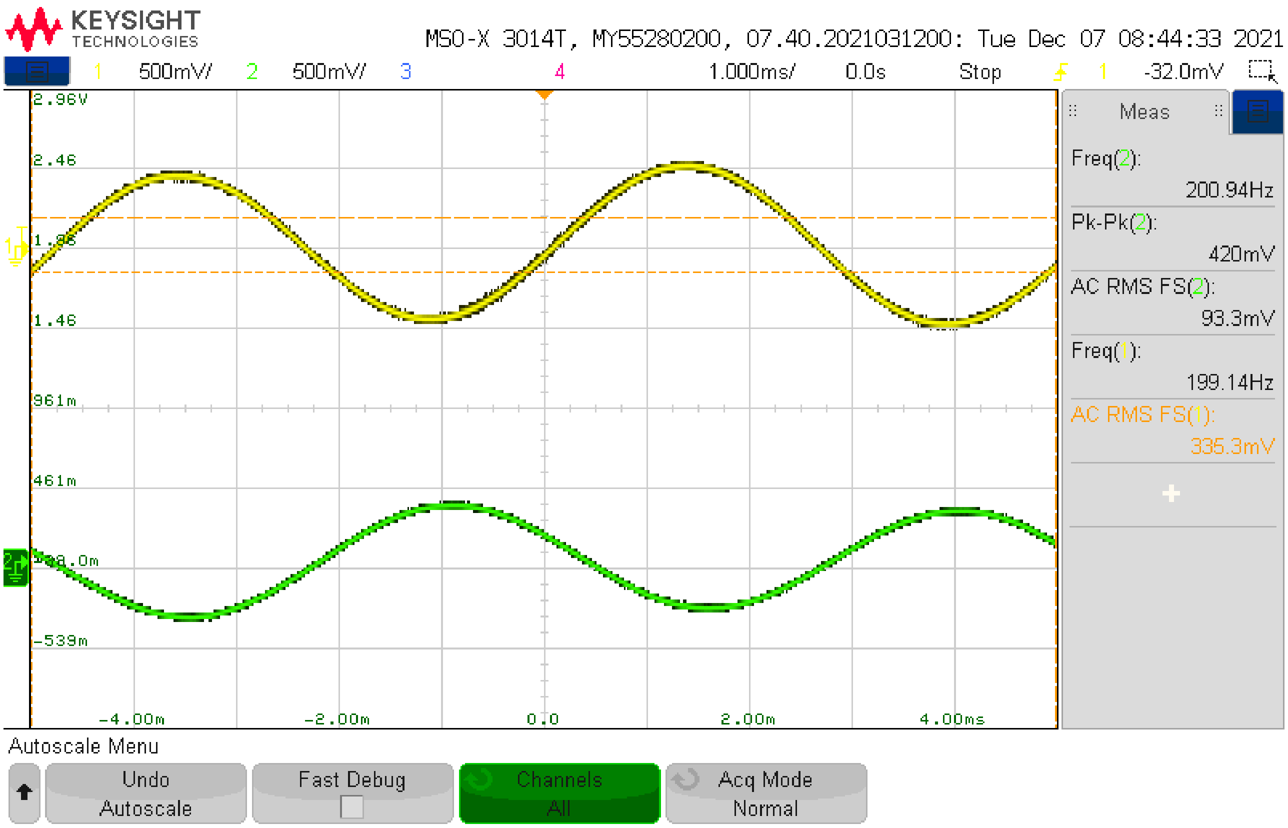

Figure 18: Amplified Voltage Output at 200Hz with All Knobs to Maximum

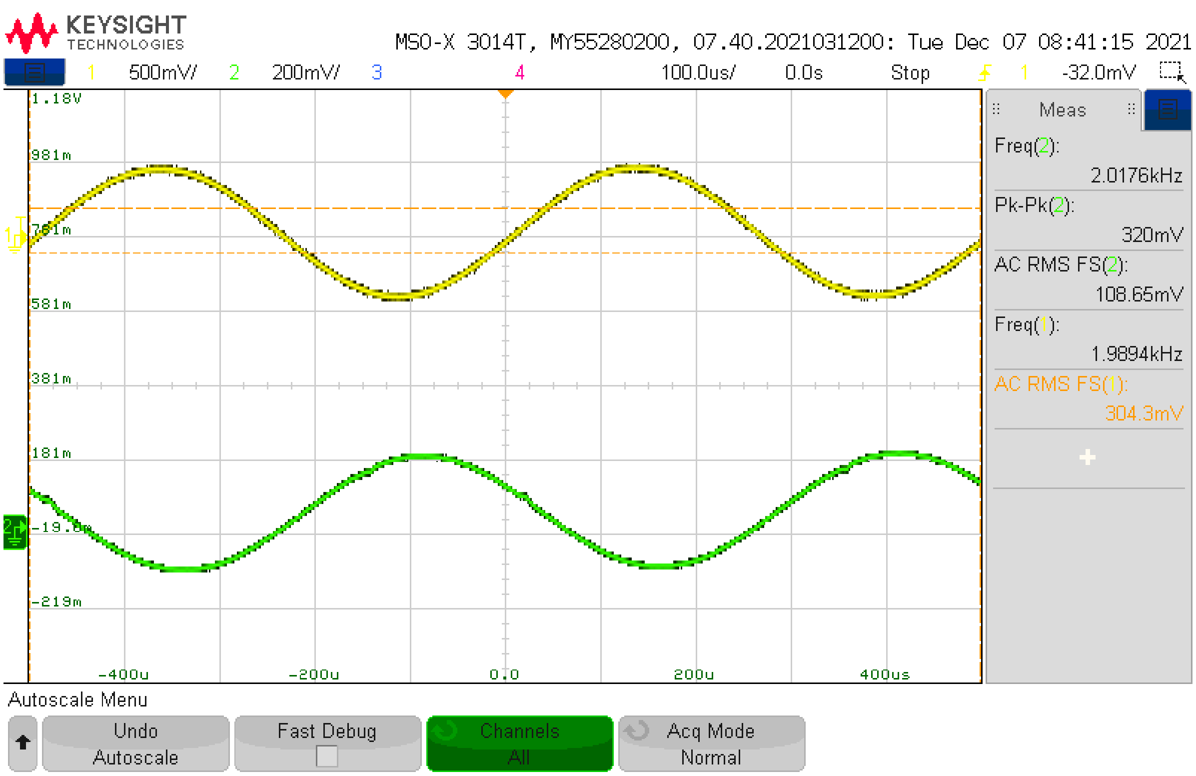

Figure 19: Amplified Voltage Output at 2000Hz with All Knobs to Maximum

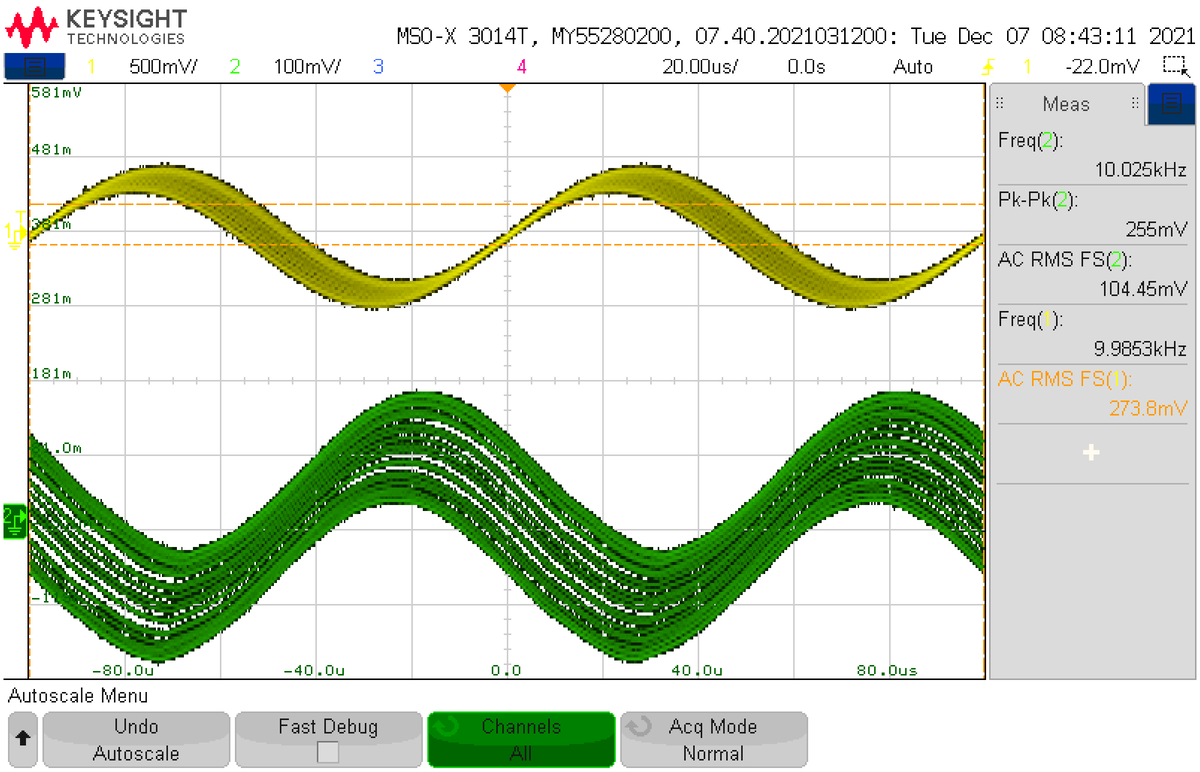

Figure 20: Amplified Voltage Output at 10000Hz with All Knobs to Maximum

Finally, we generated a plot for ripple measurement of this basic audio equalizer as shown in Figure 21:

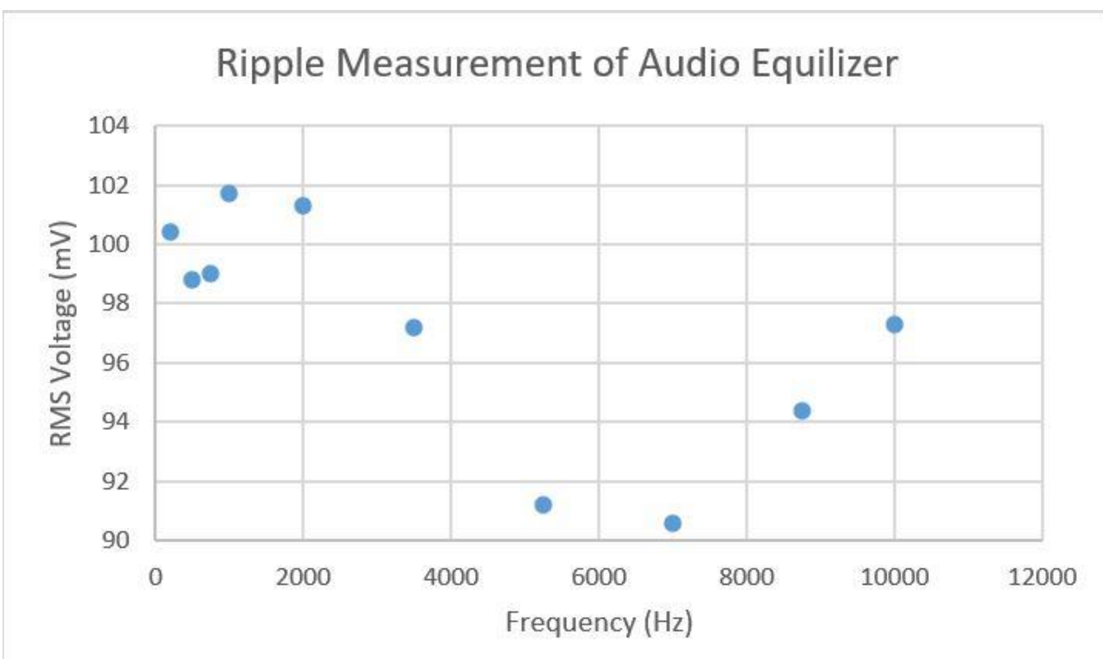

Figure 21: Ripple Measurement for Audio Equalizer

From the figures 15 to 20, we can generate a table to see how well our measurement of Vamp meets the required values:

Table 3: Amplified Output Voltages and Error Percentage

Vamp	Measured (mVrms)	Theory (mVrms)	Error Percentage
Min settings, 200Hz	14.37	<15	TRUE
Min settings, 2000Hz	13.32	<15	TRUE
Min settings, 10kHz	7.11	<15	TRUE
Max settings, 200Hz	93.3	100	6.7%
Max settings, 2kHz	108.65	100	8.65%
Max settings 10kHz	104.45	100	4.45

5. Conclusion

This report's goal is to construct a basic audio equalizer, and as far as observations go, we have very closely achieved the objective. The topology was created, constructed, and verified based on how well the graphs behave in figures 12, 13 and 14. Furthermore, amplified voltage output is also measured, which is very closed to the calculated values. Although power amplified output was not achieved, after plugging in to a speaker, this circuit can still generate a quite flat sound, which is as desired.