Audio Equalizer Project

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Date: 5/5/2022

Abstract

The main objective or goal of this experiment was to successfully create an audio equalizer. To do so, the process was broken down into five main objectives. These were the creation of the low pass filter, the band pass filter, and the high pass filter, as well as the construction of both the summing and power amplifiers. Fundamental theory and cutoff value equations were used to calculate the correct values to create frequencies corresponding to the project requirements. Once the filters were verified, the summing and power amplifiers were attached to then test the audio equalizers ability to balance and amplify sound through a speaker. Data was collected at each objective to demonstrate the performance and compare to calculated results. Fundamental data and theory obtained in the audio equalizer construction led us to meet all requirements.

1. Objectives

In this project, there were five components to build with seven requirements given. The required components were a bass filter with a -3dB cutoff, and mid pass filter with a -3DB cutoff, a treble filter with a -3dB cutoff, a summing amplifier, and a power amplifier. The filters were to be connected to corresponding amplifiers, and those amplifiers were to be connected to both the summing and power amplifier to control the output at various frequencies of inputted waves. Each component had specifications it must meet in order to meet our overall objective of building a successful audio equalizer. The bass filter at the -3dB cutoff must have a frequency of 320 Hz. For the mid filter at the -3dB cutoff, a frequency of 0.32kHz to 3.2 kHz was to be obtained. For the treble filter at the -3dB cutoff, the required frequency is 3.2 kHz. All of these filters must have an accurate frequency with a tolerance of +/- 10%. Anything in the 10% range is considered successful at meeting the overall objective. For the summing amplifier, there are different requirements for when the potentiometer is at a minimum as opposed to a maximum. At the minimum, the output voltage must me less than 15mVrms at three different frequencies: 200 Hz, 2KHz, and 10 Hz. At the maximum, the output voltage must be 100mVrms at the same three frequencies as tested in the minimum. This value must be within 10% of the 100mVrms requirement. The power amplifier must return a power greater than 4090 mW in between 200 Hz and 10 kHz.

By creating the audio equalizer with these specifications, we will be verifying the principles of filters and the theory behind choosing values of resistance and capacitance to create these filters. We will also be able to verify our theory's about the trends power amplifiers and summing amplifiers have when used to valance sound through a speaker.

1. Theory

An essential component of the overall audio equalizer is a high pass, low pass, and mid pass filter. Each one is connected to an amplifier to create a treble, bass, and mid amplifier. A high pass filter reduces the content below a given cutoff frequency. This allows higher frequencies to pass through. A low pass filter reduces the content above a cutoff frequency. This allows the lower frequencies to pass through the filter. The mid filter uses the same process to allow just the middle values through. The low will only allow waves lower than 320 Hz, the high will allow waves over 3200 Hz, and the mid will allow values in between the two. These filter configurations can be seen below in Figures 1-3

To construct the filters different combinations of resistors and capacitors were required to get the correct frequencies. The equation below was used to determine what these values should be for each type of filter at their respective frequency requirements.

$$fc = \frac{1}{2\pi RC}$$

Equation 1: Frequency Cutoff Equation

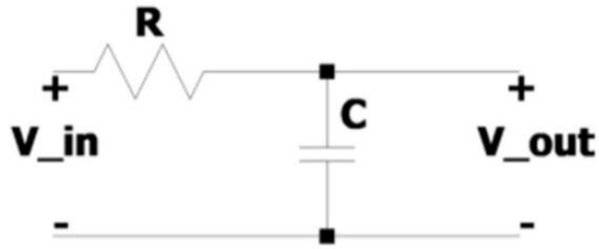

Figure 1: Low Pass Filter Schematic

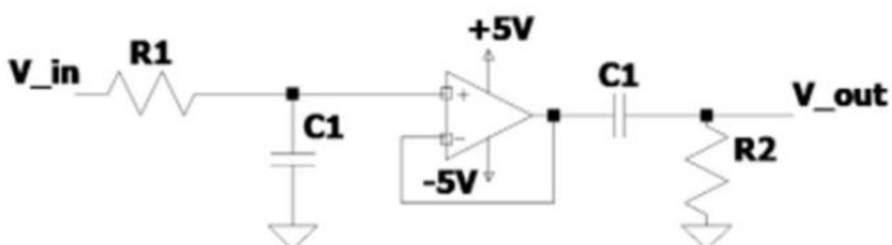

Figure 2: Mid Pass Filter Schematic

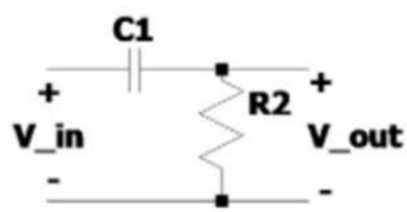

Figure 3: High Pass Filter Schematic

The filters created all connect to an LM 324 IC. The LM 324 acts as an inverting op-amp. Each LM324 has four channels to use in it so only one is needed to create the circuit, but more can be used as well. The op amp when combined with a 10 KOhms potentiometer allows for a large and stable control over how much voltage the system is outputting. Adjusting the potentiometer will adjust eh amount of outputting voltage, or the amplitude of the wave. The pinout for the LM324 as well as the pinout for the potentiometer can be seen below.

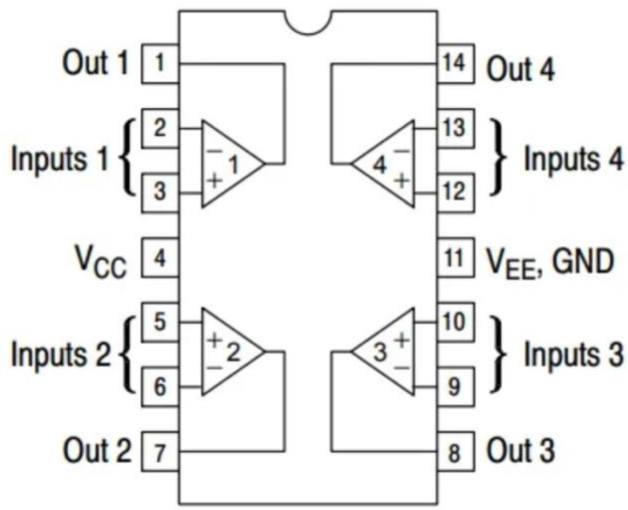

Figure 4: LM324 Pinout

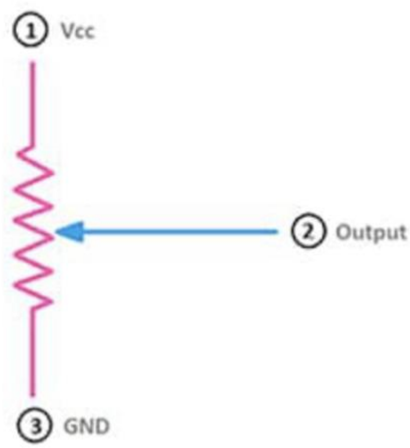

Figure 5: Potentiometer Pinout

A power amplifier takes the final output voltage and increases the power using an LM386. The pinout for this can be seen below. By increasing the power through the power amplifier, a larger input can be sent to the speaker. Because of this there will be a much more clear and loud output from the speaker. The schematic used for the construction of the power amplifier is shown below. Power through the resistor can also be calculated using a Vrms measurement. The equation to calculate power can be seen in Equation 2.

$$P = V^2/R$$

Equation 2: Power Equation

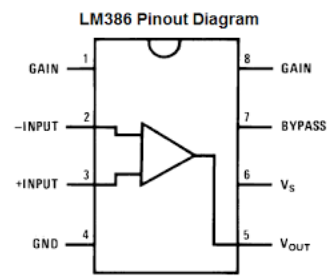

Figure 6: LM386 Pinout

A summing amplifier is the method used to combine the output voltages from each individual amplifier. The treble, bass and mid amplifier an all be summed to create one final output voltage which is the one eventually pushed through the power amplifier. The equation used to linking the summed Vamp to the individual constructed circuits via superposition can be shown below. Through this we were able to calculate the three resistor values between the individual amplifiers and the summing amplifier.

$$v_{out} = \sum_{i=1}^{n} \frac{v_{in,i}}{R_i}$$

Equation 3: Summing Amplifier Equation

2. Procedure

Within the theory section, individual components of our overall circuit were shown, however to further understand the procedure to follow a full circuit schematic is shown in Figure 7. The full circuit topology was the necessary first step our team took to create a blueprint to base our final design off of.

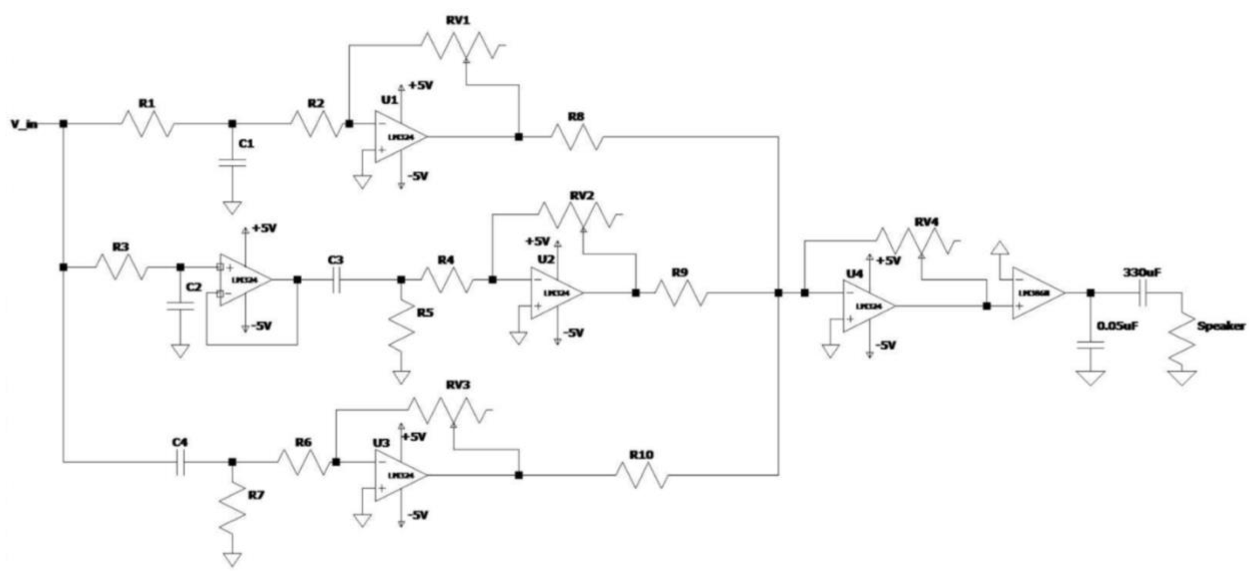

Figure 7: Full Circuit Schematic

The first task our team did was calculate the resistor and the capacitor values necessary to meet all parameters given in the objectives section using the equations shown in the theory portion of the report. Resistor and capacitor values were calculated for our low pass, band pass, and high pass, as well as resistance values to be used in between our amplifiers and summing amplifier. Resistance values were also calculated to go in between the summing and power amplifiers. These values were found by considering all of the resistance values to be the maximum value of the potentiometer, which is 10 kilo-ohms

To find our low pass R1 and C1 values, our high pass R7 and C4 values,, and band pass R3, C2, R5, and C3 values, we used equation one. The resulting values can be seen in Table 1 below

To find the second, fourth and sixth resistor values, the goal was to prevent using another op amp for a stable voltage output. To do this we chose values greater than their corresponding resistor. The chosen value for this was 10 kOhms.

In finding the eighth, ninth, and tenth resistance values, all RV values were considered to be the maximum value of the potentiometer. This resulted in 126 kilohms for all of the resistors. Equation 3 from the theory section was used to perform this task.

Component	Value
R1	220 Ohms
R2	10 kOhms
R3	470 Ohms
R4	10 kOhms
R5	220 Ohms
R6	10 kOhms
R7	470 Ohms
R8	126 kOhms
R9	126 kOhms
R10	126 kOhms
C1	2.2 microF
C2	0.1 microF
C3	2.2 microF
C4	0.1 microF
RV1	10 kOhm
RV2	10 kOhm
RV3	10 kOhm
RV4	10 kOhm

Table 1: Values for Full Circuit Schematic

Once the circuit values were calculated, the circuit was constructed according to the schematic in Figure 7. Each individual filter was built and tested first to ensure that the components worked on their own before building an entire circuit around them. These filters were tested by applying a 1 Vpp sin wave and conducting a gain phase frequency analysis. Through this, we verified the -3dB point occurred at our desired frequencies.

The next step in construction was connecting them to the amplifiers. During this step, the pinouts of the amplifiers became very important. To make sure the device is functioning properly it must be integrated into the circuit exactly as pictured in the pinout figures. Once the individual amplifiers were built, we moved on to the construction of the summing amplifier. After constructing the summing amplifier we verified its function by measuring the VRMS at various frequencies with the potentiometer at a minimum and a maximum. At the minimum, the VRMS should read very close to zero as it is essentially off. At the maximum it should be close to 100 mVrms for each frequency value.

With the summing amplifier in place and working, the next step was the instillation of the power amplifier circuit. Our team tested this circuit portion by measuring the output wave over it. The potentiometer was adjusted and could change volume correctly. The power was measured over the resistor using equation 2 from the theory section.

3. Results

Once the filters were created a gain phase frequency graph was created for each filter. The following three figures identify the -3dB point for each filter graph

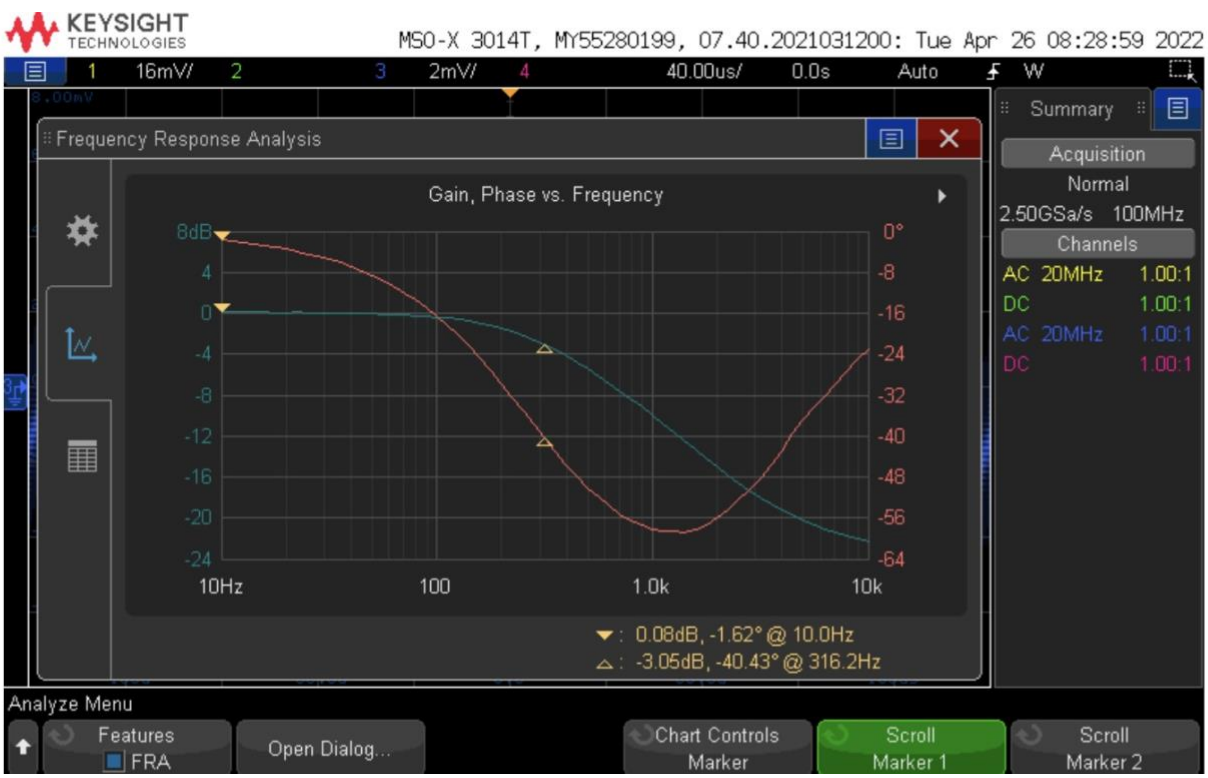

Figure 8: Low Pass Filter Gain, Phase vs. Frequency Analysis

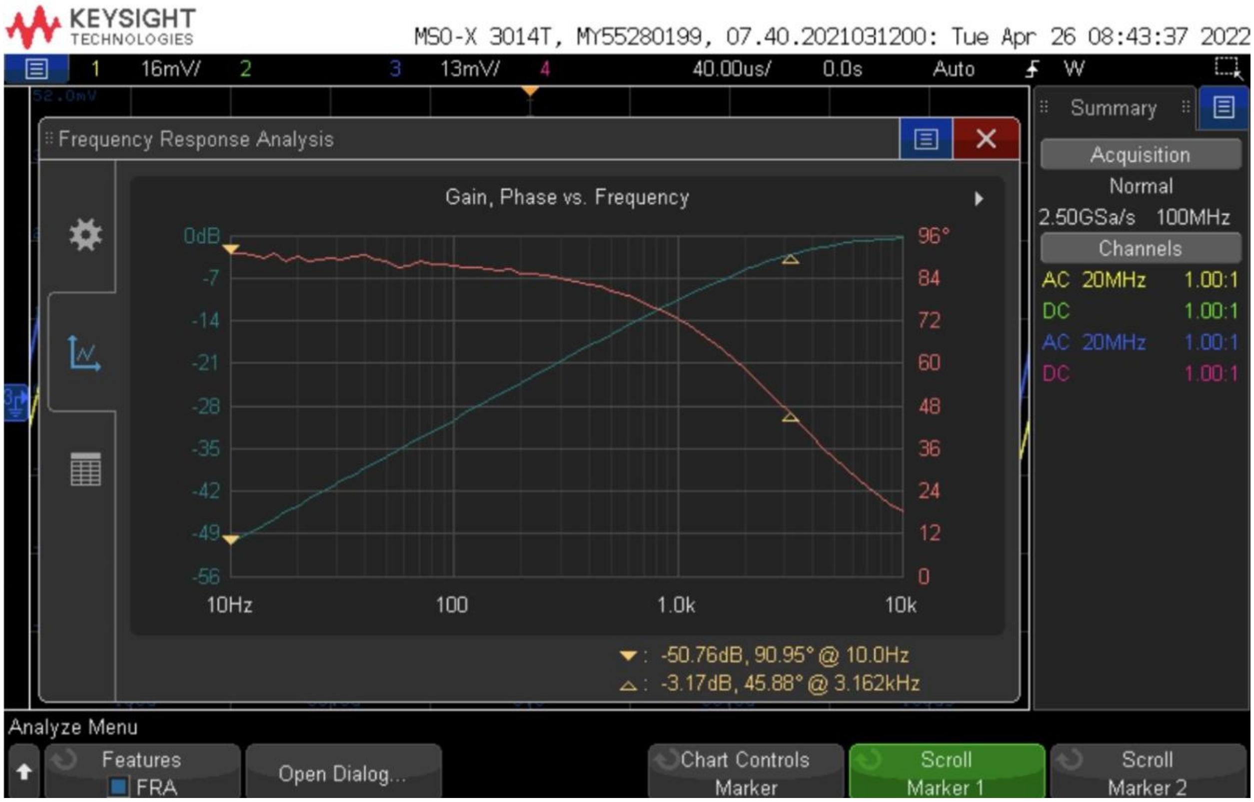

Figure 9: High Pass Gain, Phase vs. Frequency Analysis

Figure 10: Band Pass Gain, Phase vs. Frequency Analysis

To see the trends of the output voltage from the summing amplifier with the adjusting potentiometer, the Vamp RMS value at three different frequency values were measured. The output graphs are from when the potentiometers were set to a minimum at frequencies of 200 Hz, 2 kHz, and 10 kHz. The obtained values are shown below on the following three figures.

To further explore the trends of the output voltage from the summing amplifier with the adjusting potentiometer, the Vamp RMS value at three different frequency values were measured. The output graphs are from when the potentiometers were set to a maximum at frequencies of 200 Hz, 2 kHz, and 10 kHz. The obtained values are shown below on the following three figures.

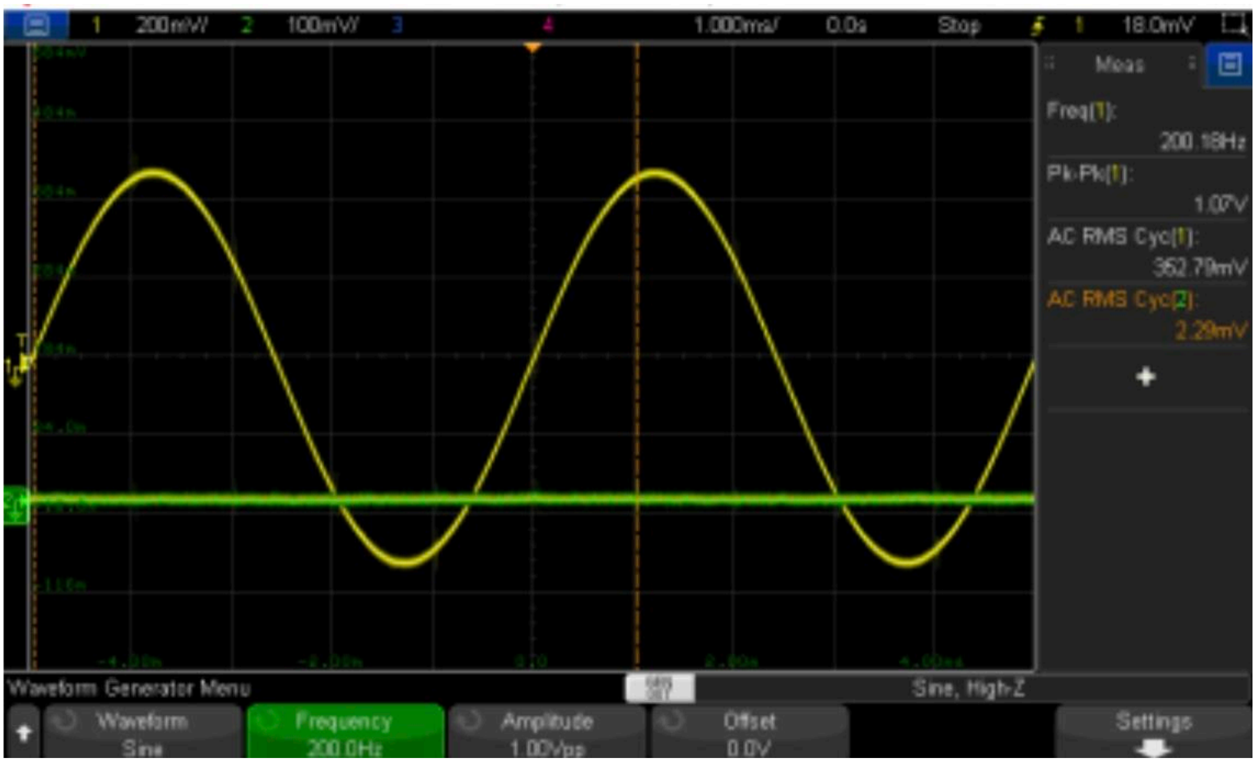

Figure 10: Minimized Potentiometer at 200 Hz

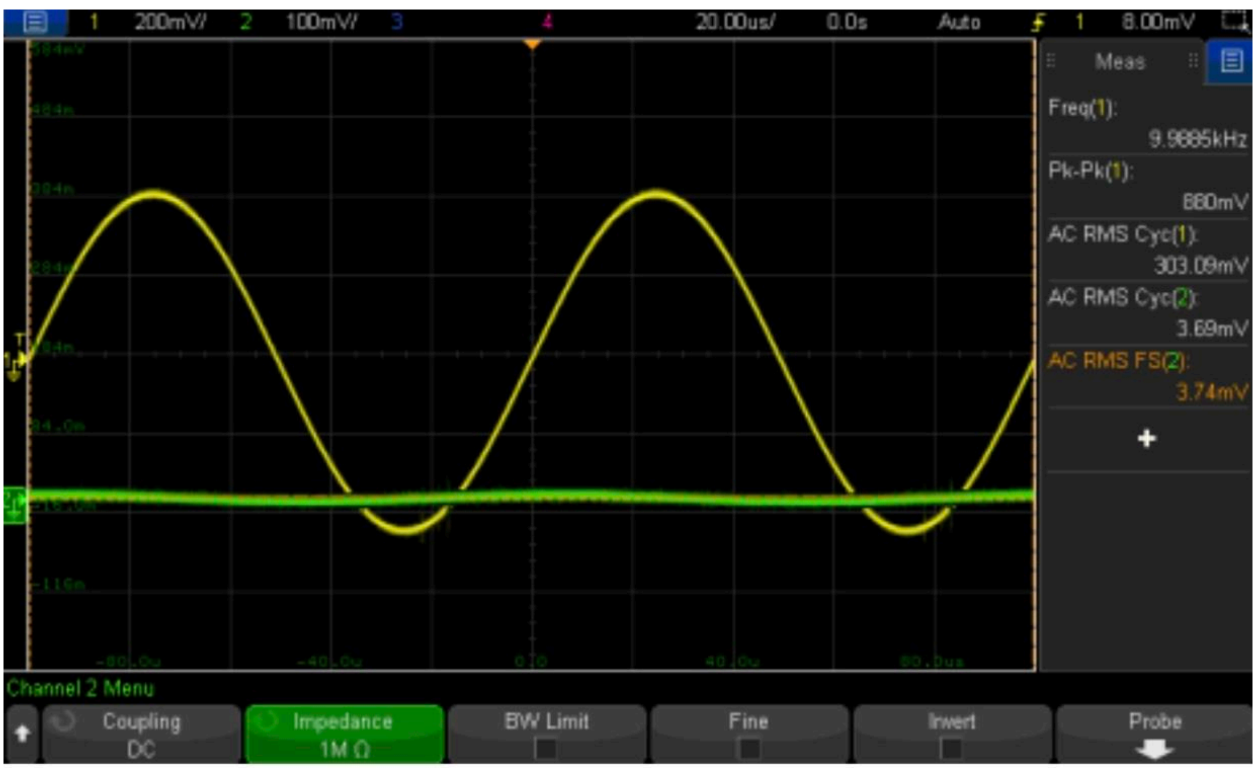

Figure 11: Minimized Potentiometer at 10 KHz

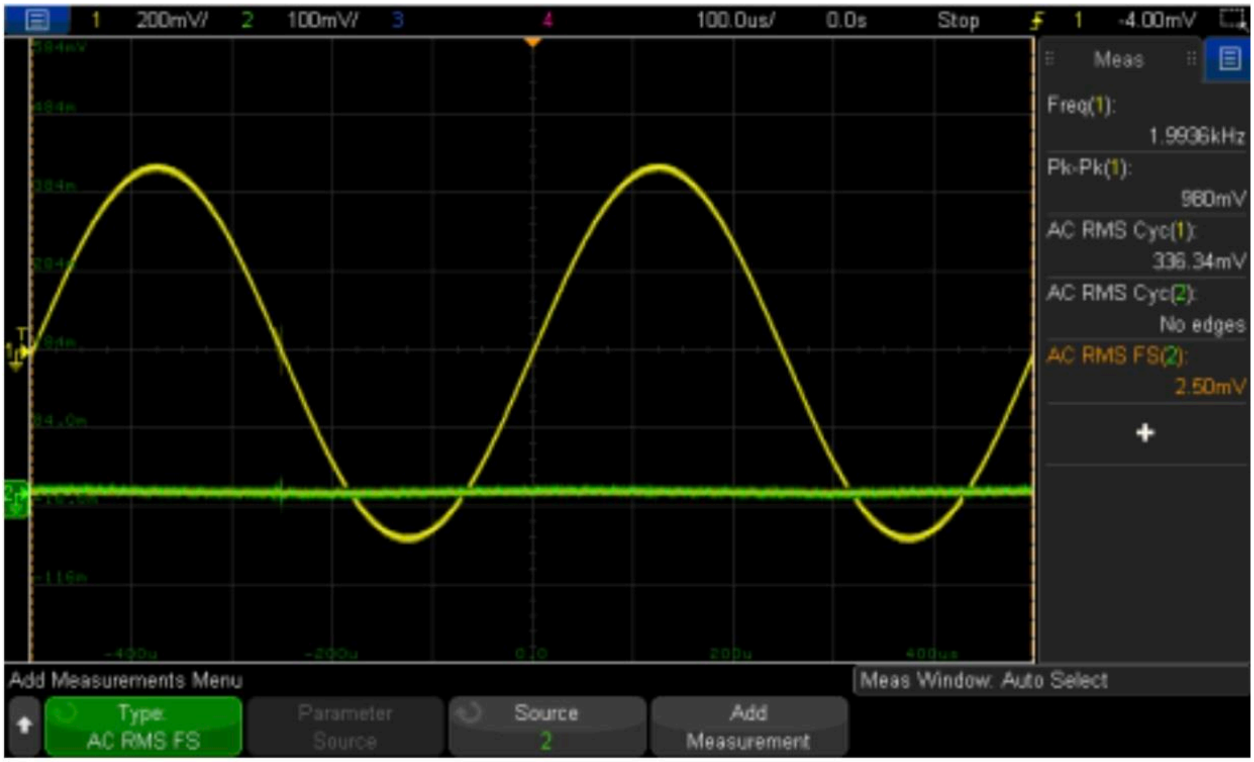

Figure 12: Minimized Potentiometer at 2 kHz

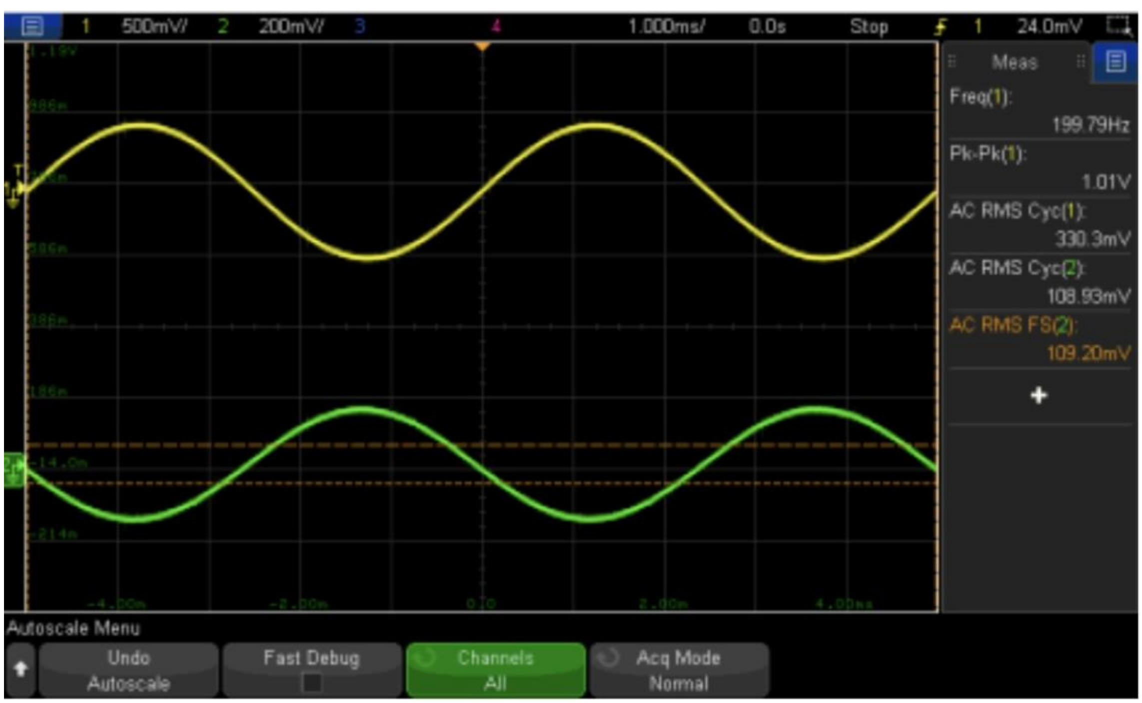

Figure 13: Maximized Potentiometer at 200 Hz

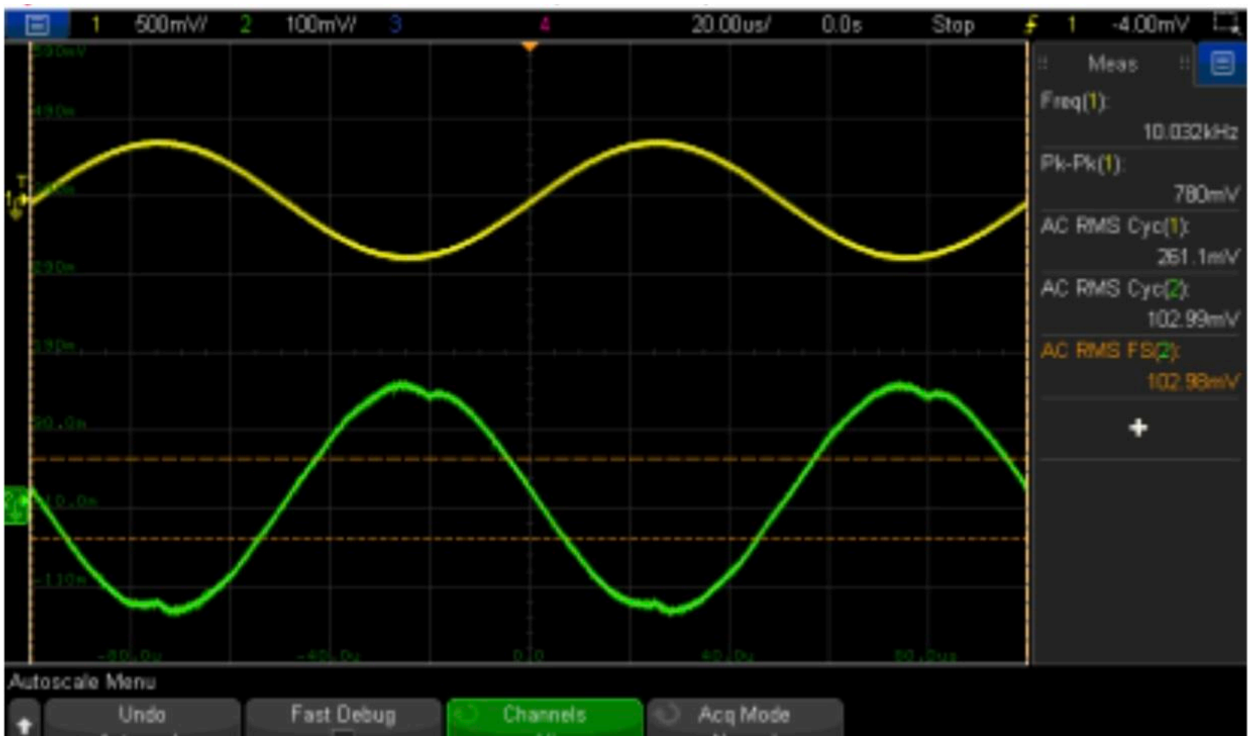

Figure 14: Maximized Potentiometer at 10 kHz

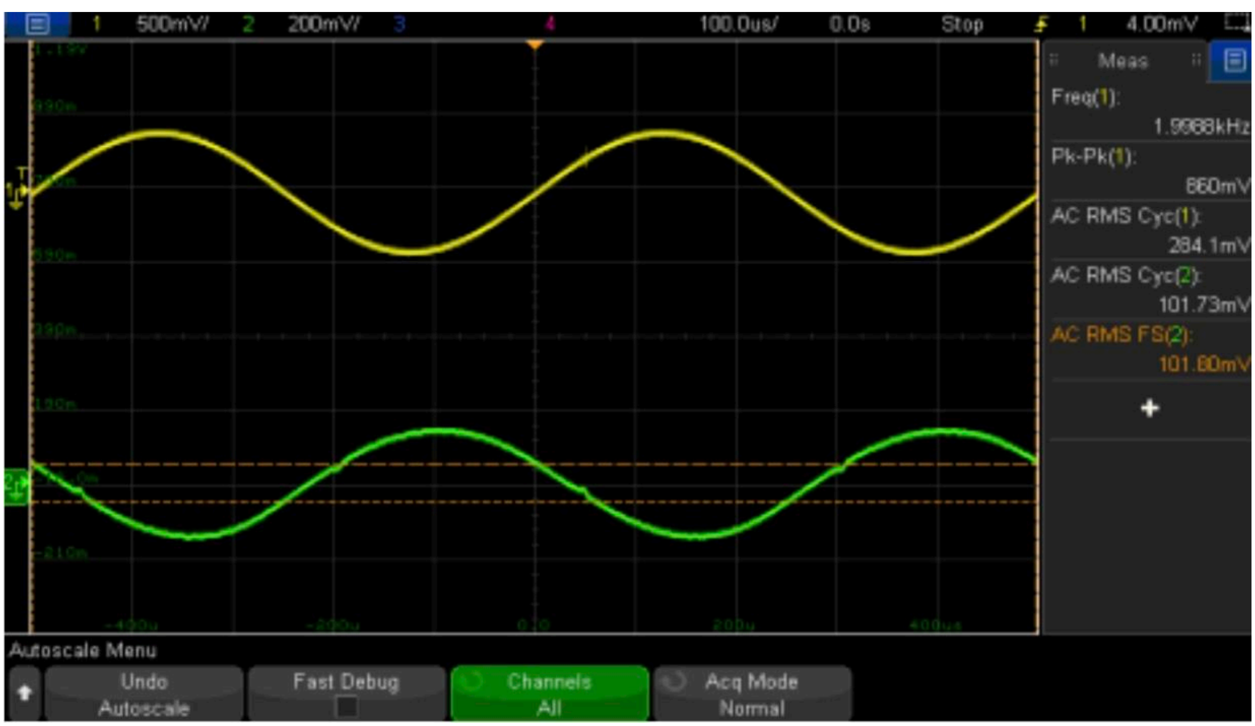

Figure 15: Maximized Potentiometer at 2 kHz

The power amplifier correctly controls the volume of the output as a trend in the peak to peak changes is shown through the graphs. As the volume increases, the peak to peak also increases. This can be shown in the following two figures demonstrating maximum and minimum volume levels for our speaker configuration

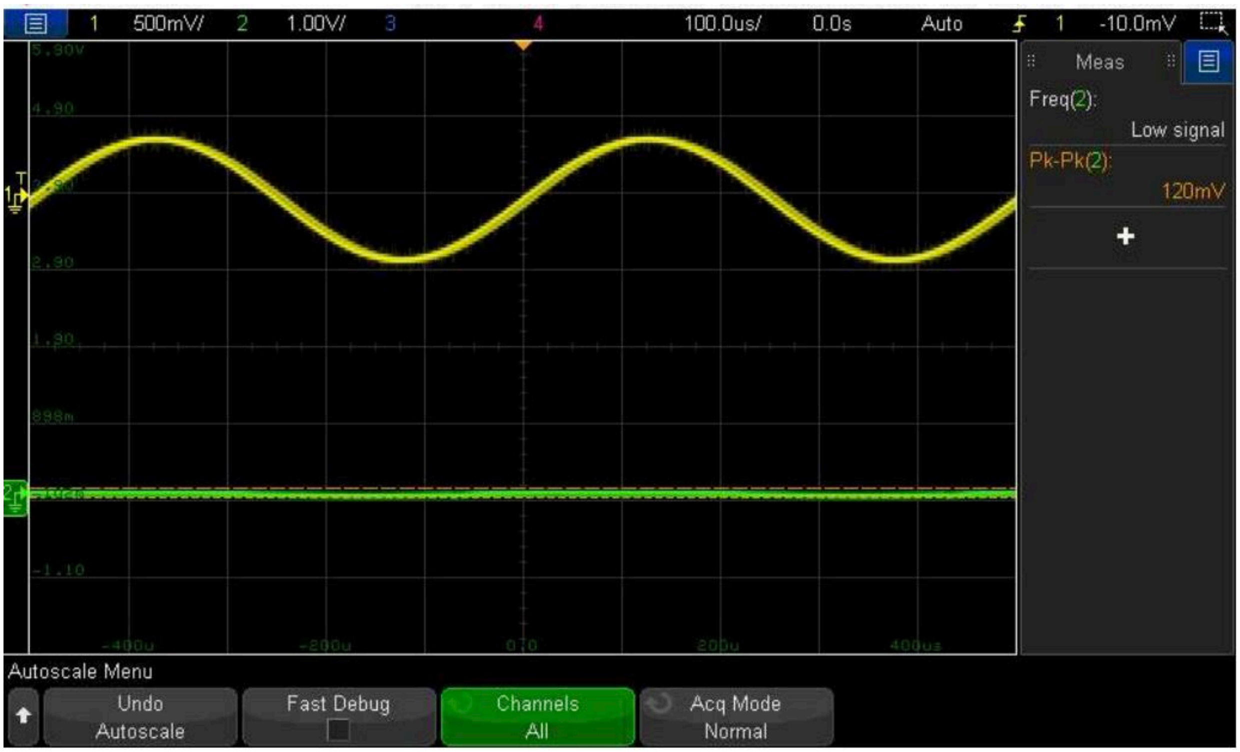

Figure 16: Minimum Volume Level

Figure 17: Maximum Volume Level

4. Conclusion

After way too many hours in the lab, we were able to successfully construct a working audio equalizer and meet all the goals of the project. Our results in the previous section show that the circuit worked successfully. The gain phase frequency analysis graphs show that at the -3DB cutoff the frequencies were within a 10% error. The low pass was within the tolerance to 320 Hz, 320-3200 Hz for the band pass, band 3200 Hz for the high pass. Once the filters were connected to the amplifiers and then summed by the summing amplifier, we were able to verify our theory by seeing that Vamp RMS was less than 15 mV at the absolute minimum potentiometer settings, and closer to 100 mV at the absolute maximum potentiometer settings. This showed us that our filters and amplifiers were working properly as it got close to zero when turned down and increased when turned up, which is the trend that the amplifiers and potentiometer combinations should follow. The power amplifier was then tested. To do this we adjusted volume. Our speaker at one point was able to output 400mW however could not successfully do it at the demonstration. The obtained measurements and values met all the required specifications. In addition to this it proved our theories on what we knew about filters, amplifiers, and how volume control as well as sound balance work within a circuit.