Mastering Electronics Final Project
Speaker and LED
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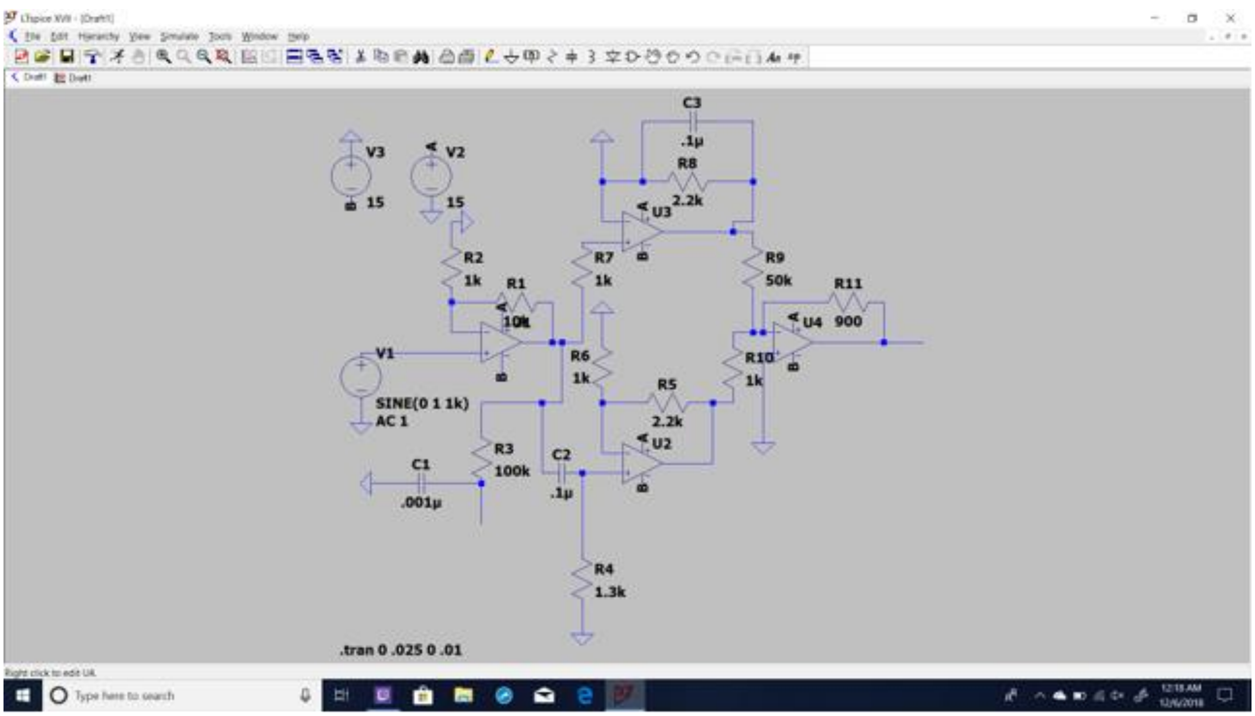
YouTube Link:
https://www.youtube.com/watch?v=qdxsKUFz5g0&fbclid=IwAR1n-cPlG-vjz16zpjBr5_oATWtVB7HL-aWydurYxJOctaLi0K6ZsLnuwLc&app=desktop

Idea:
The purpose of this final project was to put together various different circuit elements that we learned about over the course of the semester. We chose to utilize an auxiliary jack to create a speaker in which users could hear music with certain frequency attenuations. Additionally, we wanted to use an LED in our circuit that would turn on when the frequencies from the input signal were within a certain range. In order to test our circuit, we used a Waveforms sine wave input, and the results of these tests are discussed in this report. The actual circuit functionality is discussed briefly at the end of our report, in which we input a signal from a device using the auxiliary jack.

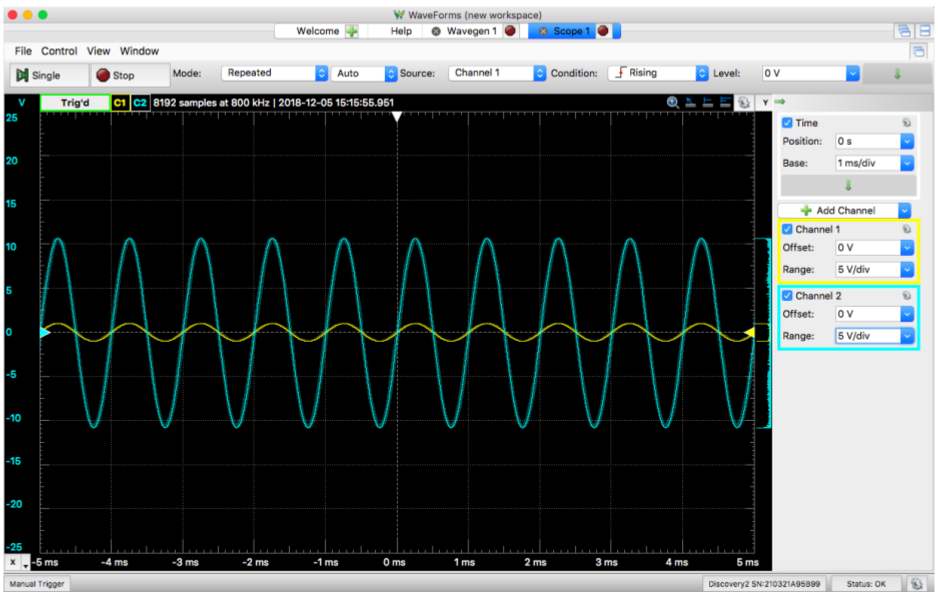


Sub-Circuit 1 – Non-Inverting Amplifier (Using an Op Amp)
The purpose of this sub circuit was to increase the amplitude of our initial signal that we were receiving from our aux jack. Initially we attempted this through use of an NPN BJT, but soon realized that this was far more difficult and tedious than using a non-inverting amplifier. We used this sub circuit to multiply the amplitude of our input wave by 10, to create a gain of 10 = Vout/Vin. We were able to do this because we knew that the gain was a factor of the two resistor values we chose to choose, (R2 + R1)/R1. Therefore, we chose for R2 = 10kOhms, and R1 =

1kOhm. This created a gain of 11000/1000 = 11. From this, we knew our signal was being amplified by 11.

$$Vo = \frac{R1 + R2}{R1} Vin = \frac{11}{1} Vin$$

To test this sub-circuit, we fed in a 1V amplitude 1 KHz peak to peak sine wave. We used this input signal to test our circuit because it was perfectly within our desired range of frequencies and one that could easily be picked up by the speaker based on its given capabilities (we used the 8ohm 0.5 W speaker). We can clearly see from our scope probes that the input amplitude is multiplied by a scale factor of 11 to output a 11V amplitude sine wave that is still in phase with its input.



Waveforms output showing amplitude gain from 1V to 11V in phase with the input.

Sub-Circuit 2- Low/High Pass Active Filters (Using Op Amps)

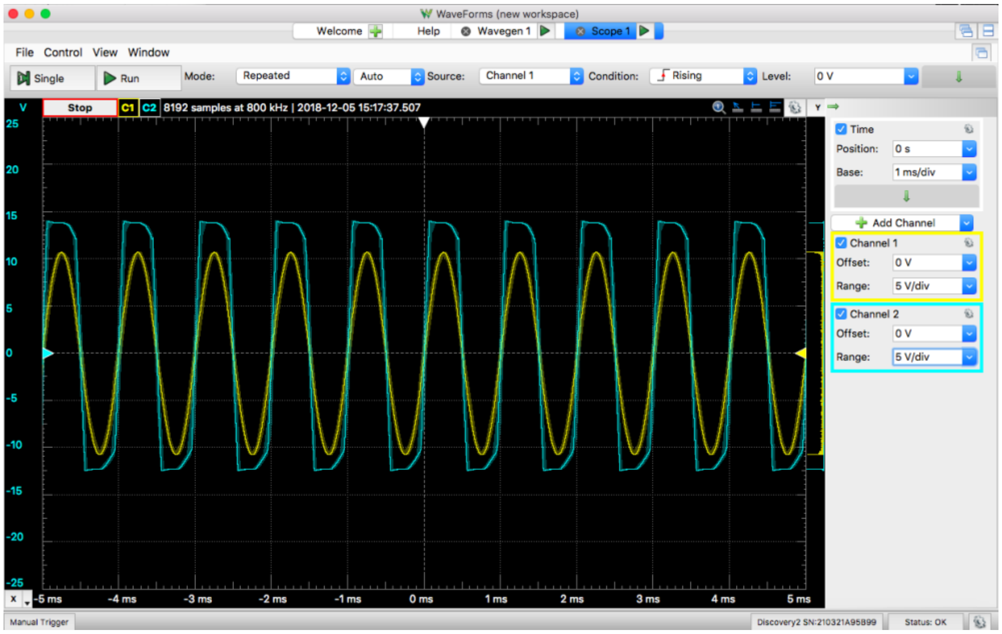
These two sub circuits were meant to serve as amplifiers while also acting as filters. We will start with the low pass filter. This sub circuit was used almost as a precautionary measure for our speaker. We wanted it to have a cutoff frequency of less than 10 kHz. In order to find our desired low frequency limit, we needed to use the equation

$$f = \frac{1}{2\pi R_2 C}$$

Based on our schematic, we used values of 0.1 microfarads for our capacitor, an R_1 value of 1kOhm and 2.2kOhms for our resistor R_2. This led us to finding a frequency of 7246.64 Hz (7.246 KHz) as our low frequency limit, which was sufficiently below our 10kHz goal. There were also some slight modifications that we made to our circuit that differed from the configurations we learned in lab. We chose to input our newly amplified signal into the *non-inverting input* of our op amp and have our feedback run through our inverting input. This was successful in that when we tested the input and output of the filter in scope, it remained almost entirely in phase. We fed in our input signal through the 1kOhm resistor. Using the below equation for the transfer function of the low pass filter…

$$K = \frac{R2}{R1}$$

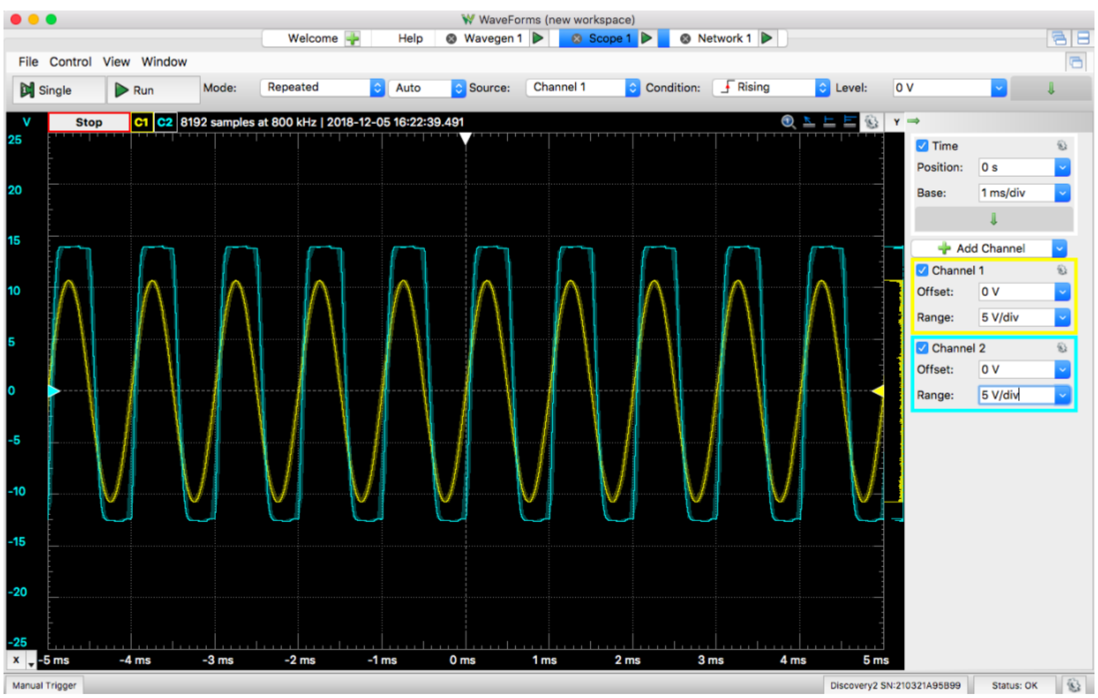
We knew that this would essentially double our input voltage amplitude, since R2/R1 = 2.2kOhm/1kOhm = 2.2, so Vo = 2.2Vin. However, we noticed that our output voltages only reached the rail voltages of the op-amp, since 2.2 * Vin was greater than the rail voltages. This is what we expected to happen, since our input voltage (after the non-inverting op amp when feeding in a 1V amplitude sine wave) would be 11V.



For our high pass active filter, we maintained the same ideology of feeding our input signal (same input signal as our active LPF) into the non-inverting input of the op amp and feeding back to the inverting input, which was a slight difference from what we performed in lab 5. The resistors that made up the feedback across the inverting input were shown as R4 = 1kOhm and R5 = 2.2kOhm, which were the two resistors that defined the transfer function ratio (creating a gain of 2.2 again, similar to the low pass filter). This also differed from the lab. We chose to use a 0.1 microfarad capacitor to feed our input signal into the non-inverting pin of the op amp. We also added another resistor going from the non-inverting input pin of the op amp to ground which seemed to affect how are circuit was performing. More importantly, however, based on the equation we found, this would lower our minimum frequency. We based our findings on

$$f = \frac{1}{2\pi R_3 C}$$

This sub circuit had a minimum frequency equal to 1/2pi(R_3C) where R3 = 1.3 kOhms. We calculated this frequency to be approximately 1.224 KHz. We see that our circuit has a cutoff frequency near 1.224 KHz in the network sweep pictured below.

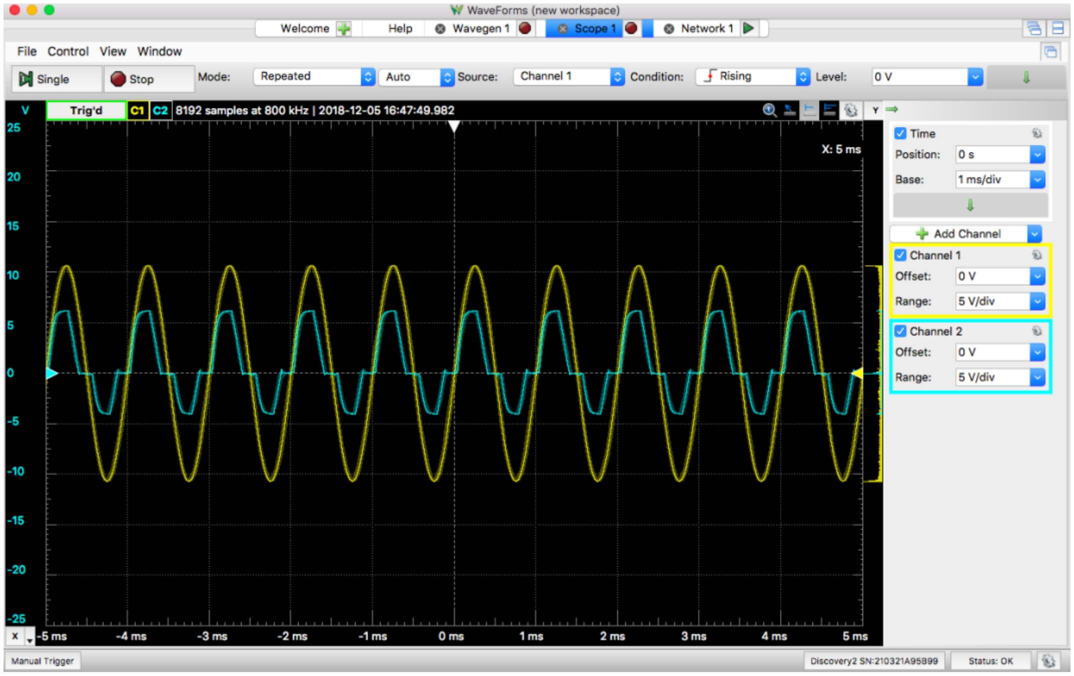


The above image shows the scope of the high pass active filter input and output. We noticed interestingly that the output wave seemed slightly out of phase with the input wave, and assumed it most likely had something to do with our slightly different circuit configuration.

Sub-Circuit 3-

The next, more minor sub circuit was two potentiometers that were used to modify the intensity of the output signal that was being fed into our final sub circuit, the summing circuit. By tuning our potentiometers, we hoped to be able to modify the output of our speaker through being able to tune how potent each high and low frequency signal was. We continued with our calculations with these potentiometers in the summing circuit portion of the report, but we were able to see visible changes in output in waveforms when we tuned our potentiometers.

This was the result of increasing the resistance of the potentiometer of the low pass signal output. The input was the initial amplified sine wave, and the output was the output of our summing circuit. When the potentiometer was tuned to a very high resistance, we noticed that our waveform no longer changed. This was because the input from the high pass filter was still being summed, and this was not being changed when tuning just one potentiometer.



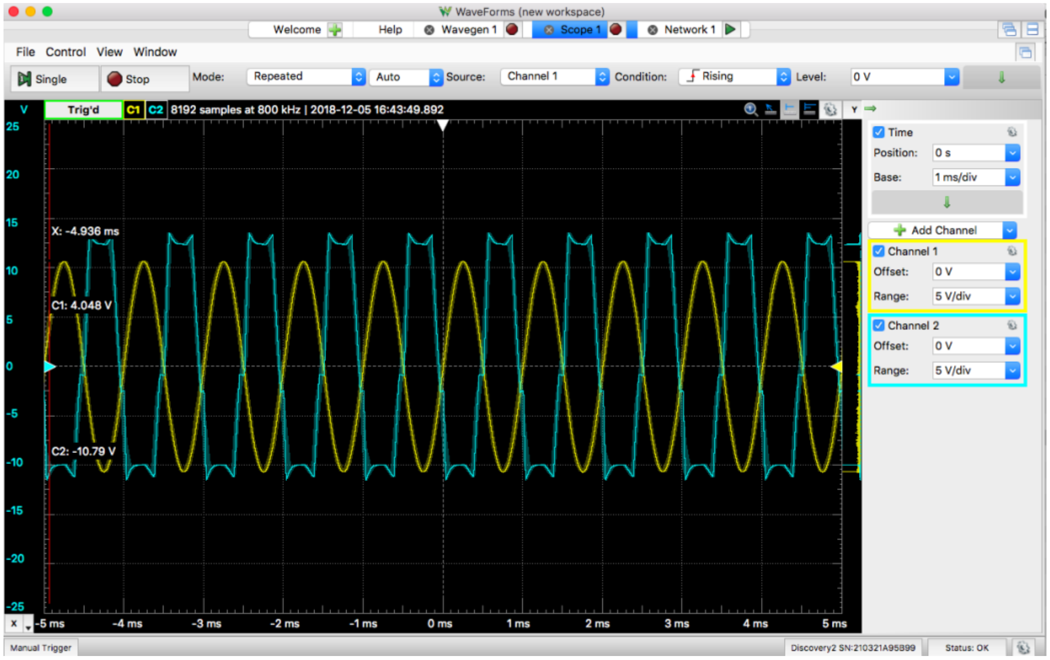
This was the output of the summing circuit when tuning the high pass potentiometer, proving that tuning the potentiometers had an effect on the output signal.

Sub-Circuit 4- Summing Circuit

The summing circuit was one of the numerous op-amp schematics that we learned about in lecture. We knew that by creating this sub-circuit we would be adding together two signals based on resistor ratios and input voltages. However, we were connecting our feedback to the inverting terminal of the op-amp, so we expected to observe a roughly 180 degree phase shift because of this. However, we knew that this would not affect how the eventual signal would be heard.

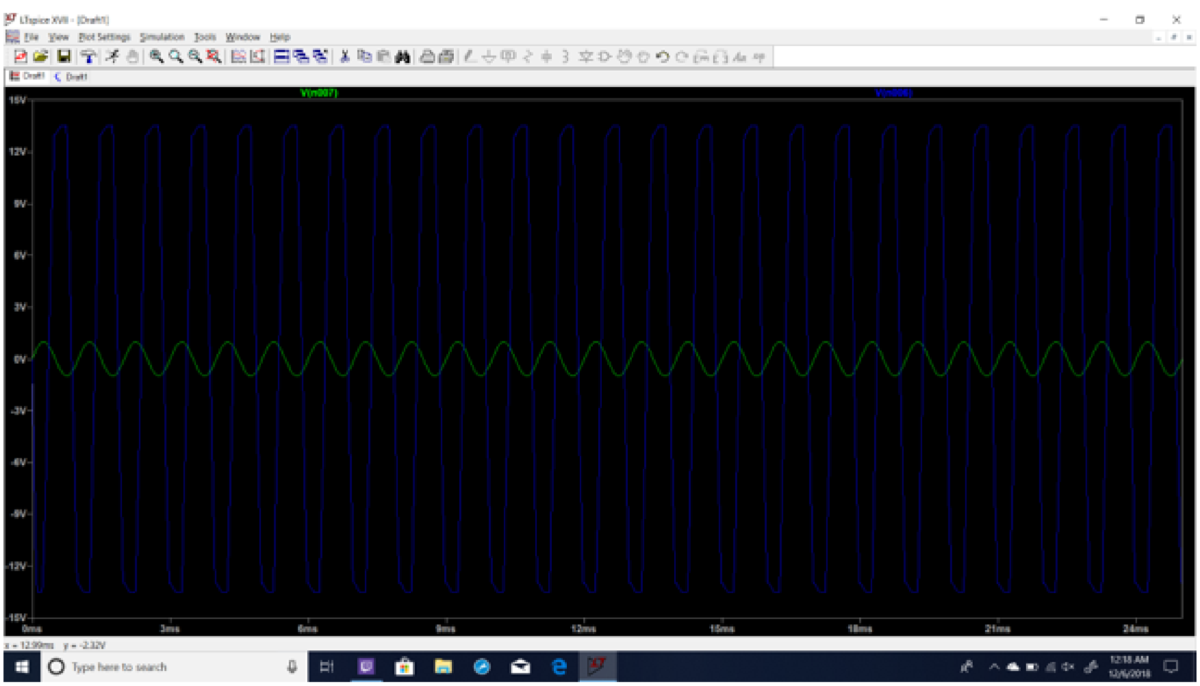
$$Vout = -\frac{Rf}{R1}V1 - \frac{Rf}{R2}V2$$

We chose to use an RF value of 900 ohms, which was less than the maximum potentiometer values we chose for both R1 and R2 (1k potentiometer and 50k potentiometer, respectively). Initially, we chose for the potentiometer coming from the low pass filter signal to also be 1kOhm. However, we noticed that this was making our output extremely hard to hear. We corrected this by changing the potentiometer to 50k- this meant that the output signal was only a fraction of the input signal. For the high pass filter, however, increasing the high frequency signals was not negatively affecting the speaker output.



This waveforms scope graph shows how our summing circuit was taking the input signal, amplifying it slightly, and then inverting it. We can see that the inversion occurred because the signals seem completely out of phase with one another. This only occurred when analyzing the signal after the summing circuit, showing that it functioned properly.

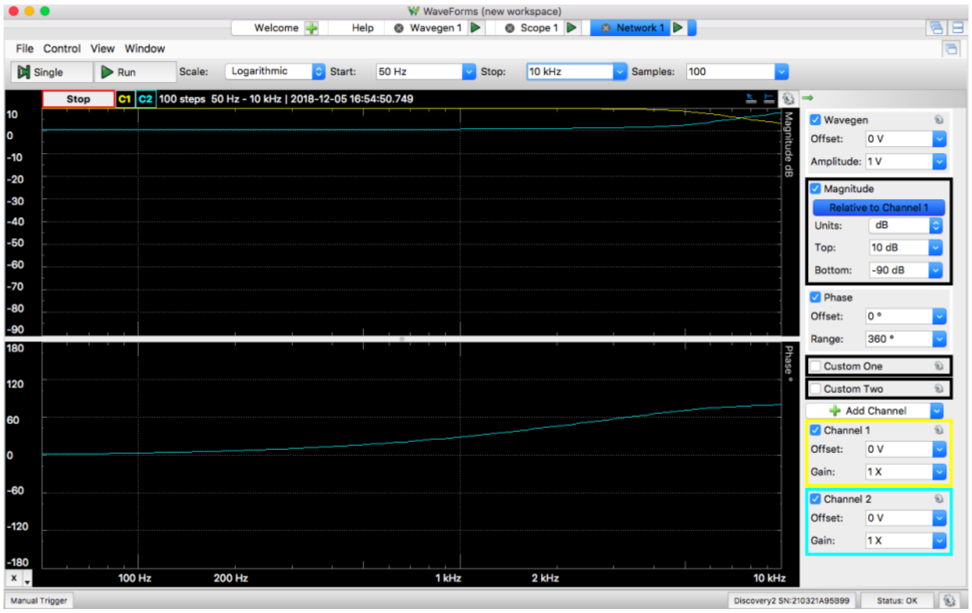
Our final output also matches what we observed on LTSpice.



We see an amplified, out of phase sign wave corresponding to our 1V input sine wave!

Sub-Circuit 5 – Passive Low Pass Filter – RC Circuit

Our final sub circuit was a passive low pass filter with a resistor and capacitor in series. We connected the output of our amplified signal (all the way back from our non-inverting amplifier, circuit element 1) through a resistor and then through a capacitor. We hoped to create a maximum frequency in which the light should turn on and off at higher frequencies. The behavior of the LED is apparent in the network sweep shown below.



Channel 1 was hooked up across the resistor and shows the low pass nature of the sub-circuit.

We calculated our -3dB frequency with the equation used above: f = 1/2(pi)RC, with R = 100 kOhms (this was a resistor we got last semester from DSF), and a capacitor with capacitance of 0.001 microFarads. This yielded a frequency value in Hertz of 1.58 kHz. This deviated slightly from what we observed on Waveforms, but we noticed a decay in the strength of the light in the LED at around this point.

Circuit Performance Overall:

When we connected our auxiliary jack and our speaker, there were numerous ways in which we were able to modify the sound we were hearing. The best, most reliable way was to tune the potentiometers. When we tuned the 50kOhm potentiometer that controlled how much of the low pass signal was being summed, we could control how loud the lower frequencies were. At the lower end (when there was very little resistance), the other frequencies were almost being tuned out. However, at the higher end (a lot of resistance), the sound was fairly clear and there was a good balance between slightly enhanced lower frequencies and higher frequencies.

When we chose to tune the 1kOhm potentiometer that controlled the input signal of the high pass filter, we noticed that the lower frequencies got significantly less noticeable. Unfortunately, for our LED/low pass passive filter, we were unable to see it turn on when we were playing music. However, we were clearly able to see its performance during network sweeps.