Filter Circuits

Experiment 5

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Section 01: Monday 9:00am – 11:00 am

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Introduction

The overall purpose of this lab is to allow students to familiarize themselves with op-amp filters and determine the behaviors that the circuits have. Along with those behaviors, we were to design our own filters to create speaker that outputs bass, treble, and both using a summing circuit which adds multiple voltage signals.

In this experiment, I compared theoretical values against my experimental values that I obtained on certain values, such as the corner frequency, or the break frequency. Along with that, I compared using magnitude and phase of transfer functions.

The first circuit given to us, was to help us use the theoretical aspect was such that, we use the transfer function Vout/ Vin which can be equal to j(f/fB) / (1+ j(f/fB)). Once solving for the cutoff frequency, which is 1/ (2πRC), then we can re-write the magnitude of the transfer function by f/fb / (1+(f/fb) ^2) ^ (1/2). As for the phase of the circuit, we can use the complex imaginary part to get 90° - arc tan (f/fB). Ultimately, we were to understand that for high frequencies f >> fb, the transfer function approaches it's max value thus the filter rejects low frequency components.

The second circuit given to us was to help use a similar approach in figuring out the phase and magnitude of the transfer function. The next filter other than high pass is low pass. It's theoretical magnitude is described as |H(f)| = 1/ (1 + (f/fb) ^2) ^(1/2) and the phase of the low pass transfer function is given by –arc tan (f/fb). Further evaluating the phase difference, we see that the phase approaches zero at low frequencies and breaks at -45°, and approaches high frequencies at 90°. The cutoff for these circuits remains the same where fb = 1/ RC*2pi. Using this equation would determine what kind of cut off frequencies the circuit has, then one can determine the type of filter the circuits are.

Part 1: Low-Pass and High-Pass Filter Bode Plots

Create the circuit displayed in **Figure 1** on the circuit board using the source voltage with a sinewave function at 1 Volts amplitude, LM741 op-amp, starting frequency of 50Hz, a resistor of 1 kilo ohms, another resistor of 1.5 kilo ohms, and capacitor of 1 microfarad.

Note: The experimental resistor that I used was at 0.98 kilo ohms and 1.57 kilo ohms therefore our result may have varied with the theoretical.

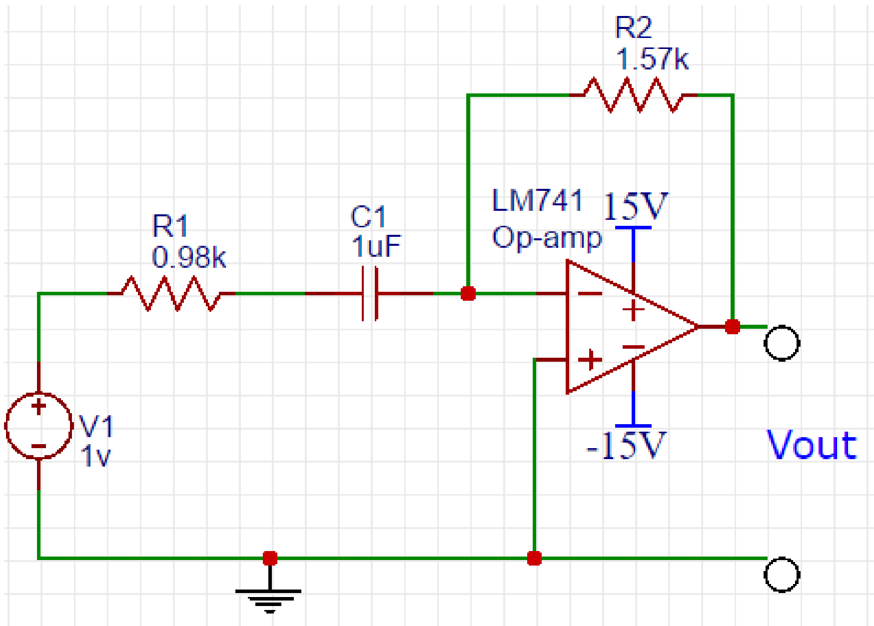

Figure 1

High Pass Schematic for Lab 5, Part 1, Circuit 1

Using the scope, I shifted the image on the oscilloscope so that the period began with the input voltage peak to the peak of the output. Using the measurement tools on the scope, I placed the vertical cursor (a) and cursor (b) at these points to find the delta time in order to obtain the phase difference, one can observe the sample of screenshots I took from Figure 2-4.

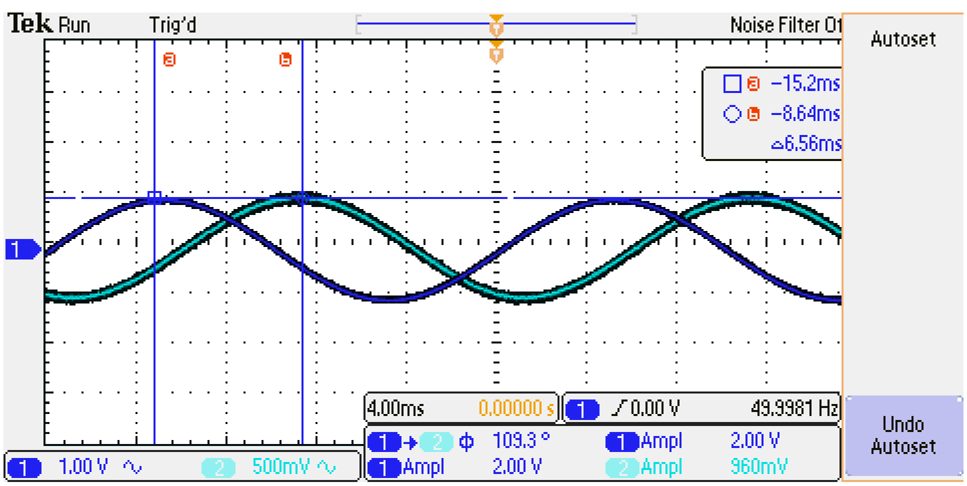

Figure 2

The wave display of Figure 1 at 50 Hz

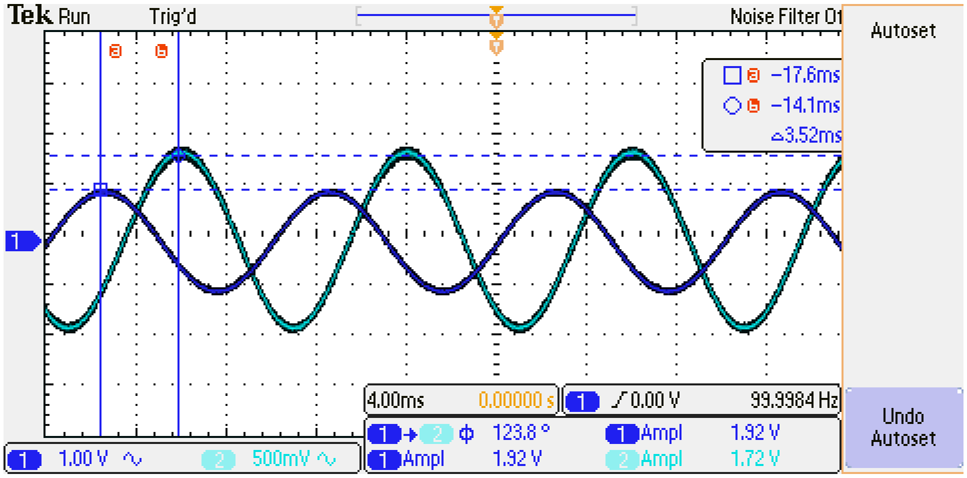

Figure 3

The wave display of Figure 1 at 100 Hz

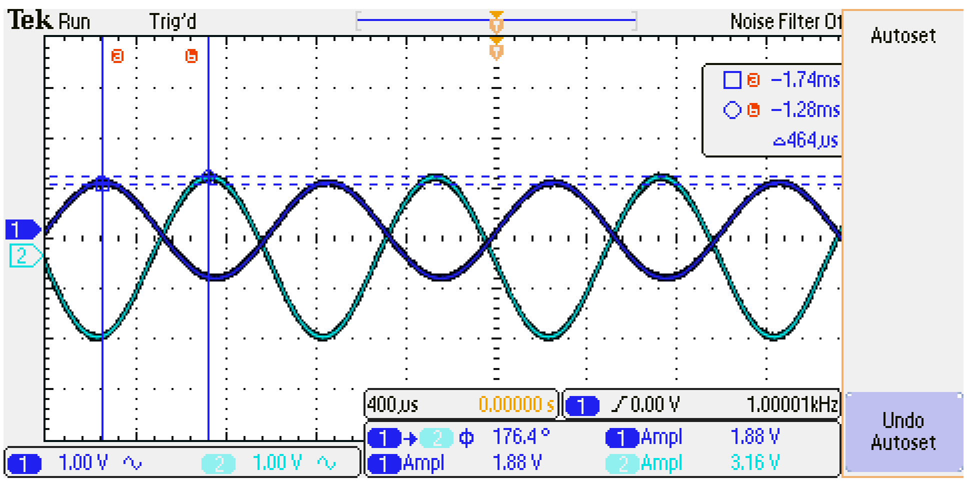

Figure 4

The wave display of Figure 1 at 1K Hz

The following table has the experimental results of magnitude and phase response corresponding to their frequencies:

Frequency	Magnitude	Phase		T Mag	T Phase
50	0.48	74		0.74	91.35
100	0.86	57		1.14	73.3
200	1.26	35.9		1.29	54.56
500	1.52	26.8		1.33	38.58
1000	1.58	20.2		1.3	32.67
2000	1.6	20.1		1.34	29.66
3000	1.62	20.2		1.42	28.65
4000	1.62	19.9		1.45	28.14
8000	1.62	19.6		1.48	27.38
10000	1.62	18.5		1.49	27.23
12000	1.62	19.2		1.494	27.24
14000	1.62	15.4		1.4961	27.24
16000	1.62	10.6		1.497	27.24
18000	1.62	10.4		1.498	27.24
20000	1.6	10.2		1.4981	27.24

Figure 5

The experimental results (left) compared to theoretical (right)

Now using our theoretical calculation in which we solve using the equation |H(f)| = (f/fb) / (1 + (f/fb) ^2) ^ (1/2). Here, we can use super positioning to obtain a theoretical equation, such that |Vo/Vs| = Figure 1. So it is that –R2/ (R1^2 + 1/(w^2C^2)) ^ (1/2), and where the cutoff frequency is fb = 1/2piRC and obtained the values that are displayed in **Figure 5** and shown graphed in **Figure 6** and **Figure 7**. Using the formula of a half-power frequency, fb would be 1/ 2πRC = 106.1 Hz.

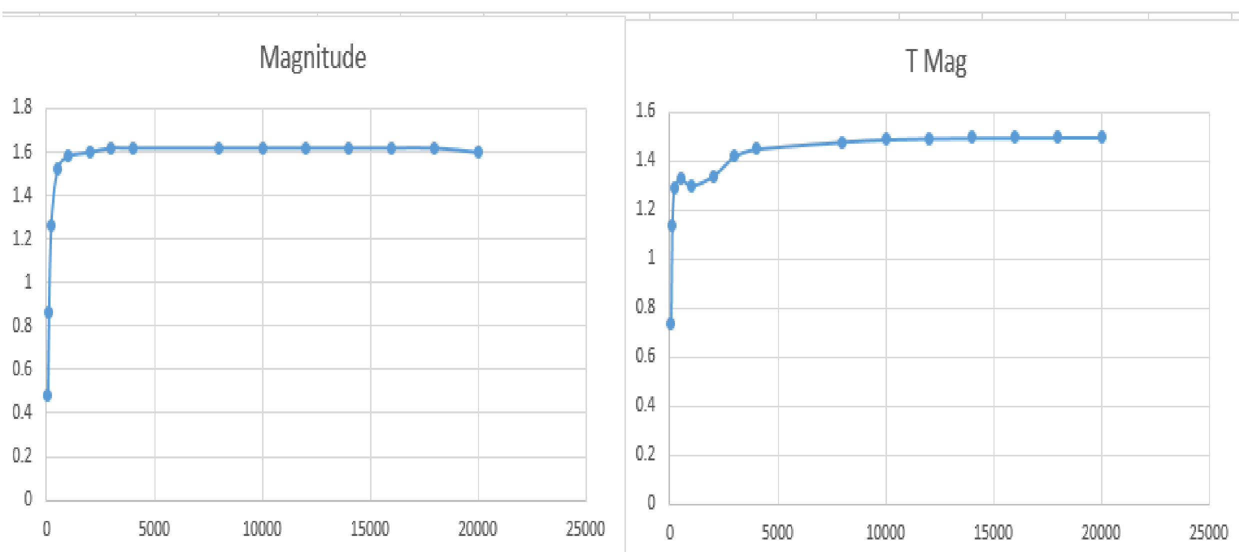

Figure 6

Experimental Magnitude (left) vs Theoretical (right)

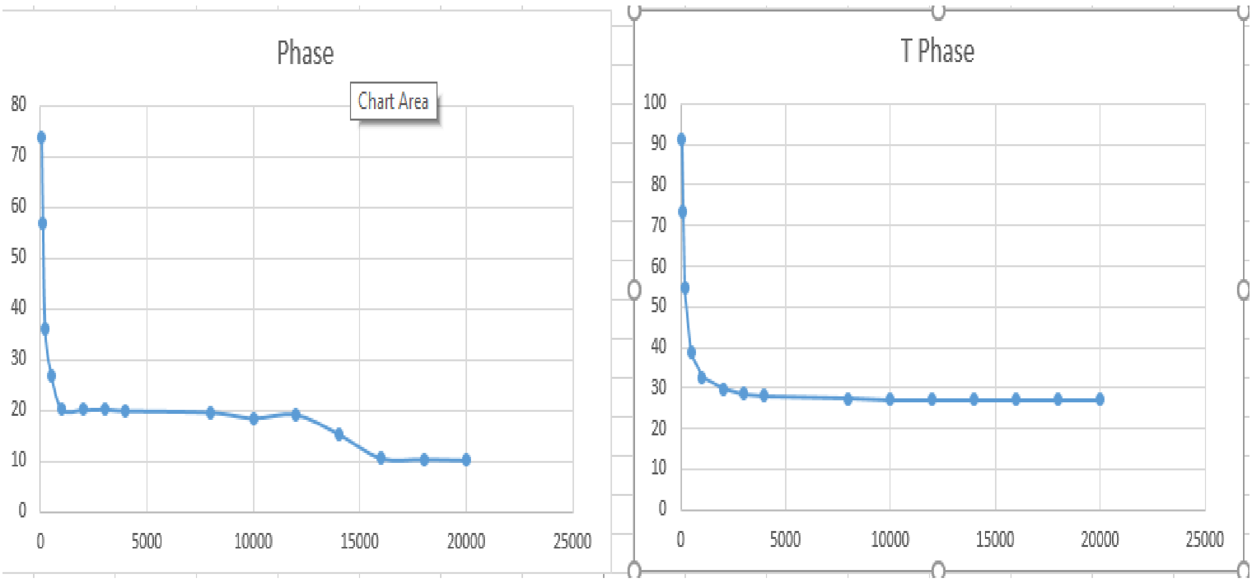

Figure 7

Experimental phase (left) vs Theoretical (right)

Since the circuit allowed high frequency inputs to be near unity and make lower frequency inputs have less output voltage, we can conclude that this indeed worked as a high-pass filter.

Part 1: Low-Pass Filter

Create a circuit on the bread board using a voltage source of 1V amplitude, 2 kilo ohm resistor, 0.1 microfarad capacitor, and another 1.5 kilo ohm resistor; but in my case 1.99 and 1.57 kilo ohms' resistor. The circuit should resemble **Figure 8**.

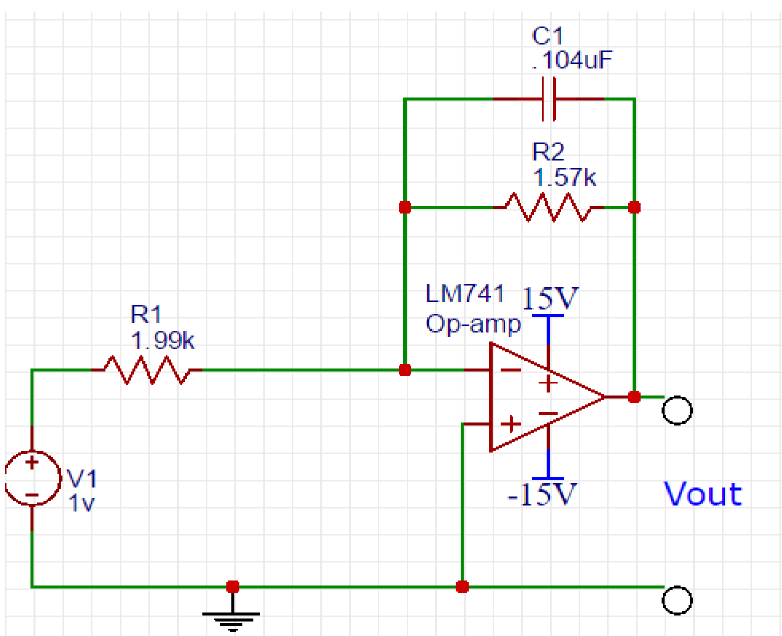

Figure 8

Second circuit schematic for Lab 5, part 1

Here using super positioning, we can have V1/R1 + Vo (1/R2 + jwc) = 0. Then what we have is to have something like the transfer function where, Vo /Vin = -(1/R1) / ((1/R2) +Jwc) = -(R2/R1)/1+jwR2C. Thus, R2/R1 will be on the real axis however negative would give it a degree 180° and thus when calculating for the phase difference we will have to take 180°-arc tan(f/fb).

Frequency	Magnitude	Phase		T Magnitude	T Phase
50	0.8	177.8		0.7478	228.9
100	0.8	172.3		0.7417	224.7
200	0.78	166.2		0.7183	216.5
400	0.74	157.2		0.64311	202.3
1000	0.57	134.3		0.423	176.9
2000	0.37	119		0.237	161.6
3000	0.264	115.3		0.163	155.3
4000	0.204	112.3		0.131	152.7
8000	0.106	111.3		0.062	148
10000	0.086	115.3		0.0498	147.1
12000	0.07	113.5		0.0416	146.4
14000	0.09	121		0.0356	146
16000	0.08	121.3		0.0312	145.6
18000	0.052	98.05		0.0277	145.3
20000	0.076	123.3		0.02498	145.1

Figure 9

The experimental results (left) compared to theoretical (right)

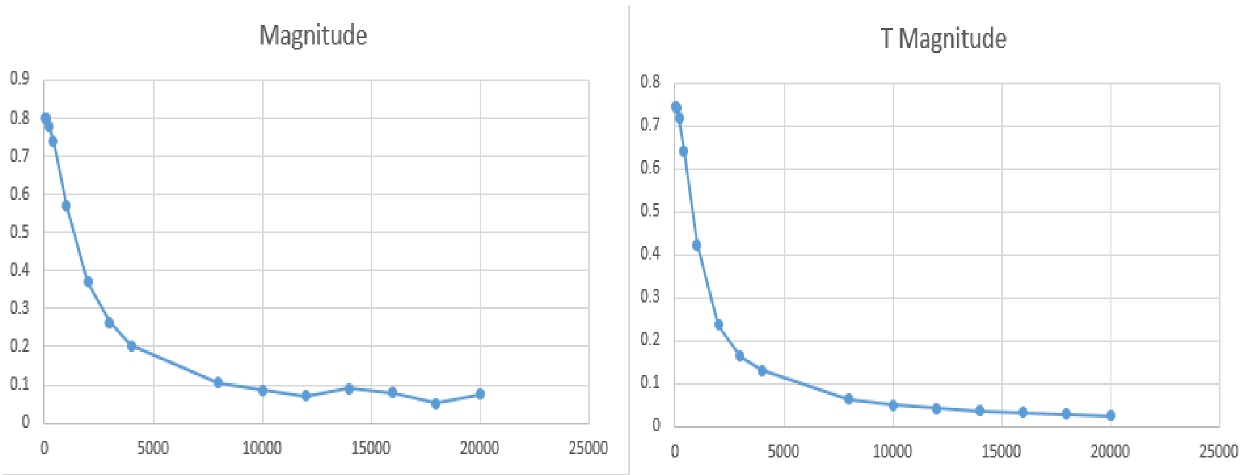

Figure 10

Experimental phase (left) vs Theoretical (right)

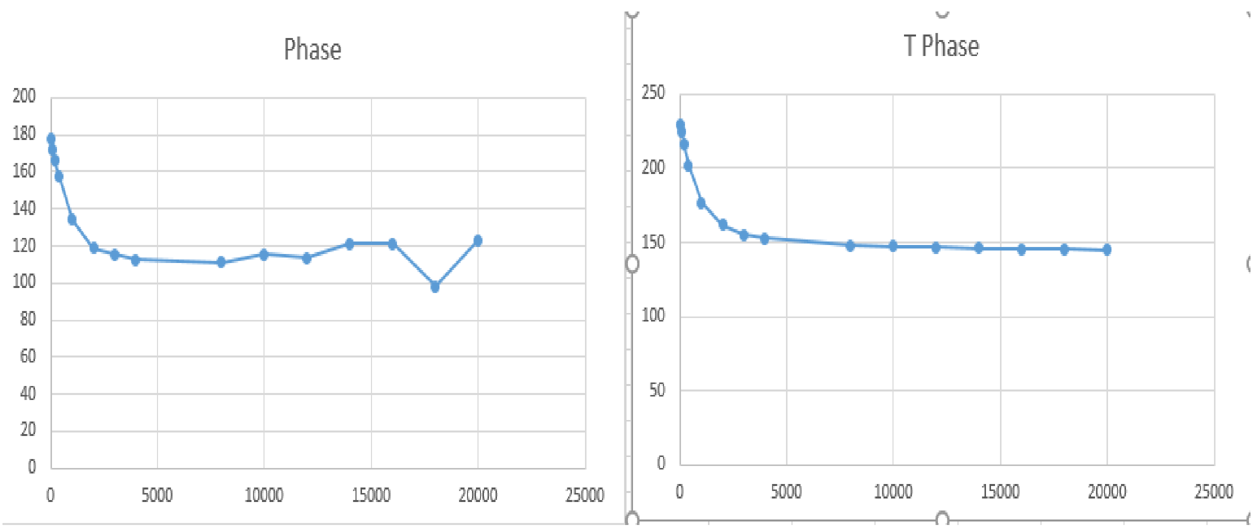

Figure 11

Experimental phase (left) vs Theoretical (right)

To determine the cut off frequency, we would theoretically use the equation fb = 1/ 2πRC, which would be 1061 Hz or 1.06 KHz, which by the magnitude of **Figure 10**, we can see a very steep drop in voltage and phase change.

So, the filter allows low frequency inputs and as the frequency goes above a certain point, then the output amplitude decreases. As such, the circuit did work as a low-pass filter.

Part 2: Audio Filtering and Combining

For this part of the lab we were to conduct a speaker using LM741 op-amp and display to Armando each circuit were to work, the treble and bass. According to the guidelines, the treble had a cutoff frequency of 4k – 20k Hz and the bass 0 – 250 Hz. Thus we separated the two using two of these LM741 op-amps.

For the first part (treble), we used a high pass filter in order to bypass the low sound frequency, we created a circuit like **Figure 8**.

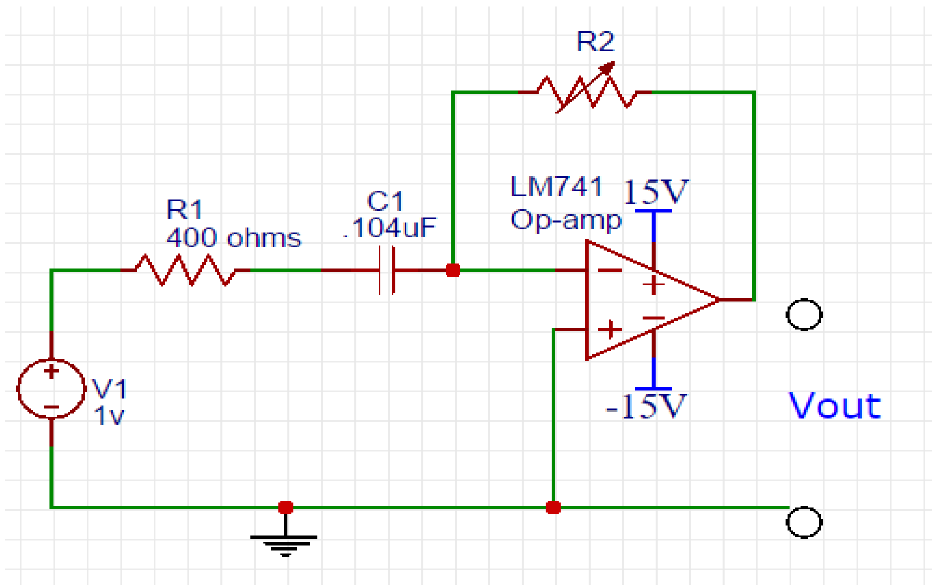

Figure 8

High-Pass Filter Treble for Part 2, Lab 5

In order to have created such a design, we had to calculate theoretical calculations first. We knew the frequency cut off using the equation fc = 1/ 2piRC; knowing fc from the manual and chosen C, we had obtained the value for R. We had it displayed on the oscilloscope; however, it was not stated to us that we needed to screenshot this waveform.

As for the second part of the design, we had made a low pass filter for the bass, which bypasses the high frequency, our design is such on **Figure 9**.

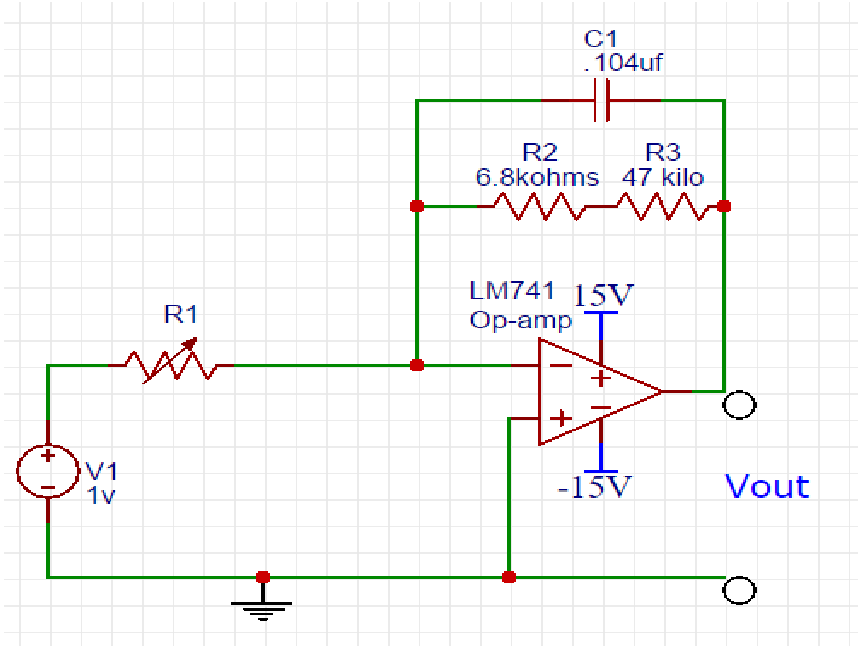

Figure 9

Low-Pass Filter Bass for Part 2, Lab 5

For us to have the design, similarly we had to theoretically calculate our resistances first. We use the save cutoff frequency equation, where the bass is from 0 – 250 Hz and we obtained that 50kilo ohms, but we put two resistors in series to complete this theoretical value due to shortage on resistors.

Conclusion

All in all, this lab was very theoretical and demanded a lot understanding about complex circuits. However, it did help us students familiarize ourselves with the calculations we were obtaining from low and high pass filters.

The first circuit was pretty simple, allowing us to see with the node voltage we could derive an expression for the high pass filter. We also saw that taking the difference between channel 1 and 2 displays delta t, which would give us the change in phase using 2πf⌂t.

As for the second circuit, we used the same principle with super position to obtain a theoretical value. Here we were able to calculate a magnitude and phase difference. We then calculated the experimental values and saw that the circuit was indeed a low pass filter.

For the second part of the lab, we designed our own audio filters using high pass and low pass circuits. Through theoretical calculations, we were able to determine our resistances and capacitance. Using fundamental theorems, we did end up creating a successful audio filter and determined that the laws are indeed valid.

Overall these labs helped me a lot as my first time experience, however I don’t know how in an electrical engineering class, we run out of resources (wires, resistors, batteries, etc.). This would lead us to think that there could have been a multitude of things affecting our results, however, the experimental results were close with the theoretical. Thanks for the experiences.