ECEN 203

Assignment 1: Hi-Fi Audio Circuit Design

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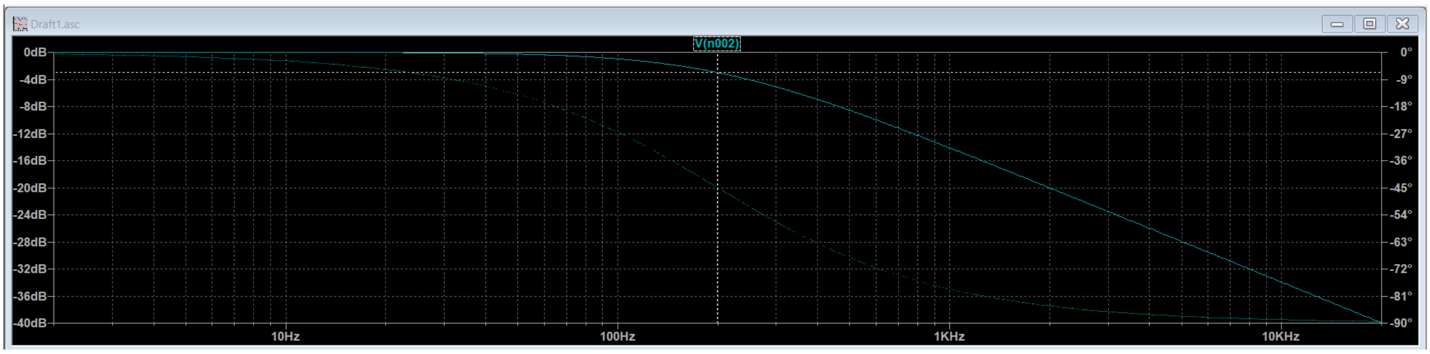
Part 1: Pre-Amp Subwoofer Filter

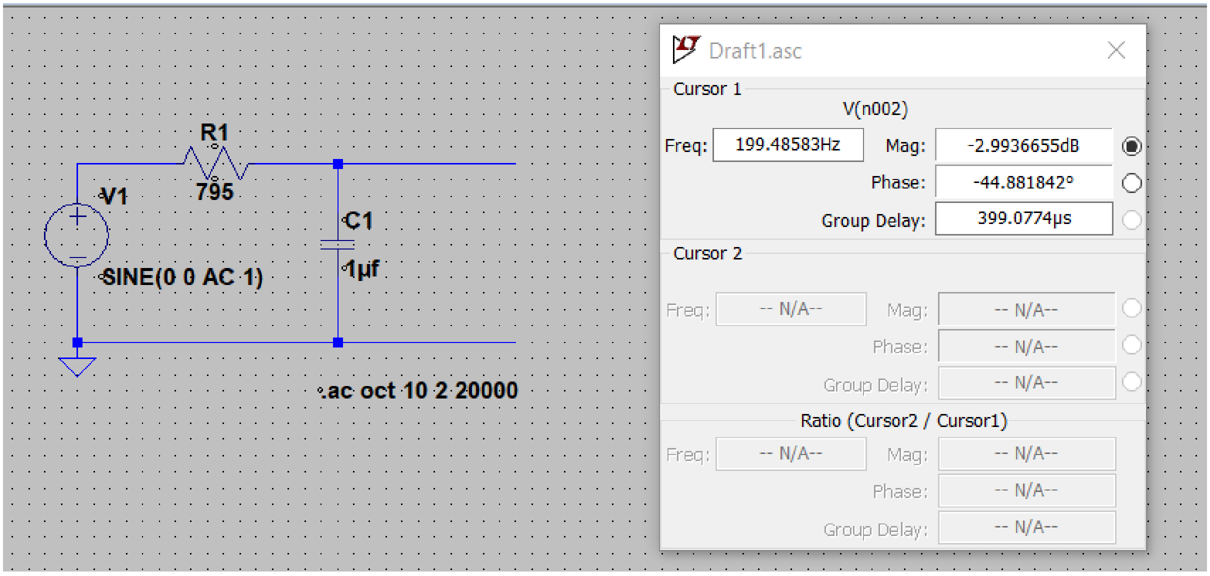
1) Using capacitors and resistors. I designed a low pass filter with the cut of frequency of 200 Hz. To do this I calculated the cut off frequency ($f_c = 1/(2\pi RC)$), by first with a standard capacitor value (1 uF) to find a resistance to produce the requested cut off frequency.

   $f_c = 1/(2\pi RC) \rightarrow$

   $200\text{Hz} = 1/(2\pi(795\Omega)(1*10^{-6}))$

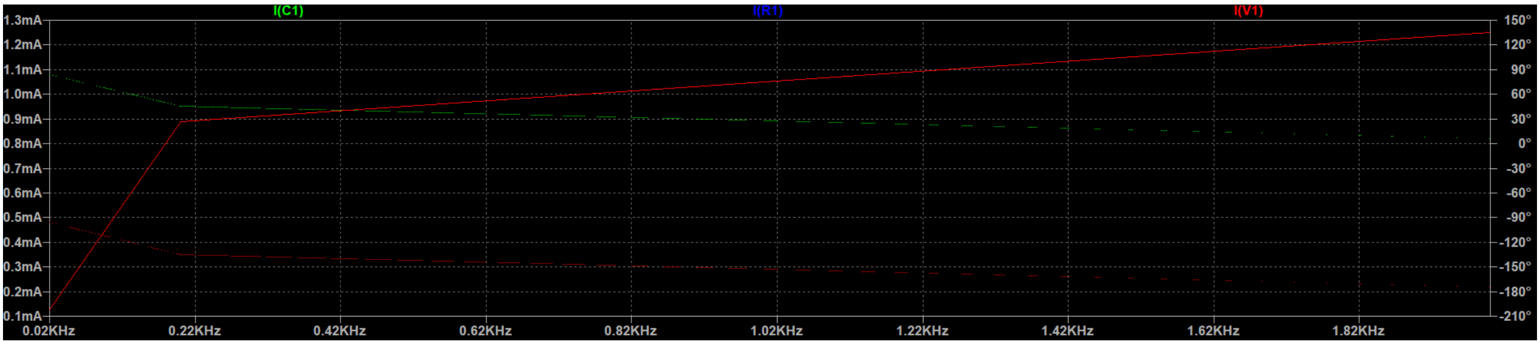
   Circuit diagram and data as follows.





Comment: So, the gain is -3db and at the cut off frequency we want the gain to be as close to 0 as possible. This is also the half power point.

2) Running AC analysis for the cut of frequency and 10fc and fc/10 gives the following gains and phase's



--- AC Analysis ---

frequency: 20 Hz
V(n002): mag: 0.995047 phase: -5.70507° voltage
V(n001): mag: 1 phase: 0° voltage

--- AC Analysis ---

frequency: 200 Hz
V(n002): mag: 0.707451 phase: -44.9721° voltage
V(n001): mag: 1 phase: 0° voltage

--- AC Analysis ---

frequency: 2000 Hz
V(n002): mag: 0.0995997 phase: -84.2839° voltage
V(n001): mag: 1 phase: -7.95139e-016° voltage

	Fc	Fc/10	10Fc
Gain (db)	-2.9948625dB	-43.465874mdB	-20.045671dB
Phase (Degrees)	-44.9721°	-5.7269909°	-84.2839°
Theoretical Phase (Degrees)	-45	0	-90

Comment:
This is as expected as the gain of the circuit should be near enough to 0 when the frequency is small and when the frequency is near cut off. This is because what goes in goes straight out, as the capacitor can charge which prevents current from passing through. As this is a low pass filter we are allowing the smaller frequencies to pass which includes all before 200z. At Fc/10 little to none of the signal should be blocked as it is far below the cut off frequency this is shown but the gain in micro decibels, it's very close to 0 showing that pretty much all signal is passing through. After the cut off frequency the capacitor does not charge and the current moves through hence the gain is high in the negative direction and the output voltage is near enough to 0. For phase (looking at frequency response) by knowing the circuits gain at certain frequencies we can get a better under standing on how the circuit is functioning. Phase response is the relationship between the input signal and the

output signal. But looking at our wave forms, both triangular and square the phase would not be like the typical sinusoidal phase. (Help?) From reading I can see that even with any waveform can be expressed as several sinusoidal components. Which can be shown by taking the Fourier transform of any wave will show these components.

After thinking some more:

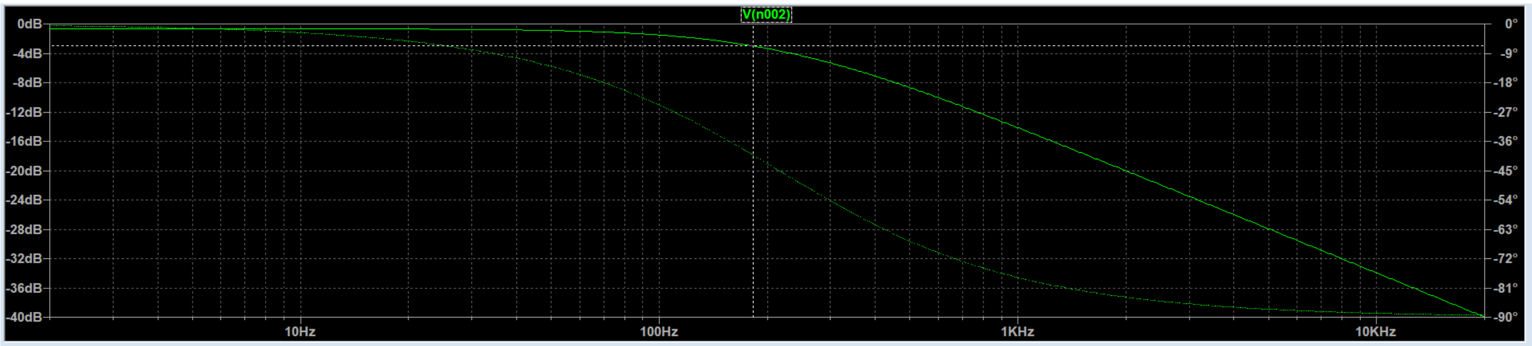
When the phase is at 0 degrees: The whole signal can pass?

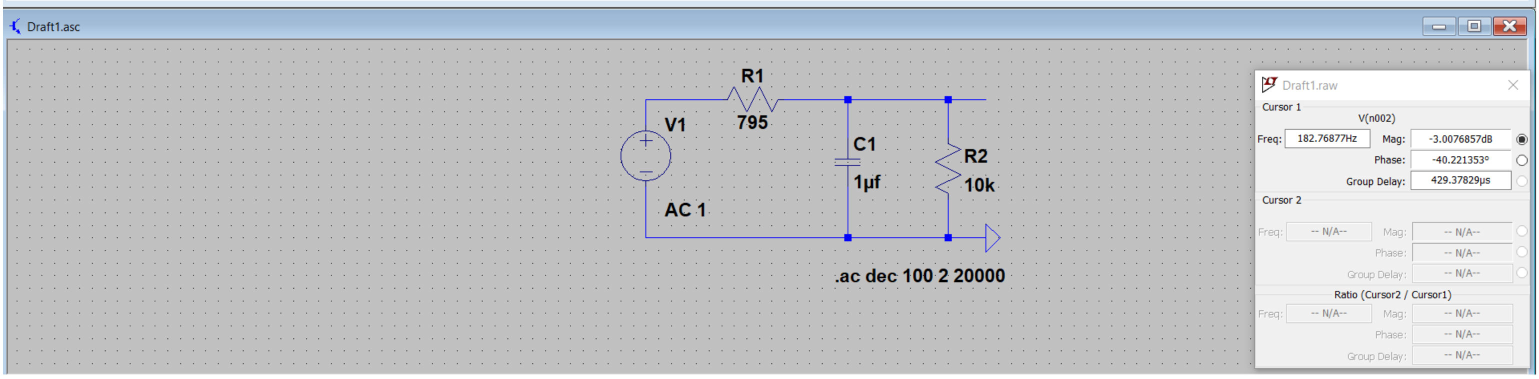
When the phase is at 45 degrees: Half the signal can pass?

When the phase is at 90 degrees: No signal can pass?

Looking at our results from above we can see that our phases correspond to the theoretical ones shown?

3) Repeating the AC analysis with a 10 kΩ load connected to the filter.



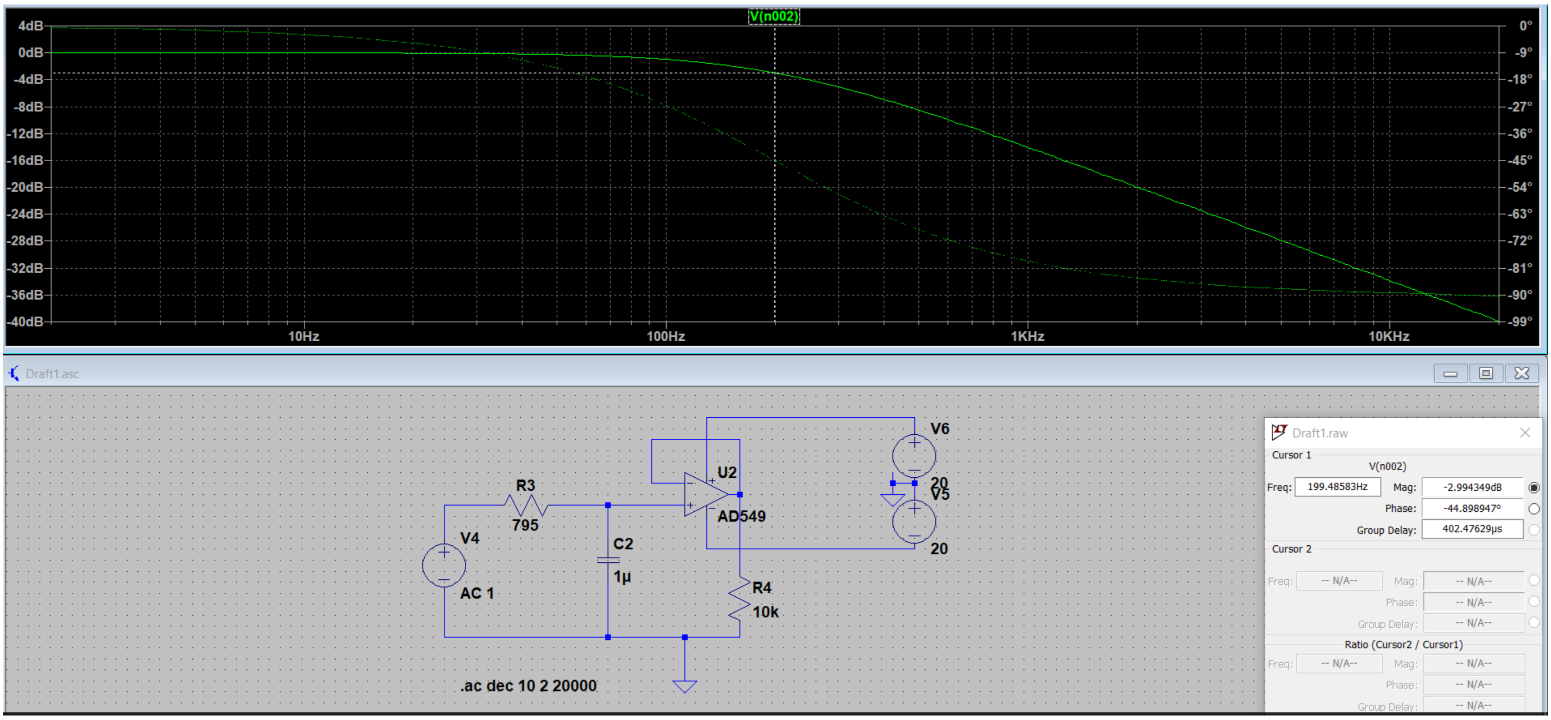


Comment:

Adding the Load resistor simulates adding another section of the circuit and shows us the behaviour of the circuit when a load is attached. This is important as we see that with a load the cut off frequency changes.

The Cut-off frequency has lowered slightly as the total resistance of the circuit has been increased. Using the formula w = 1/RC the increased resistance makes for a larger denominator and so the frequency decreases. Which is shown on the circuit. The change in the resistance alters the time constant of the capacitor and so the capacitor charges and discharges differently. This causes a change in the frequency as the capacitor takes a different amount of time to charge and discharge.

4) Voltage Follower



So, when the resistor is the only load it draws current hence the cut off frequency changes. Adding a voltage follower allows current to travel down a path when the capacitor charges and starts impeding current flow. The voltage follower acts like an open circuit and the current for the load was supplied by the voltage follower. So what I see is the cut off frequency return to what it was without the load.

Part 2: Audio Effects Unit

For this assignment, we were required to build on a breadboard a Hi-Fi audio component circuit with the goal of using the techniques of circuit analysis acquired in labs and lectures to design model and test various circuits found in Hi-Fi audio equipment. Using only Resistors, Capacitors, op-amps, wires and breadboards.

To begin I constructed an integrator circuit on a breadboard. This is shown in Circuit 1, using the data sheet of the LM741 to work out how the pins are connected. Once the circuit was constructed using various components 100uf capacitors to control the noise the occurs in the output signal, with a current limiting resistor (2.7k) and a feedback resistor (100k) this feedback resistor is used as real-world Op-amp amps have a finite input resistance what this means is that small amounts of current flow in or out of the input pins. This current varies with voltage and without this resistor these currents may differ causing significant error. The use of a high feedback resistor means that for any voltage the current through the inputs will be the same. The resistor also drains the capacitor of any residual charge, without this the capacitor would continually add this charge causing the offset.

With the circuit constructed:

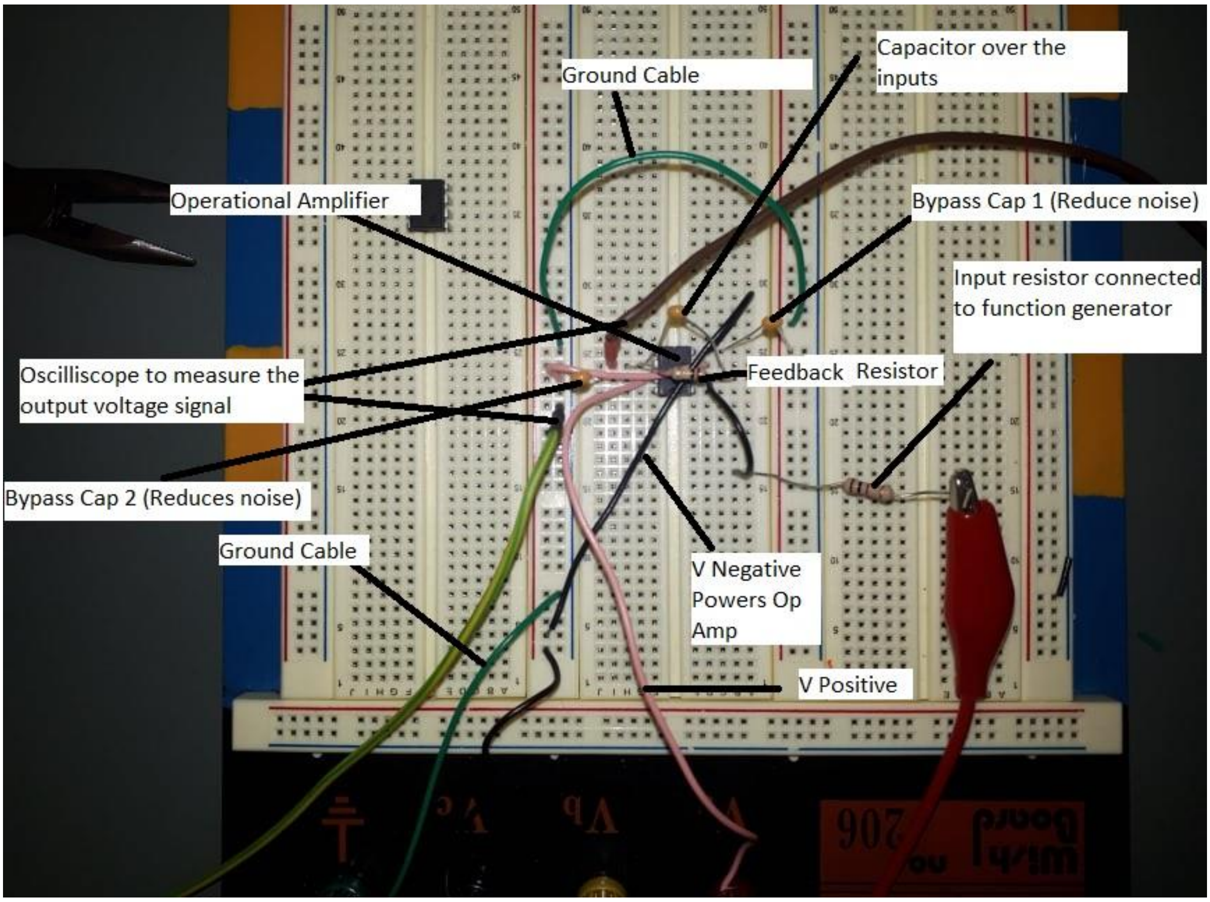
1) Providing a 1KHz, Square wave input from a function generator, to the integrator constructed in the image. Resulted a Triangular wave form as seen in waveform 1 measured with an oscilloscope attached overt the output of the op amp.
2) To reduce the DC offset I put a 100k feedback resistor can be introduced to remove the undesired DC voltage.
3) Measuring the gain from the integrator circuit gives 0.589 using the equation Av=1/wRC: so, 1/1000*2.7k*100nF = 0.589.
   The Following circuit constructed in circuit 2 is a non-inverting amplifier. Used with intent of getting an overall gain of 1x. Circuit 2 amplifies the voltage output. To what we thought was a gain of 1 in total. Instead using a non-inverting amplifier gives a gain of 1+Rf/R = in this case 1+1800/220 = 9.18
   Together these two op amp circuits in combination gave a voltage gain of 0.589*9.18 = 5.4. This is not a gain of one (See discussion)

Discussion

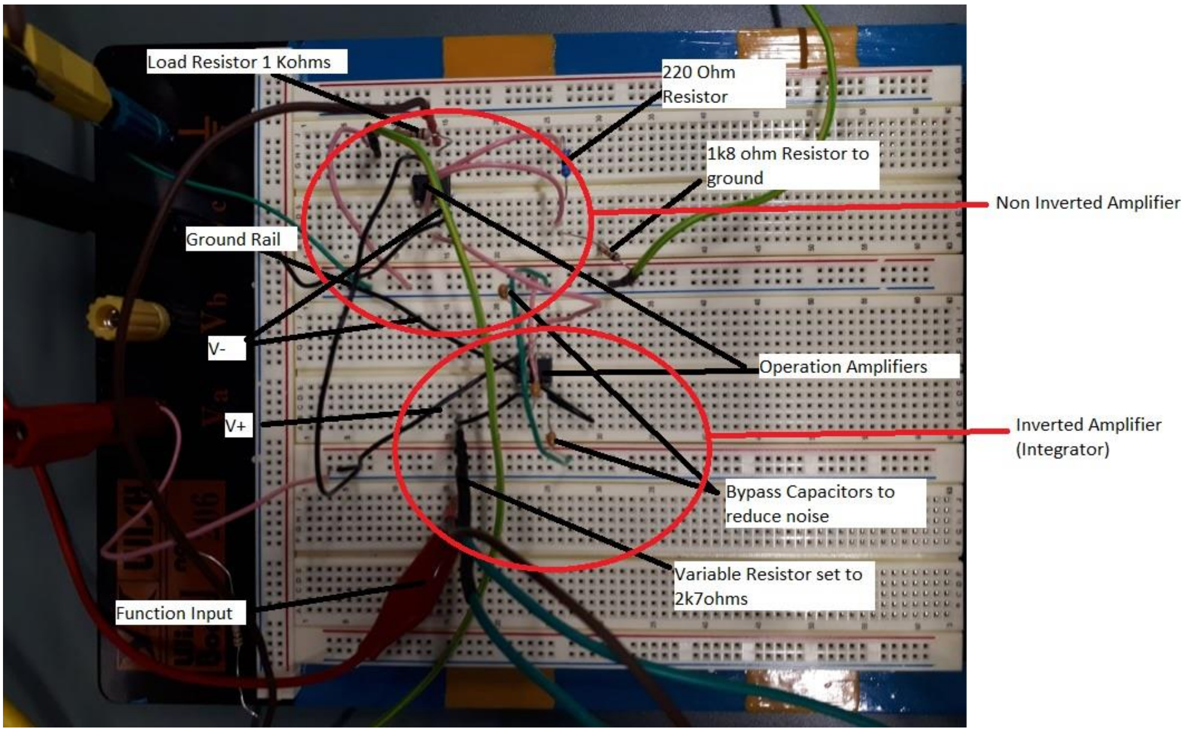
While completing this assignment and constructing the circuit I encountered several problems. With several them related to poorly picked component values, faulty components and a lack of understanding. I found using polar capacitors to be problematic compared to non-polar capacitors. Unsure as to why, but I found the larger capacitor values to be problematic. So, reducing the capacitor to a smaller value allowed for the capacitor charge faster allowing the lower frequency currents to pass through. A bigger problem was originally I had a static resistance value for the resistor between the signal input and the op-amp. This meant that the gain was always larger than one in the integrator circuit, preventing the overall gain from being less than or equal to one. Hence the resistor was changed to 2.7k allowing a smaller gain from the integrator. I noticed that once the circuit was constructed that my output signal was decreasing over time. To prevent this steady decrease over time, I added a feedback resistor to prevent this, I added a 100k resistor which allowed for more offset to be added and for the signal stays in place. One of the biggest problems I faced is the lack of understanding. Like mentioned above the overall gain of the circuit was 5.4, not 1, this was due to the fact to solve for a gain of 1, I worked to match up the output peak and input peak voltage signals shown in waveform 2. This is not how an integrator works. The output voltage is the integral of the input voltage so instead of looking at the peaks like I was I should have been looking at the gradient. Because of this, the output voltage signal peak would be high than the peak of the input as we were looking for a gradient of one whereas in my case the gradient is much higher.

On a side note: What I would have done differently for this assignment. I went into the assignment without a clear understanding of what was required. And lacked the important knowledge to complete this assignment to a high standard. If I was to redo this assignment, I would do far more research and give a little more thought to the actual report write up. Doing the physical circuit building, I based my thinking on the little evidence I had and like I said to look more into how gain works. So instead of looking at peak voltages for the input and output signals and instead look at the gradient of the output signal which is how an integrator works. What we should have seen is an output signal greater than the input signal but see that the output voltage is no more than the integral of the input voltage.

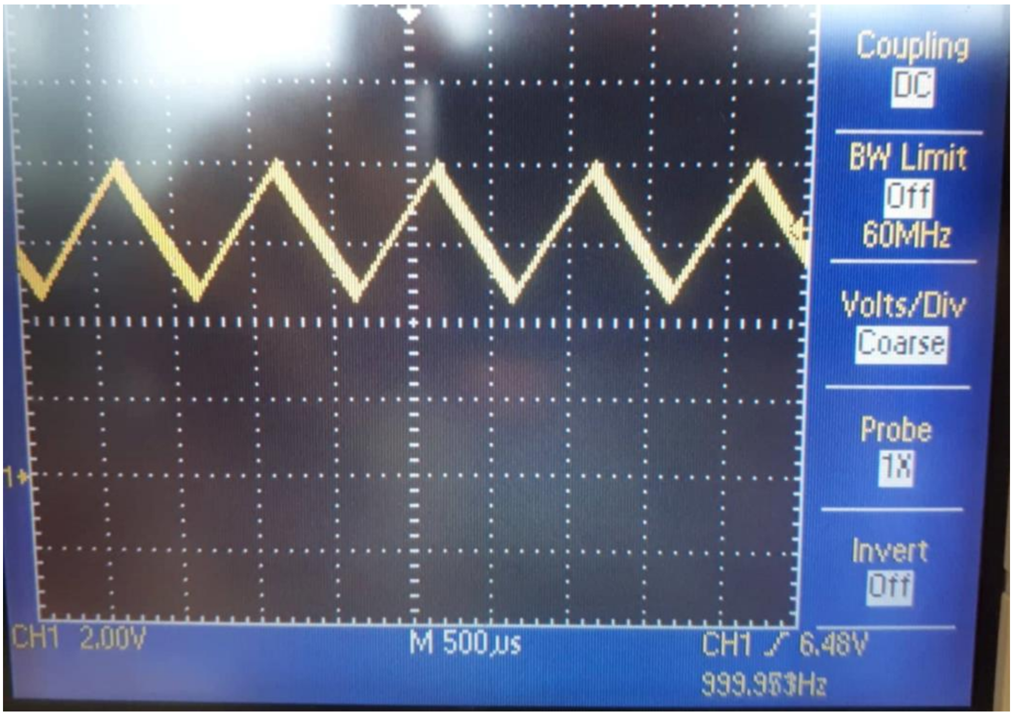
Looking at what I have learned is how to construct a circuit containing OP amp chips and how they function in an actual real-world application, looking at the faults and tolerances of said chips. This assignment has improved my knowledge of circuits and integrators and breadboard-based circuits even if the circuits I made and the results I have obtained were not quite correct. While also looking at programs like LTspice and Matlab to model circuits before there construction. This assignment has allowed me to use specific knowledge obtained from lectures and labs such as analysis techniques to then model construct and design circuits for the real world even is only small.



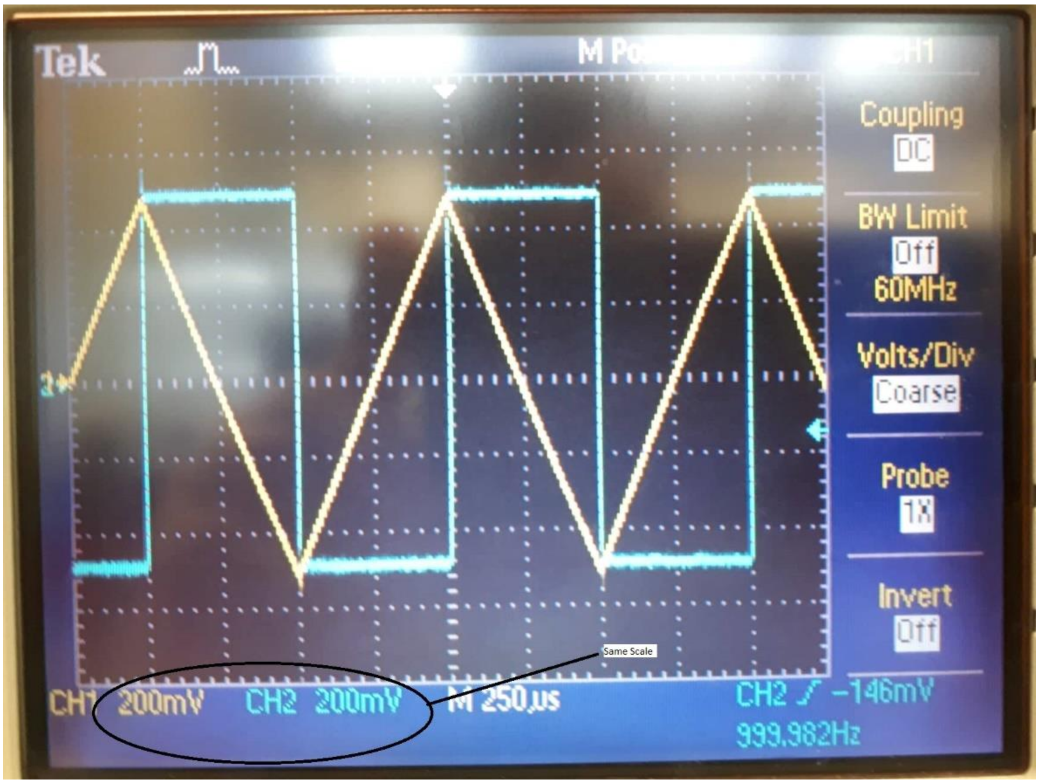
Circuit 1: Annotated circuit without the Amplifier.



Circuit 2: Annotated circuit with the Non-inverted amplifier following.



Waveform 1: Is the waveform of the output voltage from the integrator circuit. (Includes noise)



Waveform 2: The final waveform against the input voltage waveform, with less noise due to bypassing. (is also incorrect.)