ECEN 203 Lab 3 Report

Hi-Fi Audio Circuit Design

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Part 1: Pre-Amp Subwoofer Filter

1. **Design a low-pass RC filter with a cut off frequency of $200Hz$**

   $\omega = 2\pi f \quad f = 200Hz \quad \therefore \quad \omega = 400\pi$

   $\tau = RC, \quad \omega = \frac{1}{\tau} \quad \therefore \quad \omega = \frac{1}{RC}$

   Using this formula we are able to choose a capacitor size and then calculate the size of the required resistor using $R = \frac{1}{\omega C}$.
   Using the calculated $\omega = 400\pi$, and a capacitor of $1\mu F$, we find that the required resistor should be 796Ω.

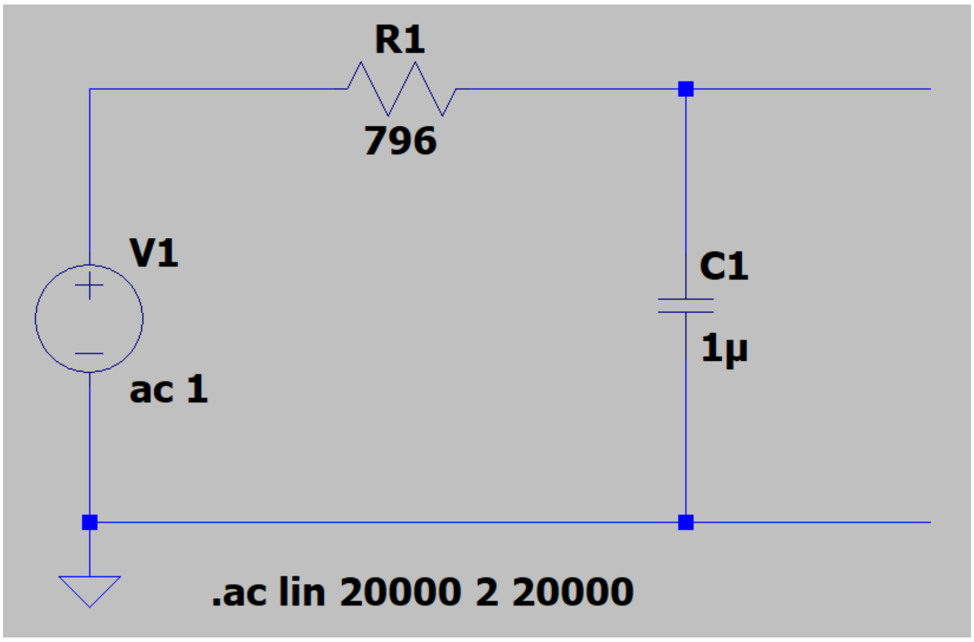

Figure 1: RC Low-Pass Filter

2. **Plot the transfer function of the filter with no load connected.**

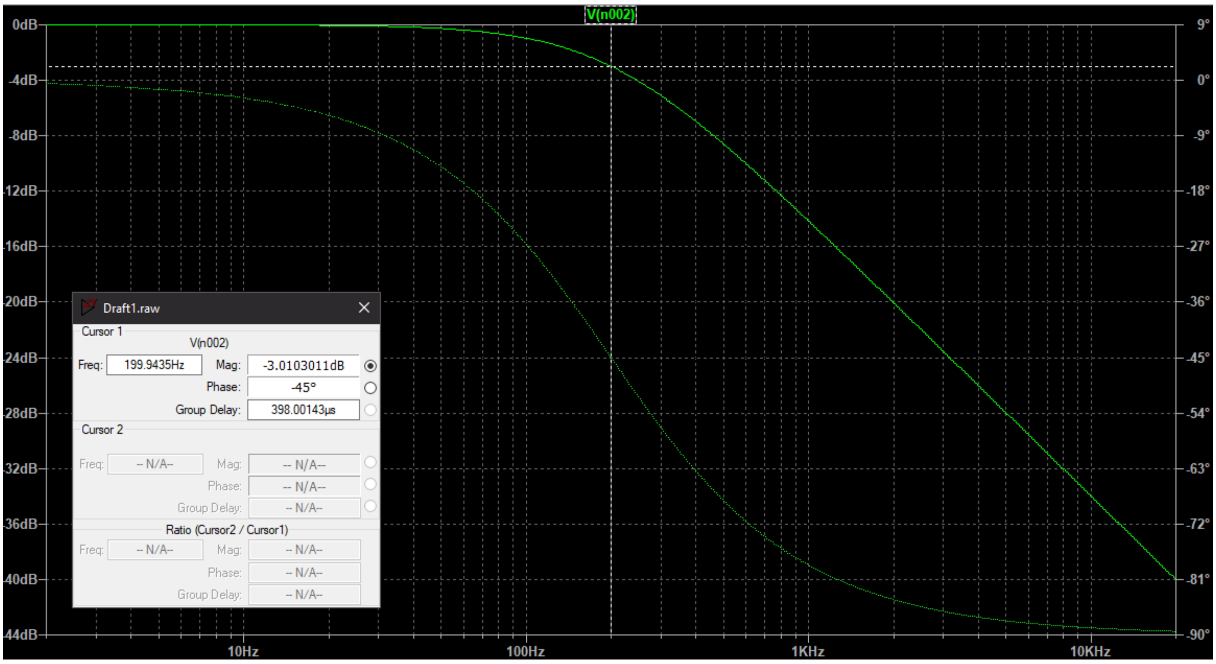

Figure 2: RC Low-Pass Transfer Function (No Load)

The transfer function of this filter is $\dfrac{\frac{1}{j\omega RC}}{1+\frac{1}{j\omega RC}}$ which can be simplified down to $\dfrac{-j}{\omega\tau - j}$

This transfer function $H(\omega) = \dfrac{-j}{\omega\tau - j}$ can now be used to find the gain of the circuit at given frequencies using the magnitude of the transfer function: $Gain = 10\log|H(\omega)|$

- $10\log|H(40\pi)| = -0.04dB$
- $10\log|H(40\pi)| = -3.01dB$
- $10\log|H(4000\pi)| = -20.04dB$

3. **Repeat the AC analysis and calculate the cut off frequency, but now with a $10k\Omega$ resistor across V_o.**

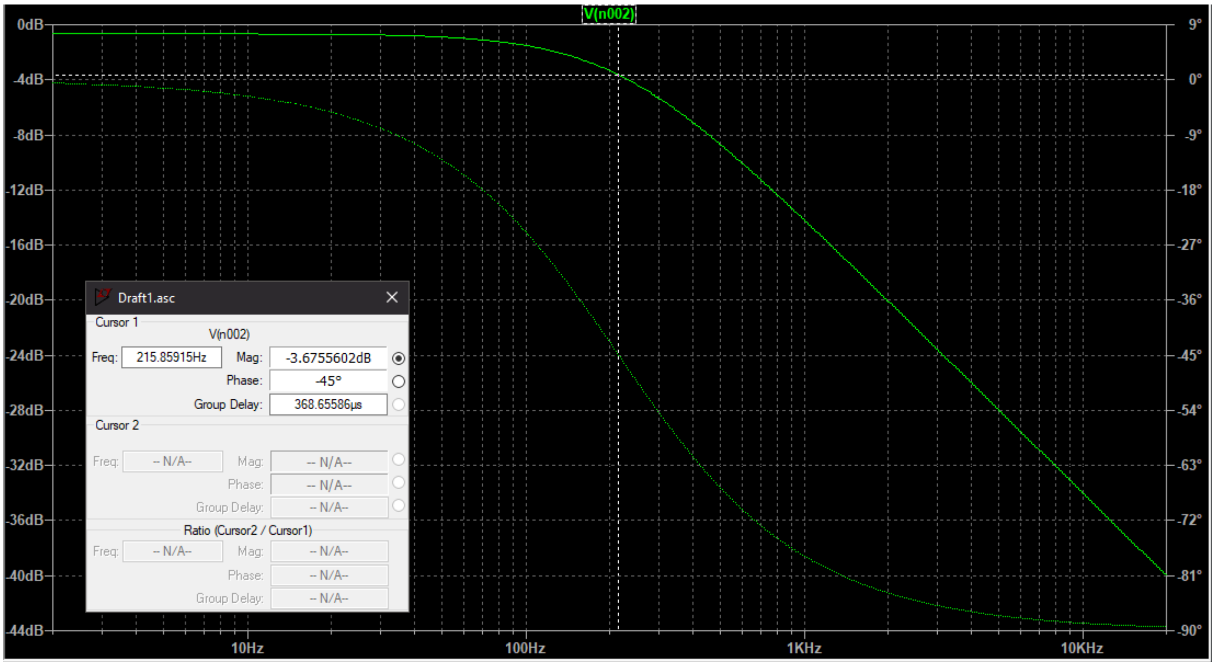

Figure 3: Loaded RC Low-Pass Transfer Function

To calculate the new f_c we can use the $f_c = \frac{(R1 + R2/CR1R2)}{2\pi}$, calculating the new f_c to be $215.86Hz$ which is corroborated by the transfer function in figure 3. This is known as a terminated RC filter, with the load acting to lower the gain of the filter, and shift the cut-off frequency to a higher frequency.

4. **Insert a voltage follower between the filter and the $10k\Omega$ resistor:**

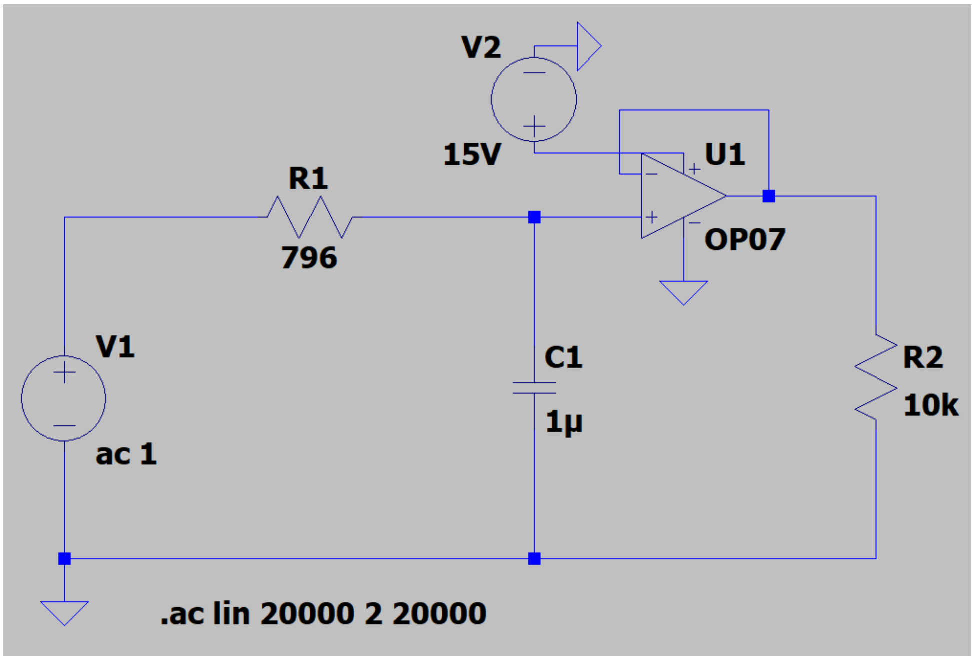

Figure 4: Voltage Follower

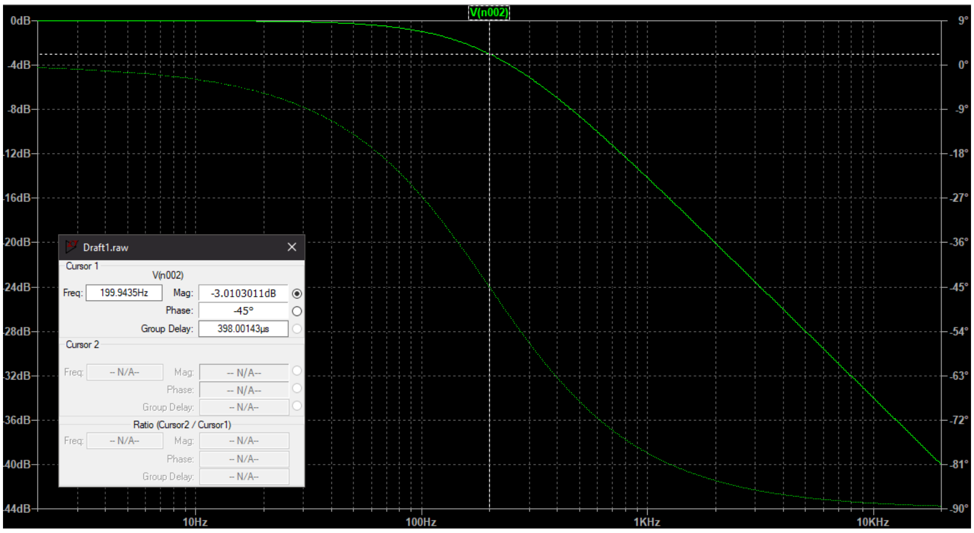

Figure 5: Voltage Follower Transfer Function

It is observed that the gain of this filter is the same as the previous low-pass RC filter with no load attached. This is due to the voltage divider actually just being an OP-Amp with a gain of 1. This means that the voltage being presented on the non-inverting terminal will be the output voltage of the OP-Amp, but powered from a seperate power supply, meaning that is it isolated from the rest of the filter.

Part 2: Audio Effects Unit

1. **Build an Integrating Circuit Using OP-Amp's and capacitors** the behaviour of

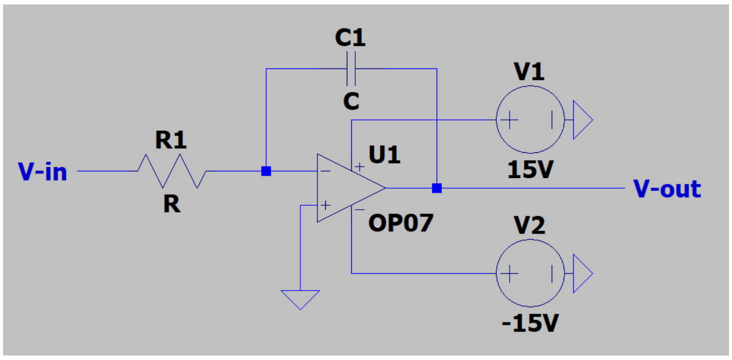

Figure 6: Integrating circuit design

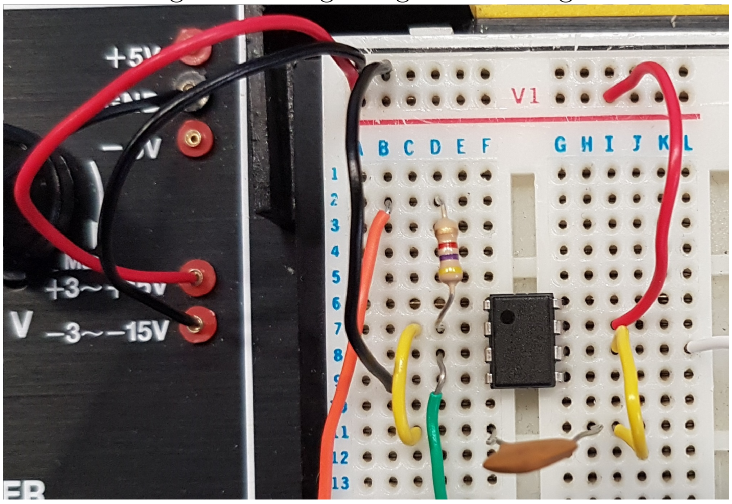

Figure 7: Integrating circuit on bread board

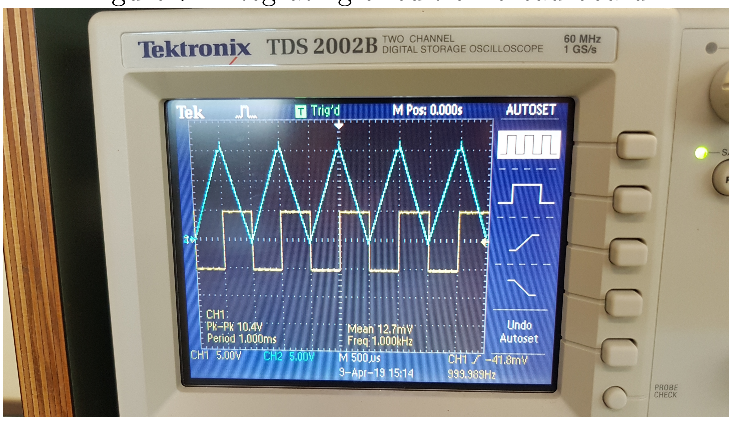

Figure 8: oscilloscope readings of the output of the OP-Amp

the integrating circuit can be explained when thinking about the charging and discharging or a capacitor. As a voltage is applied at V_{in} this voltage is then applied on the plate of the capacitor. Because of this the OP-Amp immediately supplies an equal voltage to the opposite side of the capacitor in order to cancel this out. It is because of this, that as the capacitor charges you get a linear increase in the output voltage V_{out}. It is also observed that there is an overall DC voltage bias to the output of the OP-Amp. This is due to imperfections in the chip or due to a bias in the supply voltage, and leads to the capacitor never fully discharging. The affect of this as seen in figure 8 is that the output is shifted up to either of the input rails of the OP- Amp.

2. **DC Biases and Output Wind-up**
   One way to avoid the aforementioned DC voltage bias in the output is to place a 'dissipating' resistor in parallel with the capacitor. This will ensure that the capacitor will always fully discharge and help avoid a DC bias or wind-up.

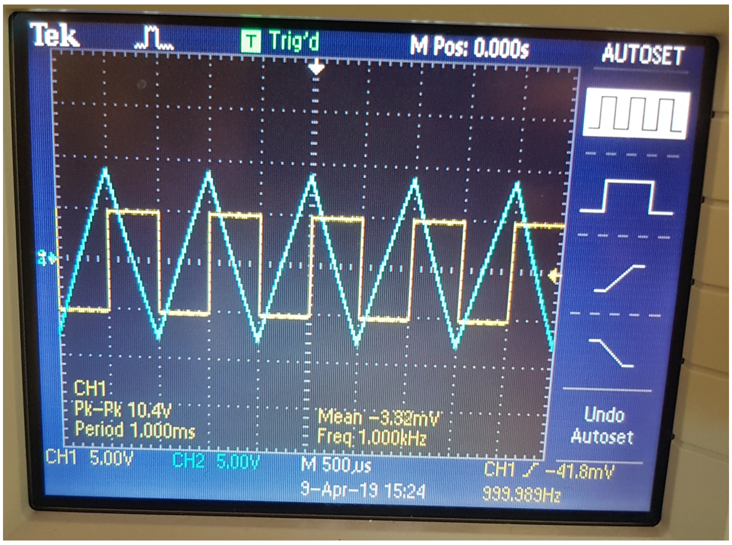

Figure 9: Output of integrator after a $10k\Omega$ was placed in parallel with the capacitor

   The differences between figures 8, and figures 9 clearly show the impact of a dissipating resistor on reducing bias and wind-up.

3. **Amplification**
   In figure 9 above, we used cursors to measure the gain of the integrator circuit, finding it to be close to 6dB, or a ratio of 1:2 from input to output. From this we know that the gain of the aplification OP-Amp must be -6dB or $\frac{1}{2}$ the original voltage.
   $\frac{V_o}{V_i} = \frac{-R_2}{R_1} \quad \therefore \quad \frac{V_o}{V_i} = \frac{1}{2} = \frac{-R_2}{R_1} \quad \therefore \quad -R_2 = 2R_1$
   From this we know that if we chose $R_2 = 20\Omega$ then $R_1 = 10\Omega$ producing the output seen in figure 10.

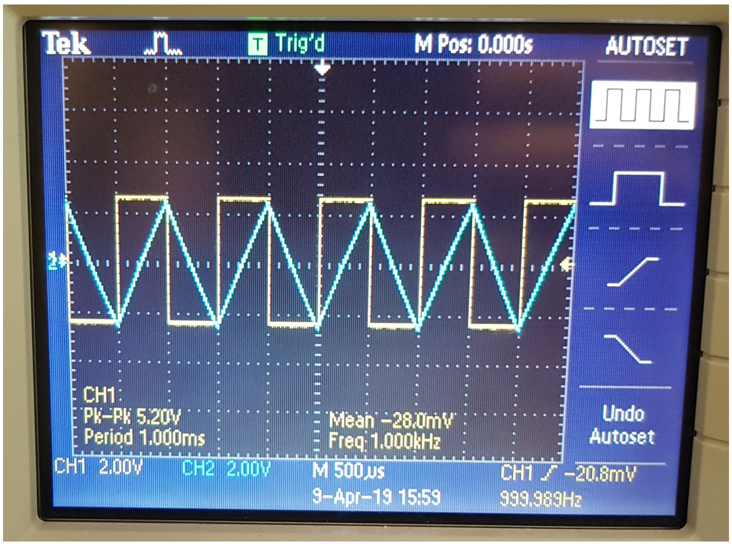

Figure 10: Integrator output amplified by OP-Amp

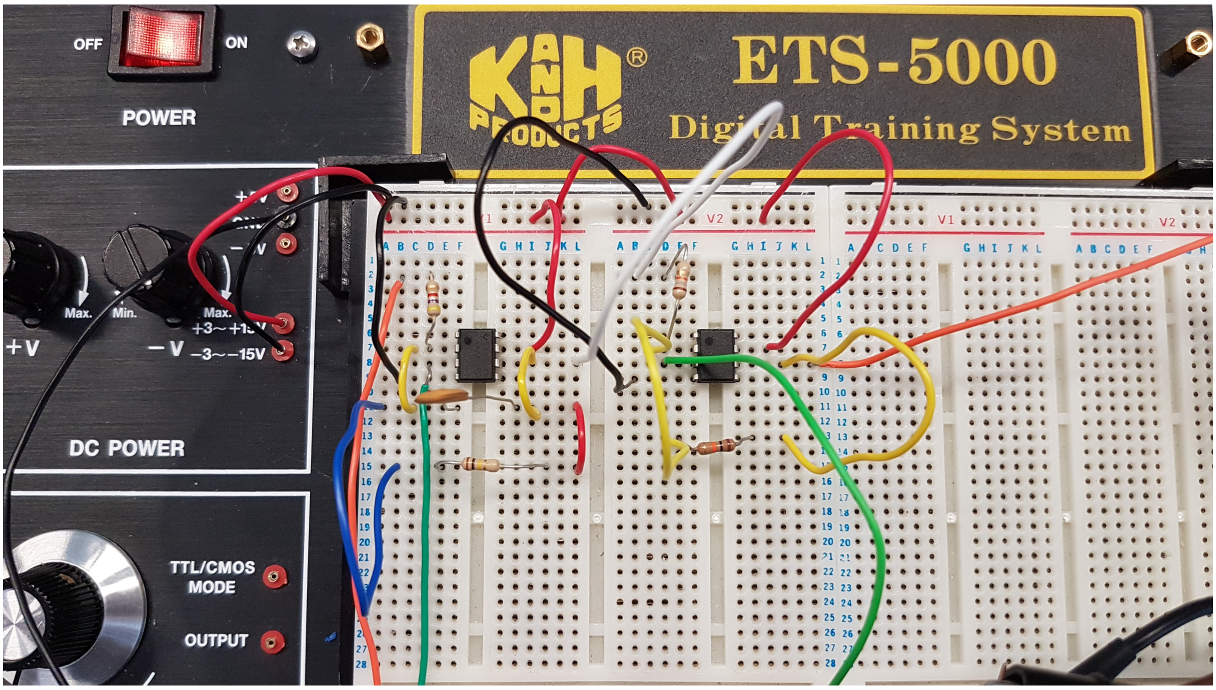

Figure 11: Integrator output amplified by OP-Amp, circuit on breadboard