PHY405 Lab 4

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Collaborators for all questions: none. Partner (for Lab 1-10): Jacob Villasana.

R-1

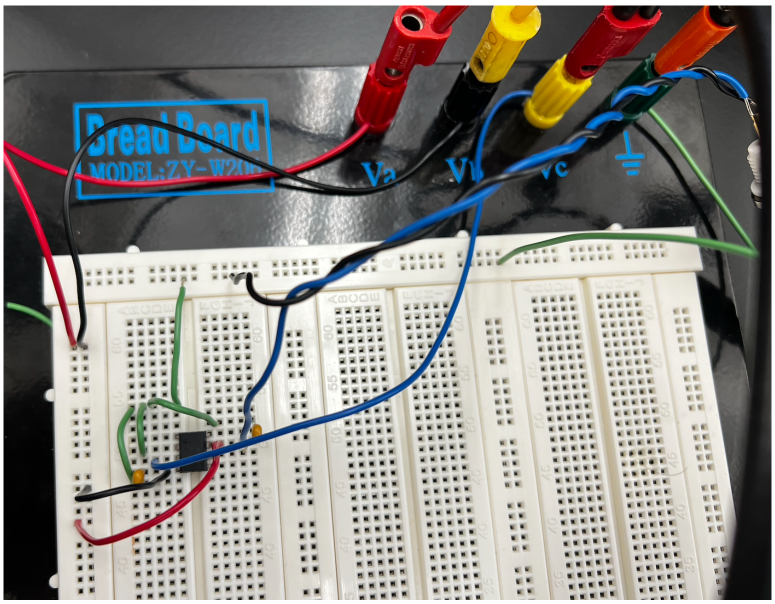

Figure 1: Initial open-loop op-amp circuit, using $1\mu F$ capacitors for voltage dampening and $\pm 15\,V$ supplies in an LF356 op-amp.

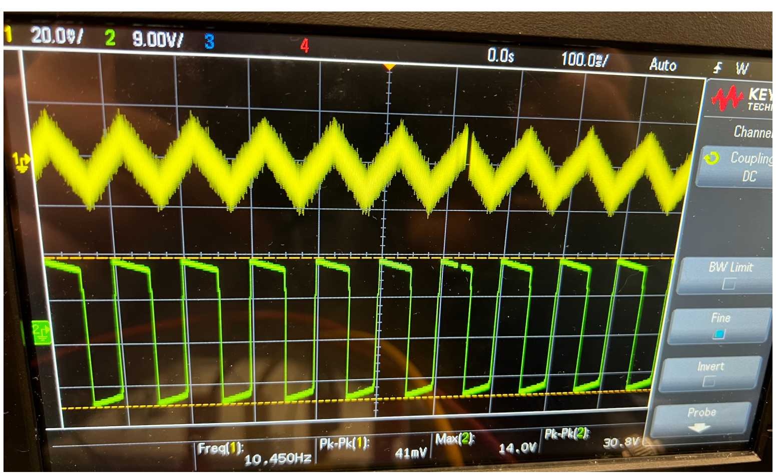

Figure 2: Screen capture of the input (yellow) vs output (green) voltages from the open-loop op-amp differential amplifier. Note that the output wave is amplified to 40dB and represents the derivative of the input wave.

R-2

What is observed is a combination of the signal amplification, then a clipping of the signal based on the maximum output voltage. Hence a square wave is as expected, since the square wave output is a measure of the change of voltage of the input wave (constant slopes up = positive derivative, negative slopes down = negative derivative).

R-3

Initially, we had chosen 1kΩ and 100kΩ resistors both with 5% tolerances, but we had found that the output gain was significantly lower, and this is most likely due to a small voltage being pushed through the circuit. We then moved to 10Ω and $1\text{k}\Omega$ resistors (also 5% tolerances) due to the smaller input voltage, and this yielded the 40 dB gain requried of the amplifier. This is because gain $= 20\log_{10}(V_{\text{out}}/V_{\text{in}})$.

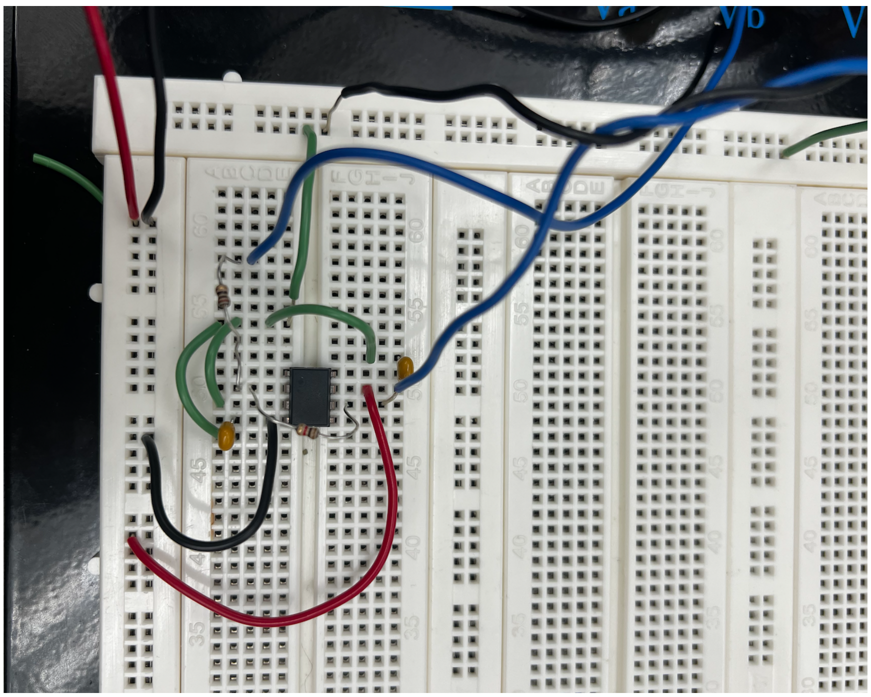

Figure 3: non-inverting amplifier circuit, using $1\mu F$ capacitors and 10Ω — $1k\Omega$ resistors to produce an output voltage of $V_{out} \sim 100V_{in}$.

R-4

Based off of the datasheet (see R-5) and the low-frequency amplification, we observe a gain of 40dB ($\times 100$ voltage increase), which is consistent with our choice of resistance values. As per the nature of the op-amp, higher frequencies are attenuated, resulting in the low-pass drop-off in the Bode plot.

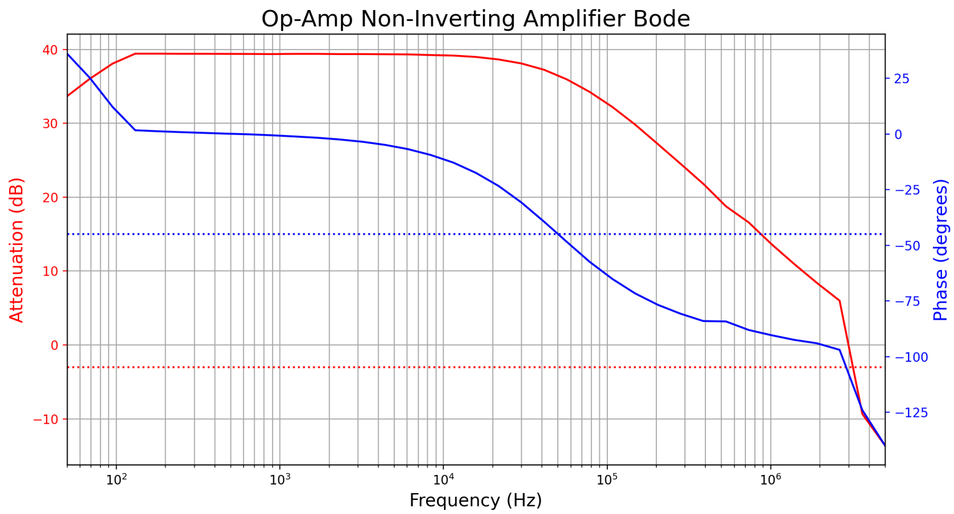

Figure 4: Bode plot of the non-inverting amplifier circuit using 10Ω *and 1k*Ω *resistors to amplify the output voltage to 40dB*

R-5

From the 'Features' section of the op-amp manual, under 'uncommon features', 5MHz bandwidth from datasheet for all LFx56 devices. In Figure 4, noticing that the -3 dB attenuation cutoff is located around the $\sim$ 5MHz mark ($(3-5) \times 10^6$). The gain of the amplifier itself is goverened by the choice of resistor values for the non-inverting feedback amplifier circuit.

R-6

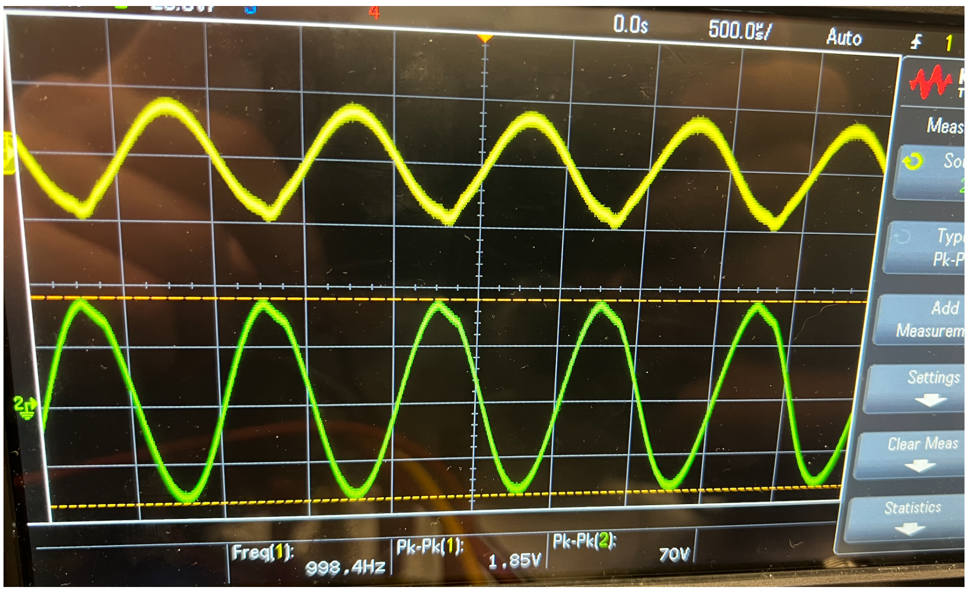

Figure 5: Screen capture of the input (yellow) / output (green) sine wave due to an inverting wave amplifier circuit. Wave is inverted and amplified.

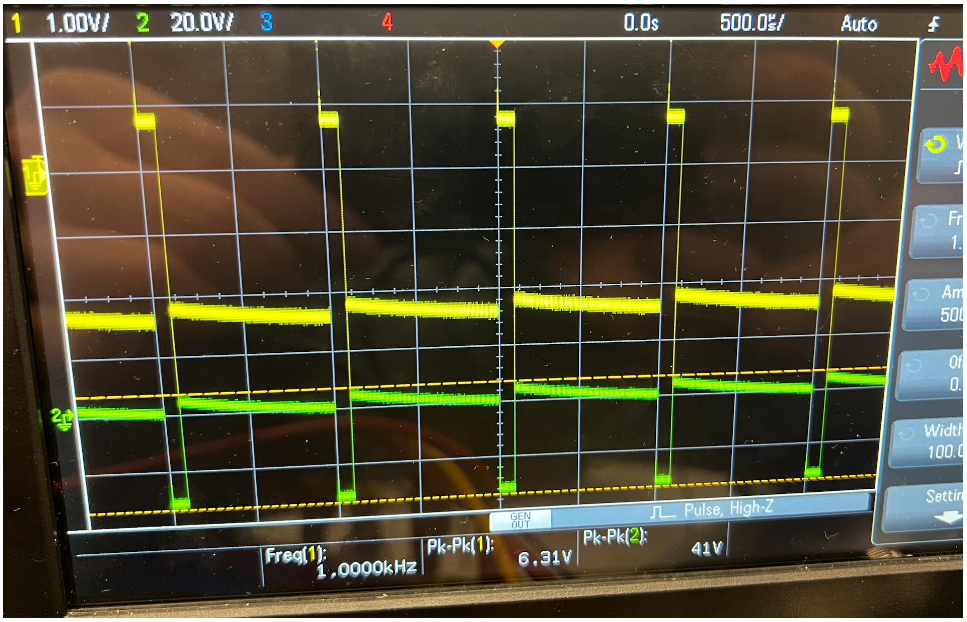

Figure 6: Screen capture of the input (yellow) / output (green) pulse wave due to an inverting wave amplifier circuit. Wave is inverted and amplified.

R-7

(A) $V_{\text{in}} = 1$ V, $I_{\text{in}} = 0$ A, so $Z_{\text{in}} \to \infty$ V/A (infinite input impedance).

(B) $V_{\text{in}} = 1$ V, $I_{\text{in}} = 178.09$ nA, so $Z_{\text{in}} \approx 5.615 \times 10^6$ V/A.

(C) $V_{\text{in}} = 1$ V, $I_{\text{in}} = 999.97\mu$ A, so $Z_{\text{in}} \approx 1.0003 \times 10^3$ V/A.

(D) $V_{\text{in}} = 1$ V, $I_{\text{in}} = 999.472\mu$ A, so $Z_{\text{in}} \approx 1.0005 \times 10^3$ V/A.

R-8

(A) We note that the gain is determined by the resistor ratio R_2/R_1. The input impedance is $V_{\text{in}}/I_{\text{in}}$, and if $V = I(R_1 + R_2)$, then doubling Z_{in} means halving I which means doulbing $R_1 + R_2$. Hence, in this case, $R_2/R_1 = 10$ and $R_1 + R_2 = 11\text{k}\Omega$, so we move them to $R_1 = 2\text{k}\Omega$ and $R_2 = 20\text{k}\Omega$.

(B) Not possible. Gain is given by $1 + R_2/R_1$, which must remain constant. To double input impedance we double $R_1 + R_2$, but that means asymptotically approaching the initial gain ratio since we add 1 to the resistance ratio. One cannot double $R_1 + R_2$ since $R_1 + R_2 = R_1(1 + R_2/R_1) = R_1 \cdot (\text{gain})$ and thus the gain would always change.

R-9B

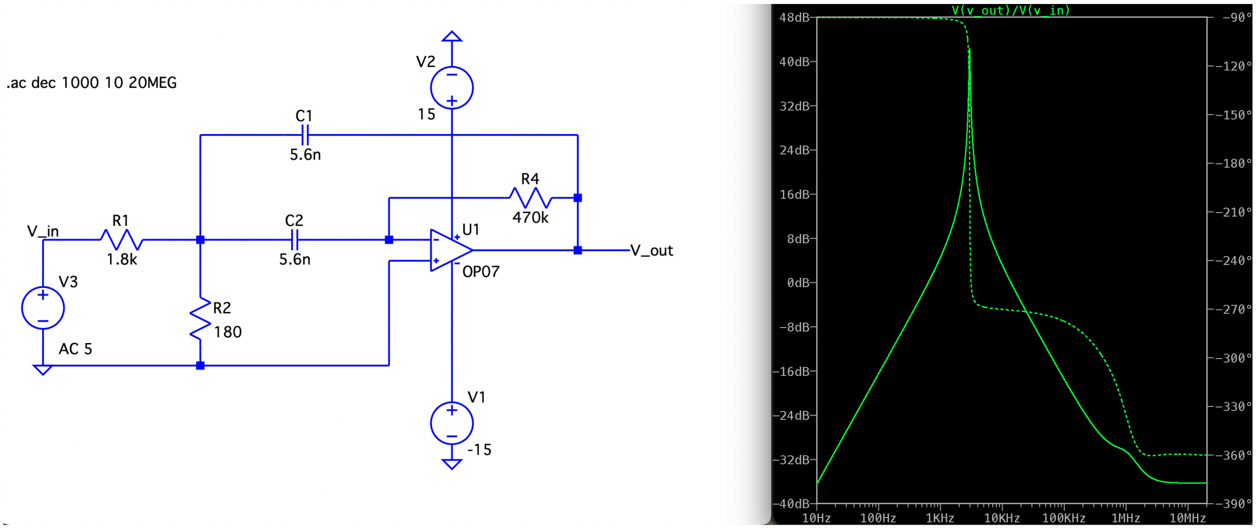

Figure 7: LTSpice schematic of an op-amp differentiator / integrator circuit in series to produce an active bandpass filter about a certain frequency with a narrow Q value. Capacitor values were chosen in the lab first, then resistance values. The peak is located at 43 dB at a frequency of 3.5kHz. Respective cufoff frequencies are ~ 500 *Hz and* ~ 18 *kHz.*

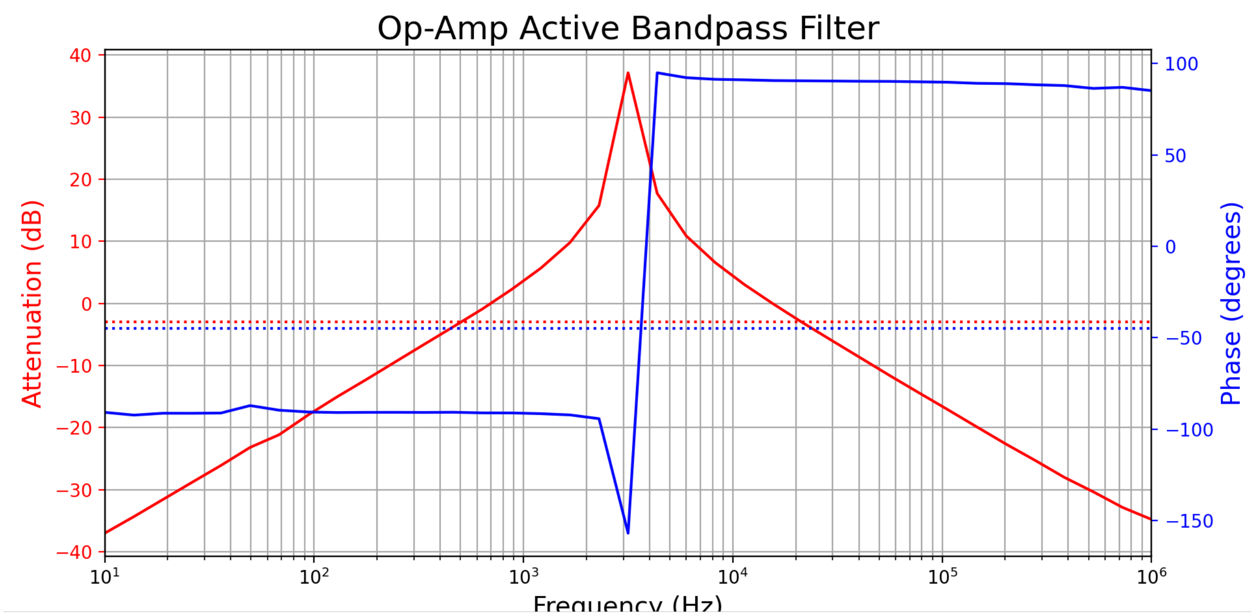

Figure 8: Bode plot generated using PyVisa and the oscilloscope to measure the response of the active bandpass filter. The peak is located at (3.162 kHz, 38.25 dB) (this is a $\times 88$ *amplification of the input voltage) with 3dB cutoffs located at 464 Hz, 21 kHz respectively.*

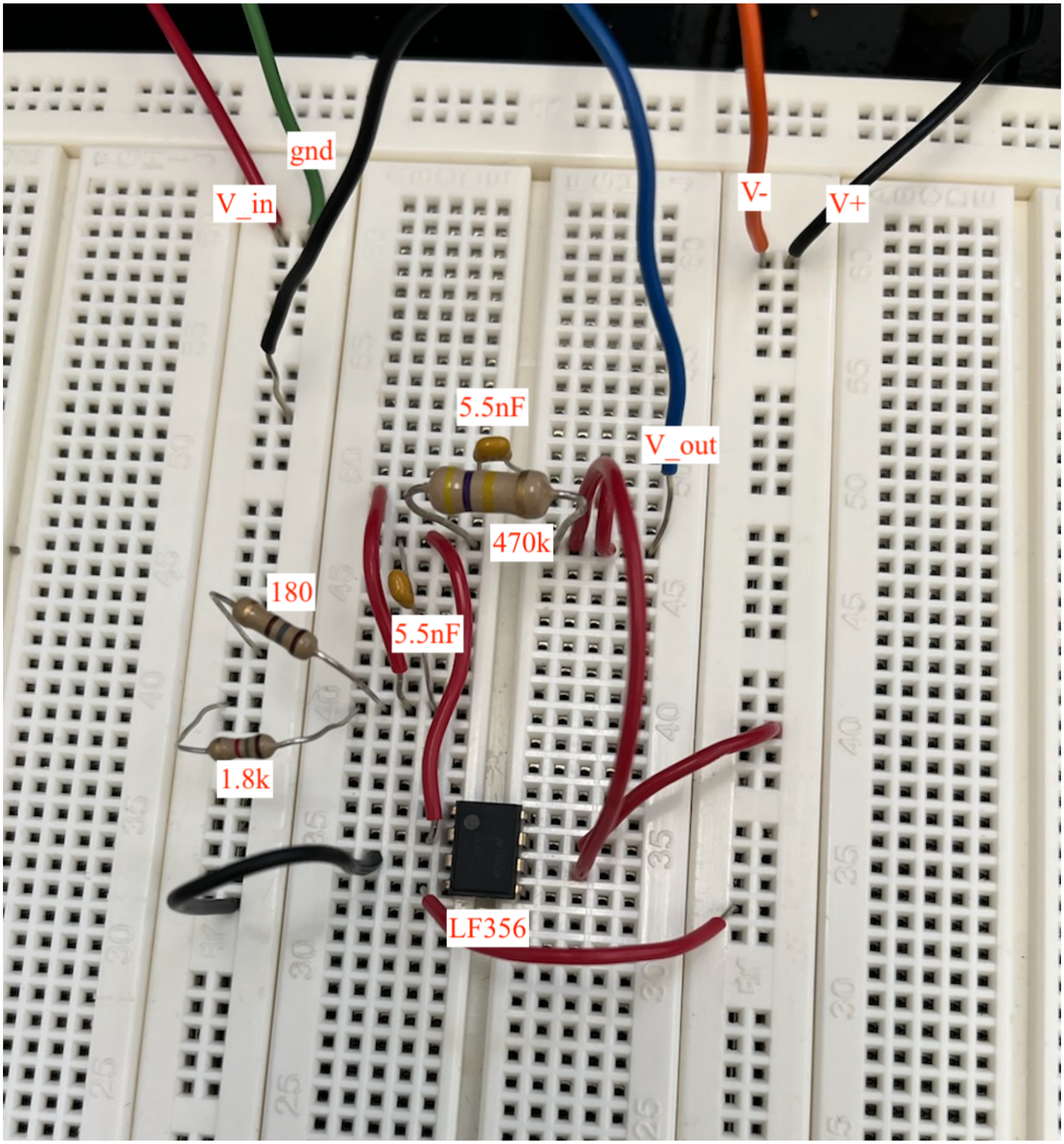

Figure 9: Circuit construction from the Figure 7 schematic, using all the same resistance and capacitance values found in the lab.

Methodology: Looked at this video https://www.youtube.com/watch?v=WHT39_G64AM and constructed the circuit accordingly. It was important to note that the differentiator circuit must proceed AFTER to the integrator circuit so that the appropriate wave is amplified, since one must also account for an integration constant. The differentiator circuit would adjust this constant produced by the integrator. Capacitor values were chosen first based off of what was available in the lab. The quality factor Q, gain value A and centre frequency must be chosen prior to construction. At first, the chosen values were given as

$$R_1 = \frac{Q}{2\pi f_c C A}$$
$$R_2 = \frac{Q}{2\pi f_c C(2Q^2 - A)}$$
$$R_4 = \frac{Q}{\pi f_c C}$$

but R_4 was increased to 470k to increase gain and R_2 was initially at 120, but we had found that 180 produced a higher Q at the centre peak to narrow the cutoffs so we had left it at that. The cutoffs are rough, and may be revisited by chosing a higher Q value when calculating resistances initially, which could imporve the circuit for the next time it is constructed.