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# CASCADE FILTERS

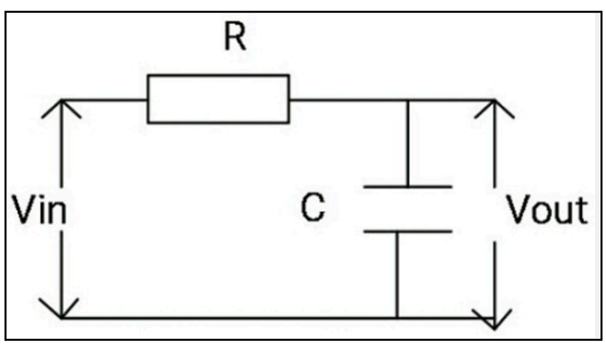
**Objectives:**
This lab will introduce the effect of using filters in parallel with each other in order to cascade their effects into an overall more effective filter, along with the side effects of cascading filters.

**Preliminary Calculations:** The preliminary calculations required us to refresh our memories on the structure of filter circuits, and review class material about these subjects.

**Results and Discussions:**

1. **FIRST ORDER LOW PASS FILTER**
    a. Design and build a first order R/C Low Pass Filter (LPF) that has a cutoff frequency of 10 kHz. Test the filter by putting in sine waves at different frequencies. Measure both the amplitude, in dB, and phase, in radians, change from input to output for at least carefully selected 10 frequencies. Measure the roll-off rate of this filter. Plot the magnitude and phase response of the filter using the 10 measurements (You may use any software package to generate the plot). Run a frequency sweep analysis on the LPF. Observe the input sweep and LPF output simultaneously. Set the parameters to show at least two sweeps on the oscilloscope screen.

***Circuit 1: LPF***




*https://electronics.stackexchange.com/questions/152159/deriving-2nd-order-passive-low-pass-filter-cutoff-frequency*

**Results 1:**

1.
    a. For this part of the experiment we were asked to create a 1st order low pass filter using the circuit diagram shown above

in **Circuit 1.** The cutoff frequency given was 10 Khz, using this cutoff frequency we were able to calculate the capacitor and resistance values using the formula “f=1/(2piRC)”. Which ended up being 0.0047 μF and 3.4 KΩ respectively. We then tested the 10 frequencies within our given cutoff range. Of which we used **Formula 1** to calculate the db and phase of each frequency. These frequency values and calculations can be observed below within **Table 1.** We were finally asked to plot these calculated values using excel to observe the effectiveness of our filter, these plots can be observed within **Graph 1.** Our final oscilloscope output can also be observed within **Figure 1.**

***Formula 1***

$$db = 20\log_{10}\left(\frac{V_{out}}{V_{in}}\right)$$

$$Radians = \frac{\pi \times degrees}{180}$$

***Table 1: Sweep LPF***

| frequency | db | phase |
|---|---|---|
| 1 | 0 | -0.7853981634 |
| 9.5 | 0 | -0.7822565707 |
| 10.2 | -3.16 | -0.7853981634 |
| 10.9 | -3.741 | -0.8136724973 |
| 12 | -4.082 | -0.8482300165 |
| 15 | -6.021 | -0.9738937226 |
| 20 | -7.104 | -1.005309649 |
| 30 | -10.13 | -1.099557429 |
| 50 | -14 | -1.225221135 |

***Graph 1: Frequency Vs db and Phase***

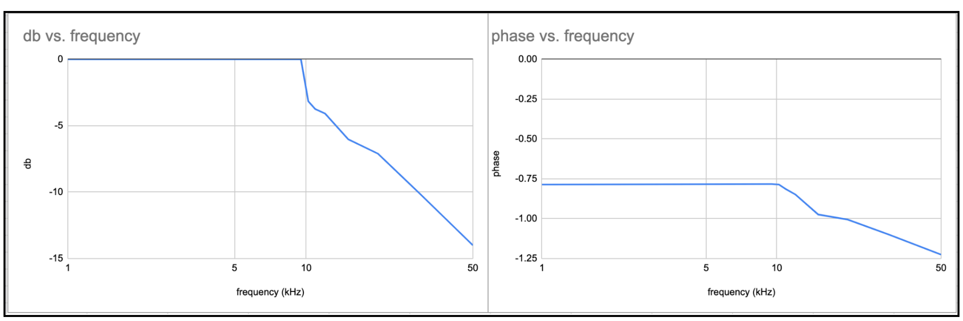



***Figure 1: LPF Oscilloscope Output***

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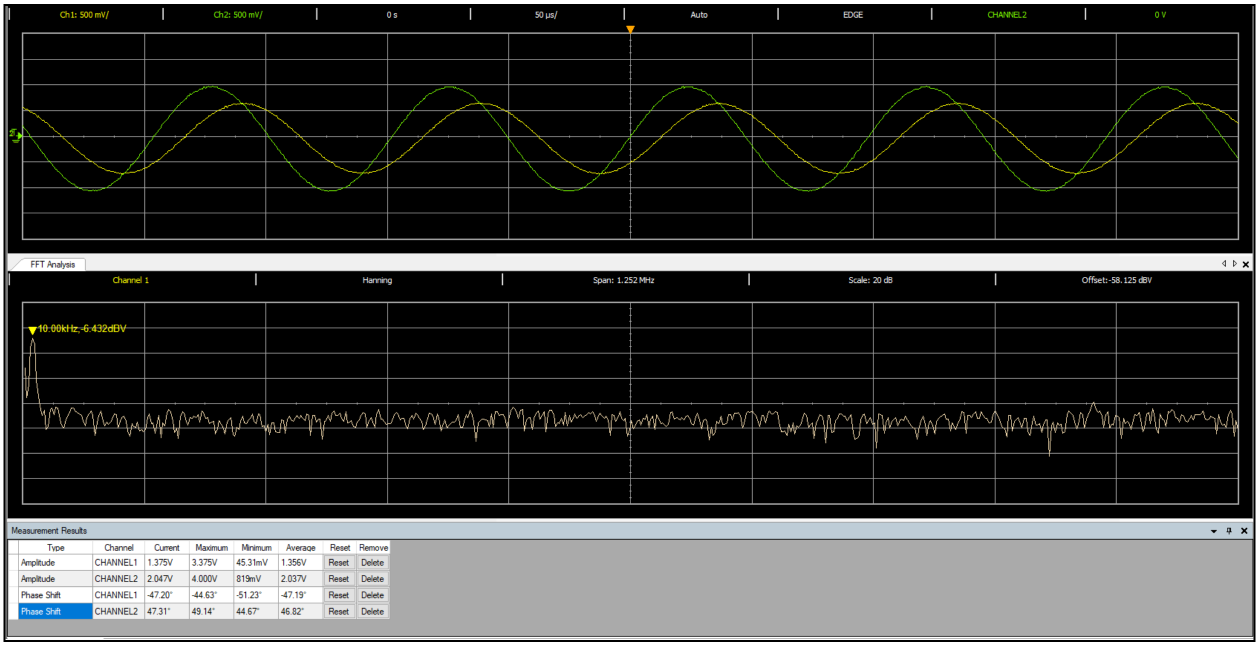
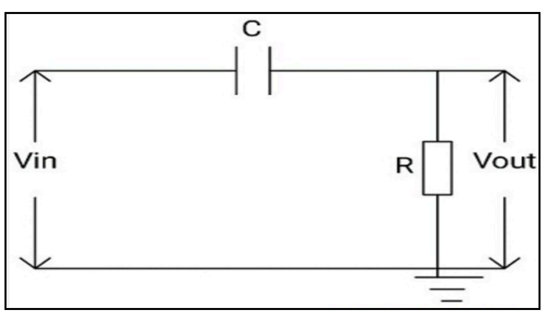



## 2. FIRST ORDER HIGH PASS FILTER

a. Design and build a first order R/C High Pass Filter (HPF) that has a cutoff frequency of 10 kHz. Test the filter by putting in sine waves at different frequencies. Measure both the amplitude, in dB, and phase, in radians, change from input to output for at least carefully selected 10 frequencies. Measure the roll-off rate of this filter. Plot the magnitude and phase response of the filter using the 10 measurements (You may use any software package to generate the plot). Run a frequency sweep analysis on the HPF. Observe the input sweep and HPF output simultaneously. Set the parameters to show at least two sweeps on the oscilloscope screen.

***Circuit 2: HPF***

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**Results 2:**

1.

a. For this part of the experiment we were asked to create a 1st order high pass filter using the circuit diagram shown above in **Circuit 2.** The cutoff frequency given was 10 Khz, using this cutoff frequency we were able to calculate the capacitor and resistance values using the formula “f=1/(2piRC)”. Which ended up being 0.0047 μF and 3.4 KΩ respectively. We then tested the 10 frequencies within our given cutoff range. Of which we used **Formula 1** to calculate the db and phase of each frequency. These frequency values and calculations can be observed below within **Table 2.** We were finally asked to plot these calculated values using excel to observe the effectiveness of our filter, these plots can be observed within **Graph 2.** Our final oscilloscope output can also be observed within **Figure 2.**

***Table 2: Sweep HPF***

| Frequency (kHz) | db | Phase |
|---|---|---|
| 50 | -0.56 | -0.1570796327 |
| 40 | -0.67 | -0.2073451151 |
| 30 | -0.724 | -0.2764601535 |
| 20 | -1.15 | -0.4335397862 |
| 15 | -1.67 | -0.5340707511 |
| 12 | -2.27 | -0.6628760499 |
| 10 | -2.91 | -0.7539822369 |
| 9 | -3.25 | -0.7853981634 |
| 4 | -7.96 | -1.187522023 |

***Graph 2: Frequency Vs db and Phase***

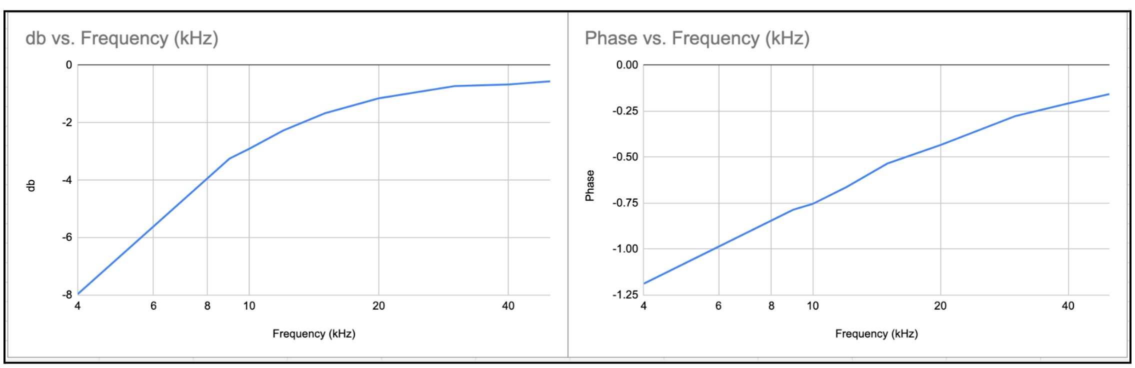
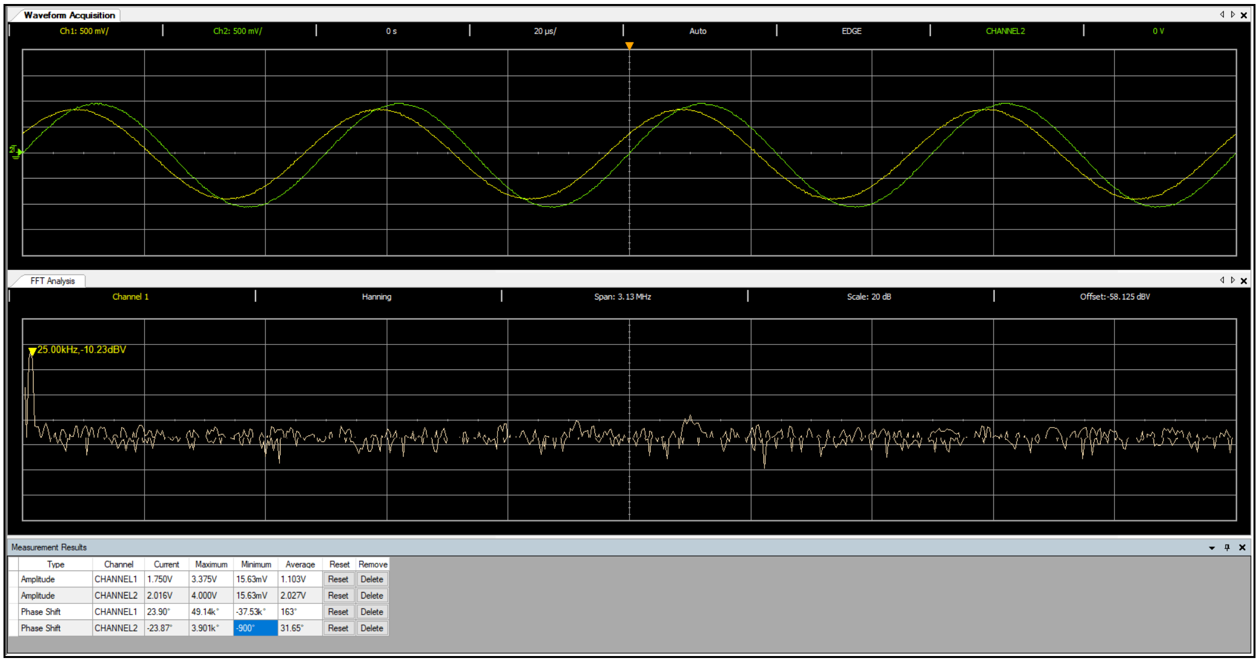


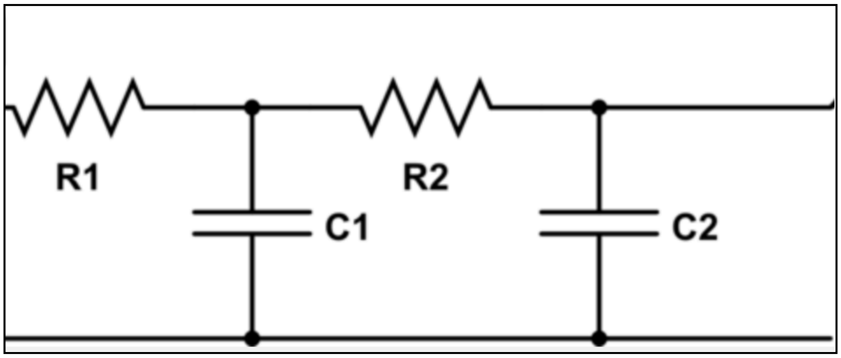

***Figure 2: HPF Oscilloscope Output***




| Type | Channel | Current | Maximum | Minimum | Average | Reset | Remove |
|---|---|---|---|---|---|---|---|
| Amplitude | CHANNEL1 | 1.750V | 3.375V | 15.63mV | 1.103V | Reset | Delete |
| Amplitude | CHANNEL2 | 2.016V | 4.000V | 15.63mV | 2.027V | Reset | Delete |
| Phase Shift | CHANNEL1 | 23.90° | 49.14k° | -37.53k° | 163° | Reset | Delete |
| Phase Shift | CHANNEL2 | -23.87° | 3.901k° | -900° | 31.65° | Reset | Delete |

3. **SECOND ORDER LOW PASS FILTER**
    a. Design and build a second order Low Pass Filter (LPF) using only resistors and capacitors, which has a cutoff frequency of 10 kHz. Try to get the gain as close to constant as you can from DC (0 Hz) to 10 kHz, and as close to -40 dB/decade as you can for everything above 10 kHz. Avoid having a resonant peak as much as possible and avoid having any range where the gain has a slope of -20 dB/decade if you can. Measure both the amplitude, in dB, and phase, in radians, change from input to output for at least carefully selected 10 frequencies. Measure the roll-off rate of this filter. Plot the magnitude and phase response of the filter using the 10 measurements (You may use any software package to generate the plot). Run a frequency sweep analysis on the LPF. Observe the input sweep and LPF output simultaneously. Set the parameters to show at least two sweeps on the oscilloscope screen.

***Circuit 3: 2nd Order LPF***

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**Results 3:**

1.
   a. For this part of the experiment we were asked to create a 2st order low pass filter using the circuit diagram shown above in **Circuit 3.** The cutoff frequency given was 10 Khz, using this cutoff frequency we were able to calculate the capacitor and resistance values using an online 2nd order LPF filter calculator. Which gave 0.0047 μF and 1.355 KΩ respectively, for each pair of capacitor and resistor. We then tested the 10 frequencies within our given cutoff range. Of which we used **Formula 1** to calculate the db and phase of each frequency. These frequency values and calculations can be observed below within **Table 3.** We were finally asked to plot these calculated values using excel to observe the effectiveness of our filter, these plots can be observed within **Graph 3.** Our final oscilloscope output can also be observed within **Figure 3.**

***Table 3: Sweep 2nd Order LPF***

| frequency (kHz) | db | phase |
|---|---|---|
| 1 | 0 | -0.1036725576 |
| 5 | -1.11 | -0.5906194189 |
| 9 | -3.06 | -0.9236282402 |
| 15 | -6.02 | -1.272345025 |
| 20 | -8.16 | -1.448274213 |
| 30 | -11.54 | -4.523893421 |
| 40 | -14.5 | -4.398229715 |
| 50 | -17 | -4.178318229 |

***Graph 3: Frequency Vs db and Phase***

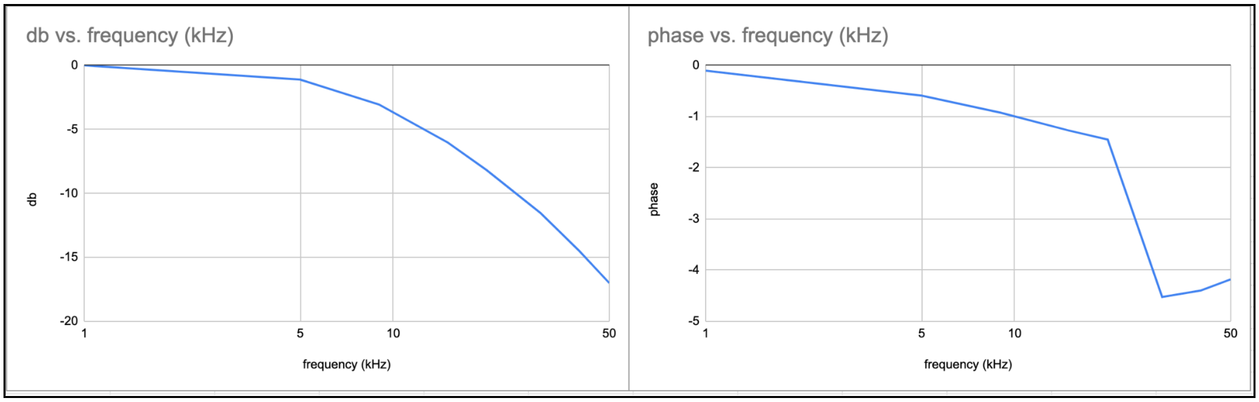
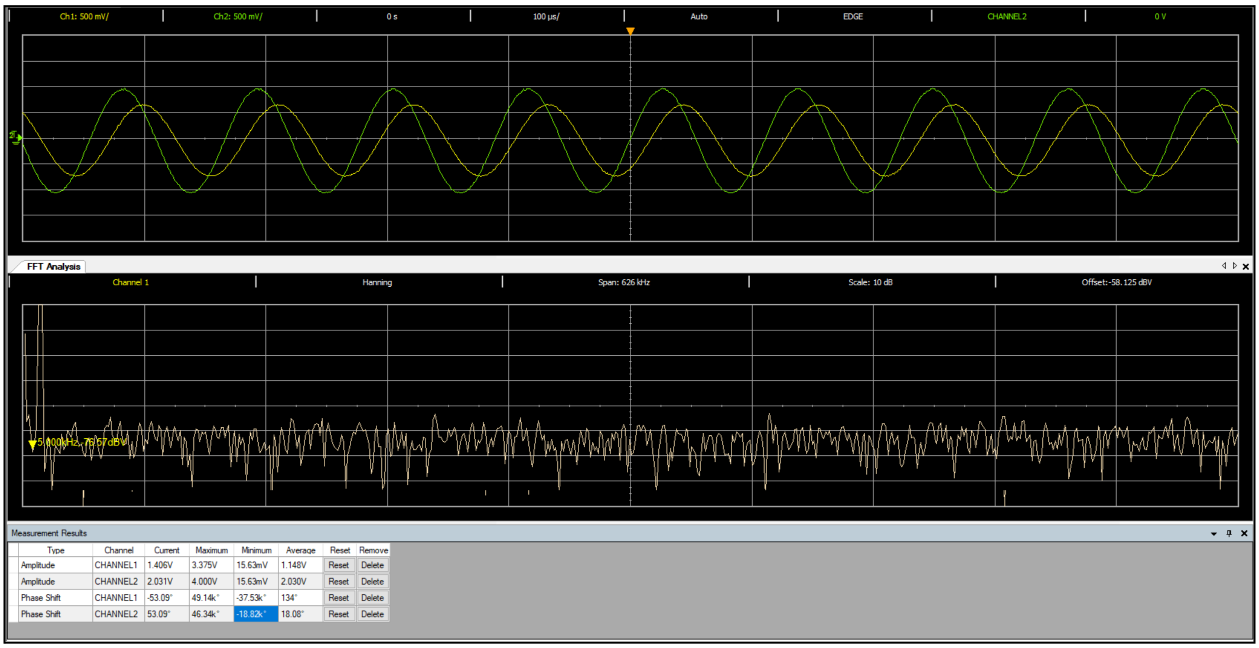



***Figure 3: 2nd Order LPF Oscilloscope Output***




## 4. MULTI-STAGE BAND PASS FILTER

a. Design and build a Band Pass Filter (BPF), which will pass signals from 1 kHz to 30 kHz. You may use as many resistors, capacitors, inductors and amplifiers as you wish (as many orders and stages as you wish). Note that you will be graded on the performance and accuracy of your filters design and performance. Measure both the amplitude, in dB, and phase, in radians, change from input to output for at least carefully selected 20 frequencies. Measure the roll-off rate of this filter. Plot the magnitude and phase response of the filter using the 20 measurements (You may use any software package to generate the plot). Run a frequency sweep analysis on the BPF. Observe the input sweep and BPF output simultaneously. Set the parameters to show at least two sweeps on the oscilloscope screen.

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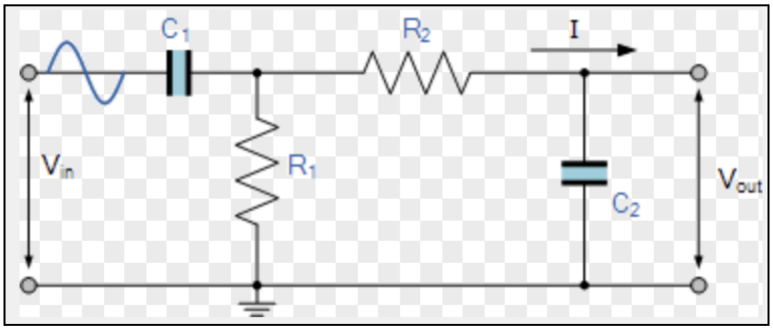
## *Circuit 4: Band Pass Filter*

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**Results 4:**

1.
    a. For this part of the experiment we were asked to create a Multistage band pass filter using the circuit diagram shown above in **Circuit 4.** The cutoff frequency range given was 1 Khz to 30 Khz, using these cutoff frequencies we were able to calculate the capacitor and resistance values using an online Band pass filter calculator. The calculated values were as follows, C1 = 100nF C2 = 1nF R1 = 1592Ω R2 = 5308Ω. We then tested the 20 frequencies within our given cutoff range. Of which we used **Formula 1** to calculate the db and phase of each frequency. These frequency values and calculations can be observed below within **Table 4.** We were finally asked to plot these calculated values using excel to observe the effectiveness of our filter, these plots can be observed within **Graph 4.** Our final oscilloscope output can also be observed within **Figure 4.**

**Conclusion:** In this lab we were introduced to the use of cascade filters and their application. The effect of using filters in parallel with each other was shown to improve the overall effectiveness of the filter. This can be observed within the difference between **Graph 1 & Graph 3.** We hypothesized that the application of these filters overall increases the effectiveness of tuning certain frequencies out with a high effectiveness within digital communications. These filters will help with the fundamentals of our upcoming final project.