University of Nevada, Las Vegas
Department of Electrical and Computer Engineering

EE 221 - Circuits II

Final Project Report
Bandpass and Bandstop Filters

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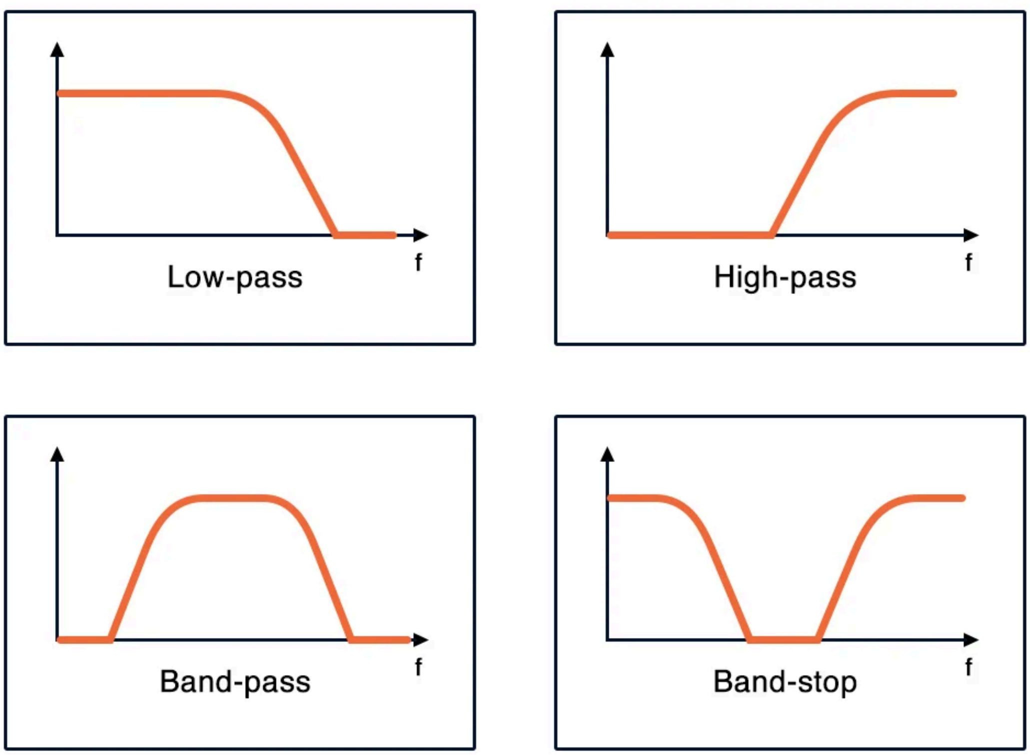
Summer 2022

1. Introduction

Background: For my final project, I implemented 4 different types of filters. Filters are circuits designed to pass desired signals and reject others. A band-pass filter passes frequencies within a band of frequencies and filters out frequencies outside this band. On the other hand, a band-stop filter rejects frequencies within a band of frequencies and passes the frequencies outside this band. These filters can be implemented by combining other types of filters which is explained in a later section. Each filter can be either active or passive. Active filters use active components like op-amps, while passive filters use only passive components like resistors and capacitors.

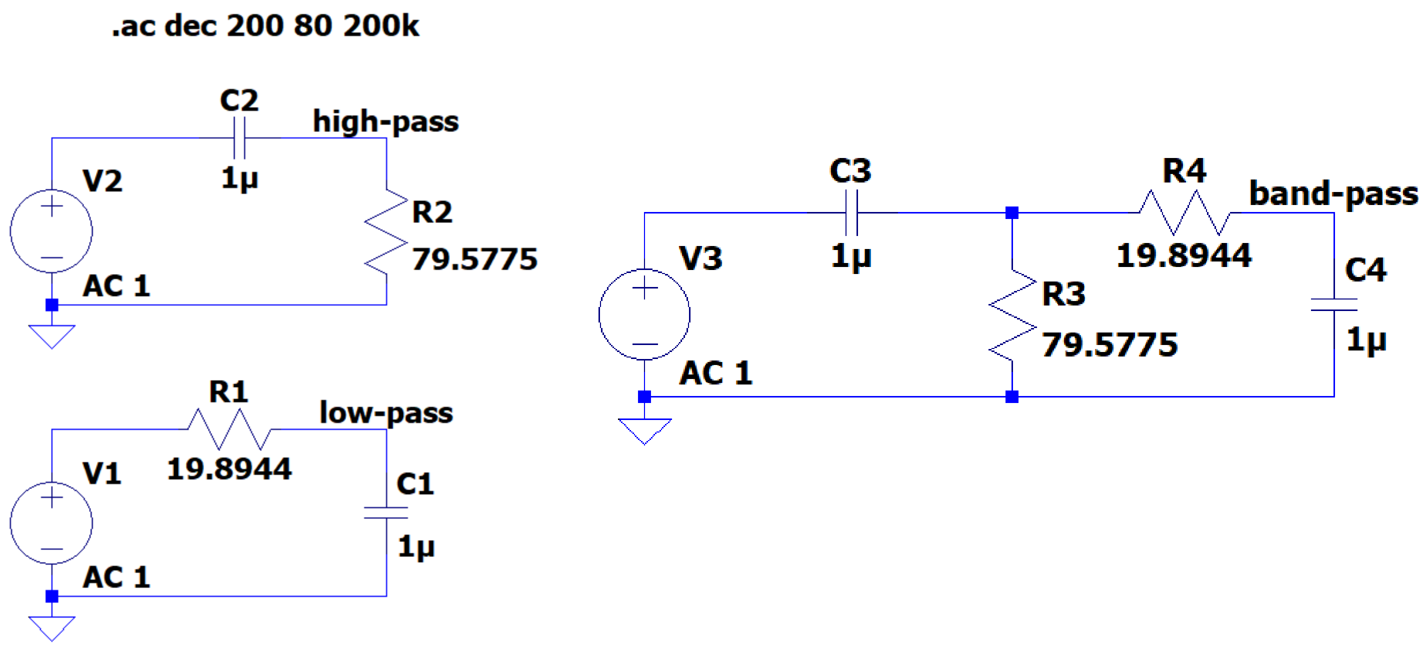
Project goals: This project aims to design and simulate band-pass filters and band-stop filters of desired frequencies using the LTspice simulation software. The band-pass filter design aims to pass signals within the bandwidth range of 2,000Hz and 8,000Hz and filter out the signals that are not within this range. The band-stop filter design aims to filter out signals within the bandwidth range of 200Hz and 800Hz and pass signals that are not within this range. Another goal of this project is to implement both passive and active versions of each filter.

Outcome: I accomplished the project goals by combining two types of filters together: the high-pass filter and the low-pass filter. A high-pass filter passes all frequencies above a specified cutoff frequency while a low-pass filter passes all frequencies below a specified cutoff frequency. By combining these circuits in different configurations, I was able to obtain the desired frequency responses from both my passive and active versions of my band-pass and band-stop filters.



2. Passive Band-pass Filter Circuit Implementation and Results

Passive Band-pass Filter (Schematic using LTspice)



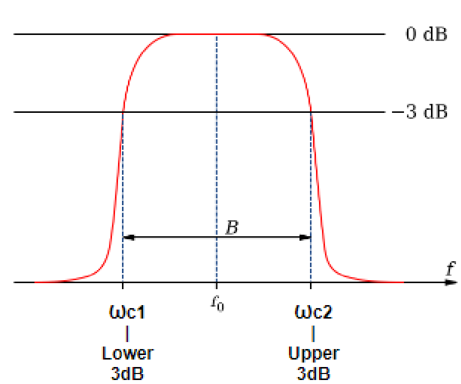
Circuit explanation: The passive band-pass filter circuit above combines both a passive high-pass filter with a cutoff frequency of 2,000Hz and a passive low-pass filter with a cutoff frequency of 8,000Hz. These filters are placed in *series* with each other. The high-pass filter is placed first as the desired lower cutoff frequency is 2,000Hz, and the low-pass filter is placed right after it as the desired upper cutoff frequency is 8,000Hz. The resistor and capacitor values were chosen using the derived equation below. Given this equation, the product of the resistor and capacitor needs to equal the right hand of the equation when the desired frequency is plugged in. I chose all the capacitors to be 1uF to keep things consistent, and I calculated the resistance needed to satisfy the equation.

$$\text{Bandwidth} = \omega_{c1} - \omega_{c2}$$

$$\omega = \frac{1}{RC}$$

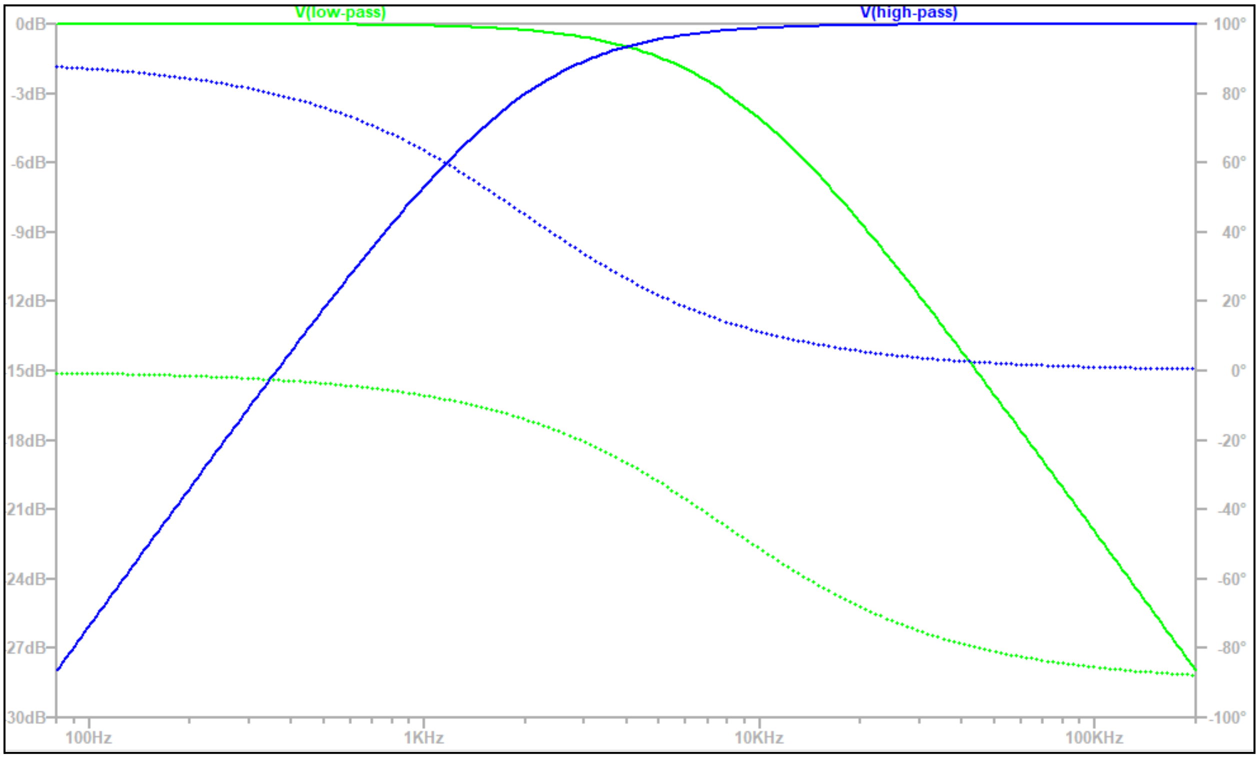
$$2\pi f = \frac{1}{RC}$$

$$f3dB = \frac{1}{2\pi RC} \rightarrow \boxed{RC = \frac{1}{f3dB \cdot 2\pi}}$$

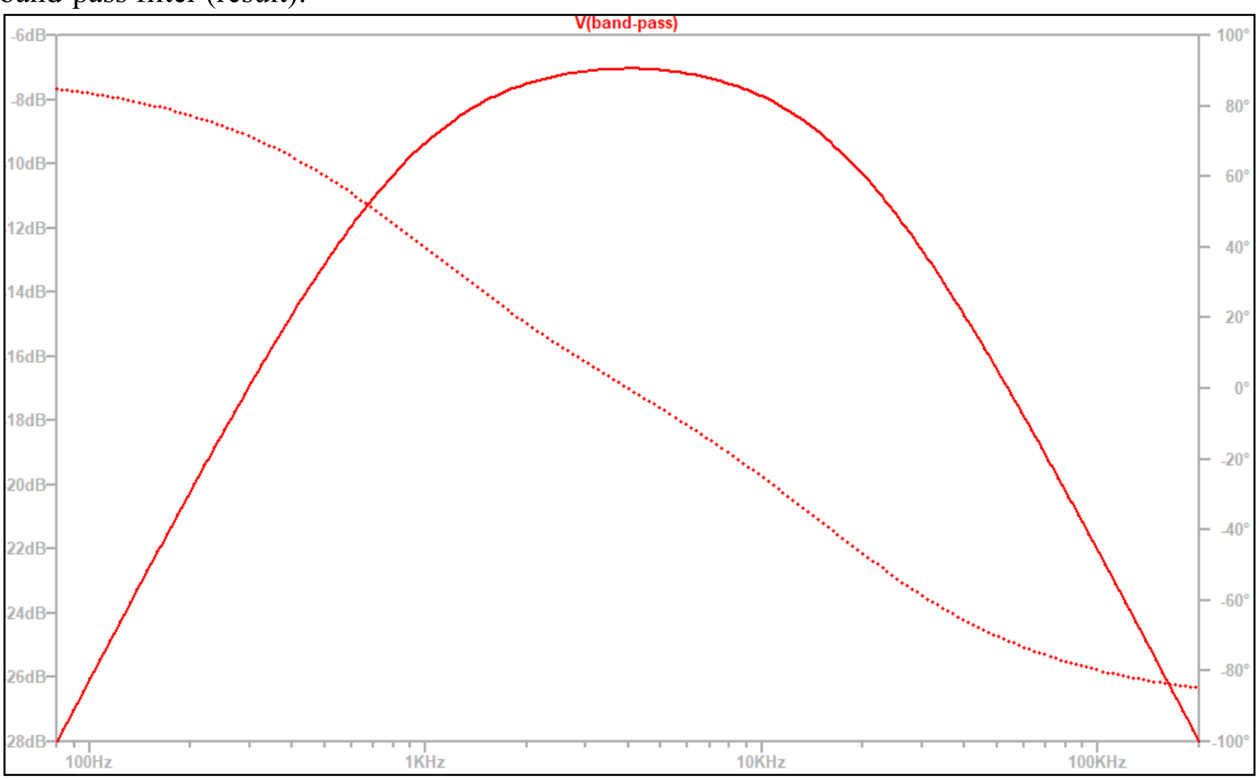


Passive Band-pass Filter (Plots using LTspice)

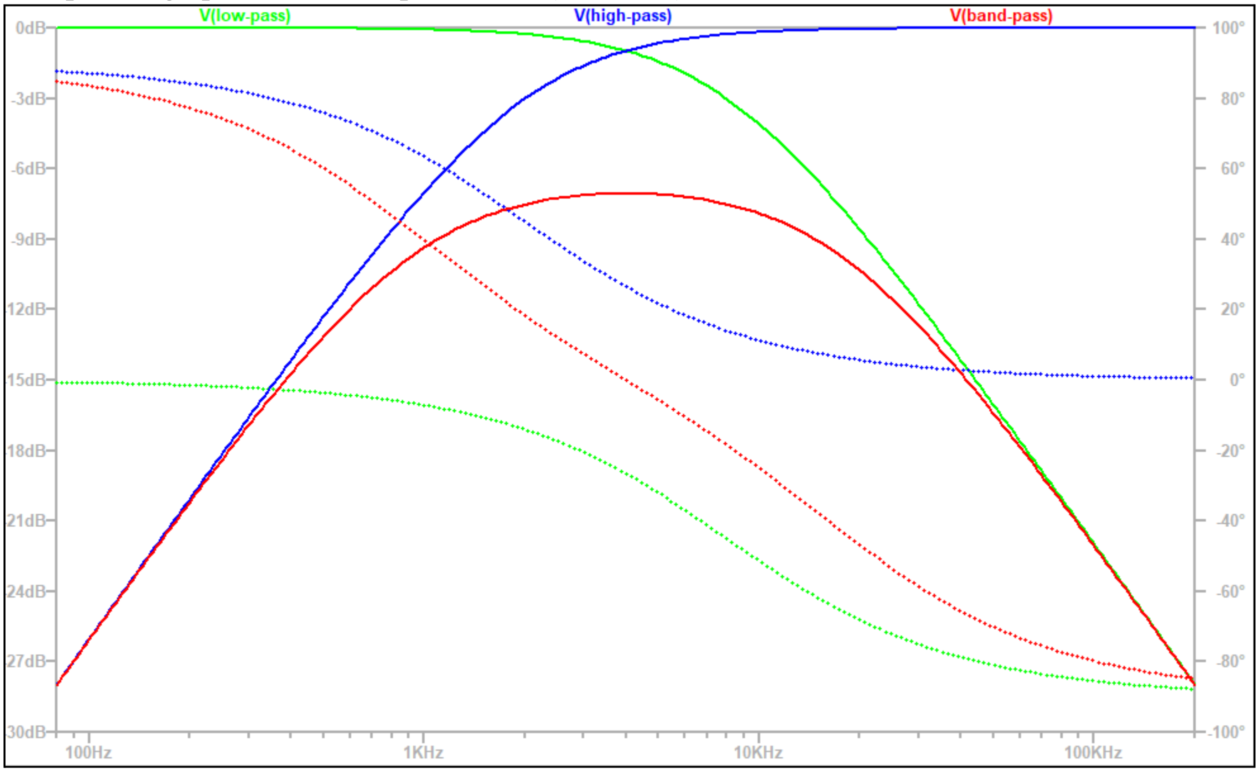
Low-pass and high-pass filters:



band-pass filter (result):



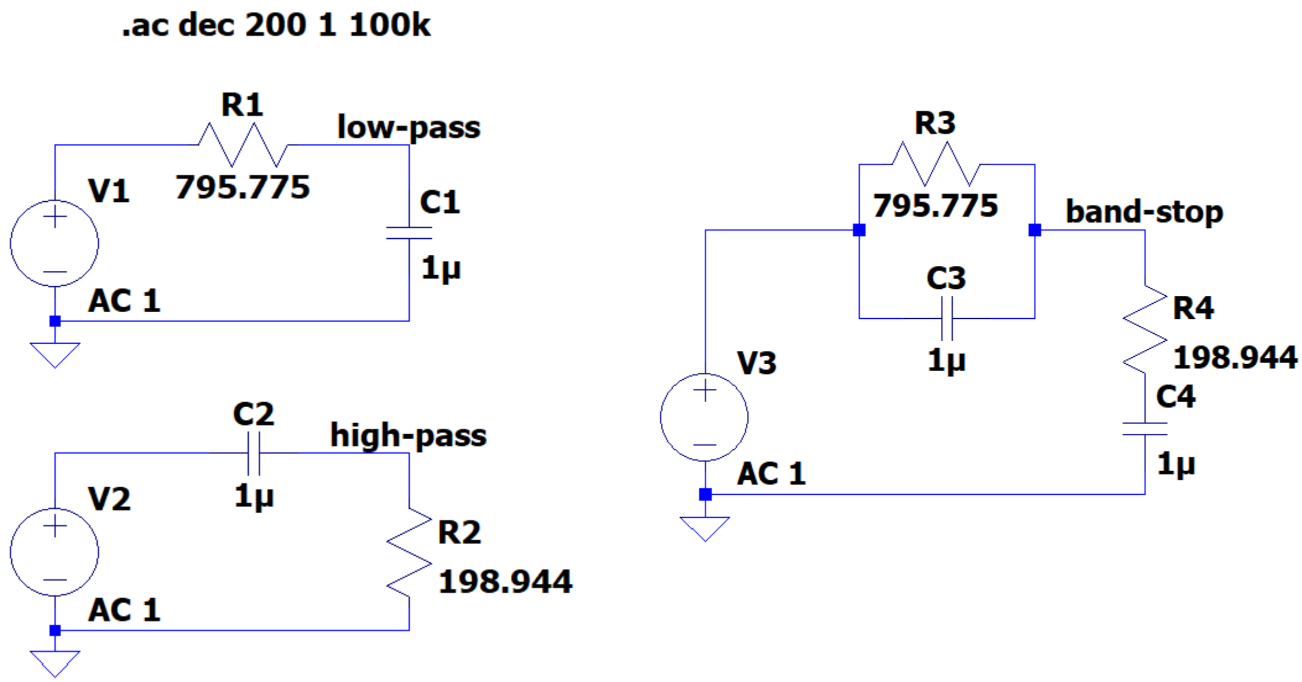
Low pass, high pass, and band-pass filters (all in one):



Plot explanation: By observing the low-pass and high-pass plots, one can see that their combined plots create a curve that mirrors that of a band-pass plot. The band-pass plot is the same shape, and this is what is expected as the low-pass and high-pass filters were combined. The high-pass filter has a cutoff frequency of 2,000Hz, although it is a bit difficult to tell since this is not an ideal version where the exact cutoff point is clear. The same applies to the fact that the low-pass filter has a cutoff frequency of 8,000Hz. Thus, the band-pass plot is a curve whose bandwidth is from 2000Hz and 8,000Hz, which is desired.

3. Passive Band-stop Filter Circuit Implementation and Results

Passive Band-stop Filter (Schematic using LTspice)



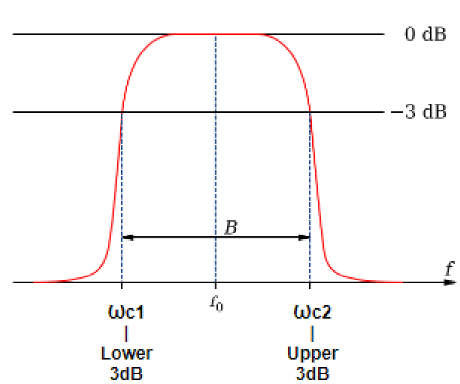
Circuit explanation: The passive band-stop filter circuit combines both a passive low-pass filter with a cutoff frequency of 200Hz and a passive high-pass filter with a cutoff frequency of 800Hz. These filters are placed in *parallel* with each other. The low-pass filter allows the lower frequencies to pass, while the high-pass filter allows the higher frequencies to pass. The resistor and capacitor values were chosen using the equation that was used to find those of the band-pass filter. The process was the same.

$$\text{Bandwidth} = \omega_{c1} - \omega_{c2}$$

$$\omega = \frac{1}{RC}$$

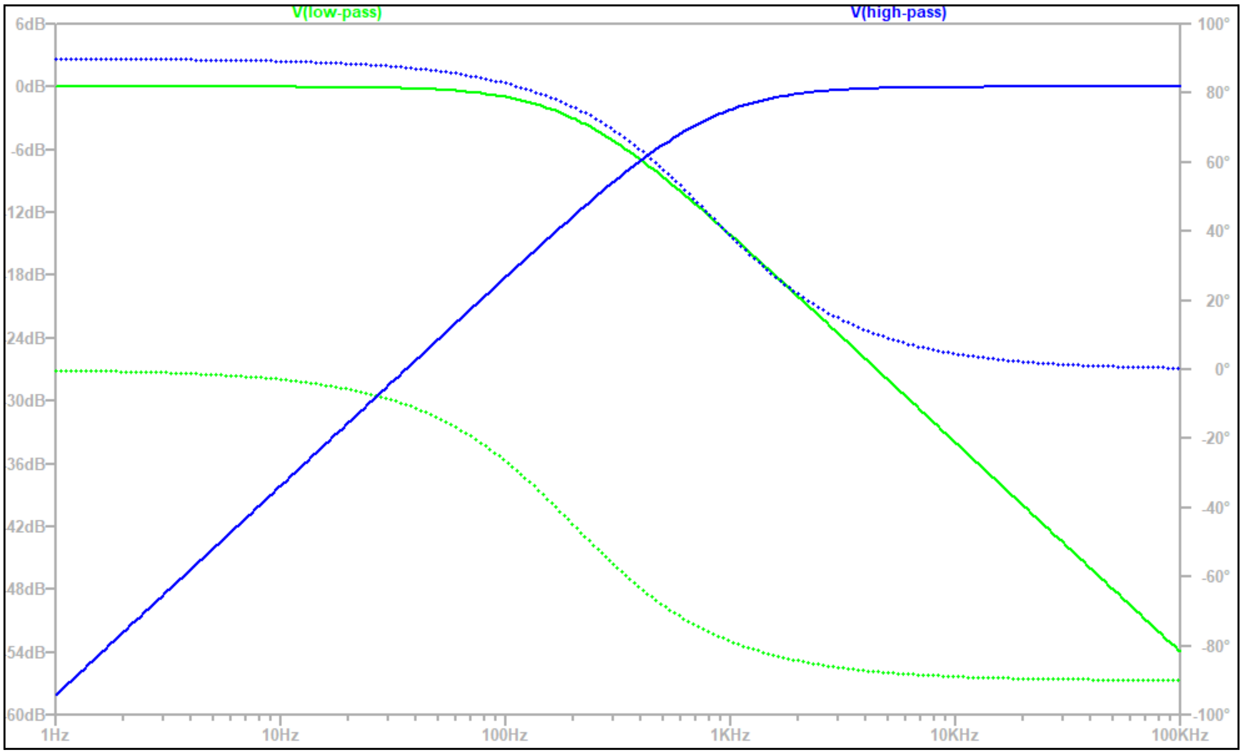
$$2\pi f = \frac{1}{RC}$$

$$f3dB = \frac{1}{2\pi RC} \rightarrow \boxed{RC = \frac{1}{f3dB \cdot 2\pi}}$$

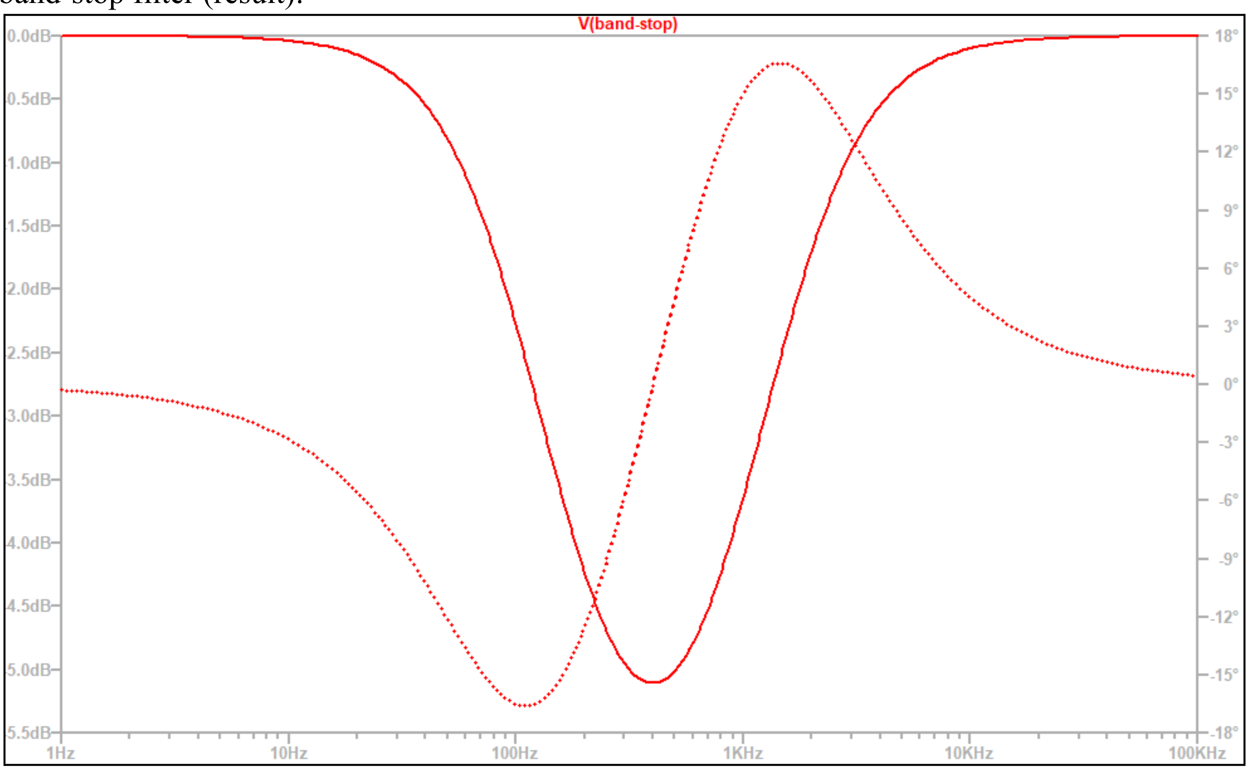


Passive Band-stop Filter (Plots using LTspice)

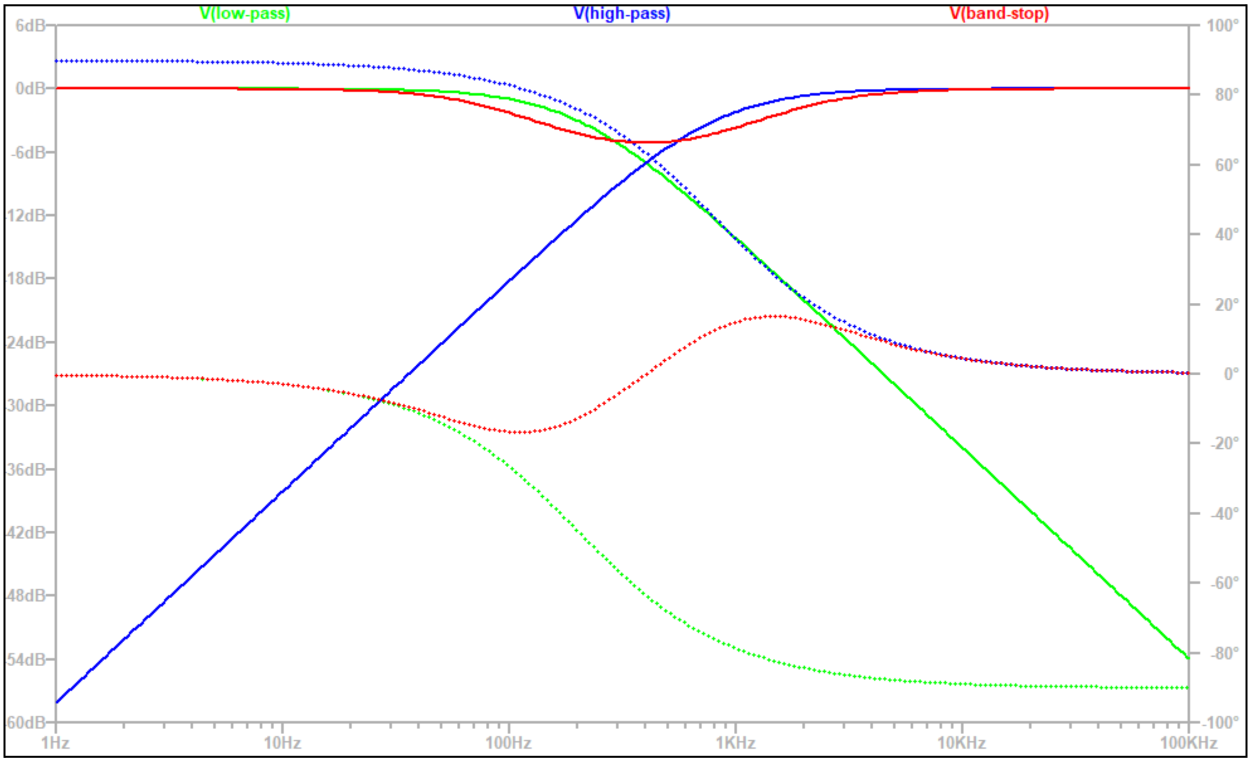
Low-pass and high-pass filters:



band-stop filter (result):



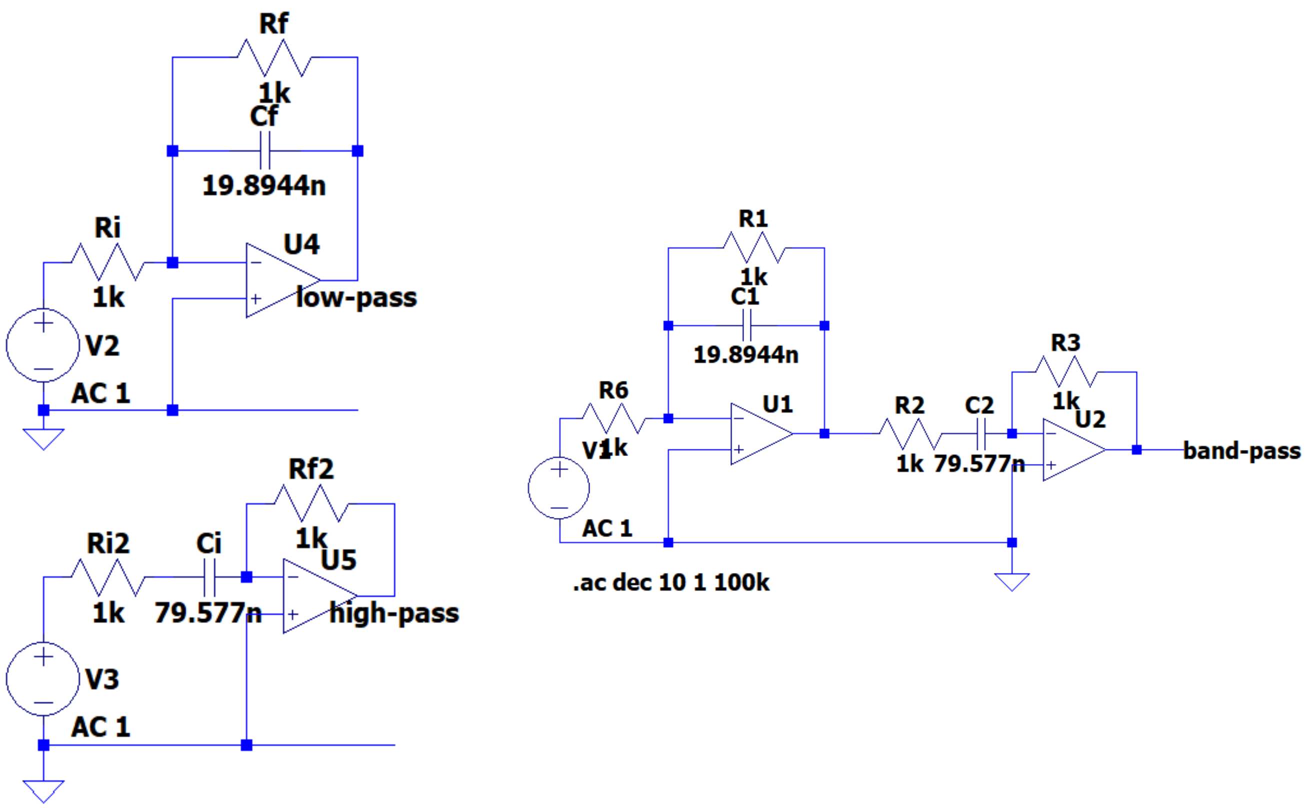
Low pass, high pass, and band-stop filters (all in one):



By observing the low-pass and high-pass plots, one can see that their combined plots create a curve that mirrors that of a band-stop plot when looking at the part of the plots above -7dB. The band-stop plot is the same shape, and this is what is expected as the low-pass and high-pass filters were combined. The low-pass filter has a cutoff frequency of 200Hz while the high-pass filter has a cutoff frequency of 800Hz. Again, it is a bit difficult to tell where the lower and upper 3db cutoff frequencies are since the circuits are not the ideal cases, but one can see that the curve is within the right range from looking at its peak The band-stop plot is a curve whose bandwidth is from 200Hz and 800Hz, which is desired.

4. Active Band-pass Filter Circuit Implementation and Results

Active Band-pass Filter (Schematic using LTspice)



Circuit explanation: The active band-pass filter circuit combines both an active high-pass filter with a cutoff frequency of 2,000Hz and an active low-pass filter with a cutoff frequency of 8,000Hz. These filters are placed in *series* with each other. The first stage is the low-pass filter which sets ω2. The second stage is the high-pass filter that sets ω1. The capacitor and resistor values were selected the same way as they were for the passive version, but this time the resistors are all fixed to 1,000Ω. This is because of the equation below where the cutoff frequencies change based on the capacitor values only. The resistor values are the same for both the low-pass and high-pass filters.

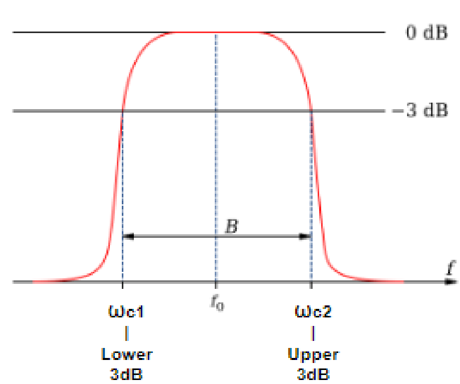
$$\text{Bandwidth} = \omega_{c1} - \omega_{c2}$$

$$\omega_{c1} = \frac{1}{RC_2} \qquad \omega_{c2} = \frac{1}{RC_1}$$

$$2\pi f = \frac{1}{RC_2} \qquad 2\pi f = \frac{1}{RC_1}$$

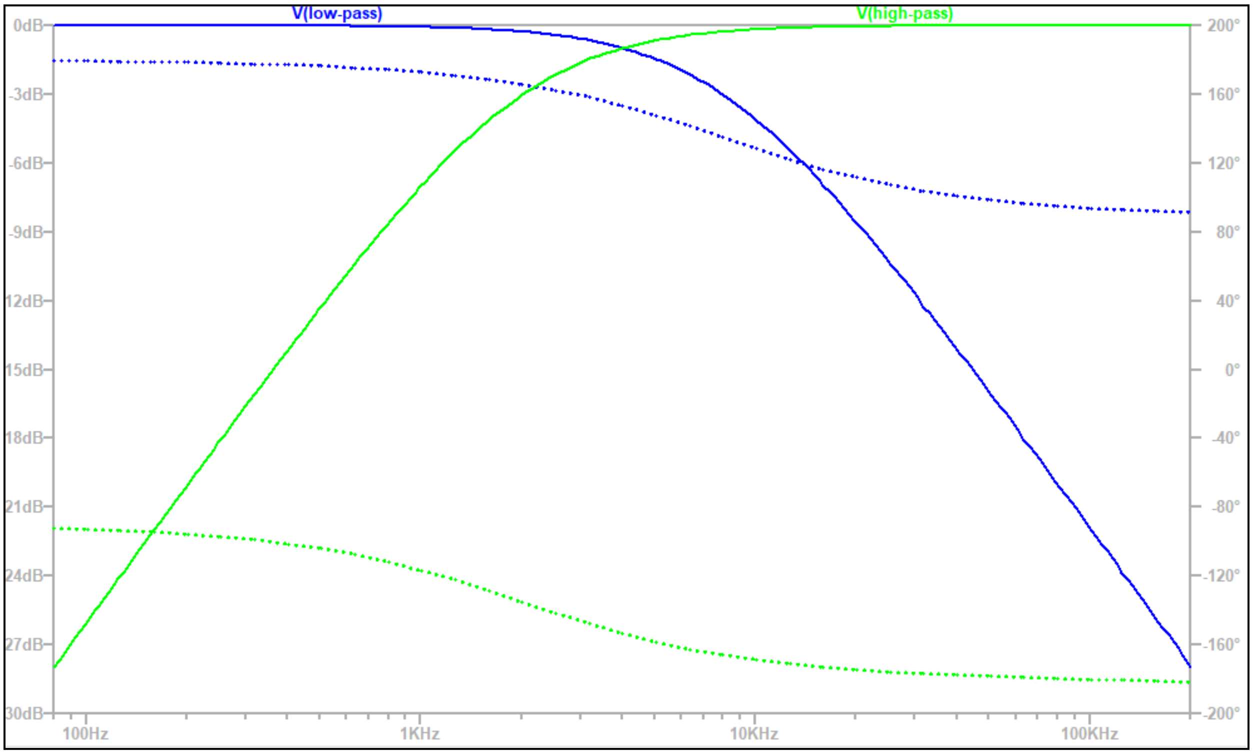
$$f3dB = \frac{1}{2\pi RC_2} \qquad f3dB = \frac{1}{2\pi RC_1}$$

$$\boxed{RC_{1\&2} = \frac{1}{f3dB \cdot 2\pi}}$$

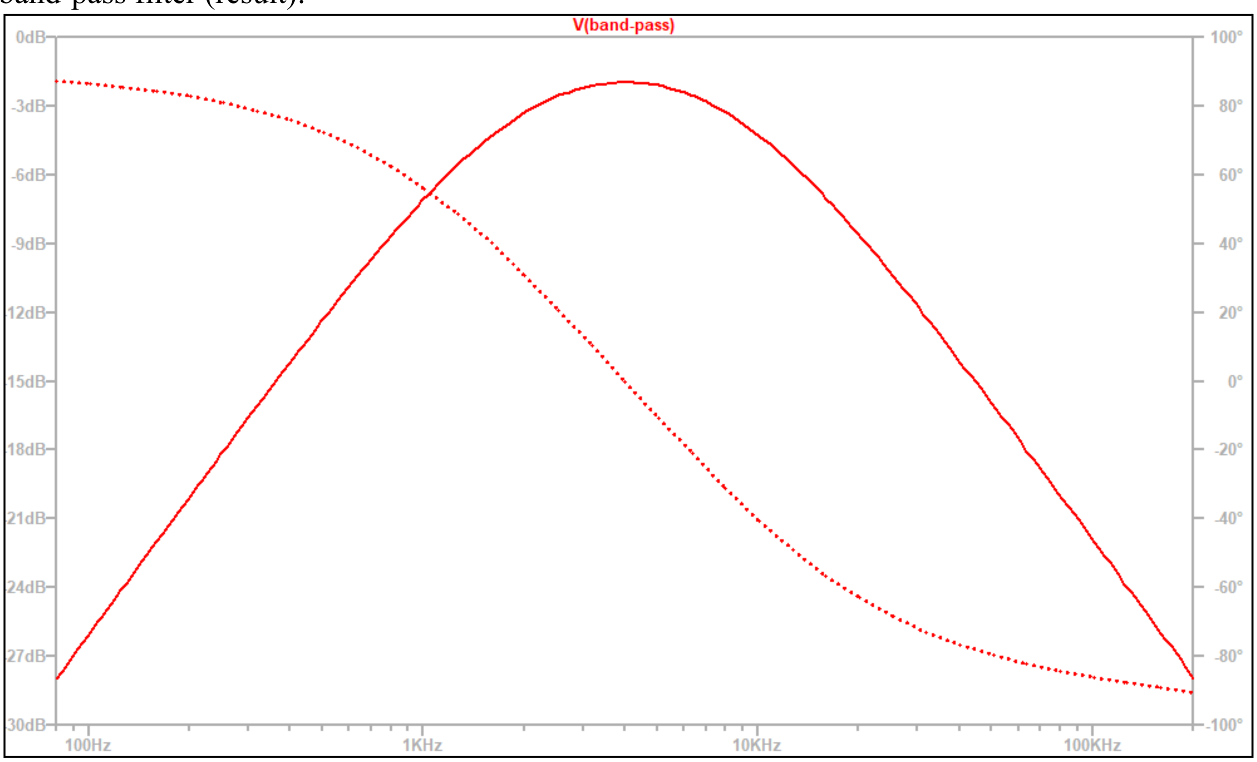


Active Band-pass Filter (Plots using LTspice)

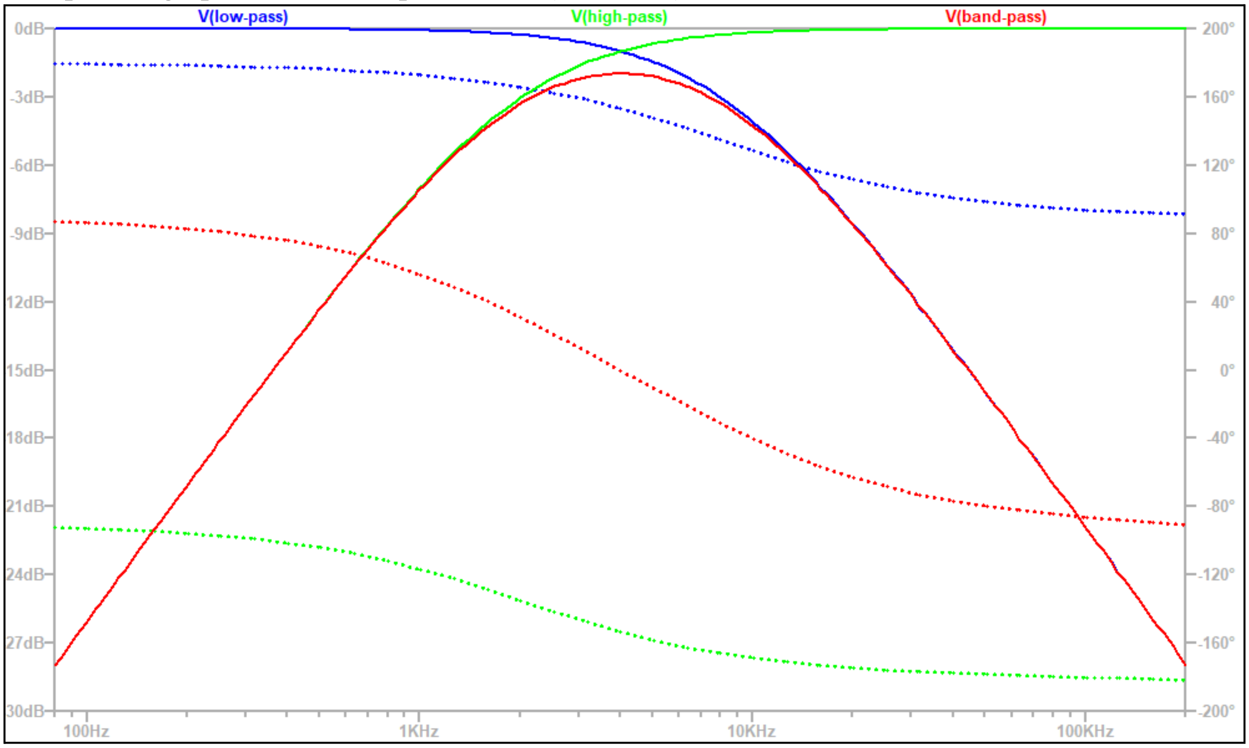
Low-pass and high-pass filters:



band-pass filter (result):



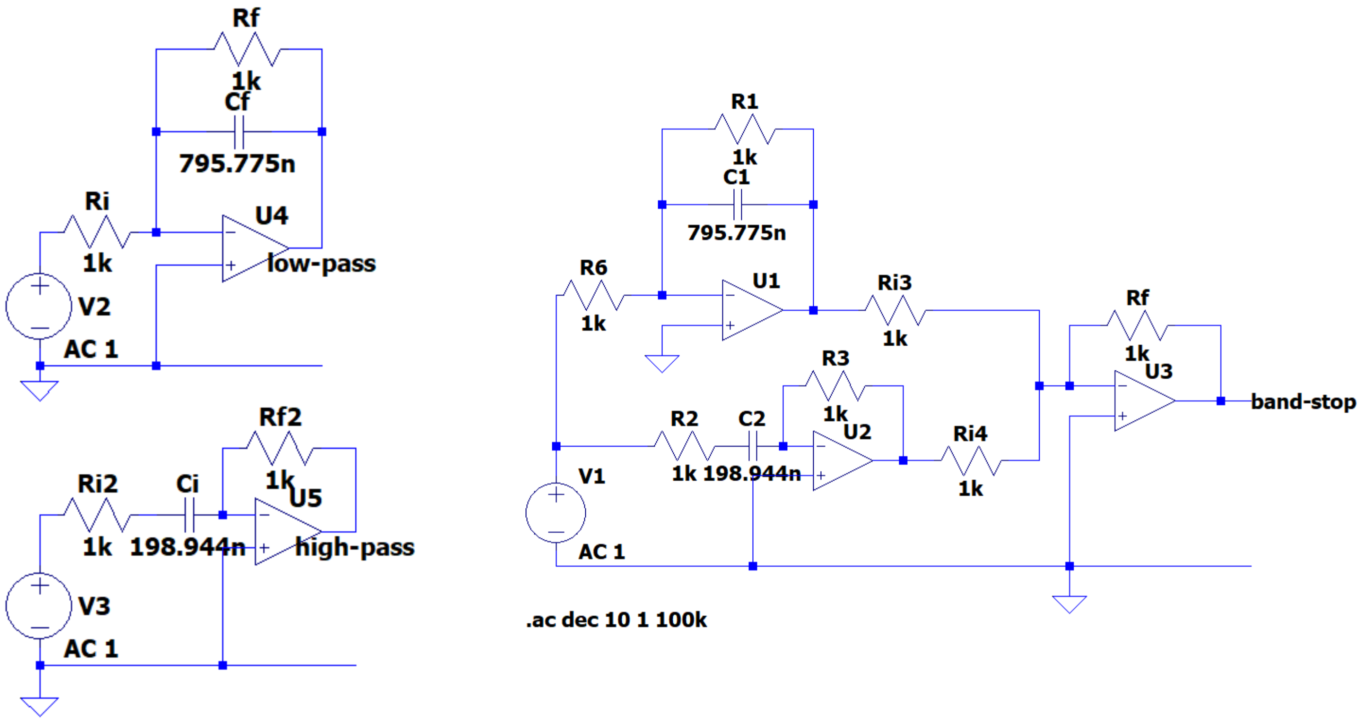
Low pass, high pass, and band-pass filters (all in one):



Plot explanation: From the plot, we can see the same pattern we saw with the passive band-pass filter(see passive band-pass plot explanation for more details). The combined plots of the low-pass and high-pass filters create a curve that mirrors that of a band-pass plot, and the combined filters give us a band-pass filter whose bandwidth is from 2000Hz and 8,000Hz. This result is desired.

5. Active Band-stop Filter Circuit Implementation and Results

Active Band-stop Filter (Schematic using LTspice)



Circuit explanation: The active band-stop filter circuit combines both an active low-pass filter with a cutoff frequency of 200Hz and an active high-pass filter with a cutoff frequency of 800 Hz. These filters are placed in *parallel* with each other. The first stage is the low pass filter in parallel with the high pass filter and the second stage is a summing amplifier to combine the voltages into a single output voltage. The resistor and capacitor values were chosen using the derived equation that was used to find those of the active band-pass filter. The process was the same.

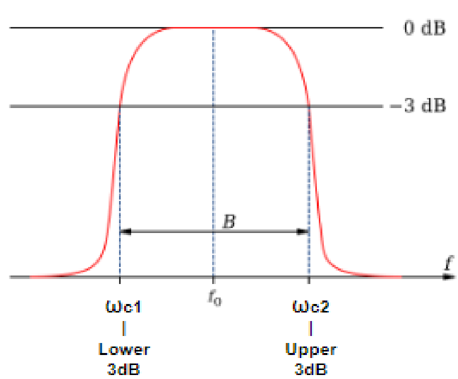
$$\text{Bandwidth} = \omega_{c1} - \omega_{c2}$$

$$\omega_{c1} = \frac{1}{RC_2} \qquad \omega_{c2} = \frac{1}{RC_1}$$

$$2\pi f = \frac{1}{RC_2} \qquad 2\pi f = \frac{1}{RC_1}$$

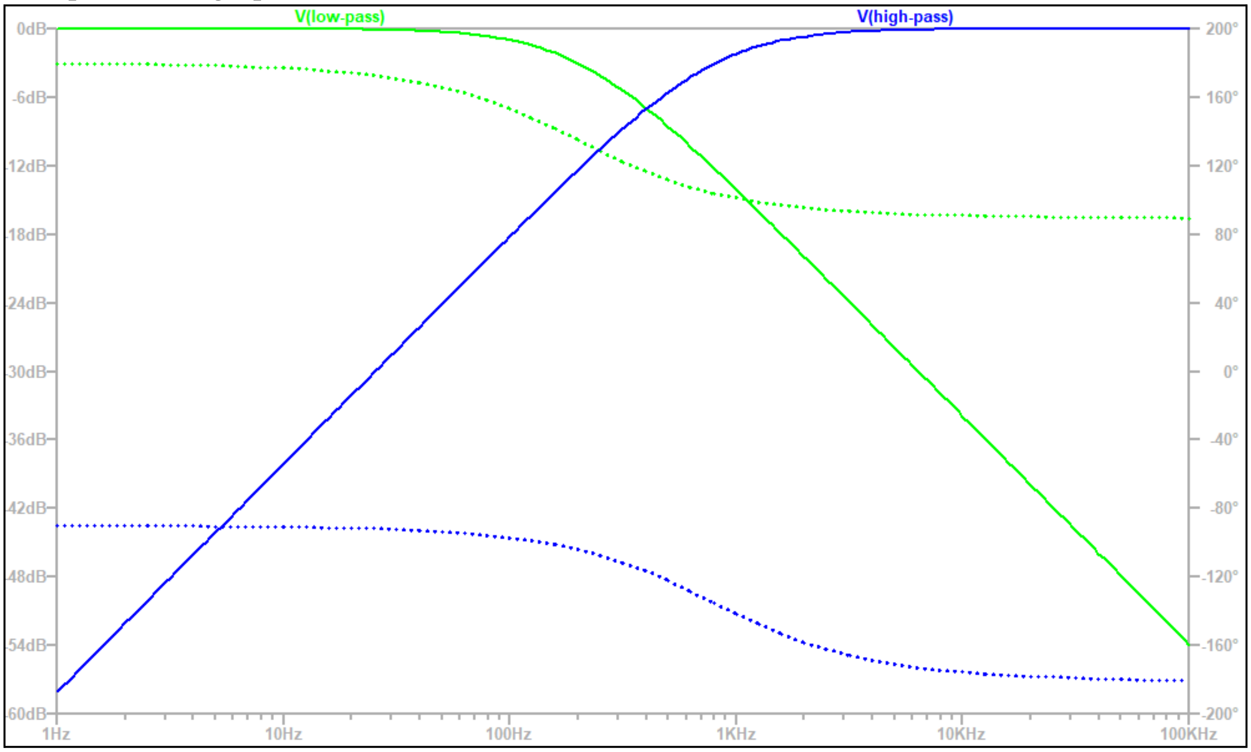
$$f3dB = \frac{1}{2\pi RC_2} \qquad f3dB = \frac{1}{2\pi RC_1}$$

$$\boxed{RC_{1\&2} = \frac{1}{f3dB \cdot 2\pi}}$$

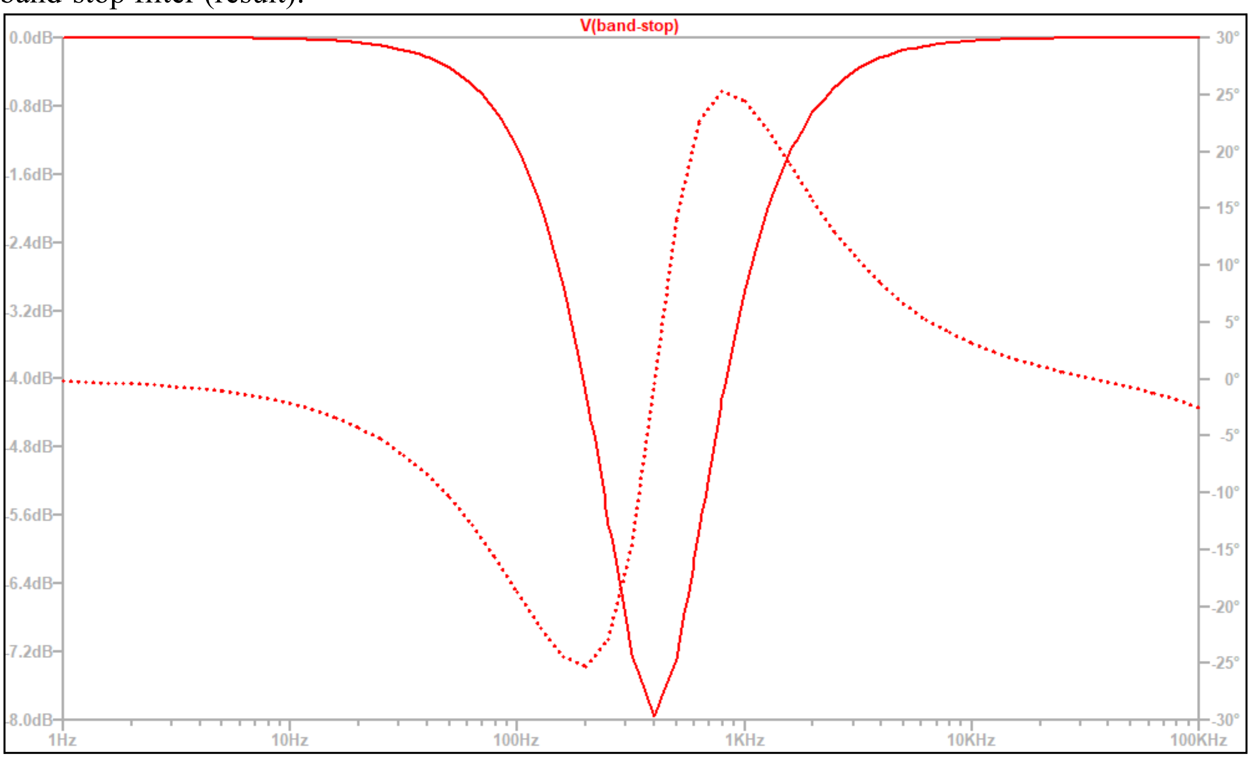


Active Band-stop Filter (Schematic using LTspice)

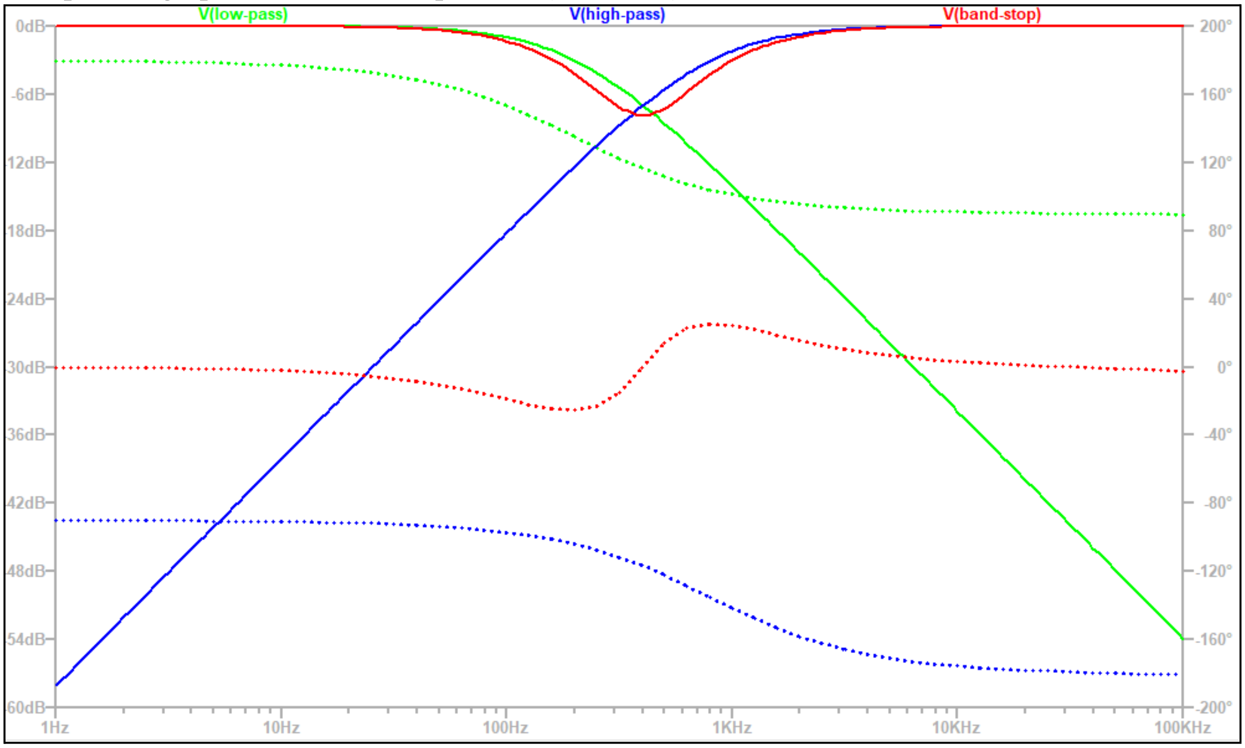
Low-pass and high-pass filters:



band-stop filter (result):



Low pass, high pass, and band-stop filters (all in one):



Plot explanation: From the plot, we can see the same pattern we saw with the passive band-stop filter (see passive band-stop plot explanation for more details). The combined plots of the low-pass and high-pass filters create a curve that mirrors that of a band-stop plot, and the combined filters give us a band-stop filter whose bandwidth is from 200Hz and 800Hz. This result is desired.

6. Video

Video link: https://youtu.be/6VONH6Zhfd4

7. Conclusion

The main issue I encountered during this project was that I had trouble figuring out the configuration needed for the low-pass filter and high-pass filter for my passive band-stop filter. For the passive band-pass filter, I connected the low-pass filter after the high-pass filter in series. I assumed that for the passive band-stop filter, I could do the same, but switch the low-pass and high-pass filter. However, this did not create the desired outcome. In fact, the results looked like a band-pass plot instead of a band-stop plot. After some research, I learned that I needed to connect the filters in parallel to get the desired outcome, and I considered this for not only my passive band-stop filter but also my active band-stop filter.

This project was about constructing band-pass and band-stop filters using low-pass and high-pass filters. By creating both passive and active filters, I was able to show that there are different ways to implement these filters. I merely showed 4 examples, but it is not surprising that band-pass and band-stop filters are used for several applications. They are used in optics, communication systems, audio signal processing, wireless transmitters, receivers, and more. The most important takeaway is that the frequency response from these filters depends on the capacitor and resistor values, as well as the configuration of the low-pass and highpass–filters. It is easy to make assumptions about how the circuits will react to frequency change, but there is no way to know until you simulate it firsthand.