PROBLEMS ENCOUNTERED

- Initially used an incorrect capacitor value which shifted the cutoff frequency
- I used the incorrect resistor values for the active lowpass filter, causing an unexpected response
- The network analyzer initially states out of range on channel 2 which then required me to verify all of the power supplies and measurements

INTRODUCTION

The purpose of this lab was to investigate the frequency response of passive and active RC lowpass and high pass filters. Each of these filters were designed and simulated in LTspice prior to implementing and testing the Analog Discovery Network Analyzer. The simulated and experimental cutoff frequencies were then compared to verify the expected filter behavior.

DISCUSSION

9.5 Pre-Lab Section

The theoretical cutoff frequencies for each of the passive and active RC filters were calculated using the provided or calculated component values. These calculations establish the expected performance prior to simulation and experimental testing.

9.5.1 LTspice Simulations

Each filter was modeled and analyzed in LTspice to verify its frequency response and 3dB cutoff frequency. These simulated results were then compared and tabulated.

Filter Type	**3dB Frequencies**
Simple RC Lowpass	15.88 Khz
Simple RC Highpass	1.06 Khz
Active RC Lowpass	1.59 Khz
Active RC Highpass	480.46 Hz

Table 1: Frequencies at which there was 3dB for each filter type shown for Circuits 1-4 below in images 1-8

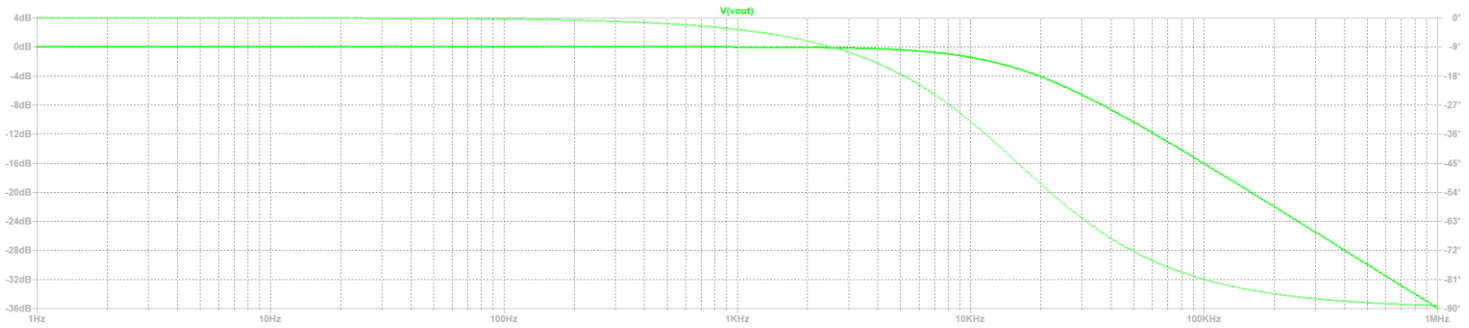


Figure 1: Frequency response of the passive RC lowpass filter showing attenuation of frequencies above the calculated cutoff frequency.

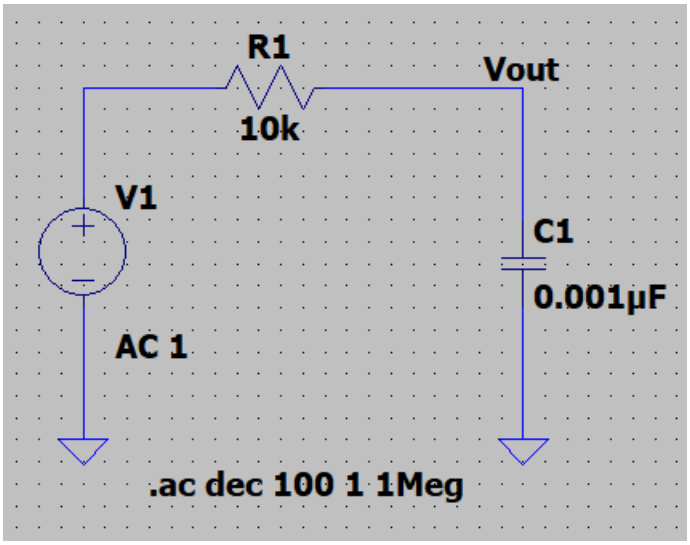


Figure 2: LTspice schematic of the passive RC lowpass filter using a 10 kΩ resistor and a 0.001 µF capacitor.

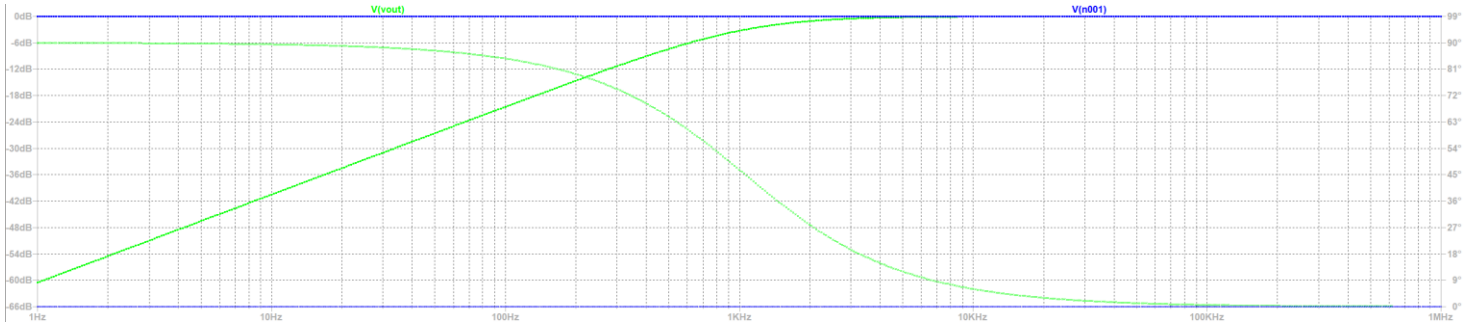


Figure 3: Frequency response of the passive RC highpass filter showing increasing gain above the cutoff frequency.

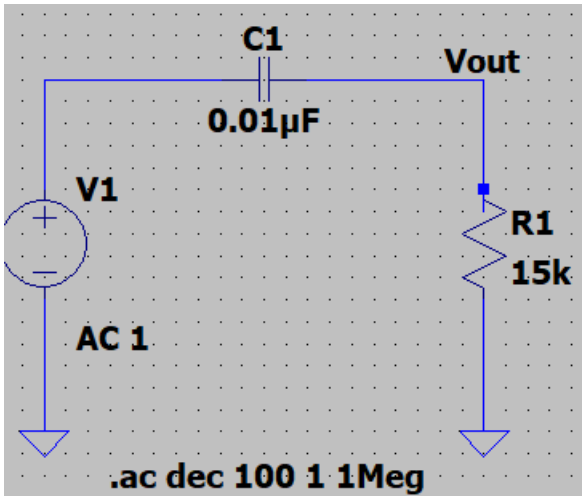


Figure 4: LTspice schematic of the passive RC highpass filter using a 15 kΩ resistor and a 0.01 µF capacitor.

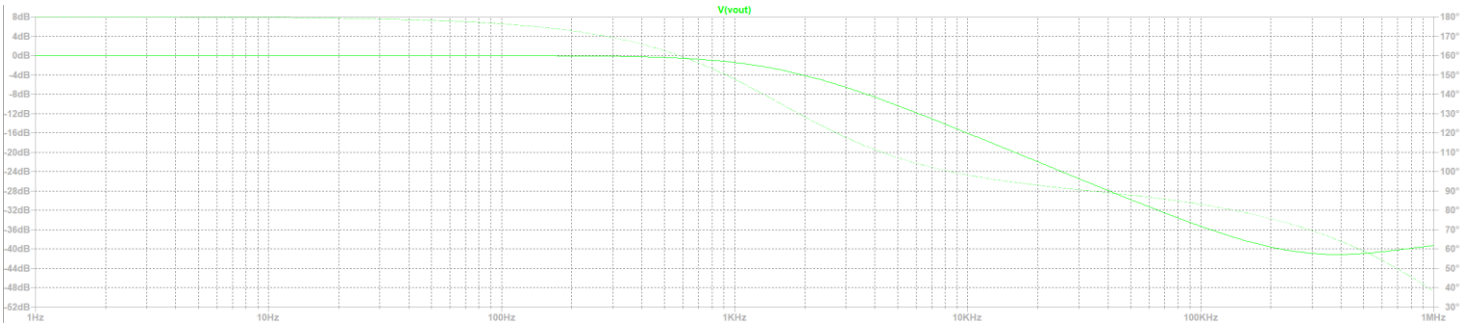


Figure 5: Frequency response of the active RC lowpass filter simulated in LTspice.

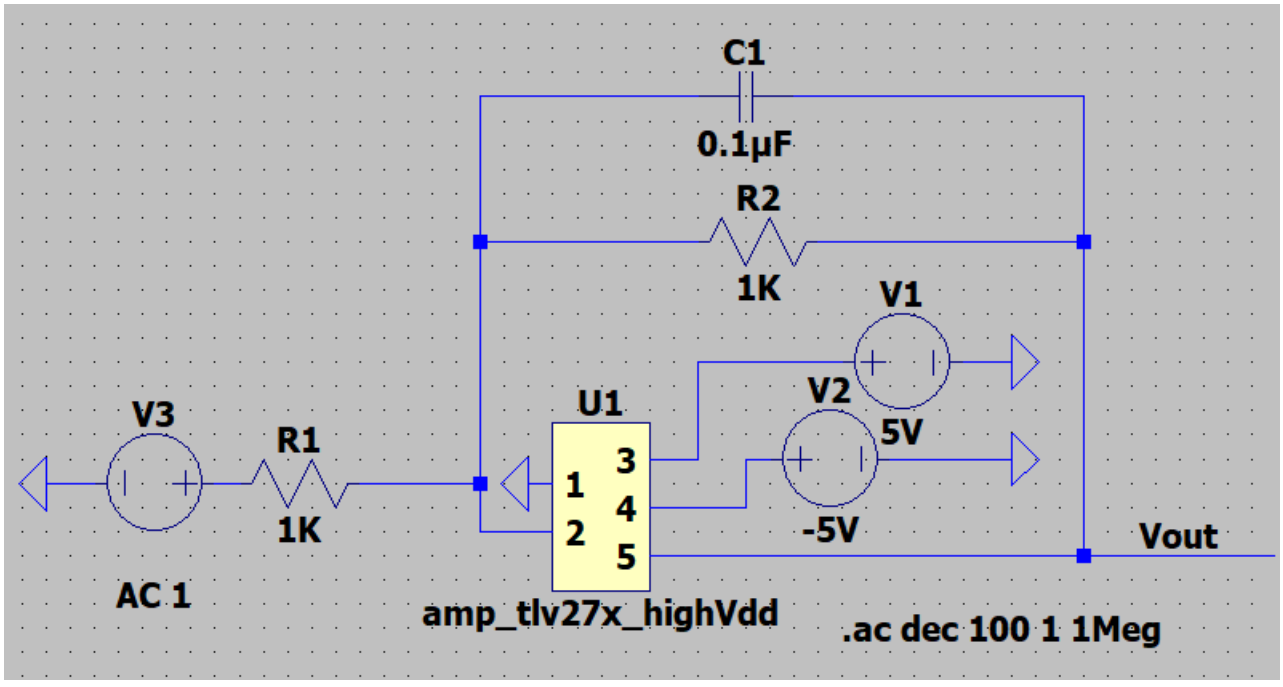


Figure 6: LTspice schematic of the active RC lowpass filter using the TLV272 operational amplifier.

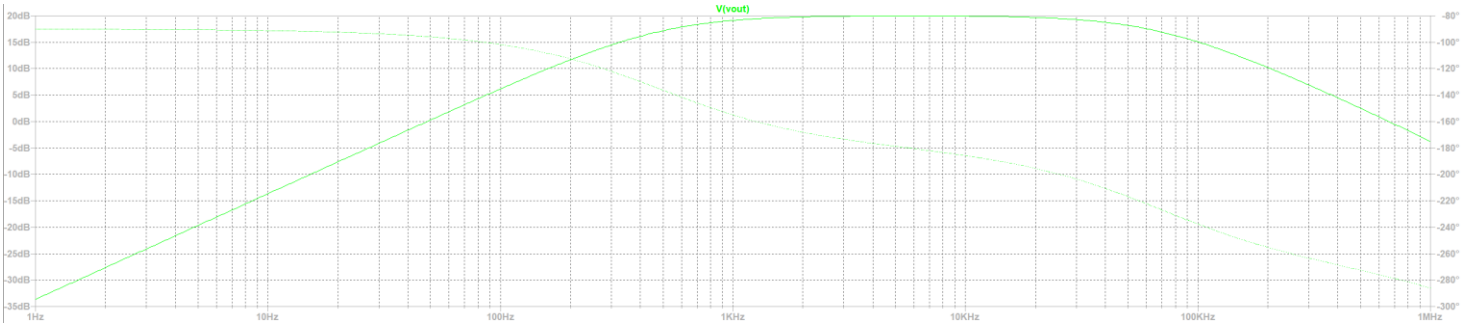


Figure 7: Frequency response of the active RC highpass filter simulated in LTspice.

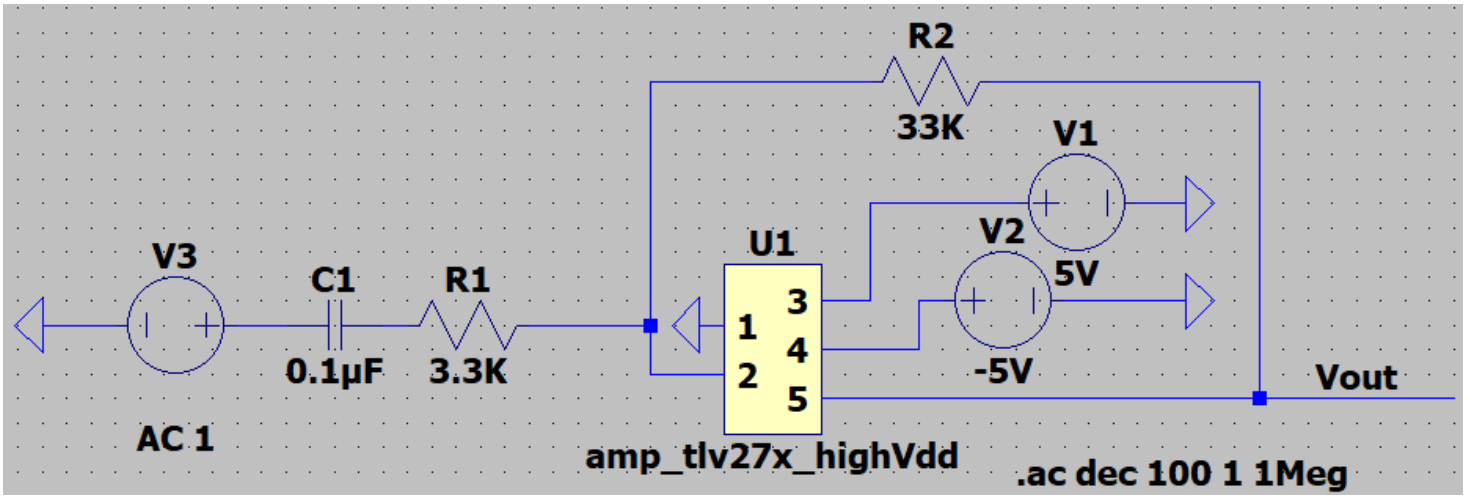


Figure 8: LTspice schematic of the active RC highpass filter using the TLV272 operational amplifier.

9.5.2 Breadboard Implementation

The active RC lowpass filter was assembled on a breadboard utilizing the TLV272 operational amplifier and then tested with the Analog Discovery Network Analyzer. This measured frequency response was then compared with the simulated results to evaluate the experimental performance.

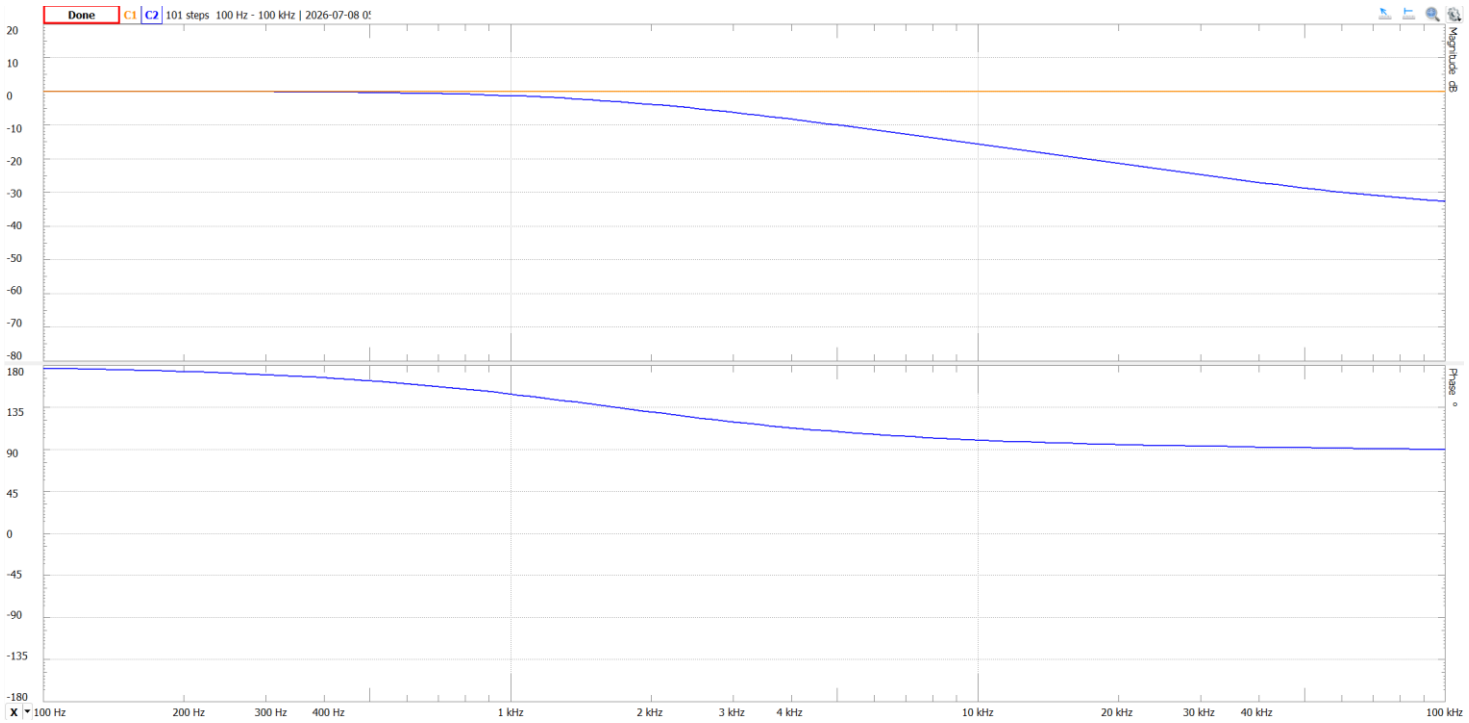


Figure 9: Breadboard implementation and measured frequency response of the active RC lowpass filter obtained using the Analog Discovery Network Analyzer.

9.6 In-Lab Section

The passive and active RC lowpass and highpass filters were assembled using an Analog Discovery Network Analyzer. The experimental cutoff frequencies were then measured from the response plots and then compared with the theoretical values simulated in the pre-lab section.

Filter Type	Simulated Frequency	Experimental Frequency	Percent Error
Passive RC lowpass	15.88 kHz	14.956 Khz	5.82%
Passive RC Highpass	1.06 kHz	1.059 kHz	0.09%
Active RC Lowpass	1.59 kHz	1.64 kHz	3.14%
Active RC Highpass	480.46 Hz	477.1 Hz	0.70%

Table 2: Comparison of Experimental and Theoretical 3 dB Frequencies.

Overall, the experimental cutoff frequencies closely matched the theoretical predictions with all percent errors being less than 6%, demonstrating great agreement between the simulated circuits and the physical implementation of these simulated circuits.

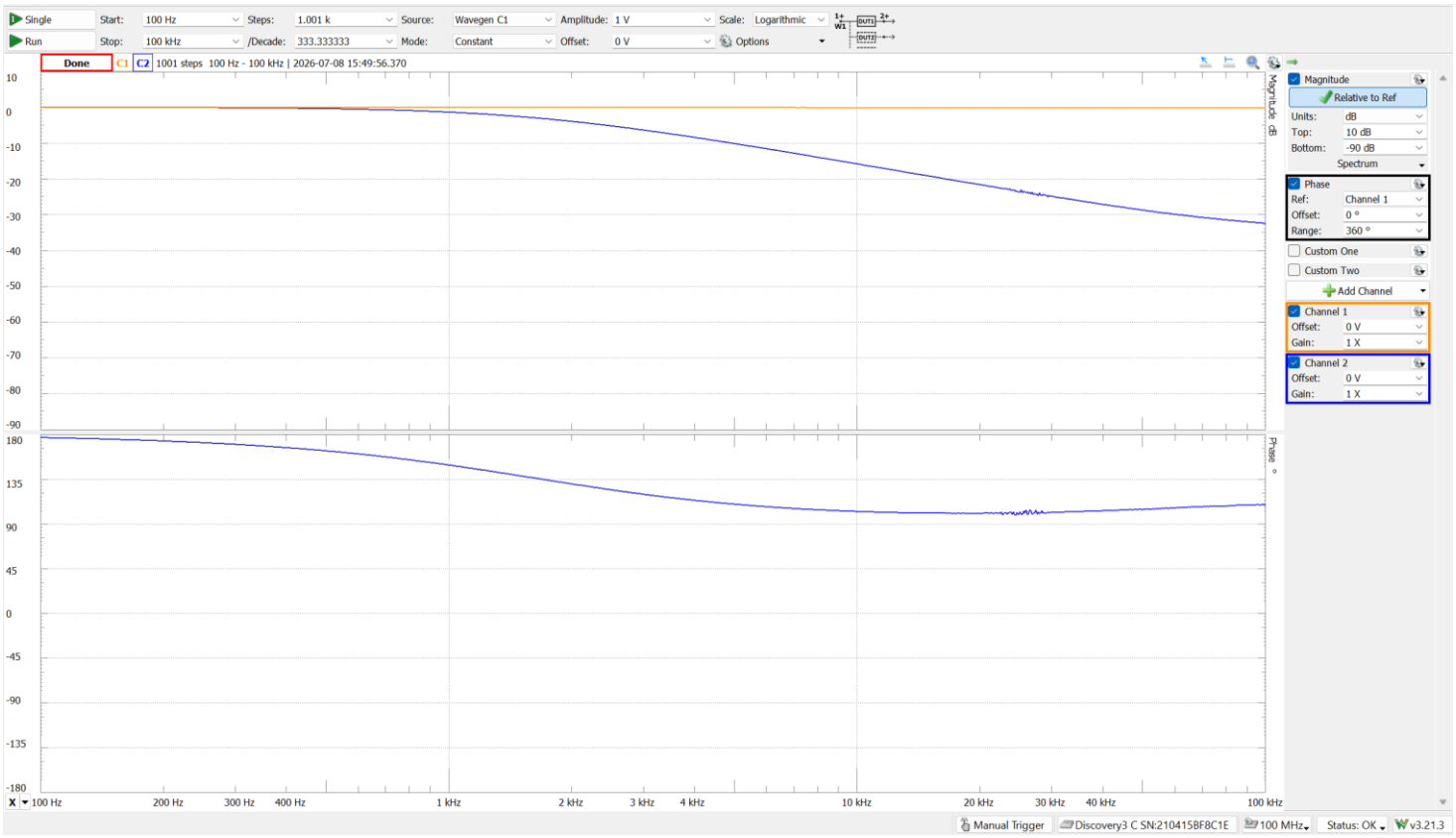


Figure 10: Experimental frequency response of the active RC lowpass filter measured using the Analog Discovery Network Analyzer.

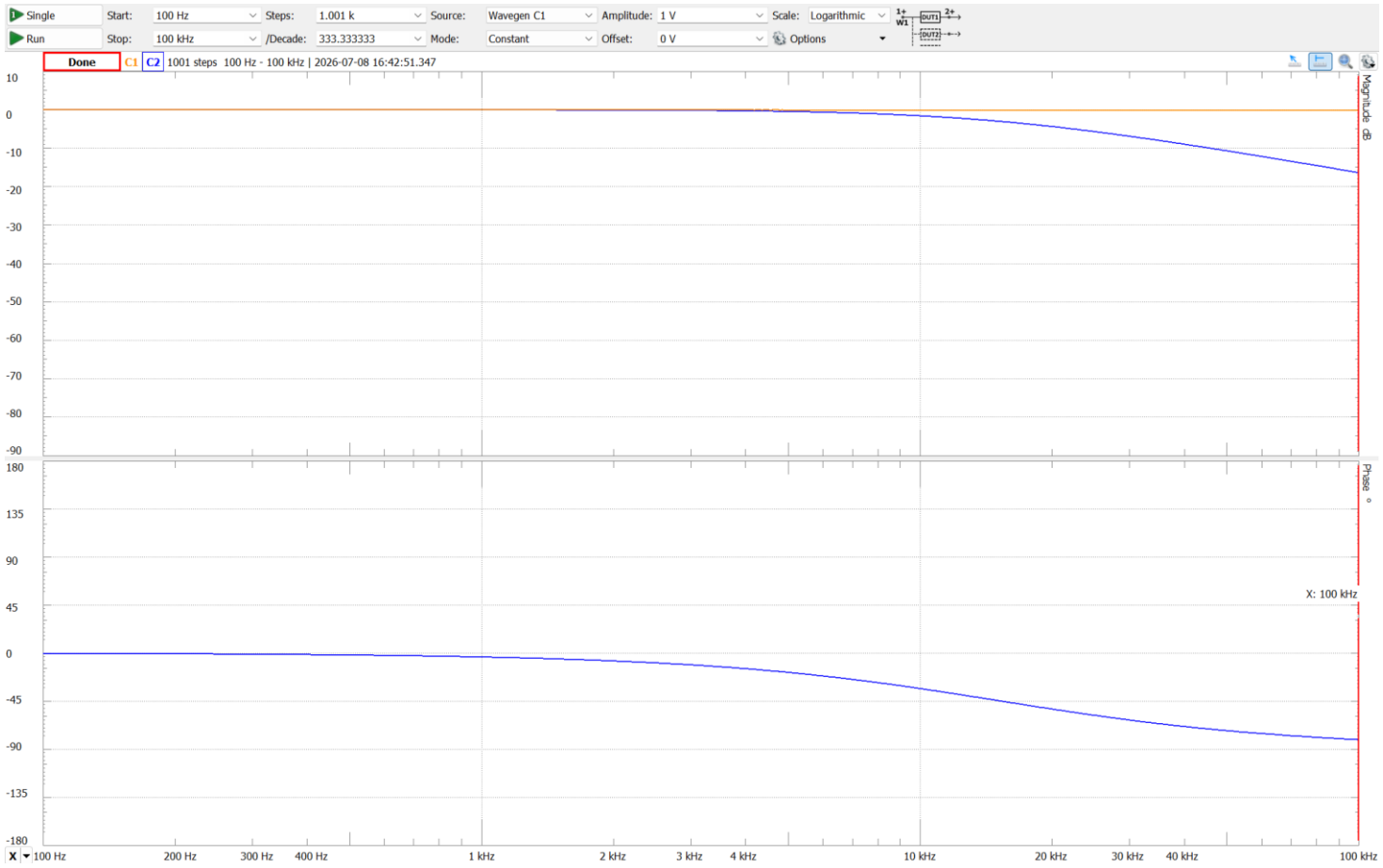


Figure 11: Experimental frequency response of the passive RC lowpass filter showing a measured 3 dB cutoff frequency of 14.956 kHz.

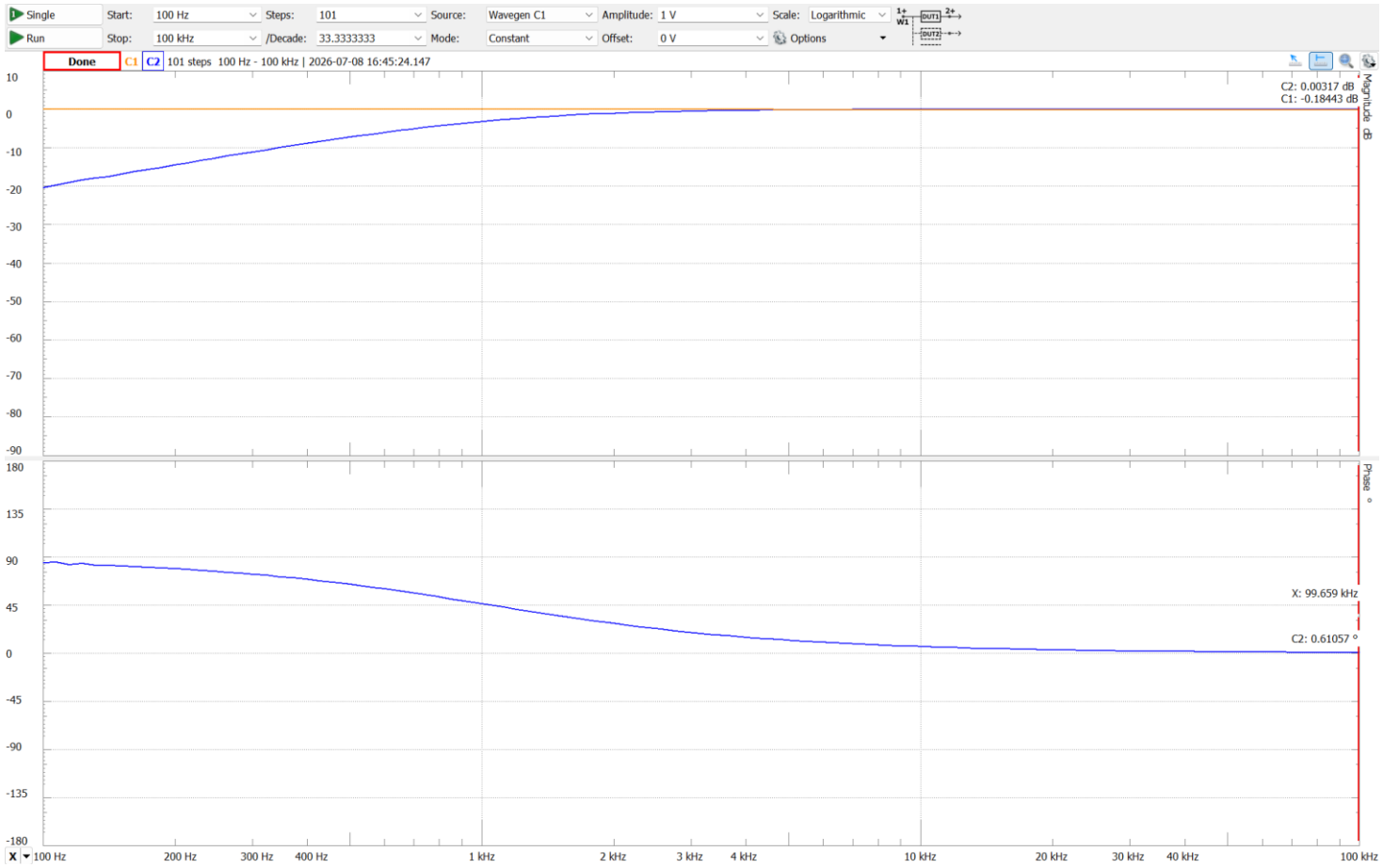


Figure 12: Experimental frequency response of the passive RC highpass filter showing a measured 3 dB cutoff frequency of 1.059 kHz.

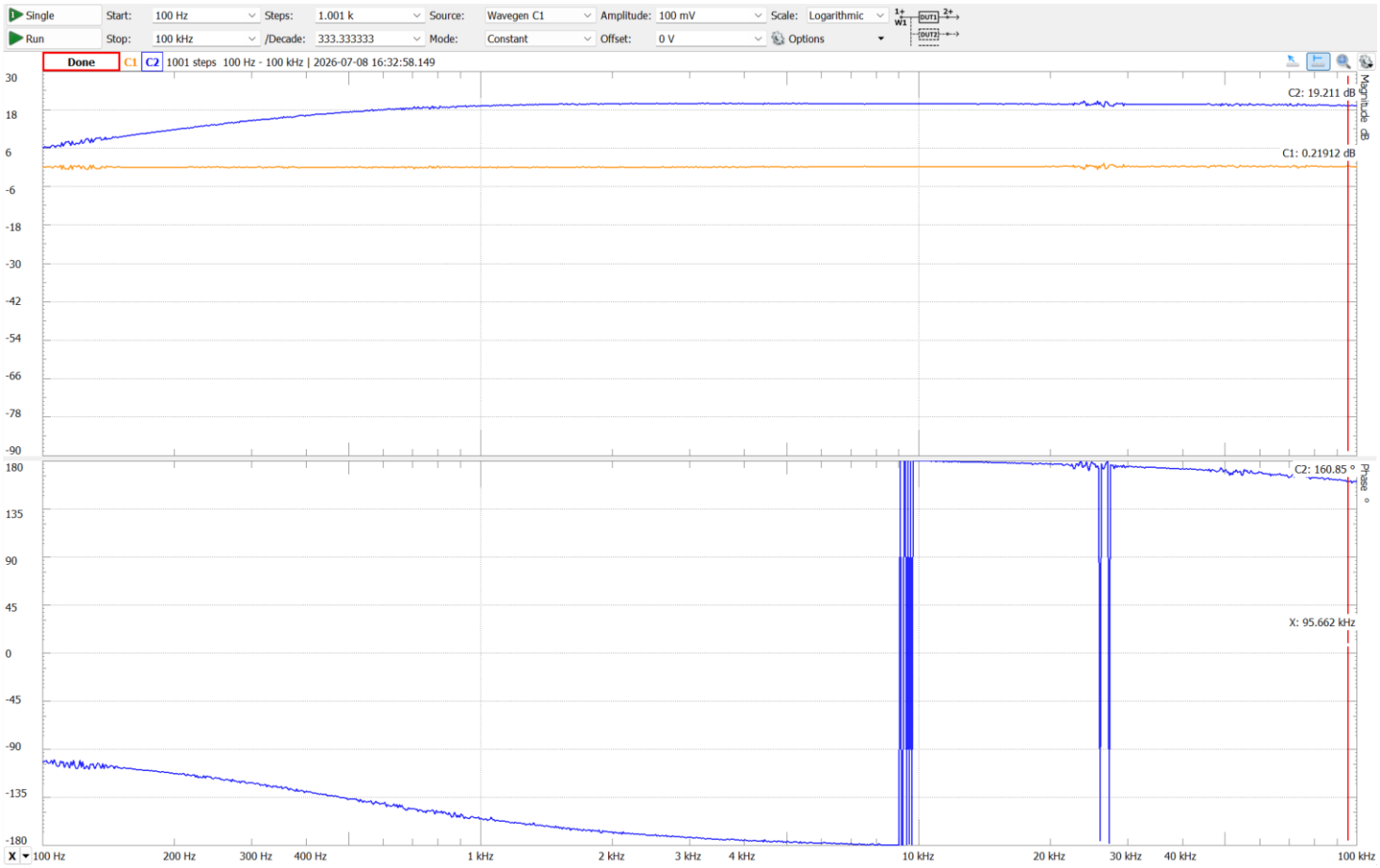


Figure 13: Experimental frequency response of the active RC highpass filter showing a measured 3 dB cutoff frequency of 477.1 Hz.

Discussion Question:

If I were to suppress a 60 Hz interference while preserving the desired signal I would select a band-stop (notch) filter centered at 60 Hz due to it specifically attenuating the powerline while allowing frequencies above and below it to pass with minimal attenuation. Unlike a lowpass or a highpass filter, notch filters remove a very small range of frequencies, maintaining most of the outside signals.

If I were to choose between an active or passive filter, I would prefer an active filter due to it providing better gain, better control of the cutoff frequency, and an improved performance without needing things like inductors. Active filters also reduce loading effects by having a higher input and a lower output impedance, making them well suited for processing low-amplitude signals.

By combining filters in this way, it allows for more complex frequency responses to be achieved such as the rejection of specific frequency ranges. Multiple filter stages can improve unwanted noise but can also introduce an additional phase shift and component tolerance that can

then affect the later response. Thus, a careful section of cutoff points is a must in order to avoid excessive signal loss.

When signals pass through lowpass filters followed by highpass filters, only the frequencies that lie in between the two frequencies are allowed to pass. Frequencies both above and below the cutoff points are attenuated, causing it to overall provide a response similarly to a band-pass filter. This resulting bandwidth depends on the selected cutoff frequencies of each of the filters.

CONCLUSION

The primary objective of this lab was to simulate, design, and experimentally evaluate passive and active RC lowpass and highpass filters. The cutoff frequencies measured utilizing the Analog Discovery Network Analyzer closely matched the theoretical and LTspice results, demonstrating that the filters performed as presumed. These small differences were primarily due to internal resistances, normal component tolerances, and outside experimental measurement limitations.