Laboratory Report

Experiment 3: Analog Signal Conditioning (Part 2 - Filter Design)

Programme: Mechatronics Engineering
Mechatronics Control and Automation Lab (MCTA 3104)
Section 2
Semester 1 2024/2025
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Objectives

- Design a first-order low-pass filter using an op-amp non-inverting amplifier with a suitable gain.

- Calculate resistor and capacitor values for a low-pass filter with a cutoff frequency of 1.6k Hz.

- Verify low-pass filter functionality using test signals.

- Design a first-order high-pass filter by swapping the resistor and capacitor positions.

- Verify high-pass filter functionality using test signals.

- Simulate all circuits in Multisim and compare the simulation results with breadboarding results

Introduction

This experiment focuses on the design and analysis of first-order filters using operational amplifiers. The objective is to construct both low-pass and high-pass filters with specified cutoff frequencies. The process begins with the design of a low-pass filter, utilizing an op-amp in a non-inverting amplifier configuration. Key circuit parameters, such as resistor and capacitor values, are calculated to achieve the desired cutoff frequency of 1.6k Hz. The circuit's functionality is then tested using appropriate input signals.

Following this, the task transitions to the construction of a high-pass filter by repositioning the resistor and capacitor within the circuit. For this configuration, new component values are selected to ensure a cutoff frequency of at least 1.6kHz. The performance of both filters is verified through experimentation and simulation in Multisim. Finally, the experimental and simulation results are compared to evaluate the accuracy and consistency of the designs.

Equipment

- Multimeter
- Oscilloscope
- Function generator
- Digital multimeter
- ±15V DC power supply
- 741 Op-amp
- 94.1 kΩ resistor
- 93.6 kΩ resistor
- 1.972 kΩ resistor
- 99.3 kΩ resistor

- 103 Capacitor
- Jumper wires

Setup

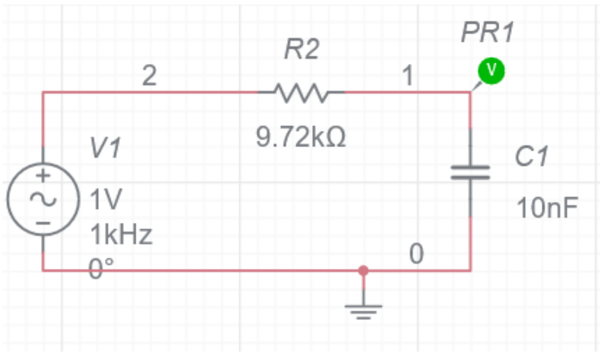

Figure 1: Circuit diagram of a passive low pass filter.

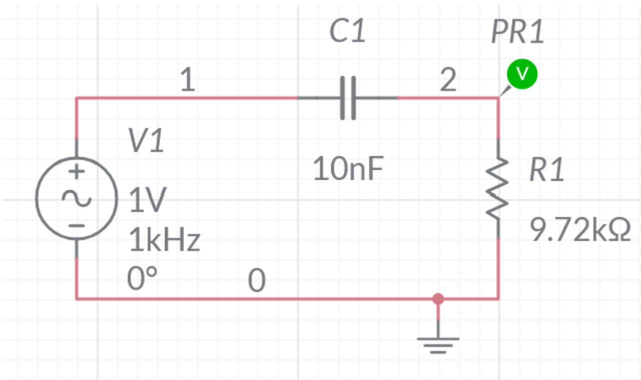

Figure 2: Circuit diagram of a passive high pass filter.

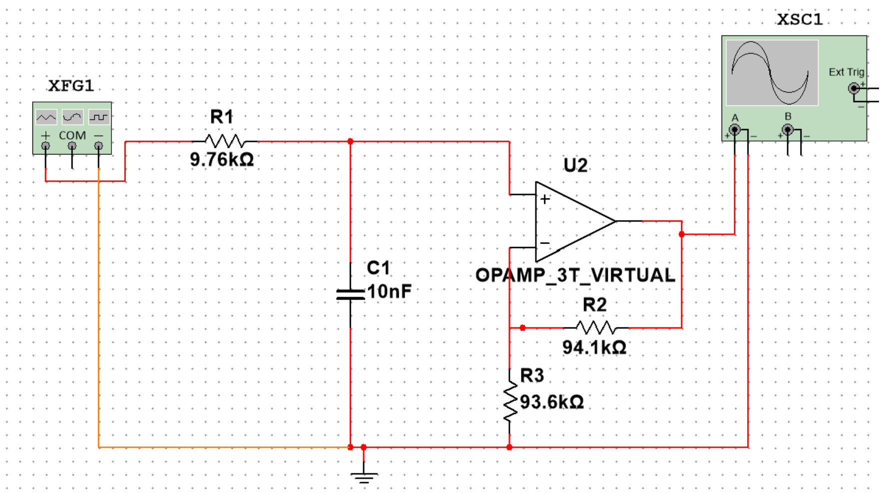

Figure 3: Circuit diagram of an active low pass filter.

Experimental Procedure

1. An op amp non – inverting amplifier with gain of 2. The waveforms generated is recorded.
2. A suitable value of resistor and capacitor are calculated and selected which corresponding to our selected cut of frequency of the low pass filter, 1.6kHz.
3. Then the filter is cascaded with op-amp non-inverting circuit.
4. The circuit function is verified using suitable test signals.
5. The previous steps are repeated by swapping the position of the resistor and the capacitor to construct a high pass filter. The circuit function is verified using suitable test signals.
6. All the circuits are simulated by Multism and the results that we obtain are compared.

Results

Below under appendices are the oscilloscope results gotten in the lab and the ones from Multisim.

Here are the results of the voltages gotten from the low and high pass filters in a table:

Filter Type	Low Pass Filter		High Pass Filter
Frequency (Hz)	**Vout (V)**		
	Passive filtering	Active filtering	Passive filtering
100	1.086	2.043	0.125
200	1.044	2.026	0.167
500	1.044	1.959	0.375
600	0.918	1.926	0.4175
800	9.03E-01	1.843	0.501
900	0.835	1.801	0.5428
1600	0.793	1.484	0.7515
5000	0.3757	0.65034	0.9603
10000	0.208	0.333	1.002
100000	0.0835	0.1668	1.044

Discussions

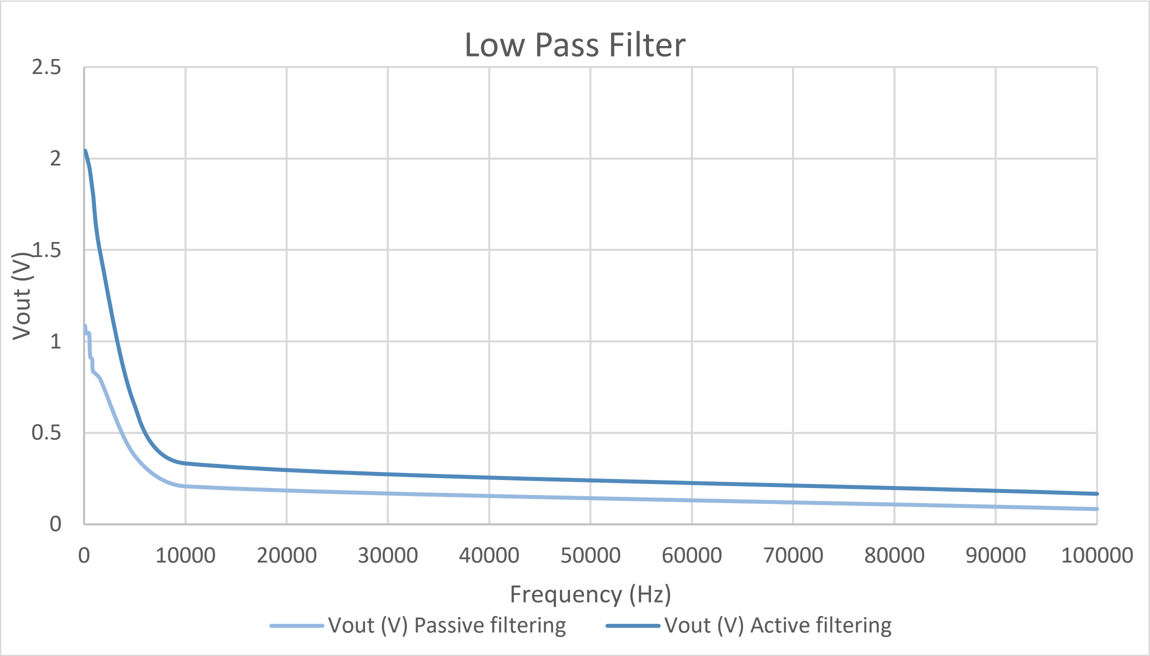

Figure 4: Plot of a low pass filter.

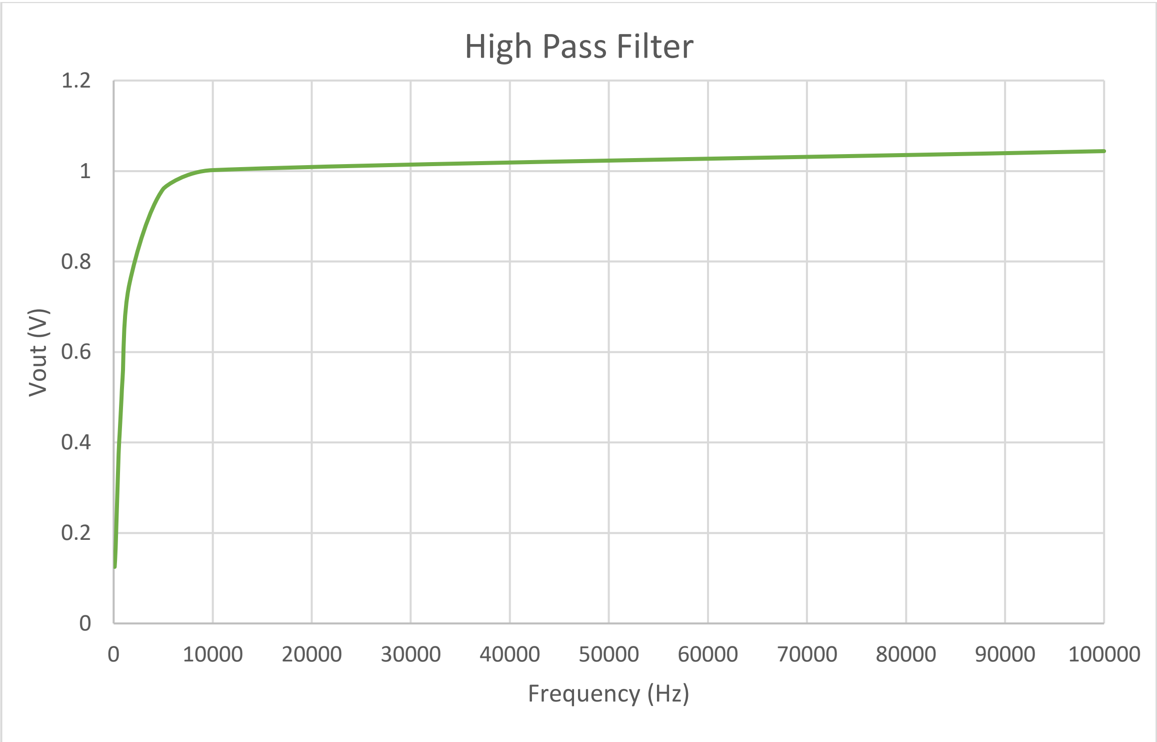

Figure 5: Plot of a high pass filter.

The circuits were simulated using Multisim, and the results were compared with the experimental data obtained from breadboarding. The simulation results closely matched the breadboarding results, demonstrating the accuracy of the circuit design and component selection. Minor discrepancies were observed in the output voltages, which can be attributed to component tolerances and potential variations during manual assembly on the breadboard. Overall, the consistency between simulation and experimental results validated the effectiveness of the theoretical design process.

The discussion from the report highlights that the results obtained from simulations closely matched those from the breadboarding experiments, demonstrating the accuracy of the theoretical design. Minor variations were observed, which were attributed to practical factors such as component tolerances and assembly imperfections during the manual construction of the circuits. For instance, in the case of passive high-pass filtering at 100 Hz, the experimental output voltage was measured as 0.125 V, whereas the active high-pass filter simulation at the same frequency yielded an output voltage of 2.043 V. These results underscore the consistency between experimental and simulation data, validating the design methodology. The slight discrepancies observed are expected and acceptable, given the inherent limitations of physical components and manual assembly.

Comment on the result the practical assembly and simulation processes demonstrated consistent results, reinforcing the reliability of the designed circuits. The inclusion of amplification in the active filter significantly enhanced its performance compared to the passive design, as evident in the higher output voltages and improved signal handling. Overall, the experiment successfully validated the theoretical design principles, highlighting the critical role of active filters in effective signal conditioning application.

Conclusion

The experiment successfully demonstrated the functionality of first-order low-pass and high-pass filters, with the low-pass filter attenuating high frequencies and the high-pass filter suppressing low frequencies effectively. Active filtering provided enhanced performance due to amplification, as reflected in the output voltages. The close match between simulation and experimental results validated the accuracy of the design process, showcasing the practical application of theoretical concepts in signal conditioning.

References

Appendices

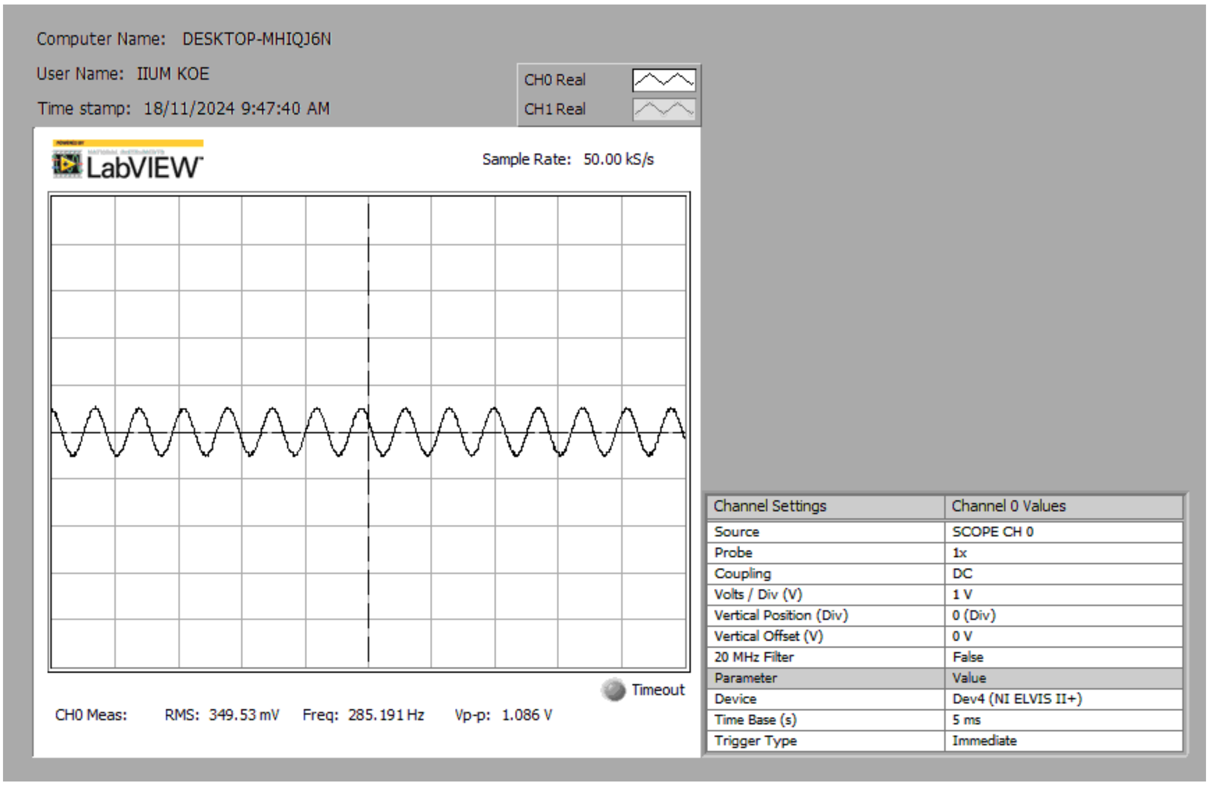

Figure 6: Low pass filter with 285Hz.

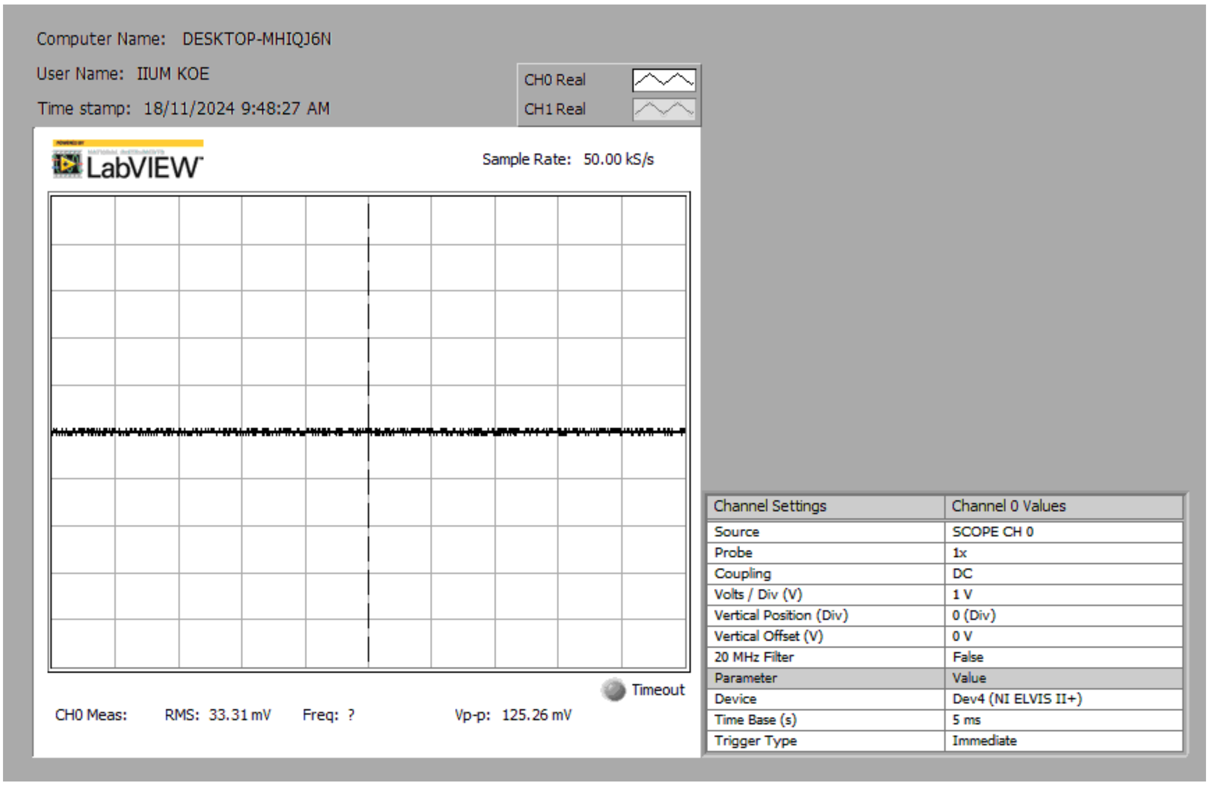

Figure 7: Low pass filter with 20.4k Hz.

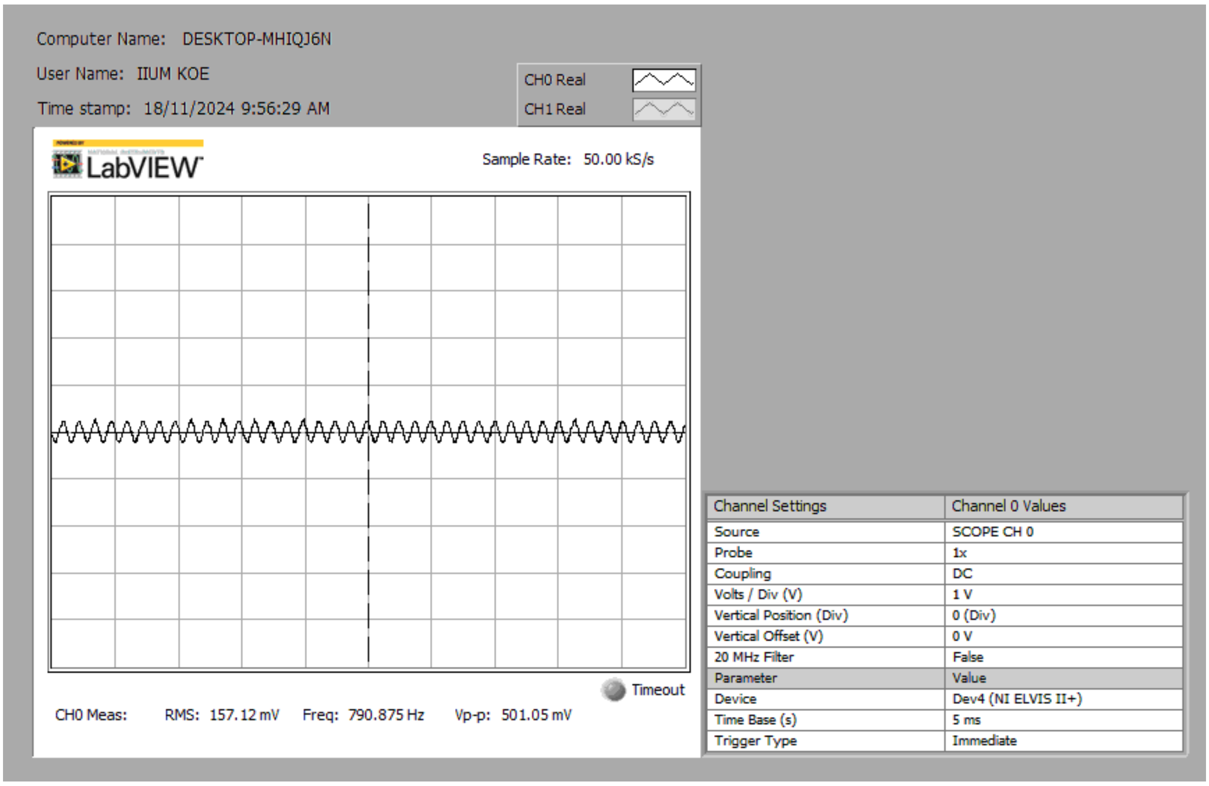

Figure 8: High pass filter with 790 Hz.

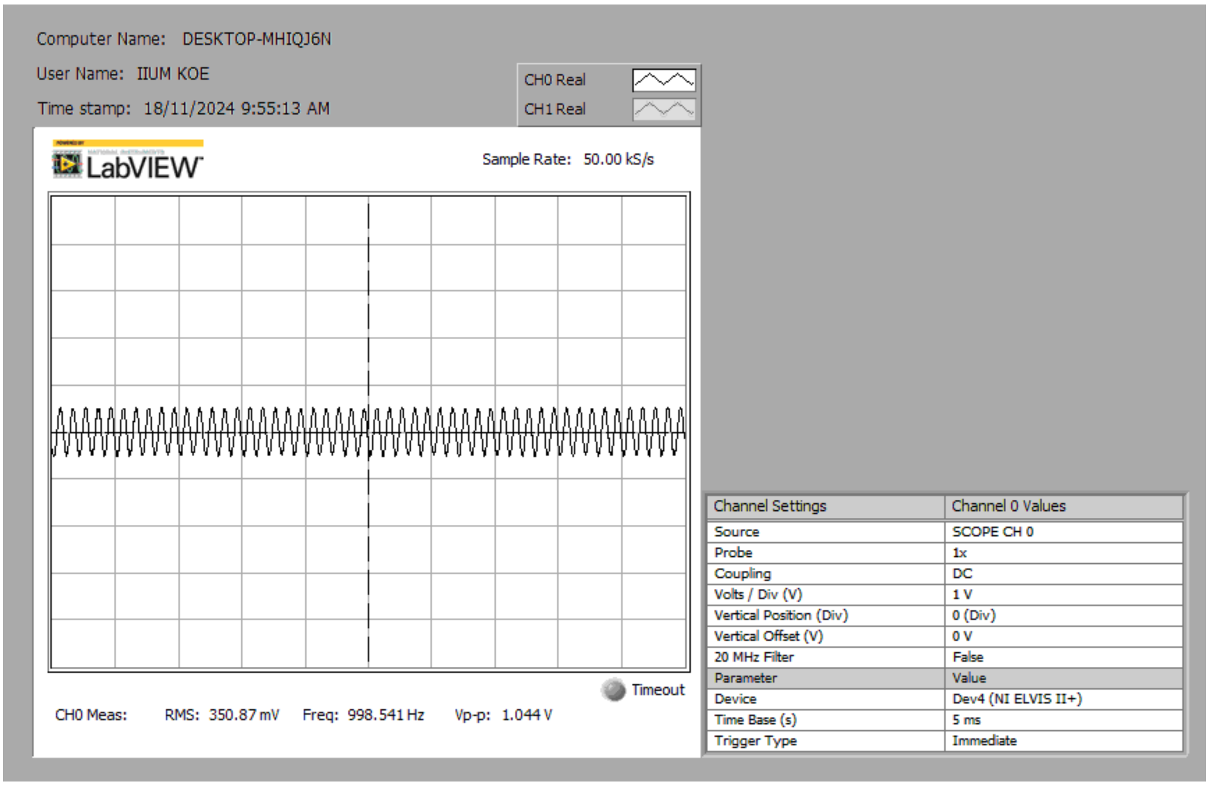

Figure 9: High pass filter with 99k Hz.

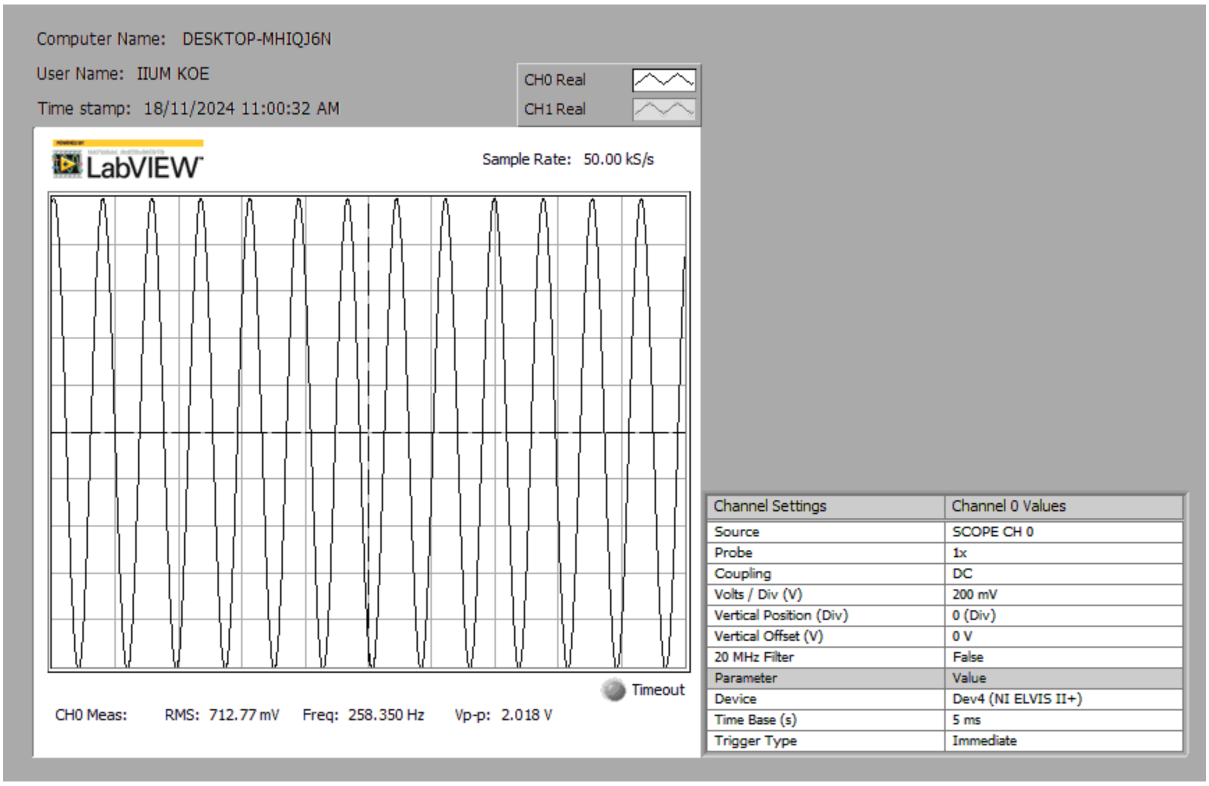

Figure 10: High pass filter with op-amp at 258 Hz.

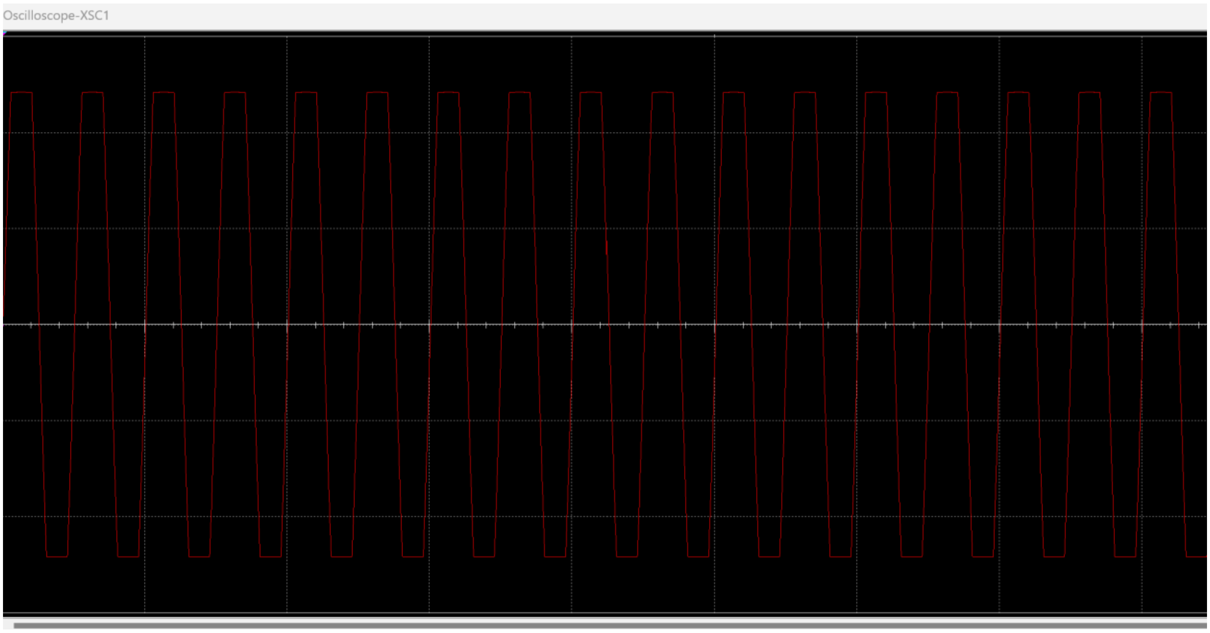

Figure 11: Multism graph of a low pass filter with op-amp at 200 Hz.

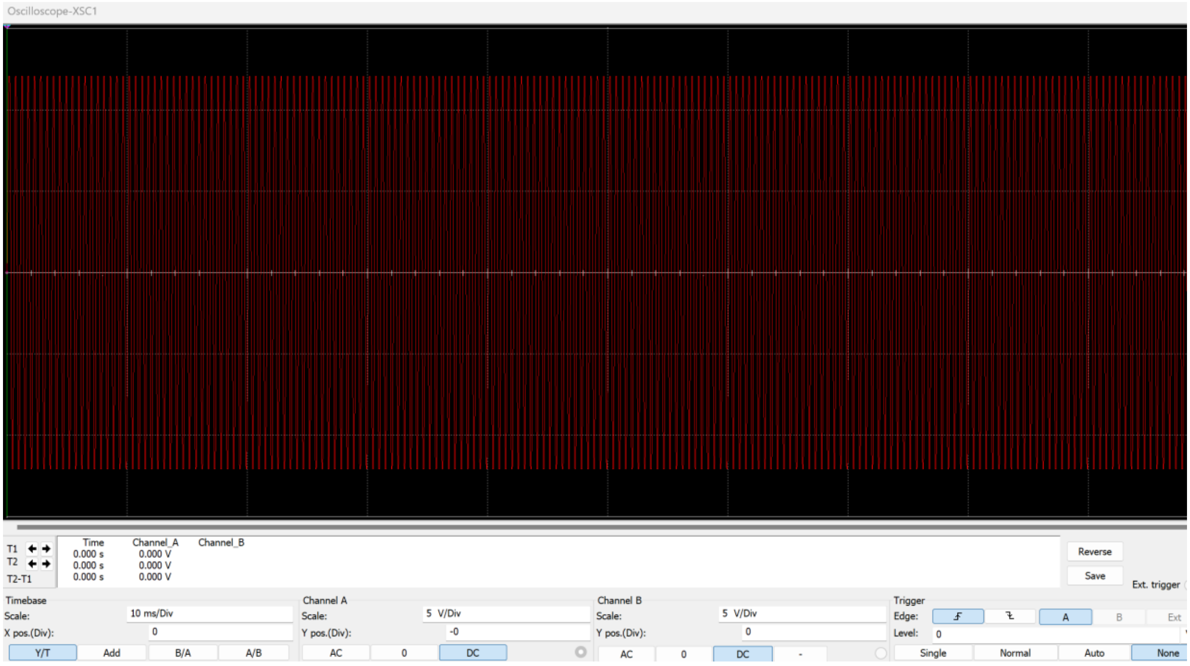

Figure 12: Multism graph of a low pass filter with op-amp at 1.9 kHz.

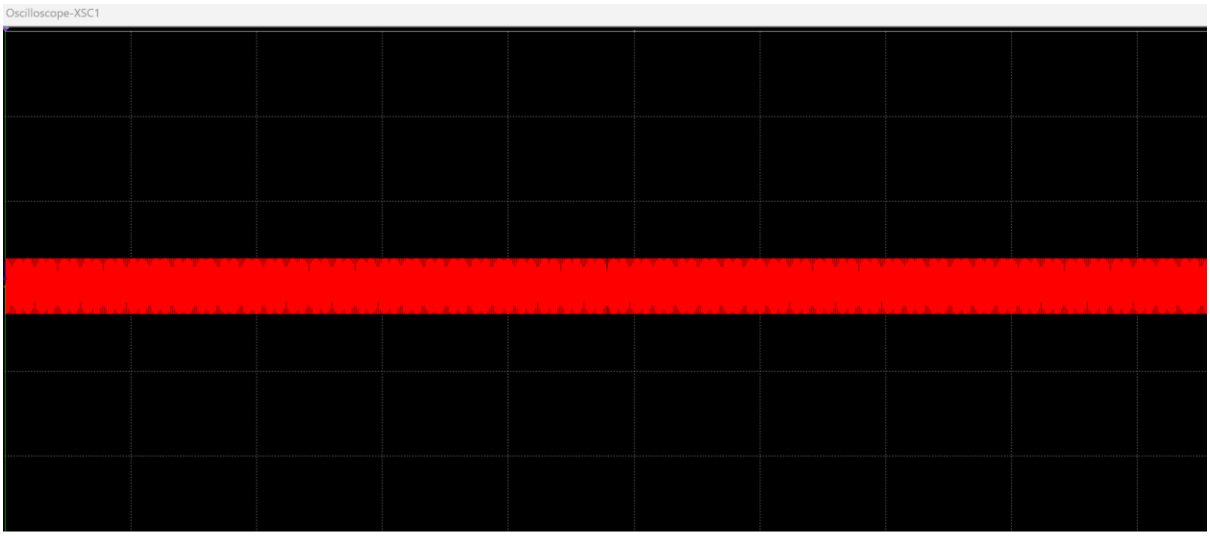

Figure 13: Multism graph of a low pass filter with op-amp at 20 kHz.

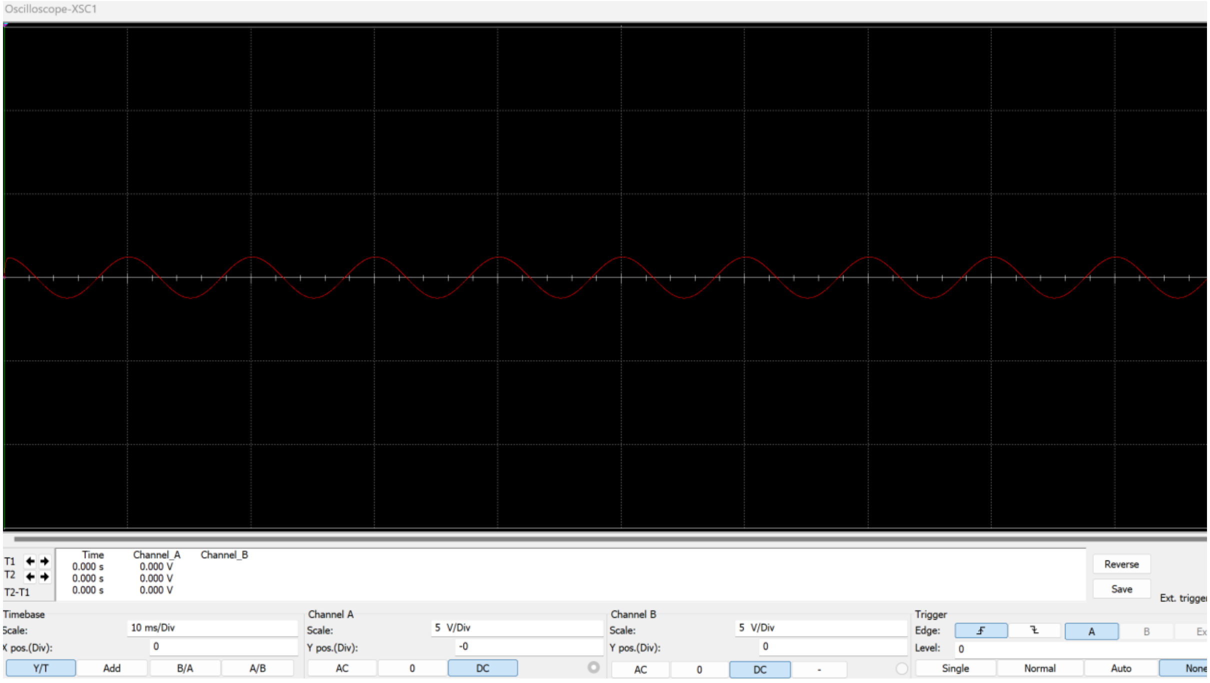

Figure 14: Multism graph of a high pass filter with op-amp at 100 Hz.

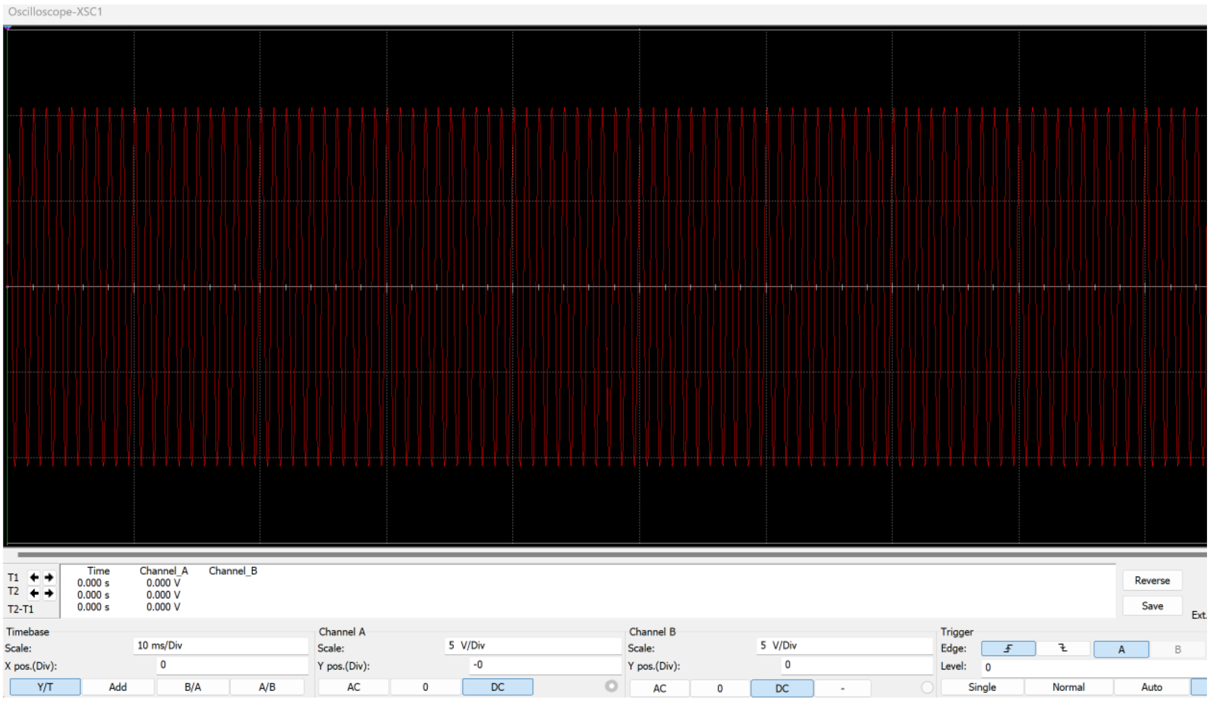

Figure 15: Multism graph of a high pass filter with op-amp at 1 kHz.

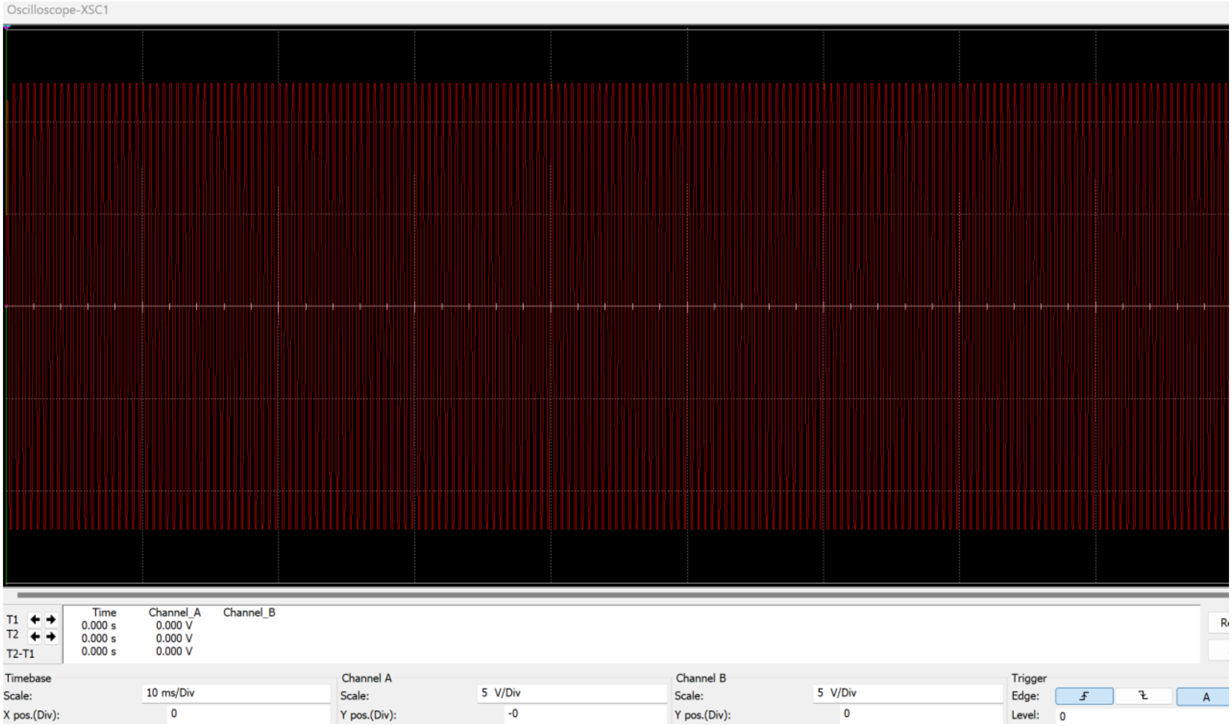

Figure 16: Multism graph of a high pass filter with op-amp at 99 kHz.

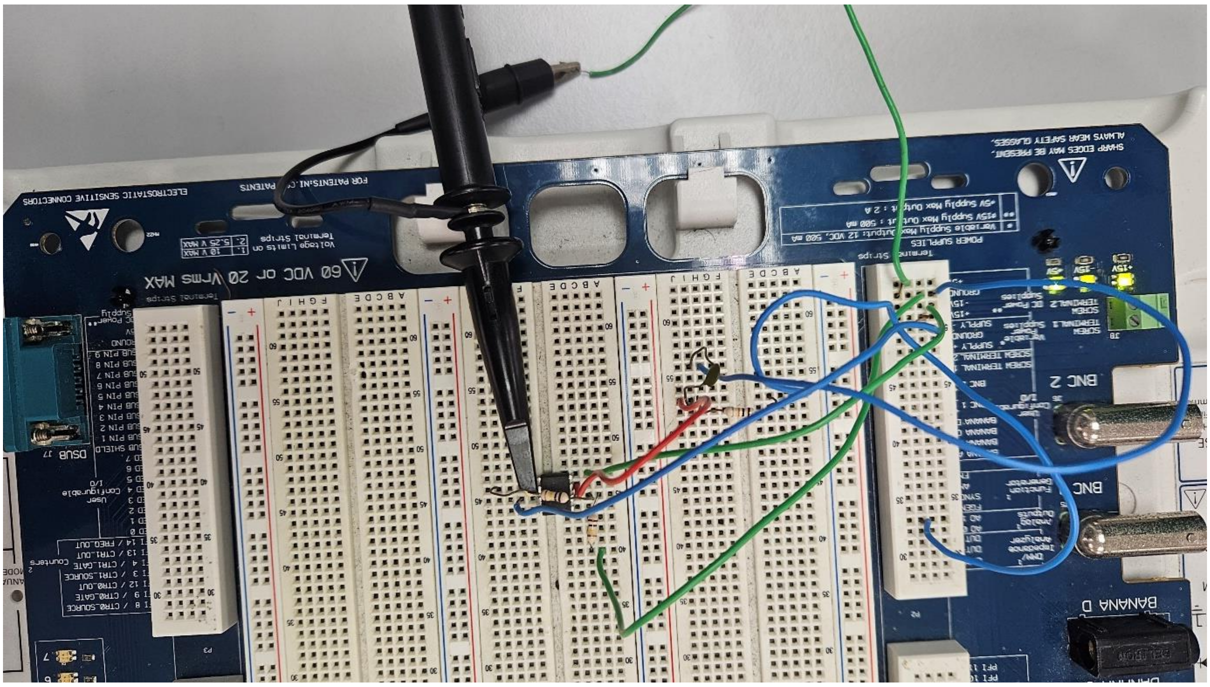

Figure 17: Circuit diagram constructed in the lab for the active low pass filter.