

# ECE 351 - Lab 12, Final Project - Filter Design

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# Contents

<b>1</b>	<b>Purpose</b>	<b>3</b>
<b>2</b>	<b>Procedure</b>	<b>3</b>
<b>3</b>	<b>Results</b>	<b>5</b>
3.1	Fourier Transforms of Input Signal . . . . .	5
3.2	Bode Plots of Designed Filter . . . . .	7
3.3	Fourier Transforms of Output Signal . . . . .	9
<b>4</b>	<b>Questions</b>	<b>11</b>
<b>5</b>	<b>GitHub Link</b>	<b>11</b>
<b>6</b>	<b>Conclusion</b>	<b>12</b>

# 1 Purpose

The purpose of this lab was to use the skills and coding experience taught in this lab in a practical application to filter a signal.

## 2 Procedure

The lab provided a .csv document that contained a noisy input signal, meant to simulate a real-world signal that a sensor would acquire. In the signal, there was the desired data from 1.8kHz-2.0kHz, along with noise at 60Hz, as well as high frequency noise (>2.0kHz) from a switching amplifier. The input signal is shown in Figure 1:

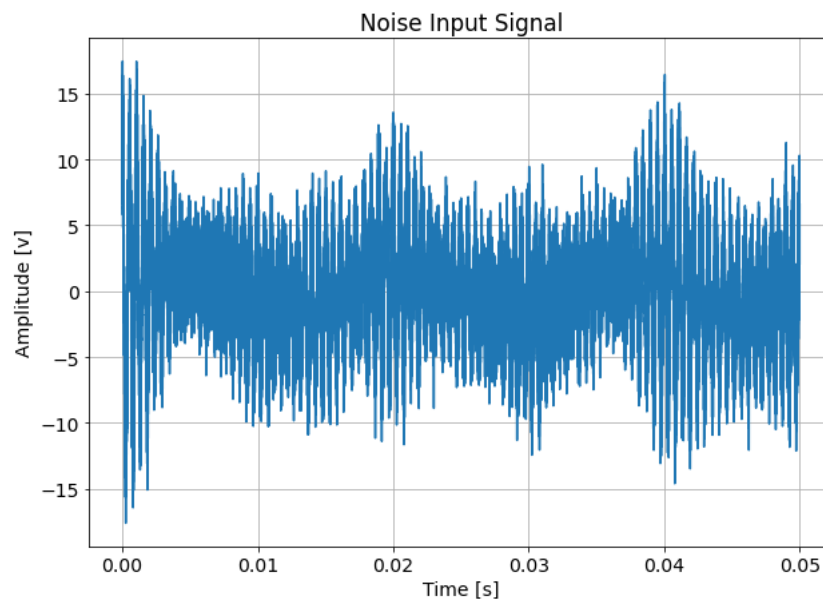


Figure 1: Noisy Input Signal

As is quite obvious from the graph, there is not much useful information that can be gained without using some kind of filter.

Next, Fourier transforms were employed to determine the noise magnitudes and corresponding frequencies. This can be seen in Figures 3 through 6, seen in the Results section, along with explanations.

A filter with the following specifications was then designed:

1. Position measurement information (1.8kHz - 2.0kHz) is attenuated by less than -0.3dB
2. Low frequency noise (60Hz) must be attenuated by at least -30dB

3. High frequency noise from the switching amplifier must be attenuated by at least -21dB
4. All noise greater than 100kHz must be fully attenuated or be at most 0.05V

These specifications resulted in the filter shown in Figure 2. The filter components were found with Alex Shipp, a classmate.

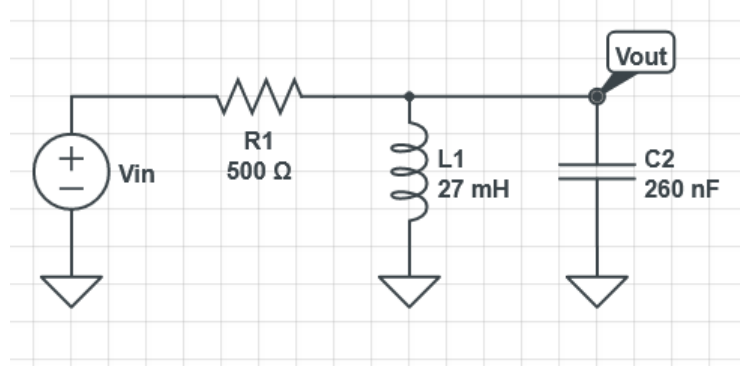


Figure 2: Designed Filter

Using these filter parameters and the transfer function shown in Equation 1, bode plots for the filter were generated to show that the filter met the specifications, as shown in Figures 7 through 10 in the Results section.

Finally, the noise input signal was passed through the the filter using the `scipy.signal.bilinear` and `scipy.signal.lfilter` commands. The noise magnitudes and corresponding frequencies at various frequency ranges are shown in Figures 11 through 14 in the Results section. Additionally, the full, filtered output signal is shown in Figure 15 in the Results section.

## 3 Results

### 3.1 Fourier Transforms of Input Signal

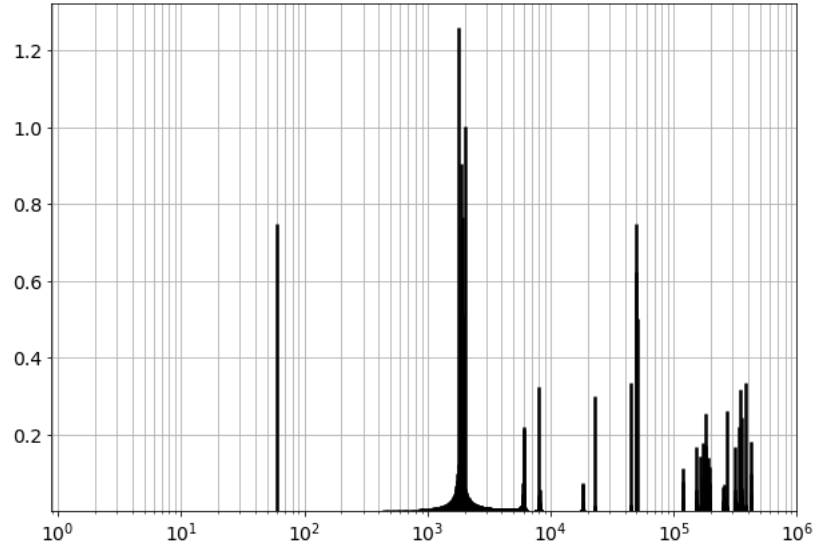


Figure 3: Fourier Transform over entire frequency range

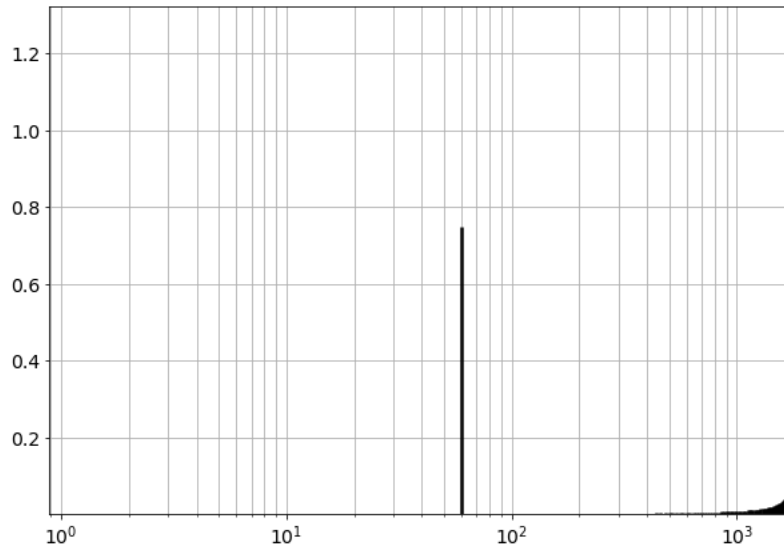


Figure 4: Fourier Transform over low frequency range (<1.8kHz)

The 60Hz noise can be seen quite clearly in this graph. Since it's not in the desired frequency band, it will need to be filtered.

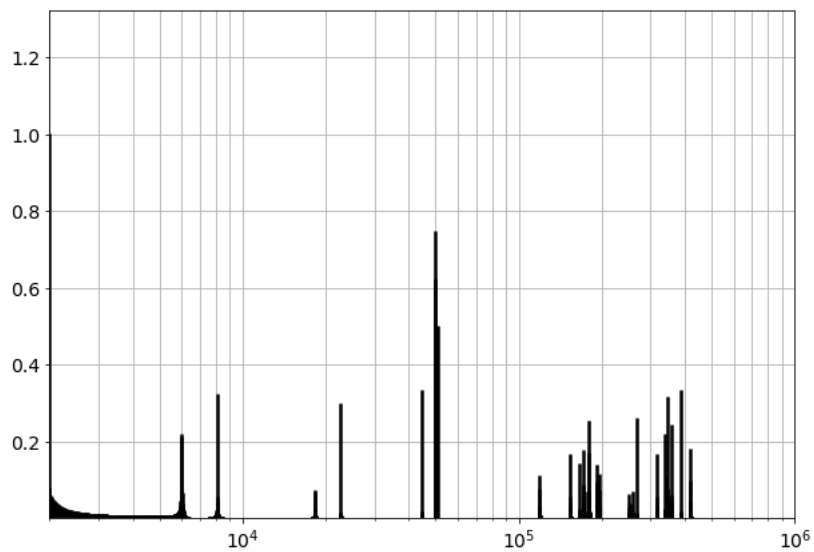


Figure 5: Fourier Transform over high frequency range (>2.0kHz)

All the data starting at around 6kHz and above is unrelated to the desired frequency, it must also be filtered.

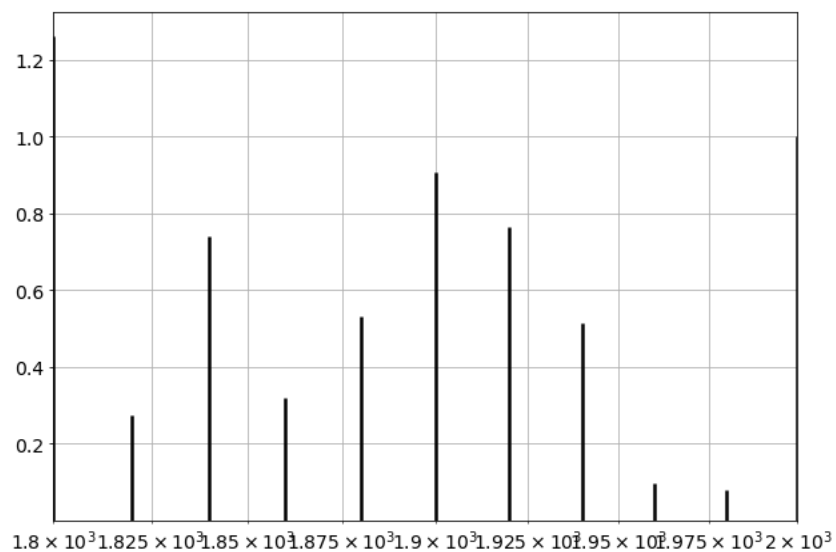


Figure 6: Fourier Transform over desired frequency range (1.8kHz - 2.0kHz)

This is the desired data, as it is between 1.8kHz and 2.0kHz.

### 3.2 Bode Plots of Designed Filter

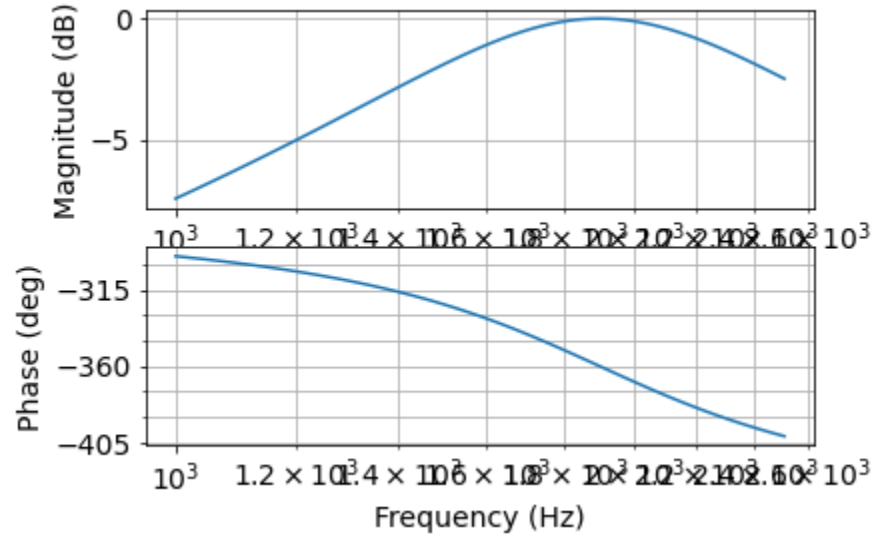


Figure 7: Bode Plot at the desired Bandpass

As can be seen, from 1.8kHz to 2.0kHz (the 5th and 6th vertical plot lines), the attenuation is less than -0.3 dB, satisfying Specification 1.

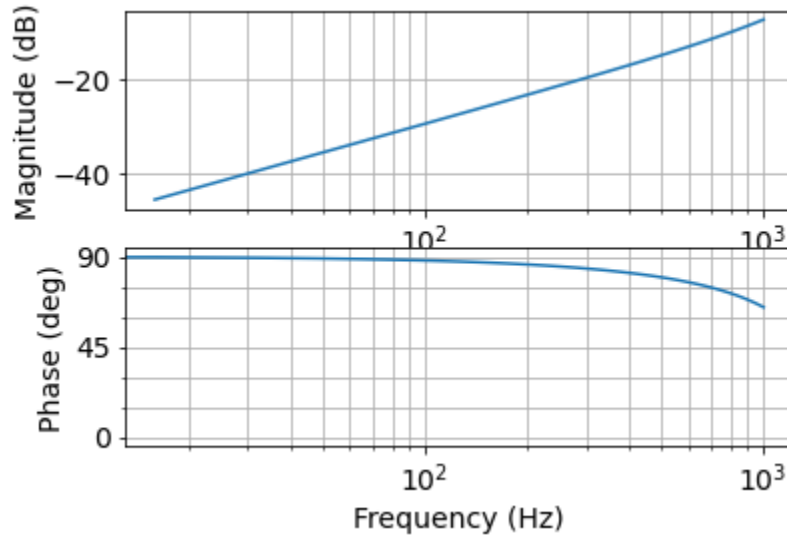


Figure 8: Bode Plot of the low frequencies

At 60Hz, the low-frequency vibration, the attenuation is around -35 dB, satisfying Specification 2.

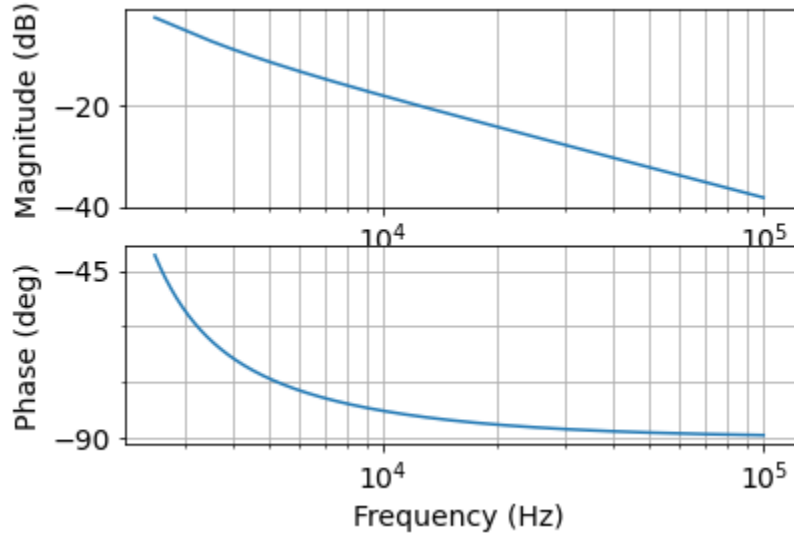


Figure 9: Bode Plot at the high frequencies

From Figure 5, the vast majority of the switching amplifier noise is found at around 50kHz. At 50kHz on this plot, the attenuation is around -30dB, satisfying Specification 3.

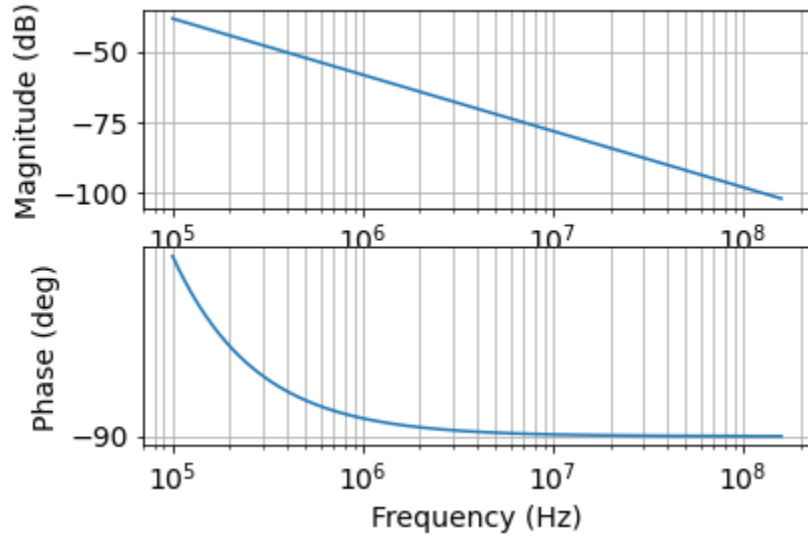


Figure 10: Bode Plot at the very high frequencies ( $>100\text{kHz}$ )

At 100kHz, the attenuation is about -40dB, and goes down to -100dB. This will result in a voltage of less than 0.05 so long as the input voltage is less than 500V, which it is, thereby satisfying Specification 4.



### 3.3 Fourier Transforms of Output Signal

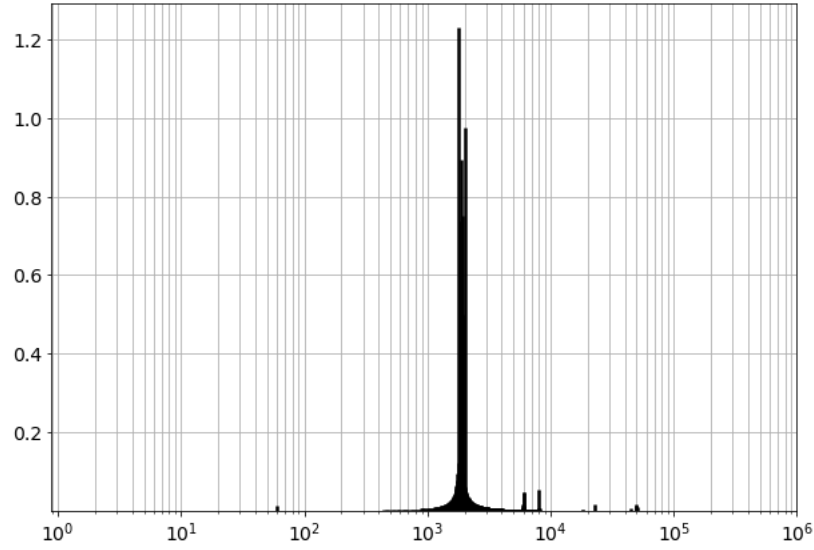


Figure 11: Fourier Transform of the filtered signal over entire frequency range

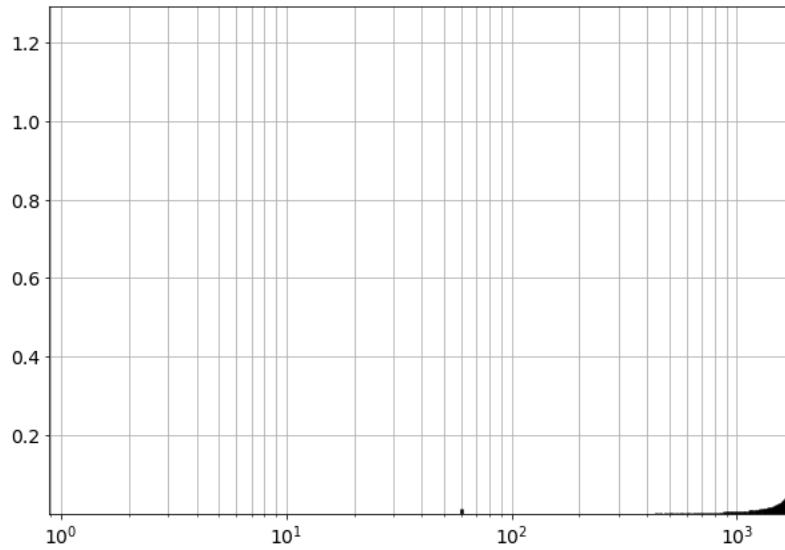


Figure 12: Fourier Transform of the filtered signal over low frequency range

The 60Hz noise generated by the low-frequency vibration due to the building's HVAC is attenuated below 0.05V, thereby being negligible for the purposes of this lab.

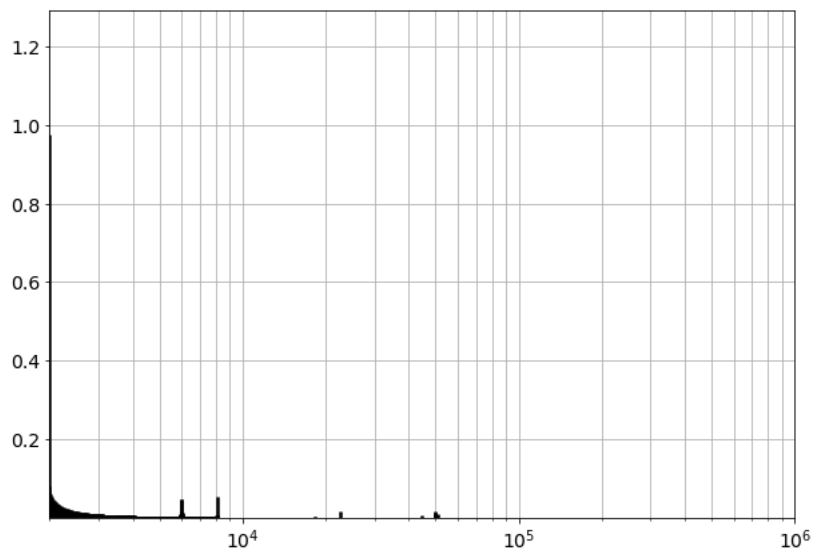


Figure 13: Fourier Transform of the filtered signal over high frequency range

All voltage levels in this graph are at or below 0.05V, thereby being attenuated to the proper degree.

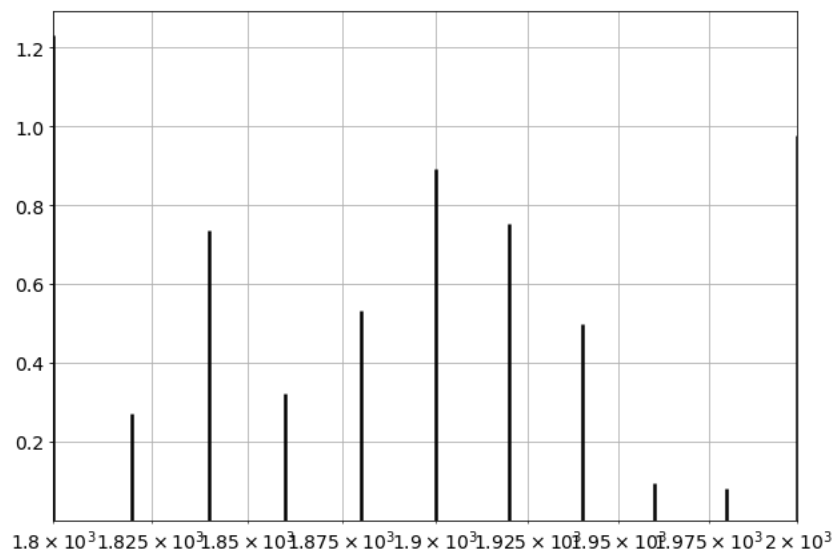


Figure 14: Fourier Transform of the filtered signal over desired frequency range

As can be seen comparing Figure 14 with Figure 8. there is no visible change, or attenuation, due to passing through the filter.

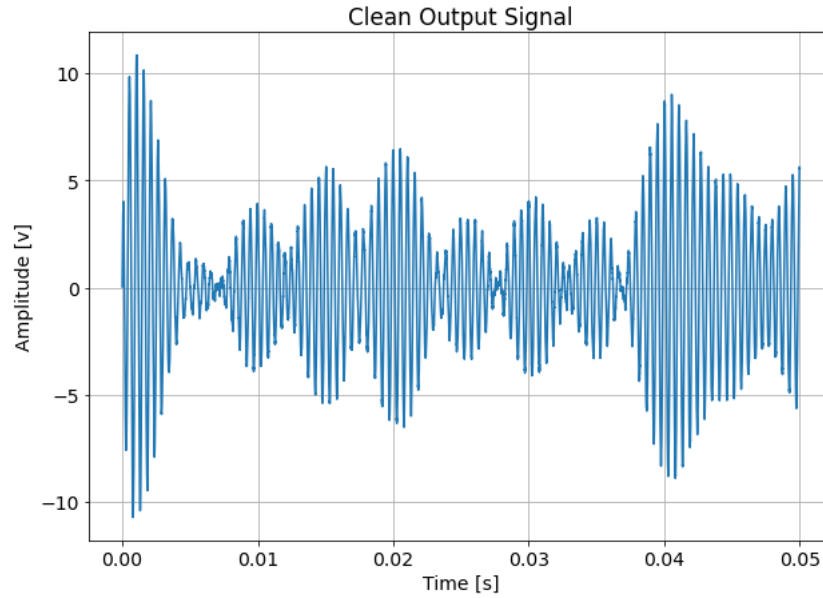


Figure 15: Filtered Output Signal

This signal is much cleaner than the one shown in Figure 1, and actually contains readable (and relevant) data. The visualization helps show that the filter eliminated noise to a sufficient degree to allow for proper measurement of the input.

## 4 Questions

Earlier this semester, you were asked what you personally wanted to get out of taking this course. Do you feel like that personal goal was met? Why or why not?

At the beginning of the semester, I said that I wanted to gain a better understanding of Python and how to use it in a practical setting. I believe that I accomplished this goal. My Python skills have advanced quite a bit, specifically using loops and functions to achieve a variety of things.

## 5 GitHub Link

<https://github.com/EReeder35>

## 6 Conclusion

In conclusion, this final project was a very educational summation of many of the topics learned in this lab, especially using Fourier transforms, filters, and transfer functions in Python. Overall, the lab course was very educational, as I detailed above in the Questions section, and it was appreciated to get a real-world example of how to apply the topics learned for this final project.