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Measurement Systems lab report
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Active filters

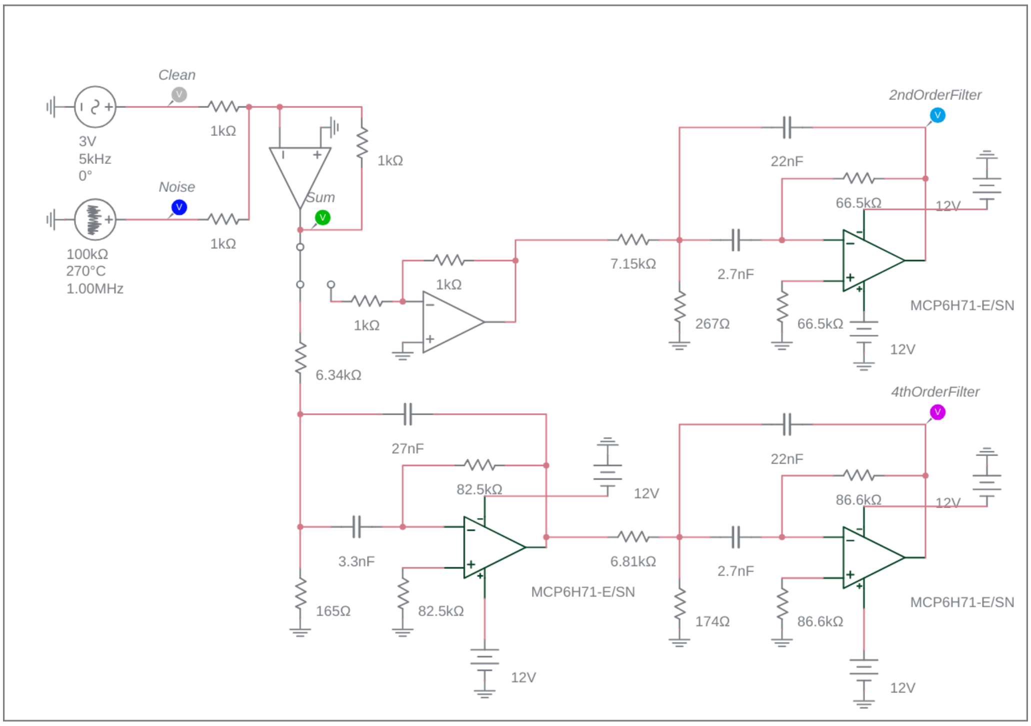
Aim
To investigate the usage of active filters to remove noise from a signal.

Theory
Signal filtering is a fundamental concept in electronics used to modify the frequency content of a signal. A filter is a circuit designed to allow certain frequencies to pass through while blocking others. Active filters, which use components like operational amplifiers, are often preferred over simple passive filters. This is because they can provide signal gain and achieve a steeper frequency roll-off, making them more effective at attenuating unwanted frequencies. A summing amplifier combines multiple input signals into a single output signal, and can be used to generate a noisy signal.

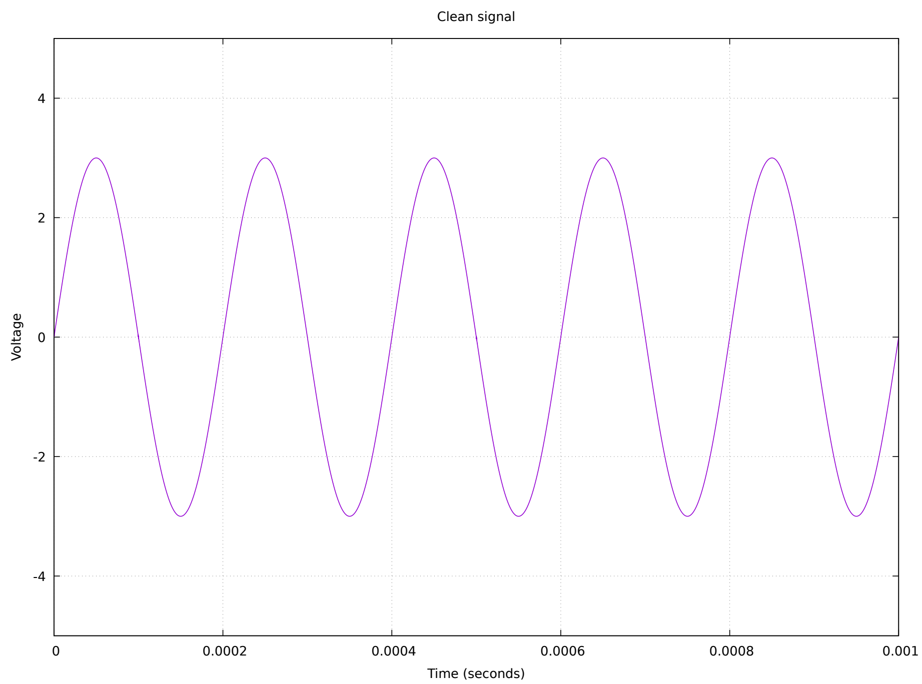
The performance of an active filter depends on it's order. A higher-order filter provides a sharper transition between the passband and stopband frequencies, leading to more effective filtering. For example, a first order filter has a roll off of -20 dB/decade, while a second order filter has a steeper roll off of -40 dB/decade. A band pass filter allows a specific range of frequencies to pass and attenuates frequencies outside of that range. The lower cutoff frequency and higher cutoff frequency of a bandpass filter determine the frequencies that are allowed to pass. The bandwidth is the difference between these two frequencies.

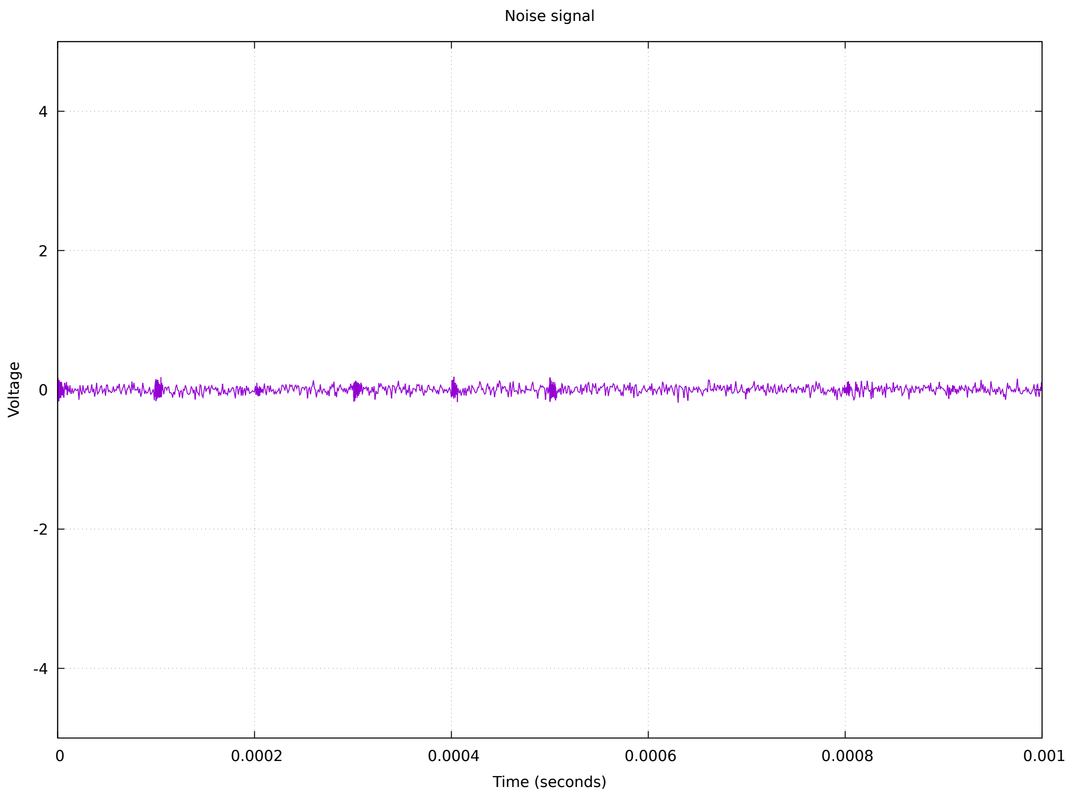
Method
An AC voltage source was set to produce a sine wave signal with a peak to peak voltage of 3 V and a frequency of 5 kHz. A second source was set up to produce a noise signal. An inverting summing amplifier circuit was created to combine the clean signal with the noise signal, producing a noisy signal. An oscilloscope was attached to the circuit to measure the clean signal, the noise signal, and the combined signal.
A second order bandpass filter was then designed using the FilterLab website. The lower cutoff frequencies was set to 4500Hz and the higher cutoff frequency set to 5500Hz. The stopband lower frequency was set to 1000Hz and the stopband upper frequency was set to 10000Hz. The resulting 2nd order filter design from FilterLab was then implemented in Multisim. The filter order was then set to 4 in FilterLab to create a circuit diagram for the 4th order filter, which was also subsequently implemented in Multisim. A thermal noise component was used in Multisim to produce a white noise signal, with the noise ratio parameter set to 1000.
Measurements were taken for the output voltage for the 2nd order filter and the 4th

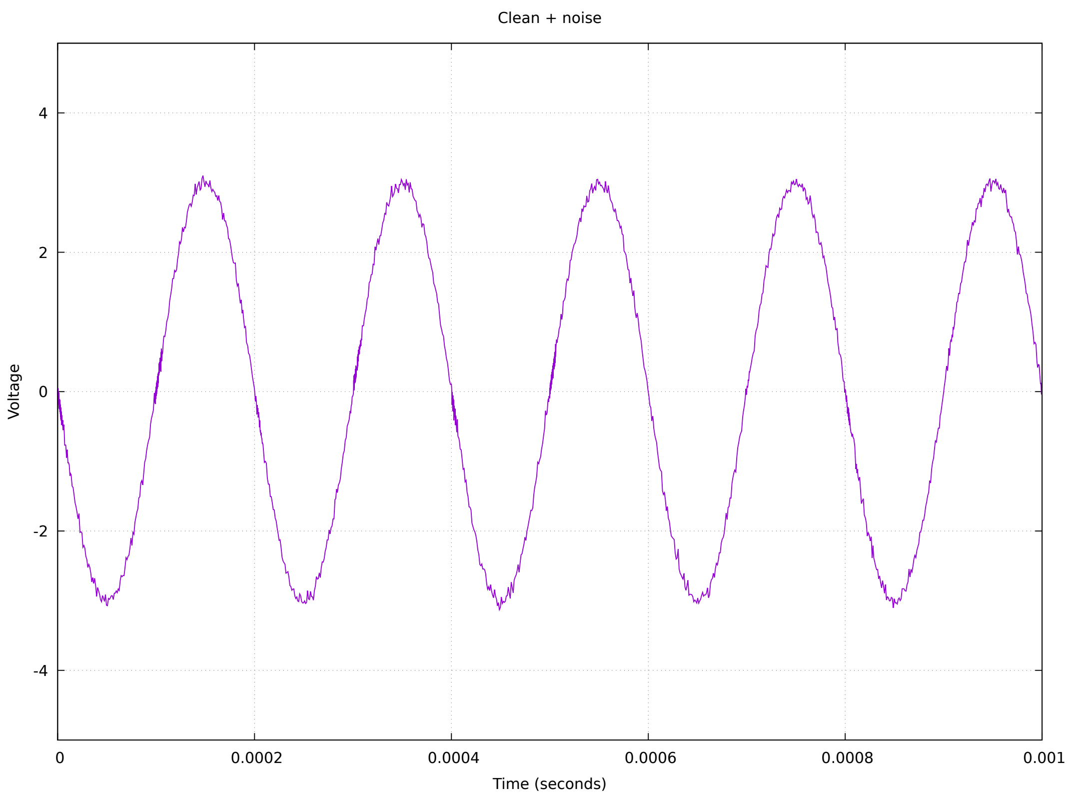
order filter. The clean signal, noise signal, combined signal, and both filtered signals were then graphed.

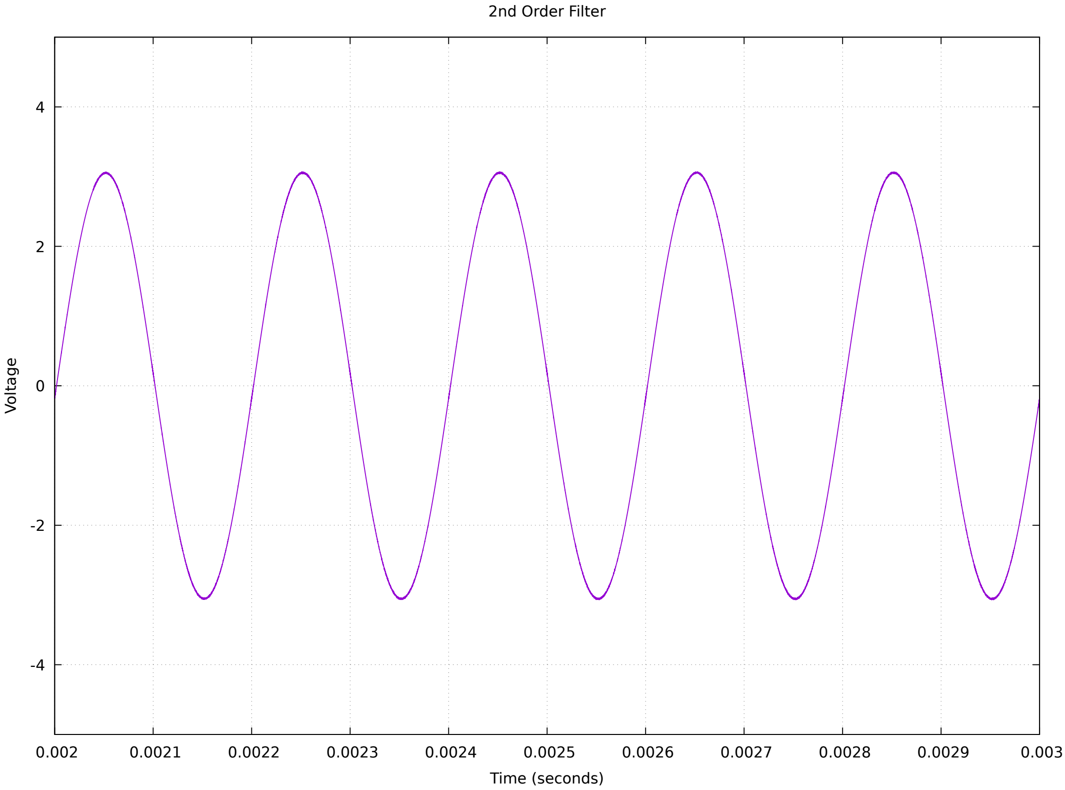


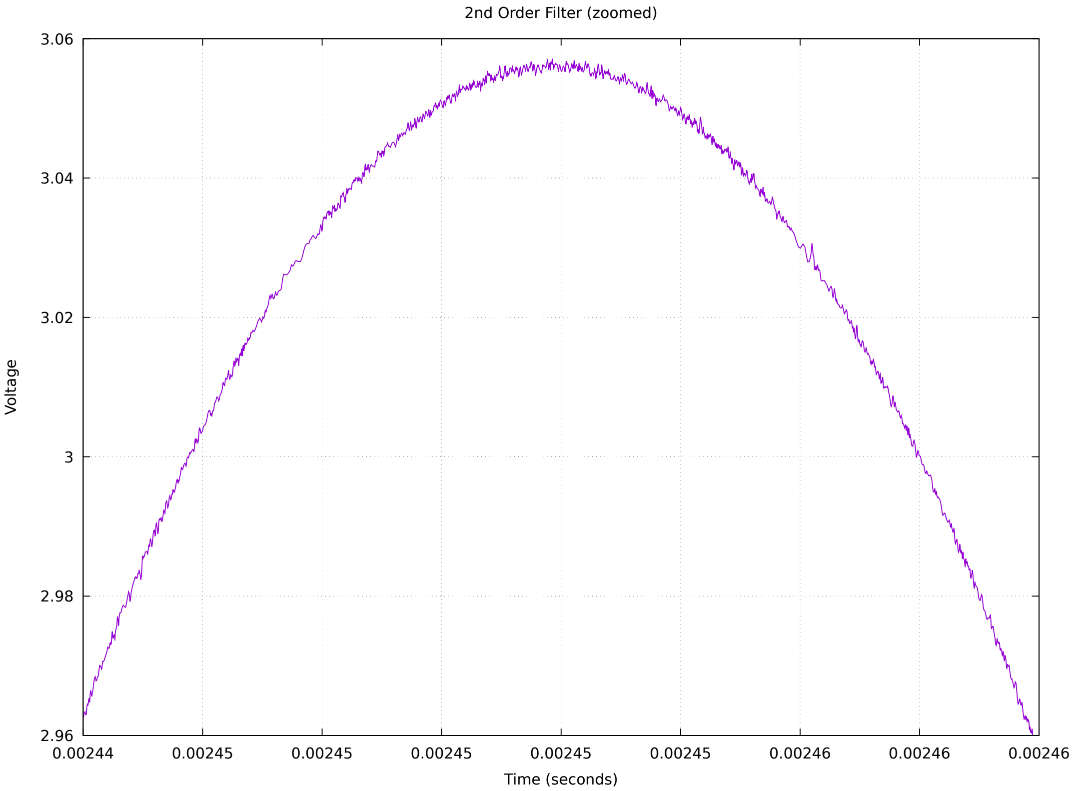
Data

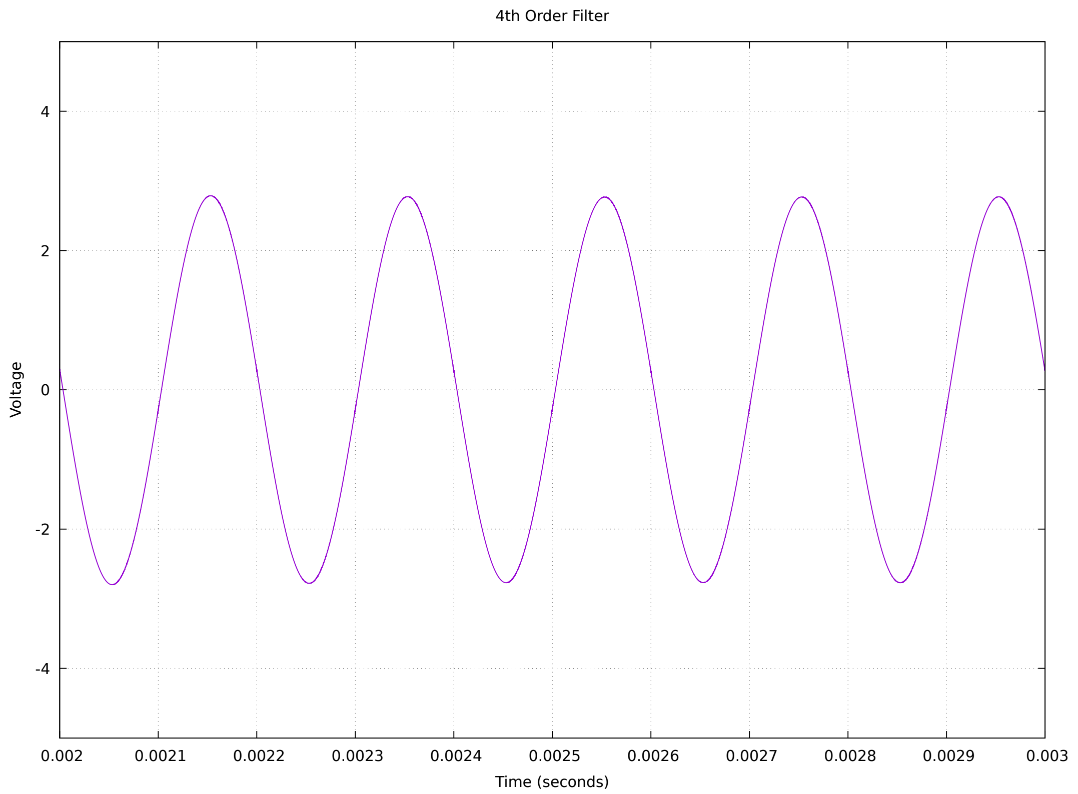


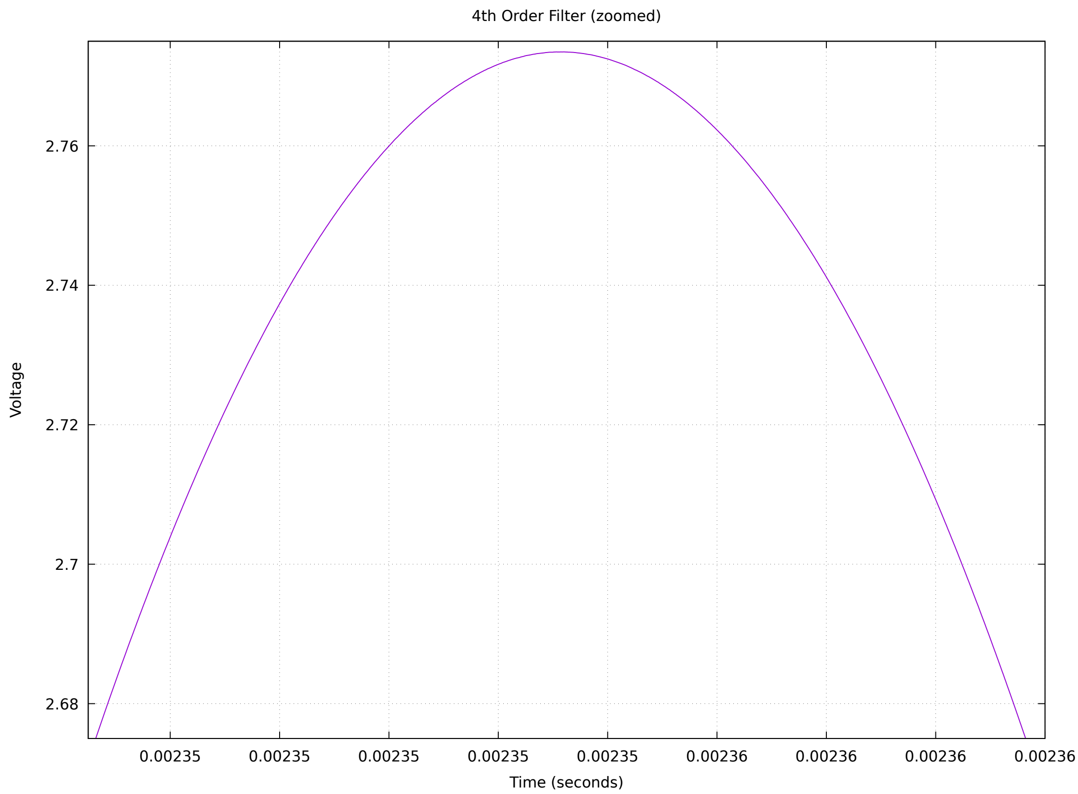

Noise signal
Voltage
4
2
0
-2
-4
0
0.0002
0.0004
0.0006
0.0008
0.001
Time (seconds)

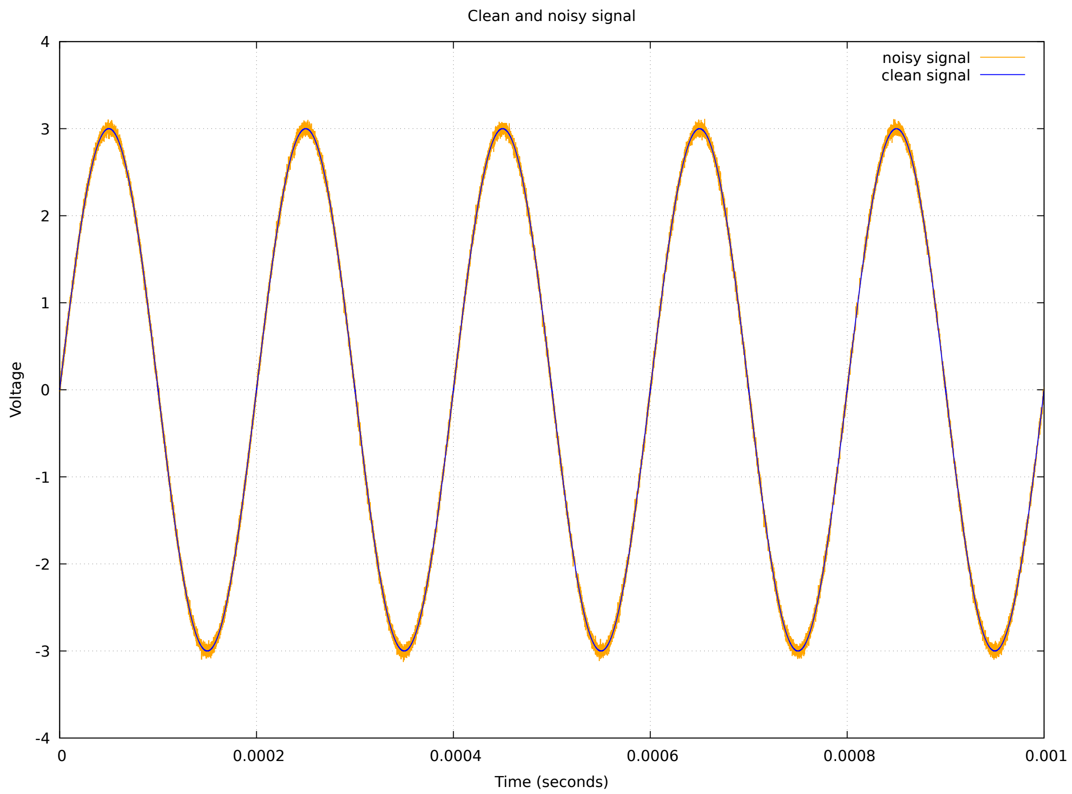

Clean + noise
Voltage
4
2
0
-2
-4
0
0.0002
0.0004
0.0006
0.0008
0.001
Time (seconds)

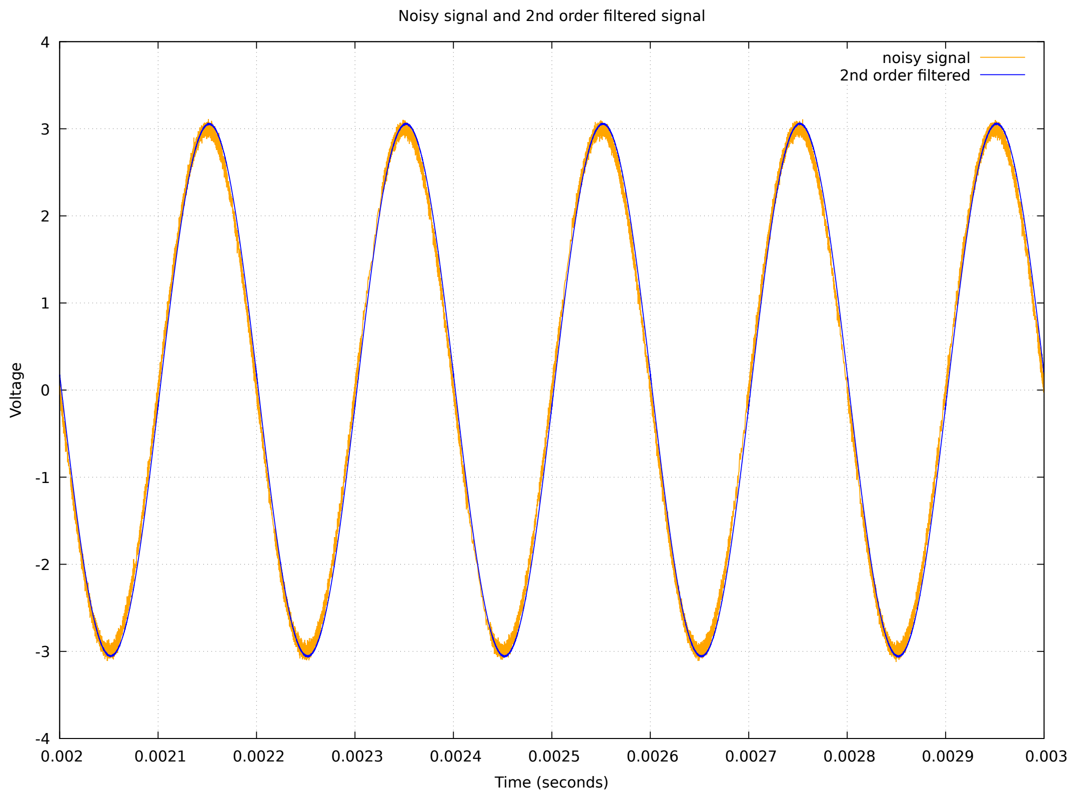

2nd Order Filter
4
2
0
-2
-4
Voltage
0.002
0.0021
0.0022
0.0023
0.0024
0.0025
0.0026
0.0027
0.0028
0.0029
0.003
Time (seconds)

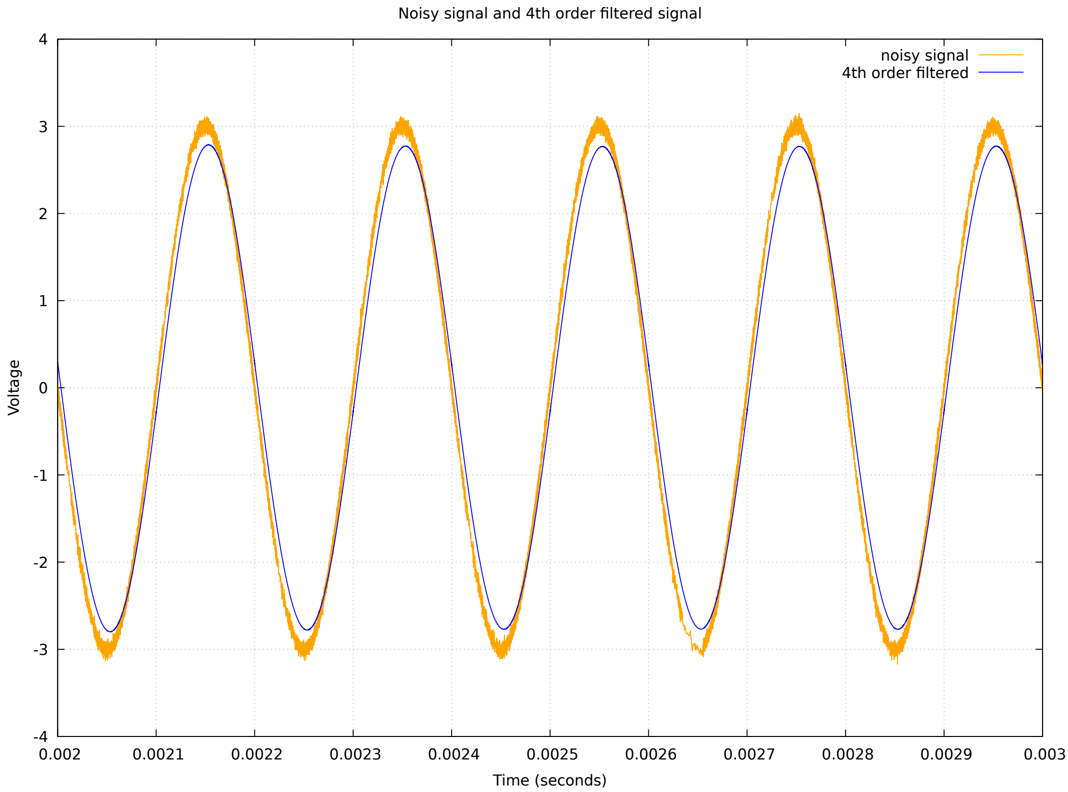

2nd Order Filter (zoomed)
3.06
3.04
3.02
3
2.98
2.96
Voltage
0.00244
0.00245
0.00245
0.00245
0.00245
0.00245
0.00246
0.00246
0.00246
Time (seconds)

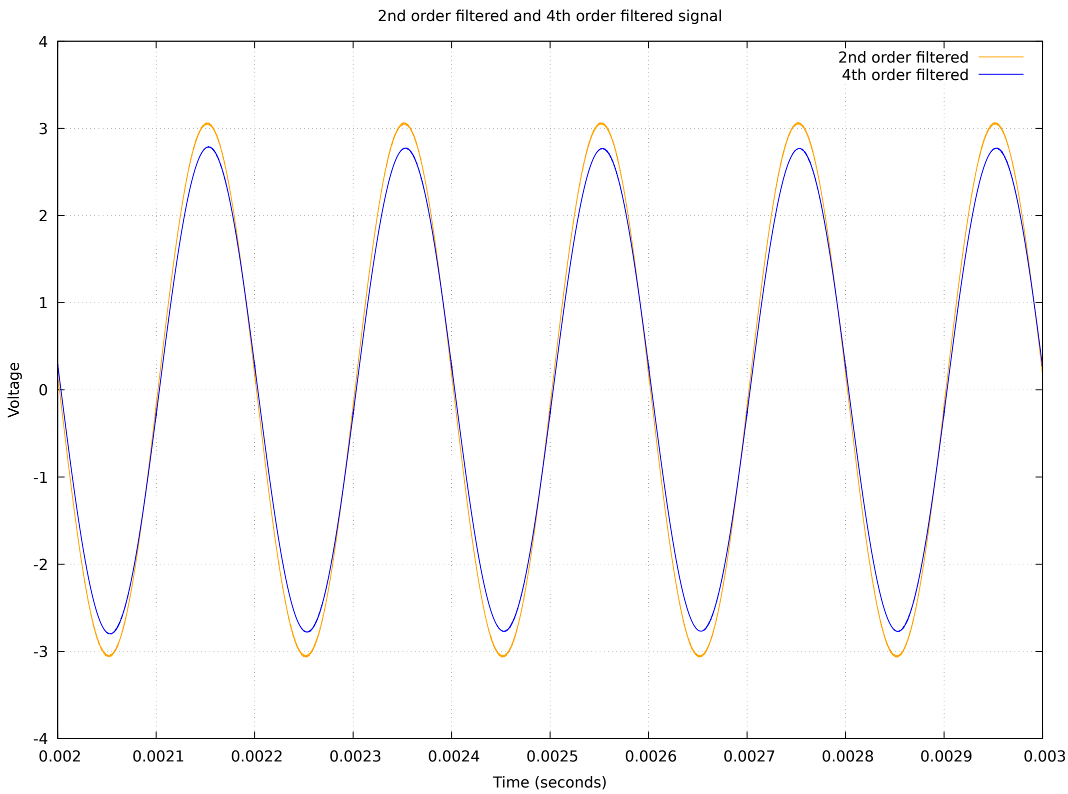

4th Order Filter
Voltage
4
2
0
-2
-4
0.002
0.0021
0.0022
0.0023
0.0024
0.0025
0.0026
0.0027
0.0028
0.0029
0.003
Time (seconds)


4th Order Filter (zoomed)
Voltage
2.76
2.74
2.72
2.7
2.68
0.00235
0.00235
0.00235
0.00235
0.00235
0.00236
0.00236
0.00236
0.00236
Time (seconds)


Clean and noisy signal
noisy signal
clean signal
Voltage
Time (seconds)
4
3
2
1
0
-1
-2
-3
-4
0
0.0002
0.0004
0.0006
0.0008
0.001


Noisy signal and 2nd order filtered signal
noisy signal
2nd order filtered
Voltage
Time (seconds)
4
3
2
1
0
-1
-2
-3
-4
0.002
0.0021
0.0022
0.0023
0.0024
0.0025
0.0026
0.0027
0.0028
0.0029
0.003


Noisy signal and 4th order filtered signal
noisy signal
4th order filtered
Voltage
Time (seconds)
4
3
2
1
0
-1
-2
-3
-4
0.002
0.0021
0.0022
0.0023
0.0024
0.0025
0.0026
0.0027
0.0028
0.0029
0.003


2nd order filtered and 4th order filtered signal
2nd order filtered
4th order filtered
Voltage
Time (seconds)
4
3
2
1
0
-1
-2
-3
-4
0.002
0.0021
0.0022
0.0023
0.0024
0.0025
0.0026
0.0027
0.0028
0.0029
0.003

Discussion

The results were as expected. The clean signal and the noise signal graphed as expected. The summing amplifier worked correctly in combining the clean and noise signal, as can be seen on the "Clean + noise" graph. The 2nd order filter at first appeared to have removed all noise, but a zoom in shows still perceptible noise in the original signal, although highly attenuated. The 4th order filter has a higher roll off and thus was able to reduce the noise to imperceptible levels. From the graphs, it can be seen that the 2nd order and 4th order filtered signals lag the original input signal. The 4th order filtered signal lags more than the 2nd order filtered signal. This is expected due to the capacitors in the filter circuits, which take time to charge and discharge. The 4th order filter shows a greater lag due to using more capacitors. The 4th order filter also displays a small amount of attenuation of the desired original signal, as compared to the 2nd order filter which doesn't. This is likely attributable to the higher roll off of the 4th order filter compared to the 2nd order filter. This can be seen in the graphs comparing the filtered signals to their input signal. It shows the 2nd order signal having the same amplitude as the original input signal, while the 4th order signal shows a reduction of a few hundred millivolts. This also demonstrates the tradeoffs involved with higher order filters, with higher order filters having more lag and being more likely to attenuate desired frequencies. They also require more components as seen with the 4th order filter requiring twice as many components in the circuit diagram as compared to the 2nd order filter. filter.

Conclusion

The experiment demonstrated the operating characteristics of active bandpass filters. It showed the creation of a noisy signal with a summing amplifier, and the action of filters on the noisy signal. It demonstrated the differences between a 2nd order filter and 4th order filtering. The sharper roll off of the higher order filter led to the benefit of increased noise reduction along with the downside of partially attenuating the desired signal. It also demonstrated the time lag on the output signals of active filters due to the reactive components used to construct them.