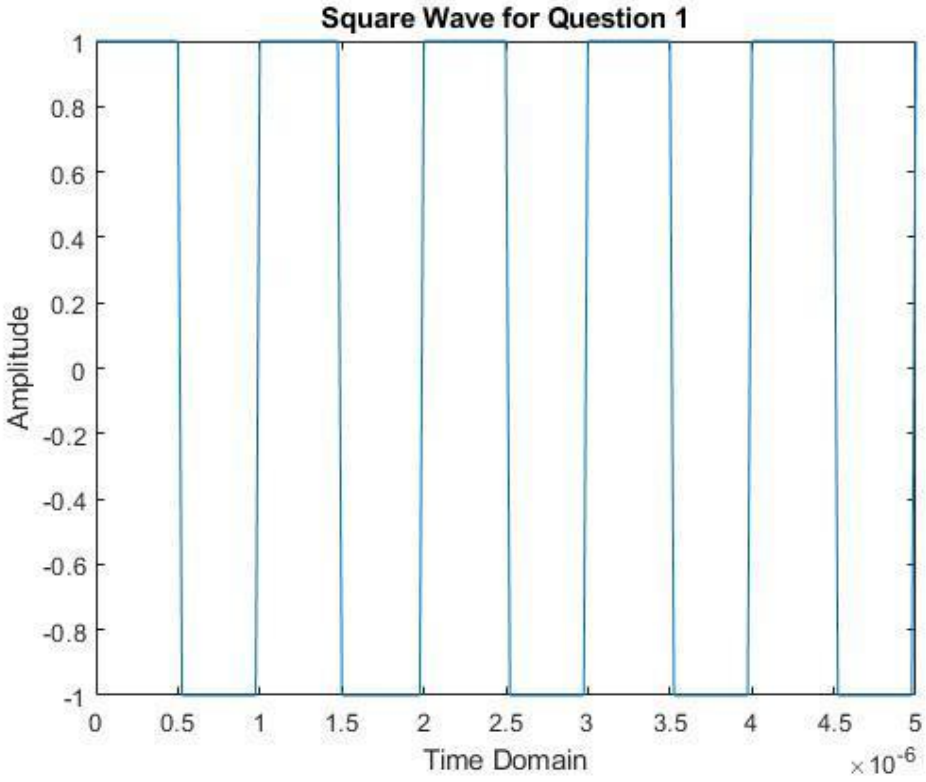
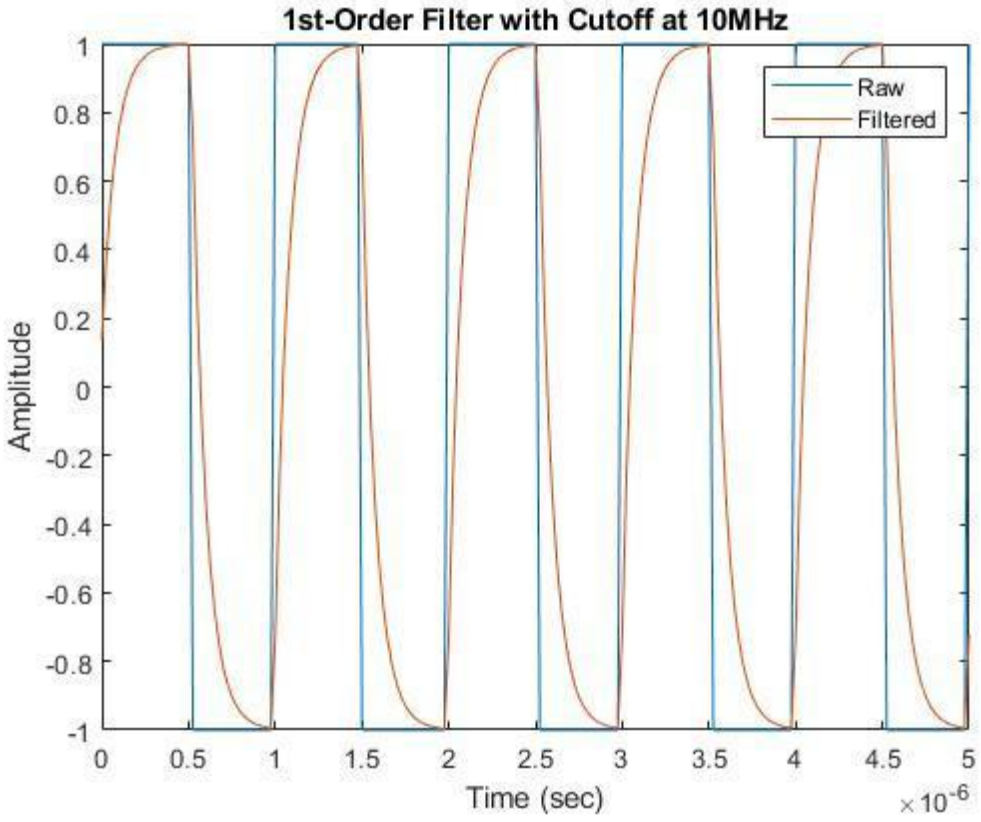
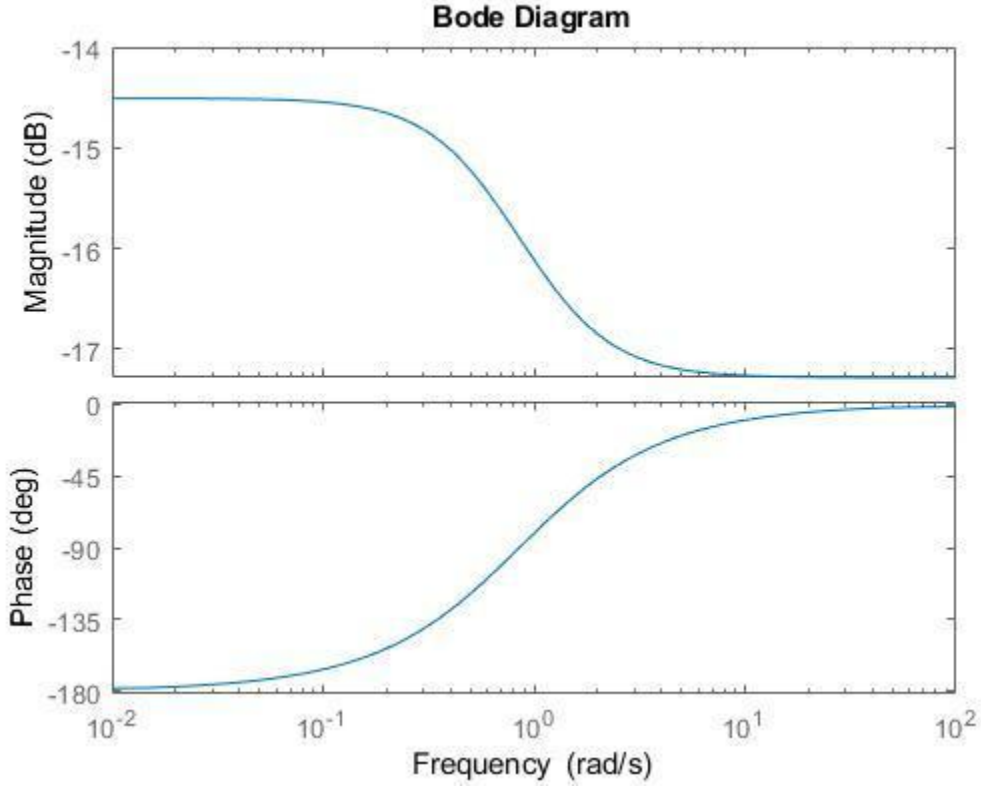
Sean O’Brien – 213735741

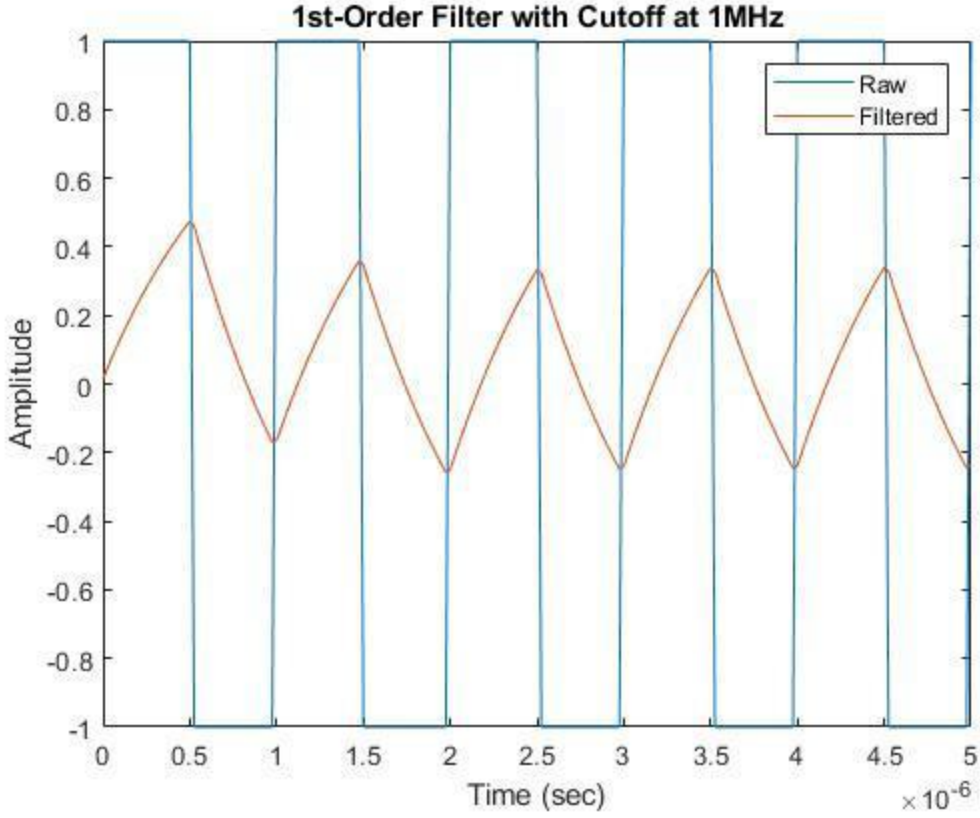
EECS 4214: Digital Communications - Amir M. Sodagar

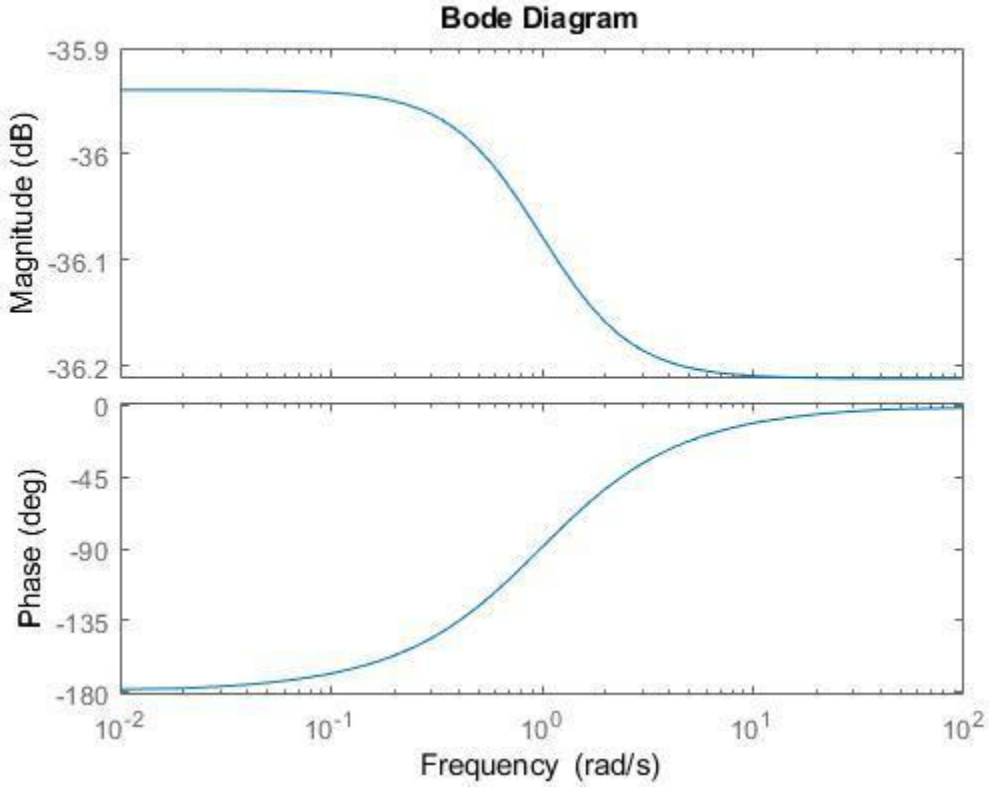
Lab 3: Transmission of Signals through Linear Systems

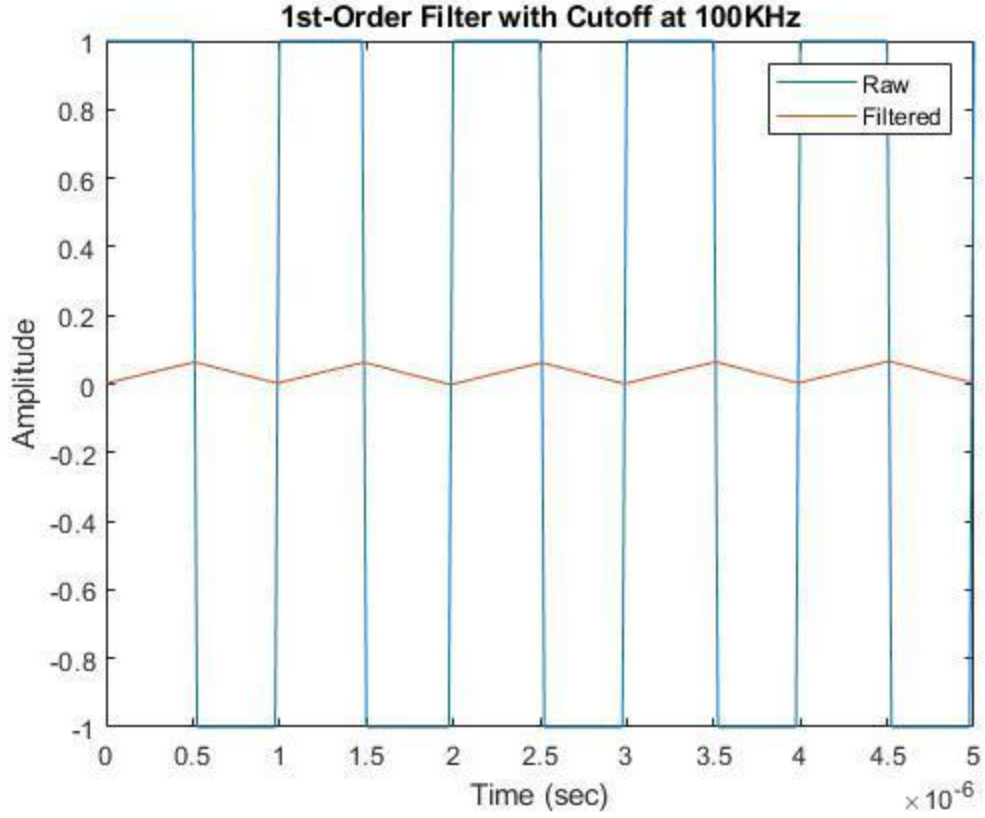

Square Wave for Question 1
Amplitude
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
Time Domain
×10^-6

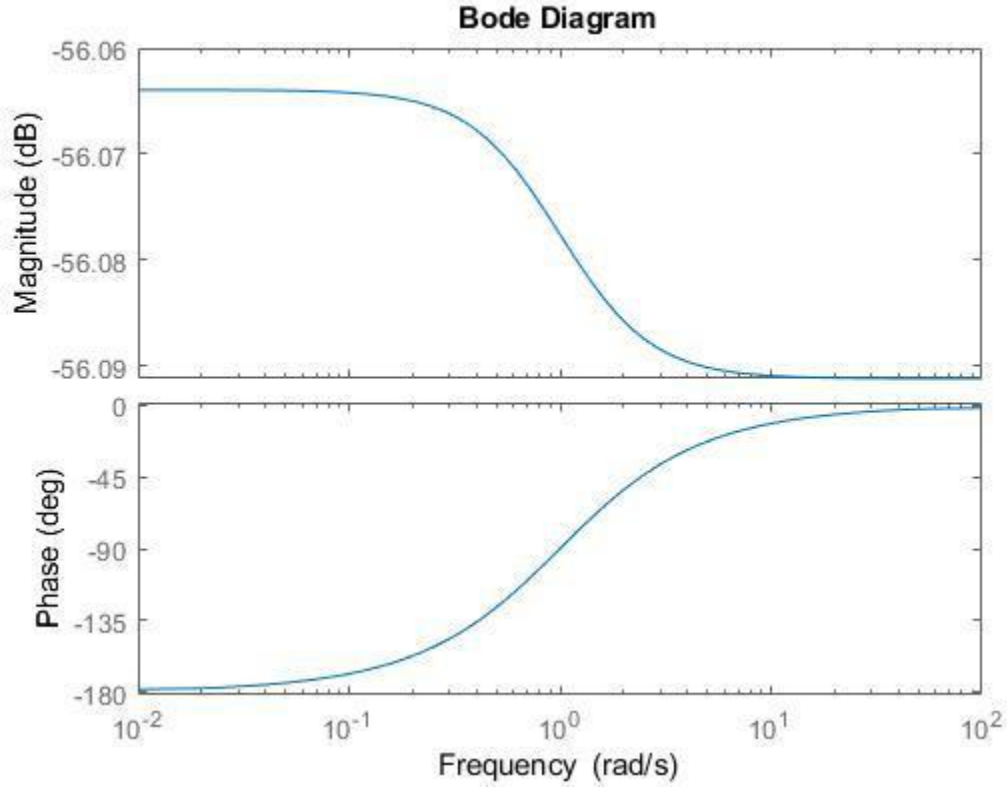

1st-Order Filter with Cutoff at 10MHz
Raw
Filtered
Amplitude
Time (sec)
×10^-6

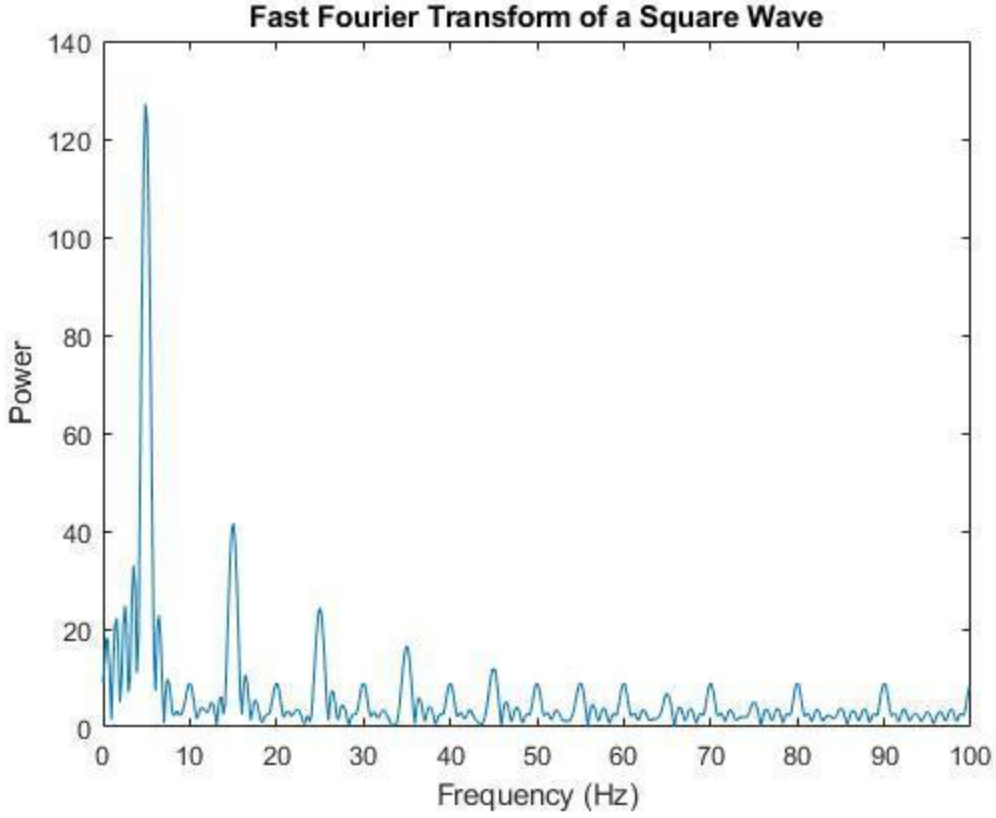

Bode Diagram
Magnitude (dB)
Phase (deg)
Frequency (rad/s)

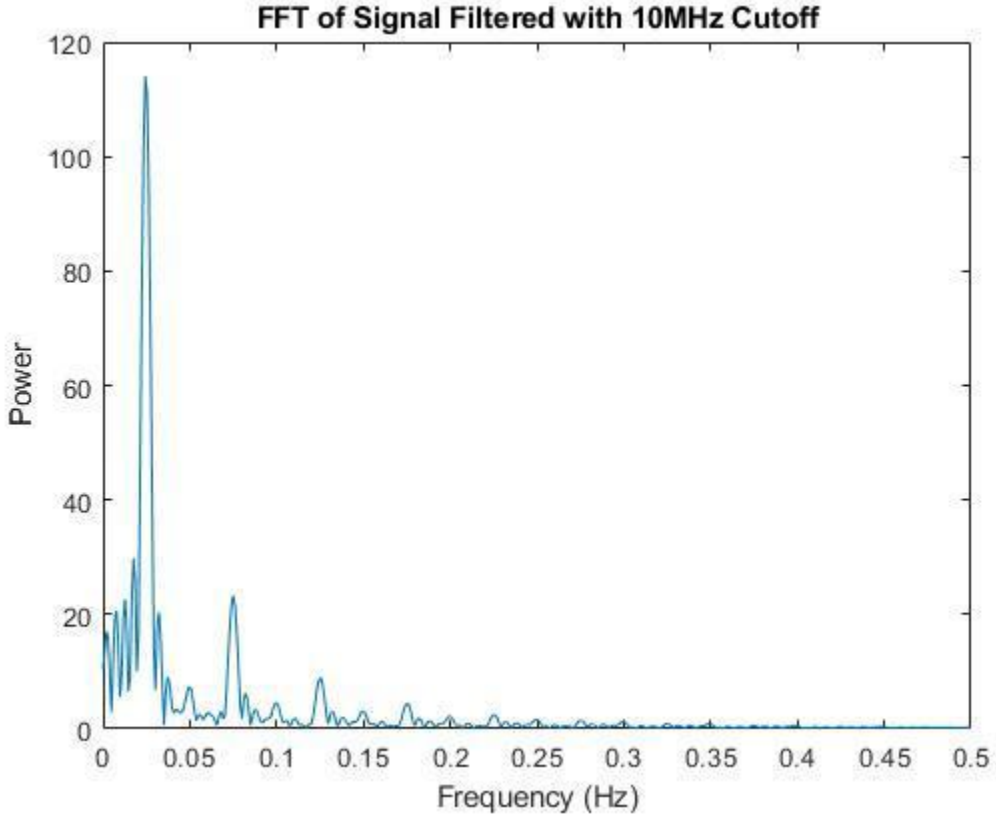

1st-Order Filter with Cutoff at 1MHz
Raw
Filtered
Amplitude
Time (sec)
× 10^-6

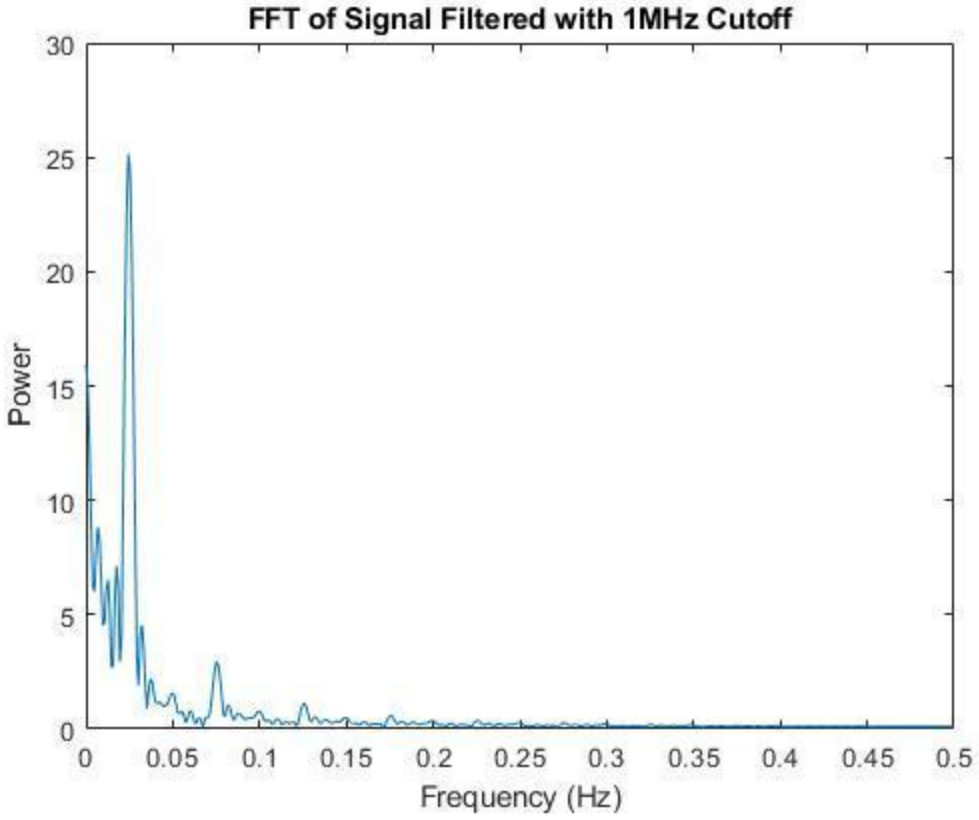

Bode Diagram
Magnitude (dB)
Phase (deg)
Frequency (rad/s)

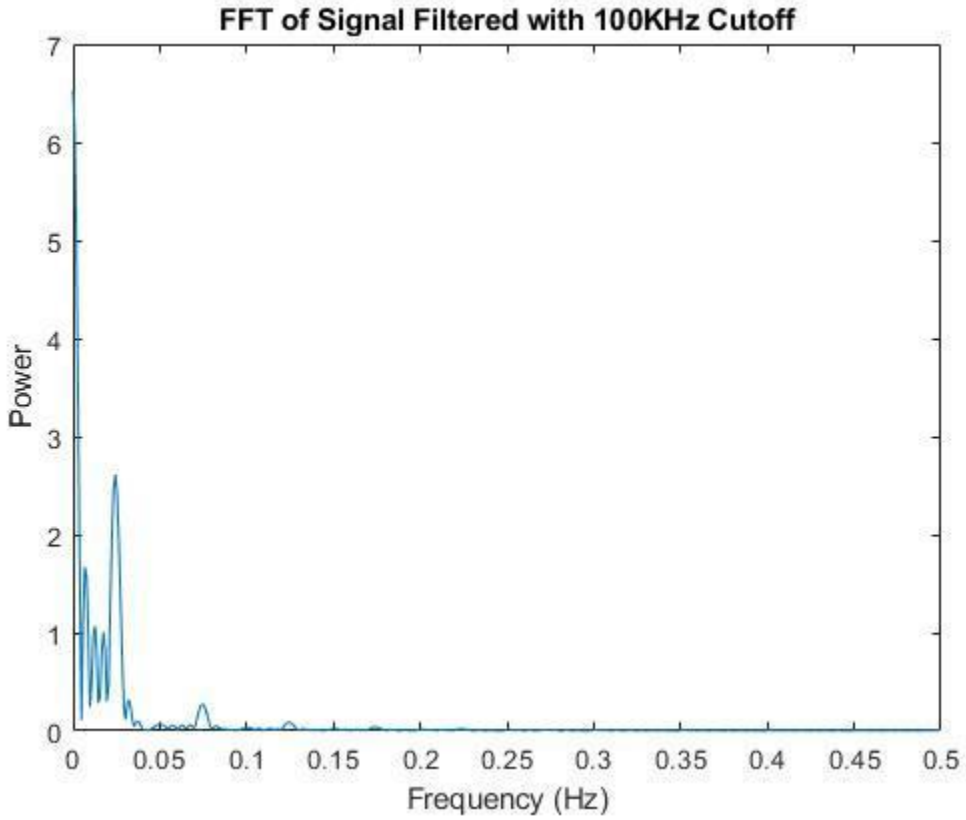

1st-Order Filter with Cutoff at 100KHz
Raw
Filtered
Amplitude
Time (sec)
× 10^-6


Bode Diagram
Magnitude (dB)
Phase (deg)
Frequency (rad/s)

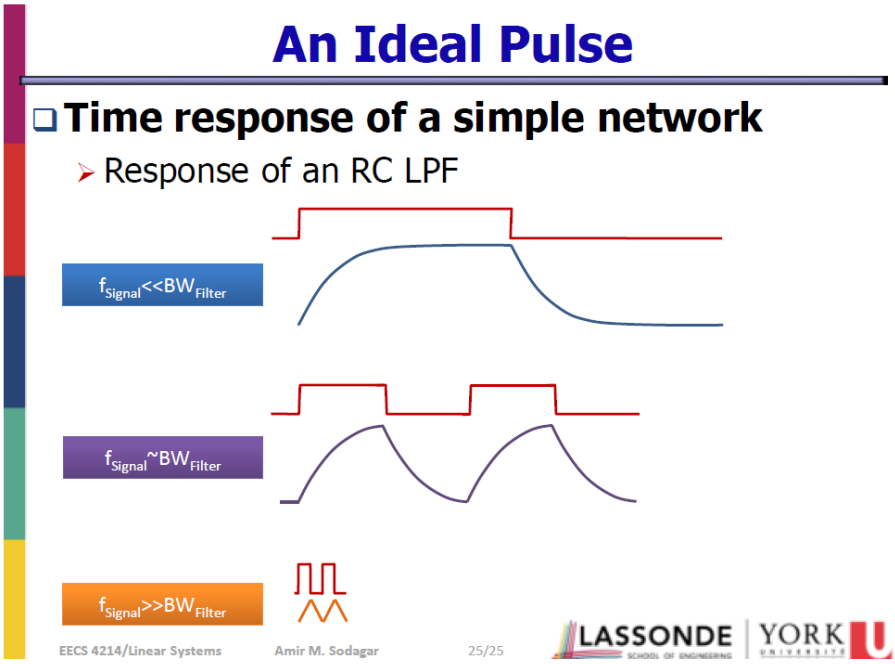

Fast Fourier Transform of a Square Wave
Power
Frequency (Hz)
0
20
40
60
80
100
120
140
0
10
20
30
40
50
60
70
80
90
100


FFT of Signal Filtered with 10MHz Cutoff
Power
Frequency (Hz)
0
20
40
60
80
100
120
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5


FFT of Signal Filtered with 1MHz Cutoff
Power
Frequency (Hz)
0
5
10
15
20
25
30
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5


FFT of Signal Filtered with 100KHz Cutoff
Power
Frequency (Hz)
0
1
2
3
4
5
6
7
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5

Upon analyzing the filters, we can see through plotting in the time domain that our changing the cut-off frequency has a significant effect on the output waveform. The changes in the waveform match the description in the lecture slides.



As you can see, for the cutoff frequency 10MHz, we have a waveform shape matching the F << BW, which is true in this case since the signal frequency is 1MHz. As the cut-off frequency becomes smaller, the waveform becomes more triangular and with less amplitude, which is true in my graphs as well. The magnitude of the bode diagrams changes with a changing cut-off frequency, but the phase stays the same.

2.

$$\tau = RC = \frac{1}{2\pi f_c} = \frac{1}{2\pi \cdot 1MHz} = 0.000000159$$

Lab 3

Time From -0.4 to $0.4V$ + Time From 0.4 to $-0.4V$

$$-0.4 = 1V\left(1 - e^{\frac{-t}{RC}}\right) \qquad 0.4V = 1V\left(1 - e^{-t/1MHz}\right)$$

$$-1.4 = -e^{-t/1MHz}$$

$$\ln 1.4 = \frac{-t}{0.000000159} \ln e \qquad -0.6 = -e^{-t/1MHz}$$

$$\ln 0.6 = \frac{-t}{0.000000159}$$

$$-0.000000053 = t_1 \qquad t_2 = 0.000000081$$

$$0.4V = 1V\left(1 - e^{-T/RC}\right) e^{\frac{-t-T}{RC}} \qquad T = \frac{1}{f} = \frac{1}{1MHz} = 0.000001$$

$$0.4V = 1V(1 - 6.29)\, e^{\frac{-t - 0.000001}{0.000000159}}$$

$$-\ln 0.0156 = \frac{-t - 0.000001}{0.000000159} \qquad \ln 0.0756 \cdot 0.000000589 = -t - 0.000001$$

$$t_3 = -0.000000589 \qquad t_4 = 0.000000521$$

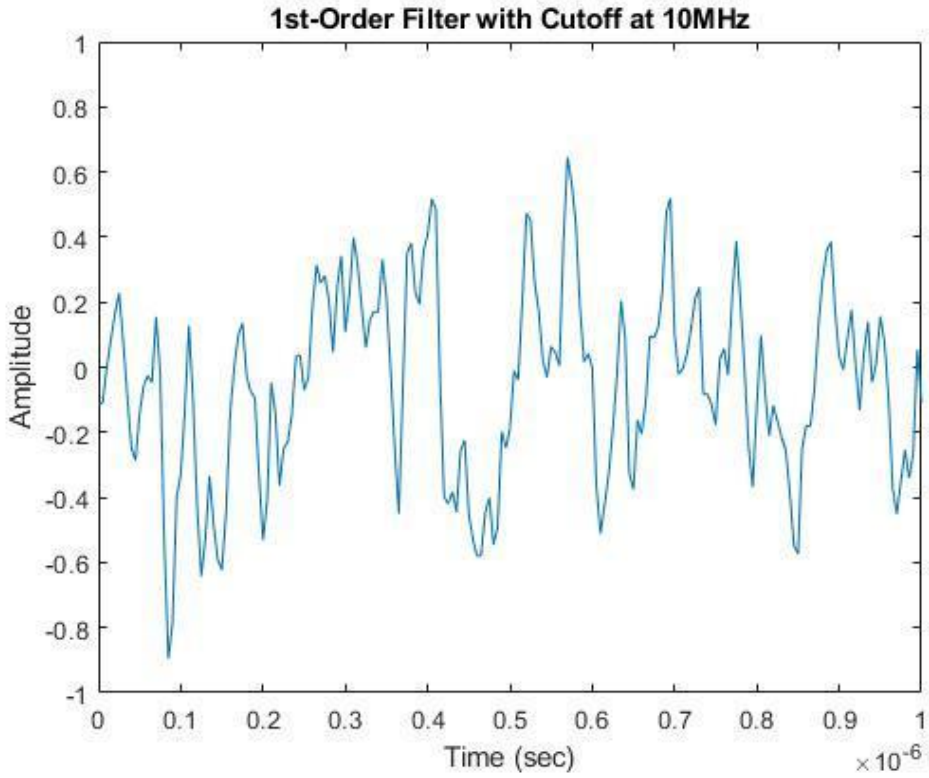
$$t_2 - t_1 = 0.000000134 \qquad t_4 - t_3 = 0.00000111$$

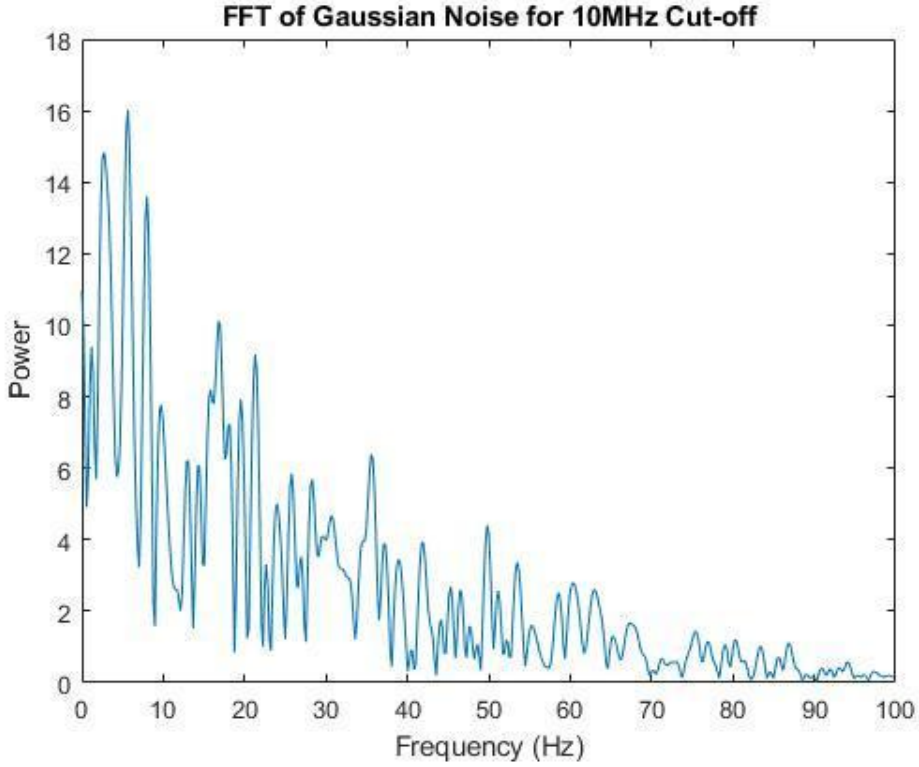
$$t_2 - t_1 + t_4 - t_3 = 0.000001244\,s/bit \rightarrow 803,858\,bits/s$$

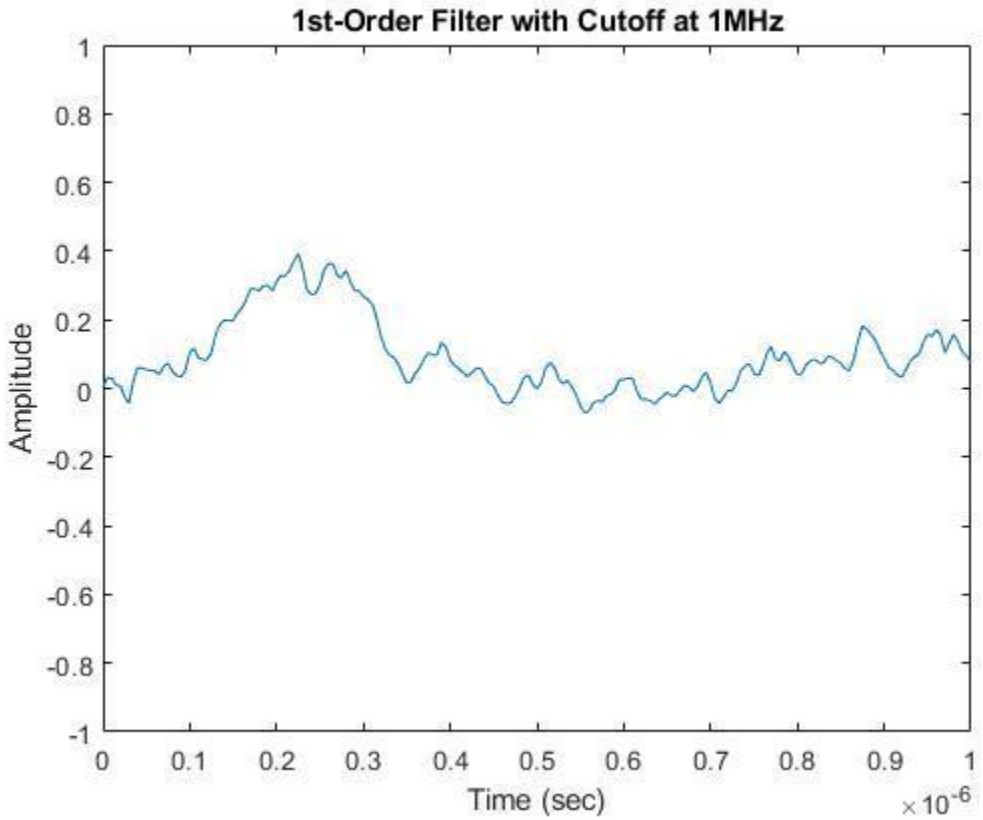
Using the matlab function stepinfo on my filter from the previous question, the time for rising from 0.3 to 0.7 is 0.5921. The time to descend from 0.7 back to 0.3 is

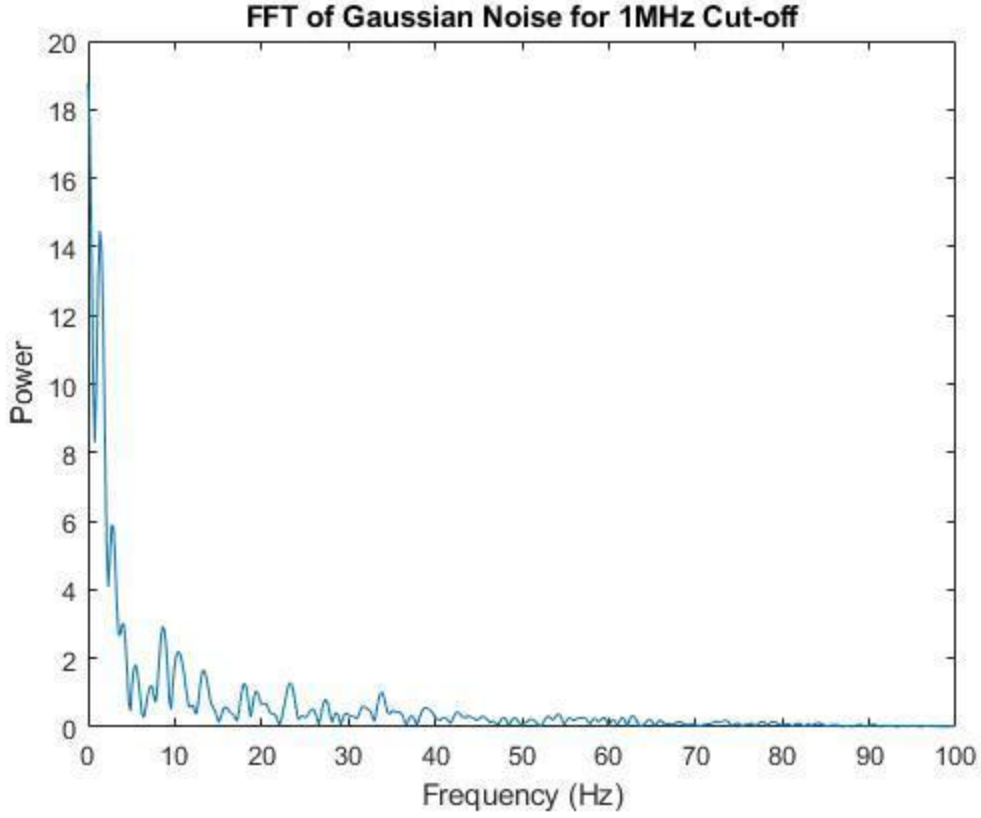
```
      RiseTime: 0.5921
  SettlingTime: 199.6350
   SettlingMin: -1.9692e-04
   SettlingMax: 0.0650
     Overshoot: 947.3130
    Undershoot: 3.1745
          Peak: 0.0650
      PeakTime: 181
```

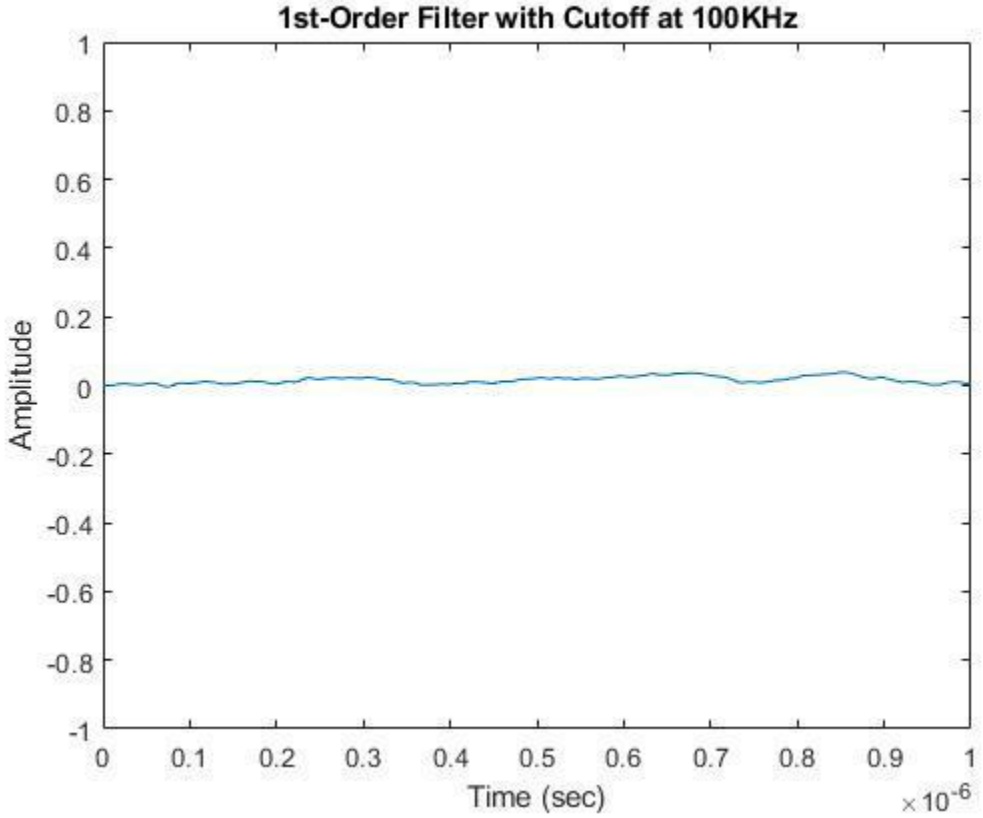
3.

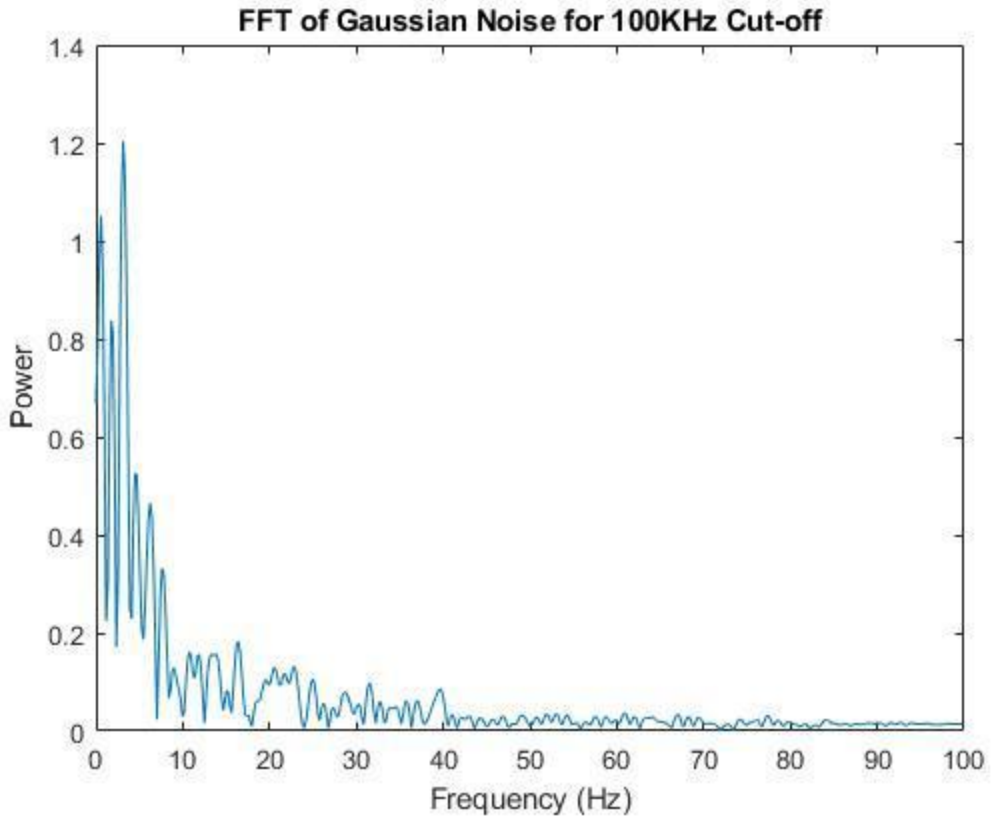

1st-Order Filter with Cutoff at 10MHz
Amplitude
Time (sec)
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
× 10^-6


FFT of Gaussian Noise for 10MHz Cut-off
Power
Frequency (Hz)
0
2
4
6
8
10
12
14
16
18
0
10
20
30
40
50
60
70
80
90
100


1st-Order Filter with Cutoff at 1MHz
Amplitude
Time (sec)
×10^-6
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1


FFT of Gaussian Noise for 1MHz Cut-off
Power
Frequency (Hz)
0
2
4
6
8
10
12
14
16
18
20
0
10
20
30
40
50
60
70
80
90
100

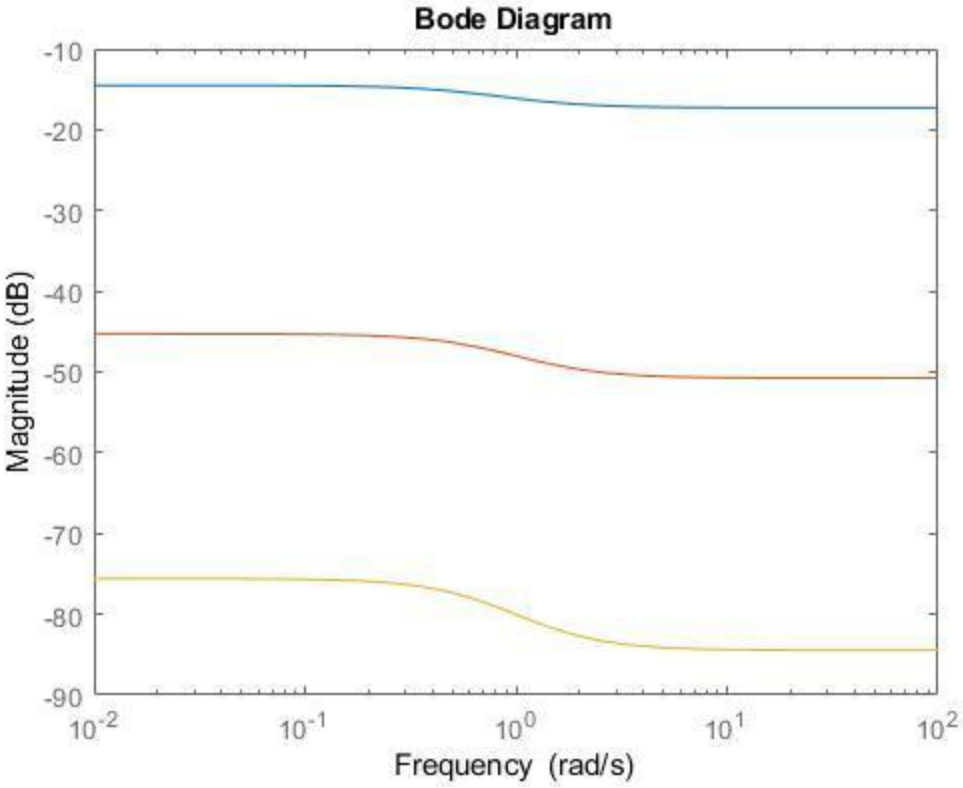

1st-Order Filter with Cutoff at 100KHz
Amplitude
Time (sec)
×10^-6
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1

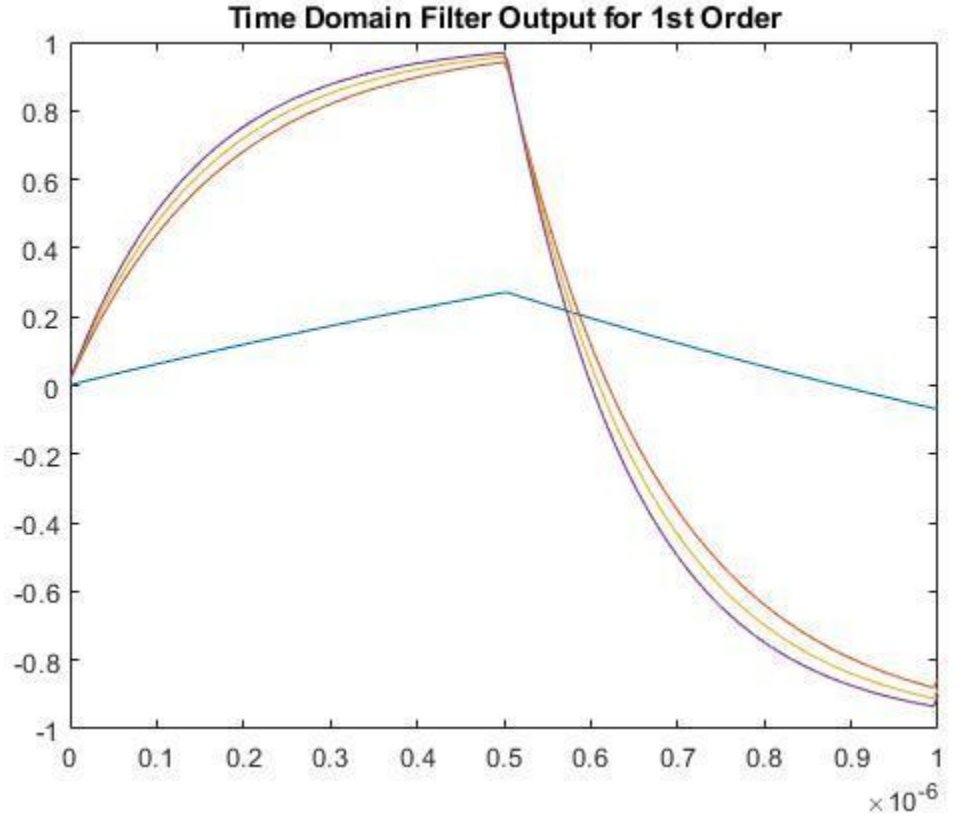


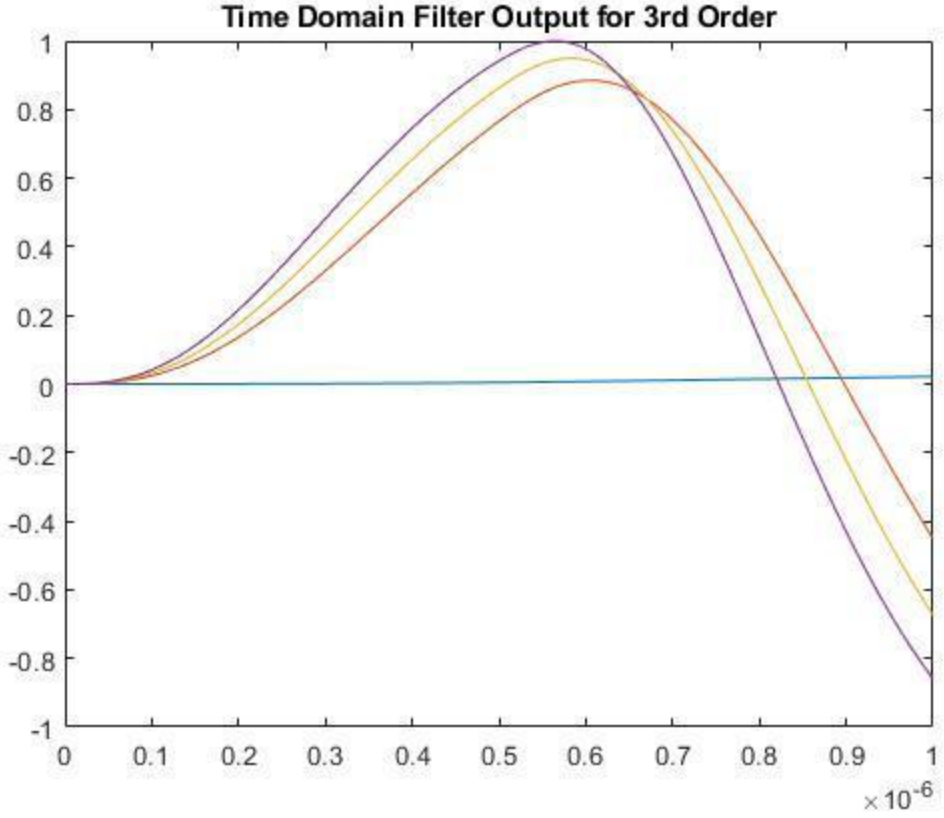
As the cut-off frequency is reduced, the amplitude of the frequencies present in the waveform goes down. This makes sense since this filter is a low pass filter, so decreasing the cut-off frequency means that less frequencies are being passed.

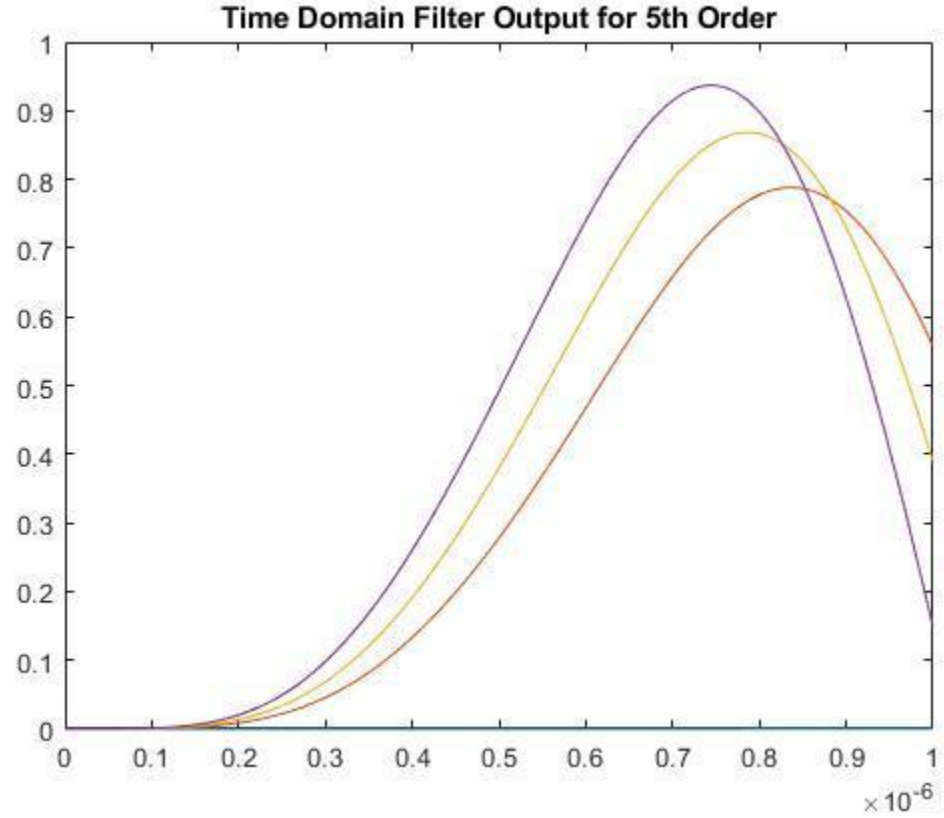
4.

Blue – 1st order(Highest), Red – 3rd order(Middle), Yellow – 5th order(Lowest)


Bode Diagram
Magnitude (dB)
-10
-20
-30
-40
-50
-60
-70
-80
-90
10^-2
10^-1
10^0
10^1
10^2
Frequency (rad/s)


Time Domain Filter Output for 1st Order
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
×10^-6


Time Domain Filter Output for 3rd Order
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
× 10-6


Time Domain Filter Output for 5th Order
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
× 10-6

The order differences appear to have a significant impact on the effect of the filter on input signals. The filters seem to shift towards the right indicating a longer cycle time. The shape of the waveforms becomes much less ideal as the order is increased as well. The largest frequency values deviate from the others in shape so much that it is hard to even keep them on the same graph.