University of Moratuwa

Department of Electronic and Telecommunication Engineering

BM4152

Bio-signal Processing

Assignment 2

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200664P

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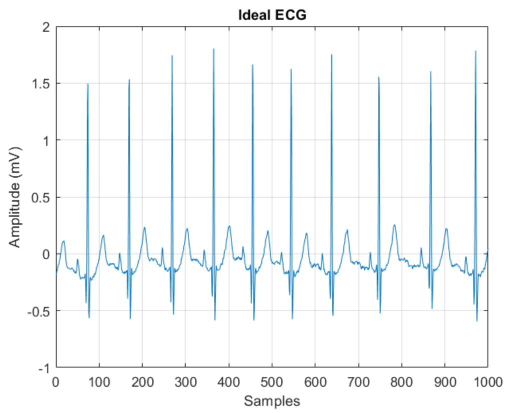
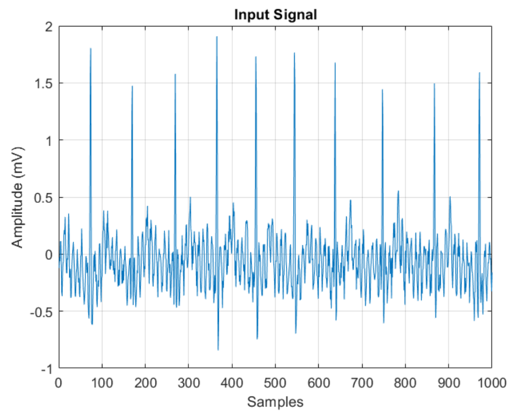
Optimum and Adaptive Filters

1. Weiner filtering

Data construction

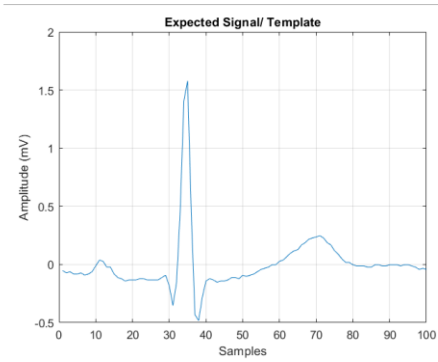
Zoomed versions of the data signals are added.

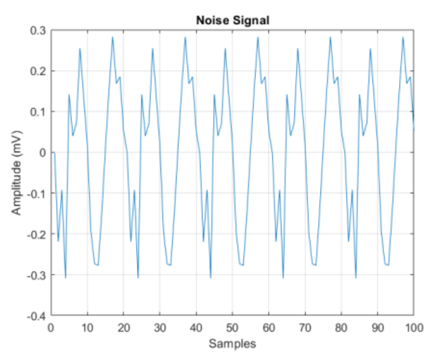




1.1 Discrete time-domain implementation of the Wiener filter

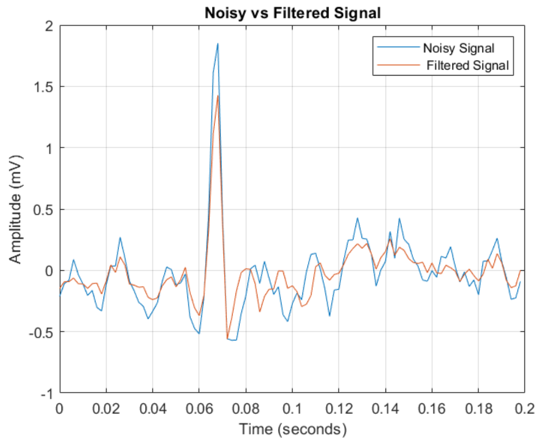
Part 1





Noise signal is the noise template extracted from the input ECG.

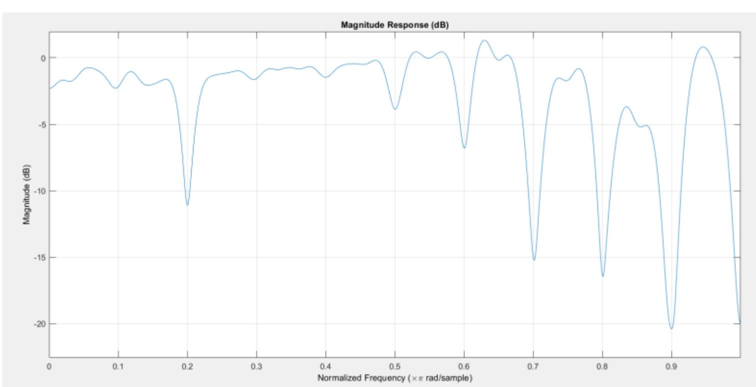
a) Weiner filtered signal for order = 25.



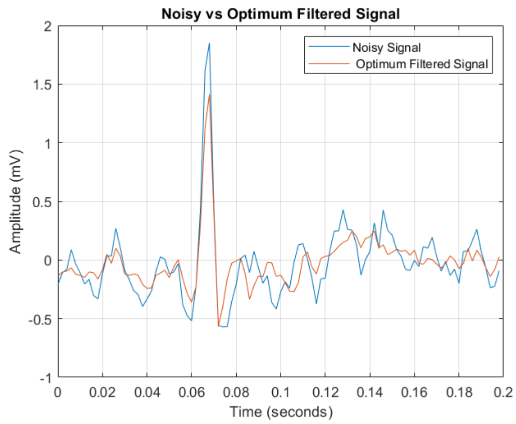
b) Calculating optimum order:

Optimum order for Weiner filter: 62

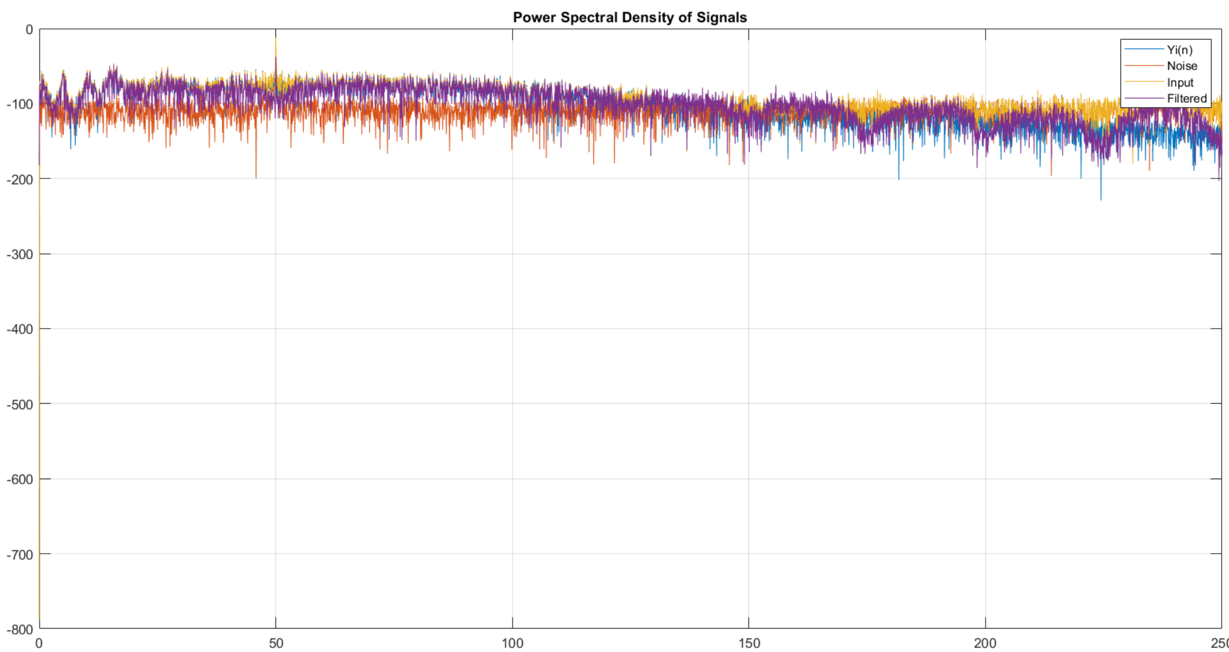
Magnitude response of optimum order filter:



c)


Noisy vs Optimum Filtered Signal
Noisy Signal
Optimum Filtered Signal
Amplitude (mV)
Time (seconds)
2
1.5
1
0.5
0
-0.5
-1
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16
0.18
0.2

d)


Power Spectral Density of Signals
Yi(n)
Noise
Input
Filtered
0
-100
-200
-300
-400
-500
-600
-700
-800
0
50
100
150
200
250

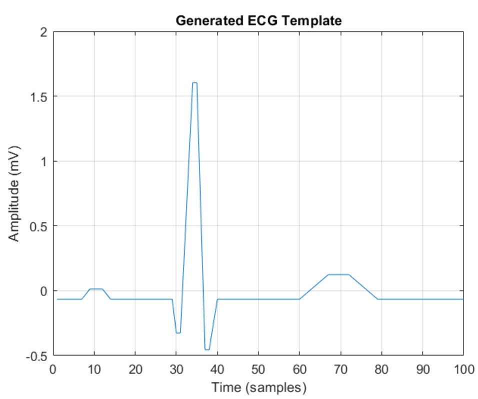
Zoomed:

e)

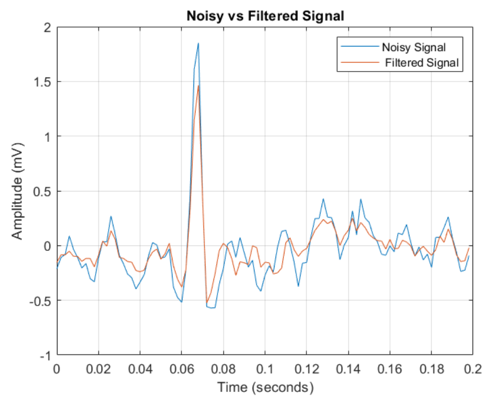
Since the added noise contained 50 Hz, noise, we can see a drop in the magnitude response at 50 Hz, and also in the power spectral density of the filtered signal at 50 Hz.

Also the ECG signal is only comprised of frequencies upto 150 Hz. The magnitude response shows that it has attenuated for higher frequencies which have been correctly identified as noise.

Part 2

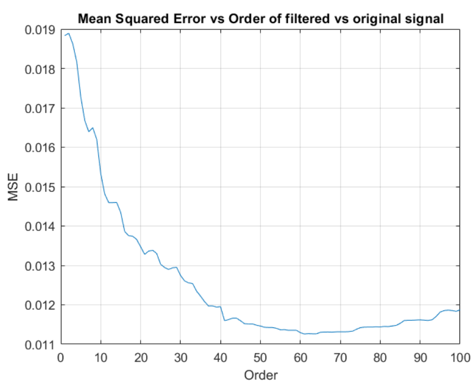


a)

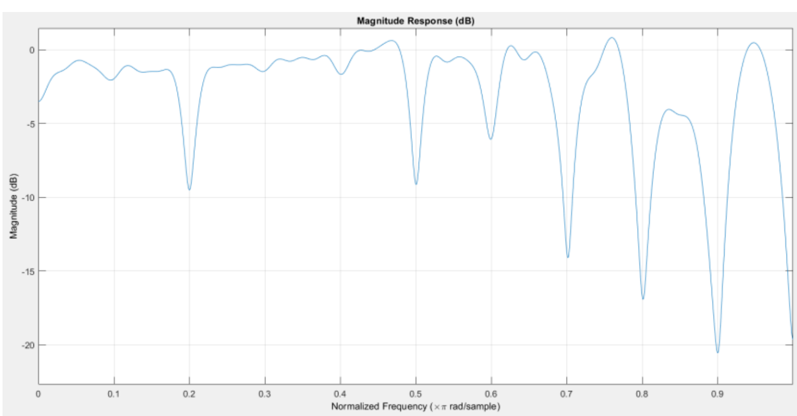


For order = 25

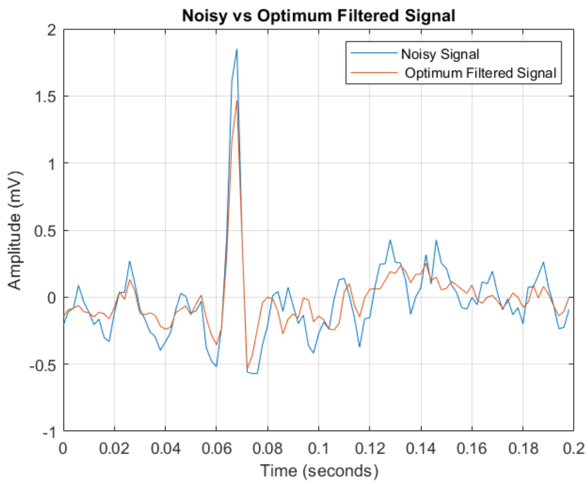
b)



Optimum order for Weiner filter with constructed ECG: 61

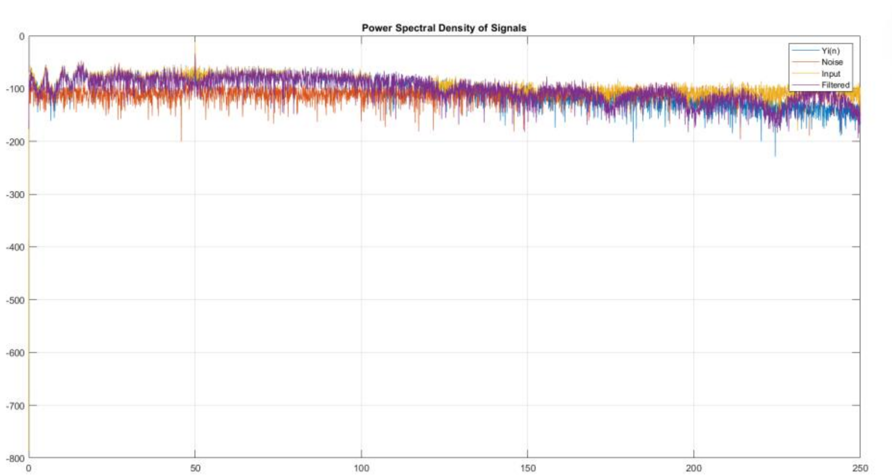


c)



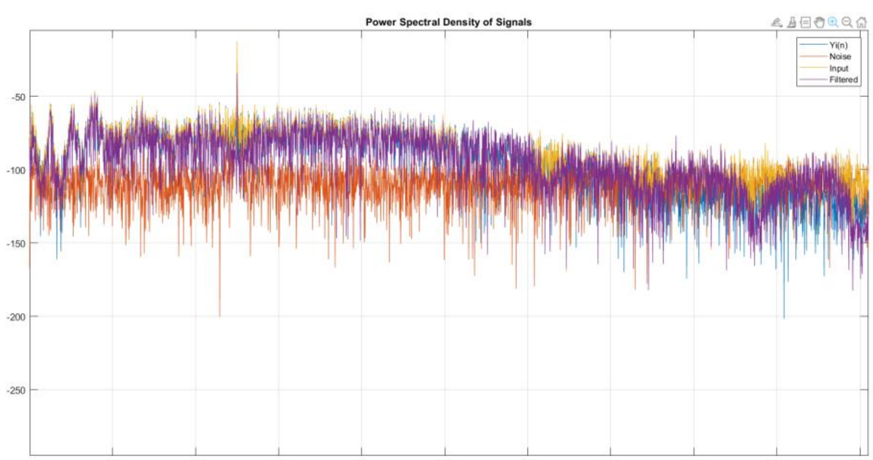
Noisy vs Optimum Filtered Signal
Noisy Signal
Optimum Filtered Signal
Amplitude (mV)
Time (seconds)
2
1.5
1
0.5
0
-0.5
-1
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16
0.18
0.2

d)



Power Spectral Density of Signals
Yi(n)
Noise
Input
Filtered
0
-100
-200
-300
-400
-500
-600
-700
-800
0
50
100
150
200
250

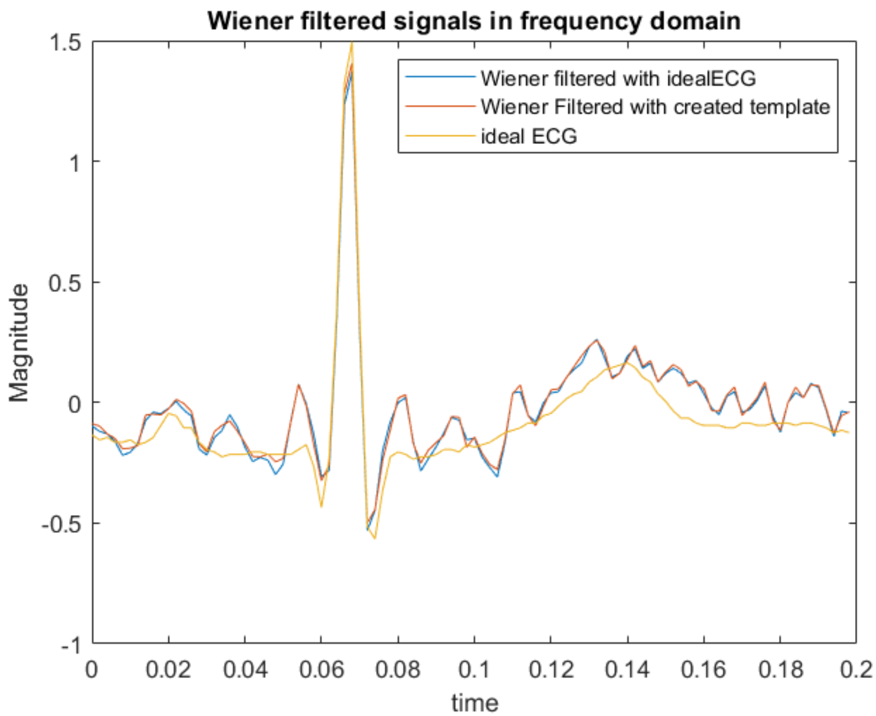
Zoomed:



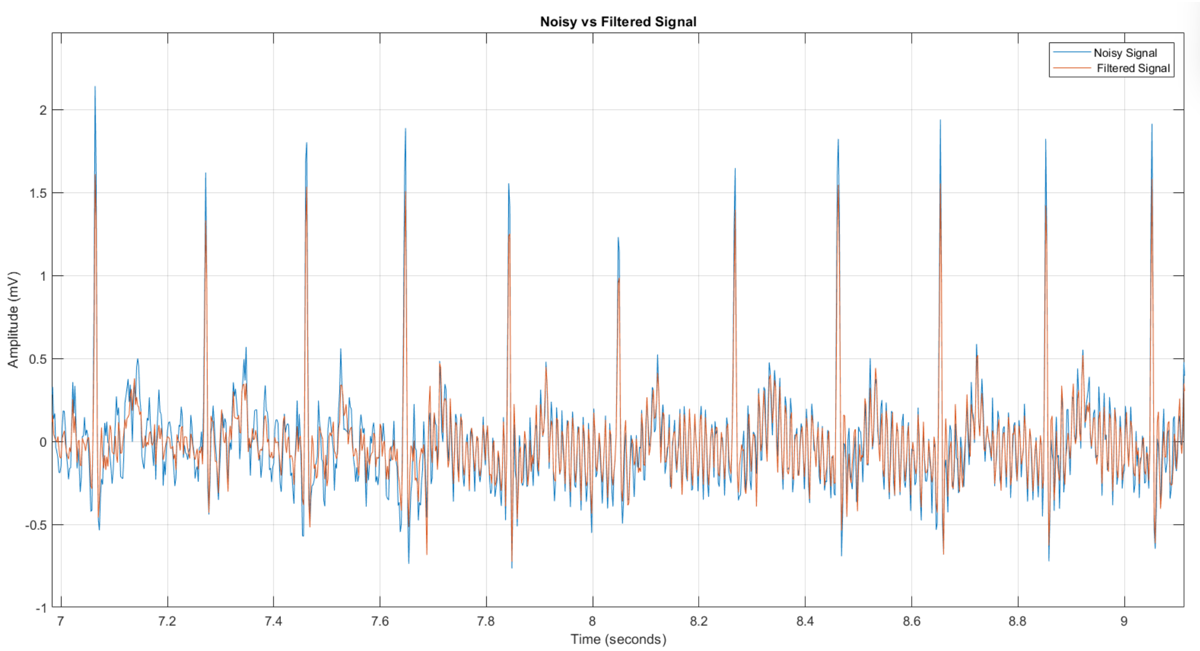
Power Spectral Density of Signals
Yi(n)
Noise
Input
Filtered
-50
-100
-150
-200
-250
20
40
60
80
100
120
140
160
180
200

A similar situation to the previous case is observed in the magnitude response and the power spectra. The noise at 50 Hz and at higher frequencies are identified and removed by the filter.

1.2 Frequency domain implementation of the Wiener filter



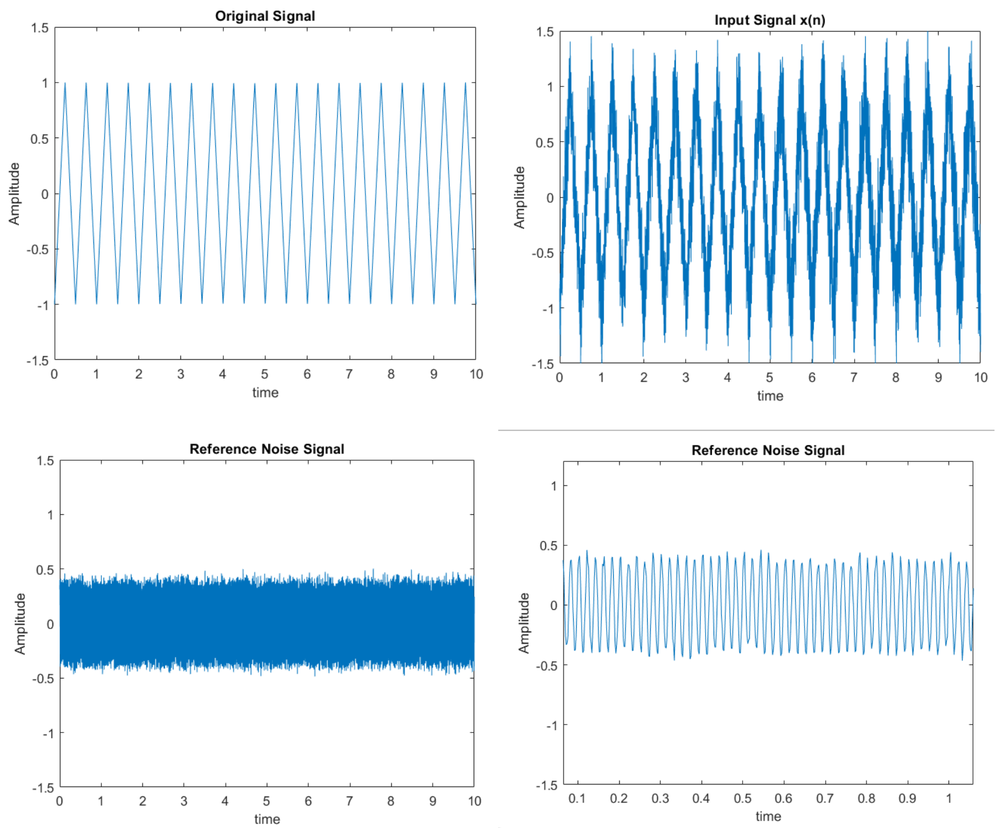
1.3 Effect on non-stationary noise on Wiener filtering



Even though the filter is successful at removing 50 Hz noise, the high frequency noise at 100 Hz, has not been filtered. This is because the Wiener filter has not adapted to the new noise, as it uses the same set of coefficients learnt from the known template noise to filter the signal. This known filter did not include 100 Hz noise.

2. Adaptive filtering

Data construction



Coefficients used:

snr = 10; (dB)

a = 0.2;

phi = pi/3;

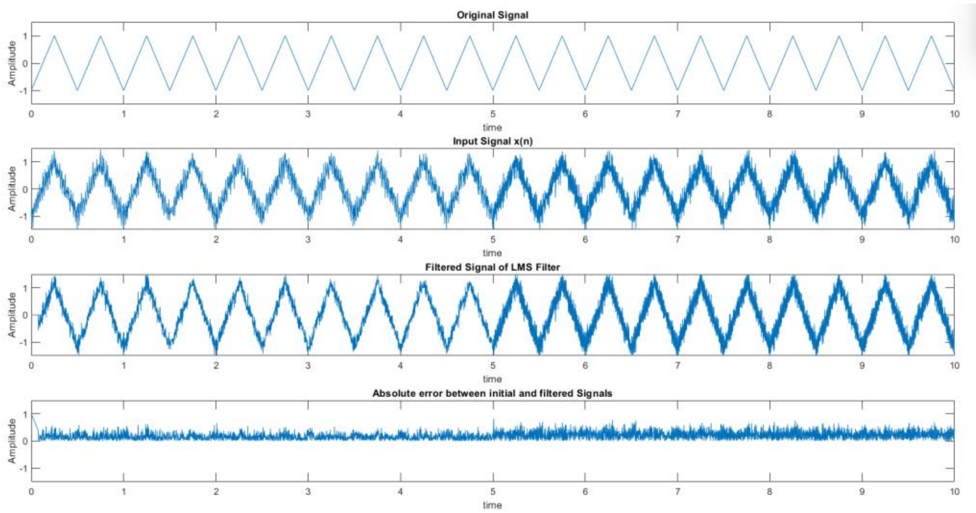
phi1 = pi/6;

phi2 = pi/4;

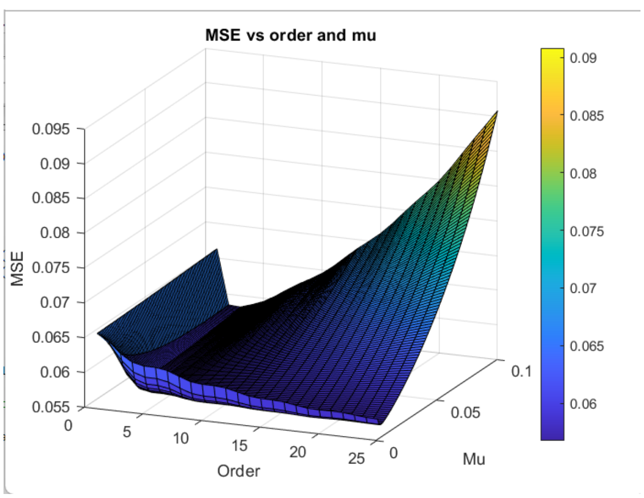
2.1 LMS method

b)

Order = 40; mu = 0.05;



c)



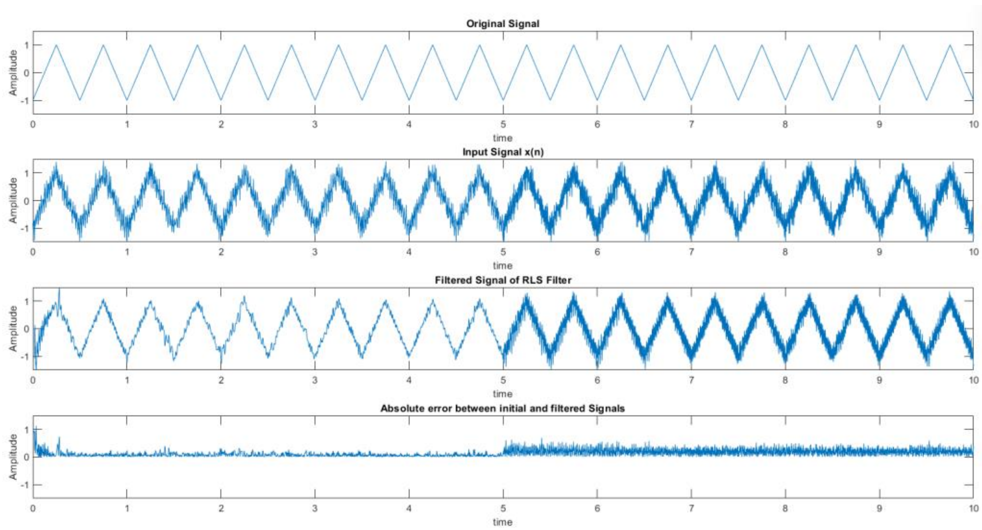
Optimum → Order: 9   Mu: 0.01

2.2 RLS method

a)

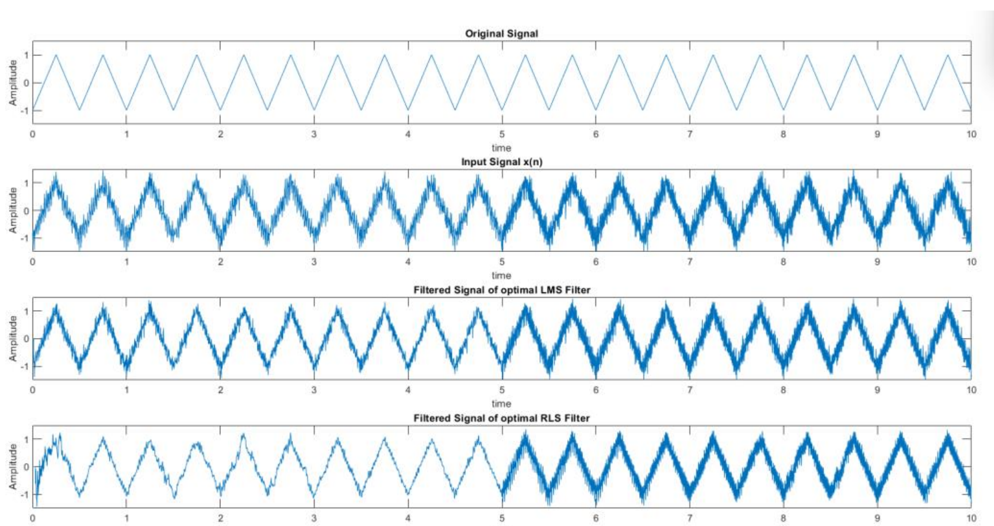
lambda = 0.999;

order = 10;

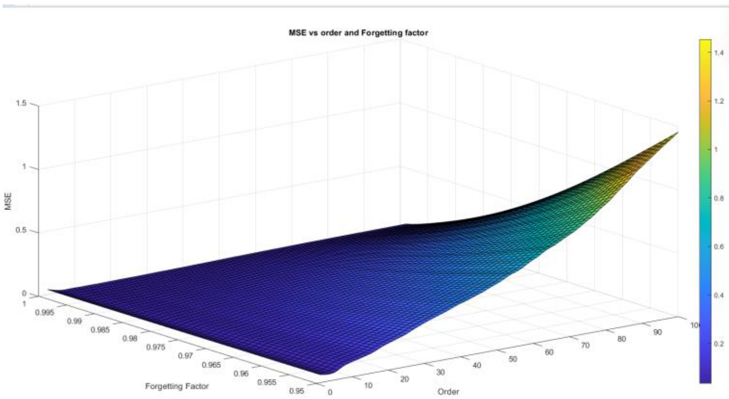


b)

Comparing performance:

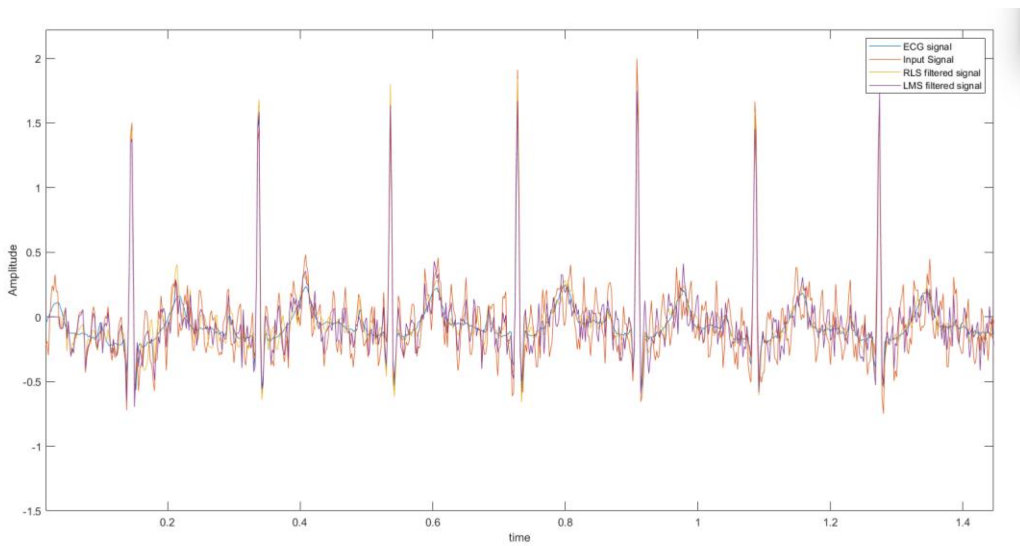


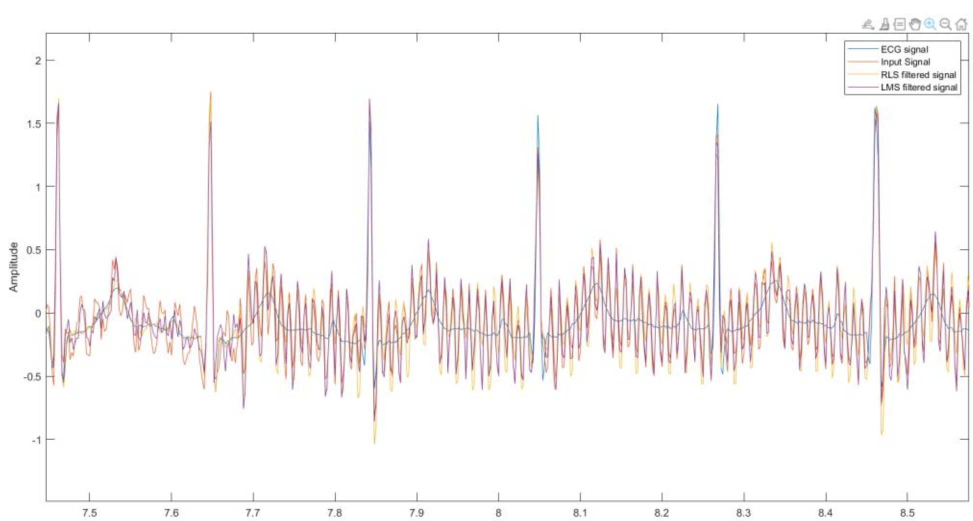
c)



Optimum → Order: 15 Mu: 0.999

d)





Here, RLS and LMS were filtered using the previous optimal parameters. We can see the optimal order of RLS filter is higher. However, also by observing the initial part and the region where the noise shifts, we can see that the RLS filter has adapted to the noise comparatively faster. This scenario can also be observed in the previously plotted sawtooth signals.