Homework 12 Solution

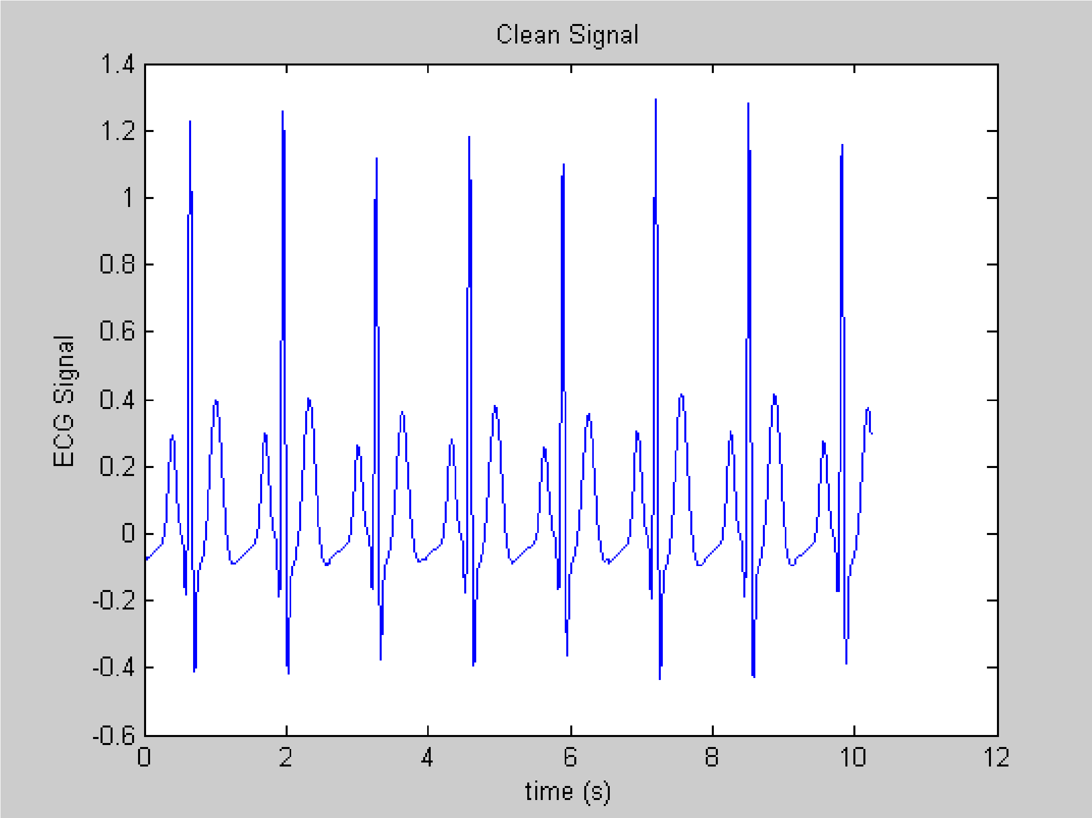
Contents

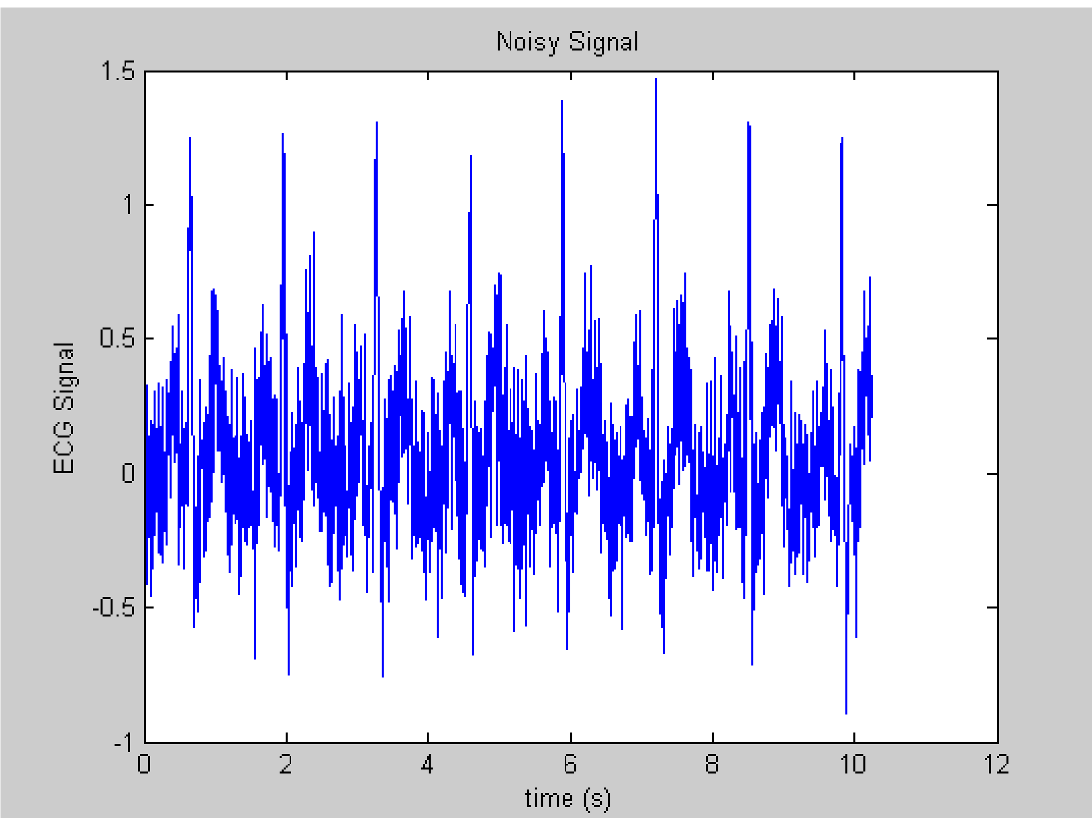
Problem 12.1

From the clean figure, the first heart beat is at s = 0.65s, and the second is at 9.82s. -> 7 heartbeats in 9.17 seconds = 7/9.17s * 60s/1min

```
clear
clc
close all

HeartRate = 7/9.17*60 %beats per minute

load HW12Signals.mat;
N = length(clean_sig);
fs = 200;
t = [0:1:(N-1)]/fs;
plot(t,clean_sig)
xlabel('time (s)')
ylabel('ECG Signal')
title('Clean Signal')

figure
plot(t,noisy_sig)
xlabel('time (s)')
ylabel('ECG Signal')
title('Noisy Signal')
```

```
HeartRate =

   45.8015
```

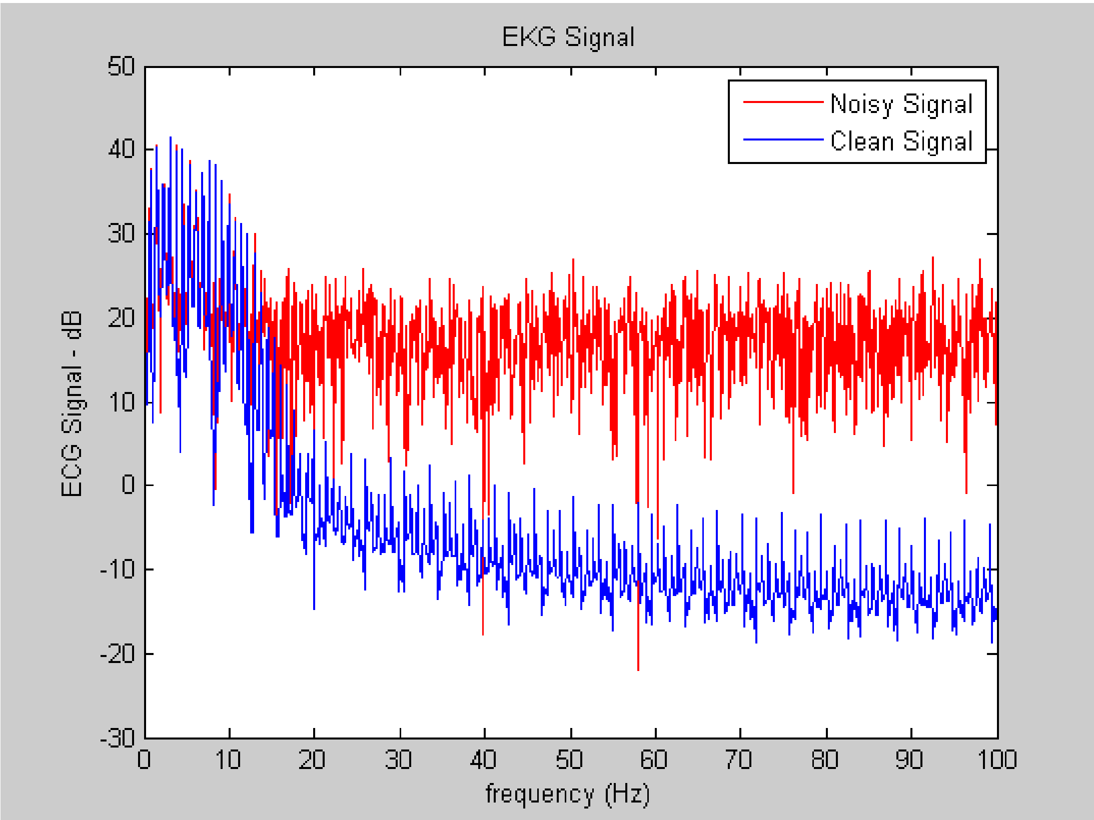




Problem 12.2

```
From the a plot of the frequency content, it might be logical to filter
all content above 23 Hz, and keep anything below 17 Hz.  Also, let
|H| in the passband be > 0.9, and |H| < 0.1 in the stop band
```

```
CLEAN_sig = fft(clean_sig);
NOISY_sig = fft(noisy_sig);
f = [0:1:N-1]*fs/N;

figure
plot(f(1:N/2),20*log10(abs(NOISY_sig(1:N/2))),'red')
hold on
plot(f(1:N/2),20*log10(abs(CLEAN_sig(1:N/2))))
xlabel('frequency (Hz)')
ylabel('ECG Signal - dB')
title('EKG Signal')
legend('Noisy Signal','Clean Signal')
```

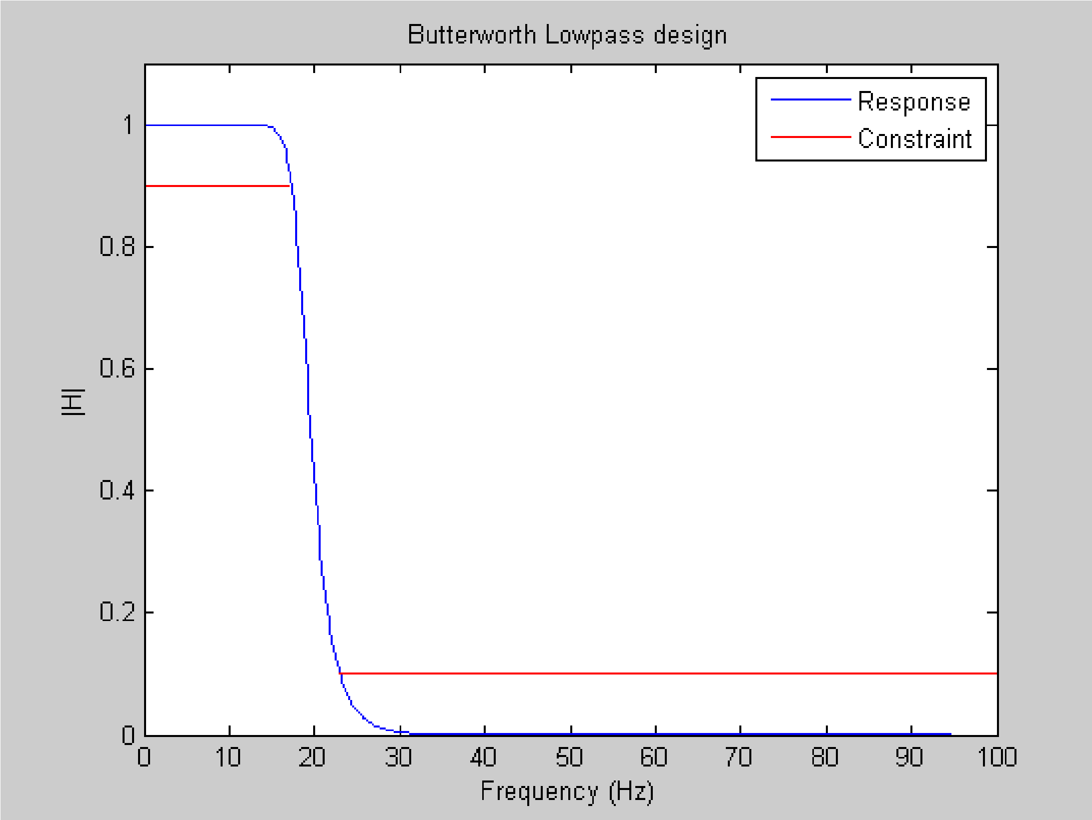


Problem 12.3

Butterworth filter design - red shows constraint, blue shows response

```
Wp = 2*pi*17/fs/pi
Ws = 2*pi*23/fs/pi
Rp = -20*log10(.9)
Rs = -20*log10(.1)
[n,Wn] = buttord(Wp,Ws,Rp,Rs)
[b_iir,a_iir] = butter(n,Wn)
[h,w] = freqz(b_iir,a_iir,[],fs);

figure
plot(w,abs(h))
hold on
plot([0 17], [0.9 0.9],'red', [23 100], [0.1 0.1],'red')
axis([0 100 0 1.1])
ylabel('|H|')
xlabel('Frequency (Hz)')
title('Butterworth Lowpass design')
legend('Response','Constraint')
```

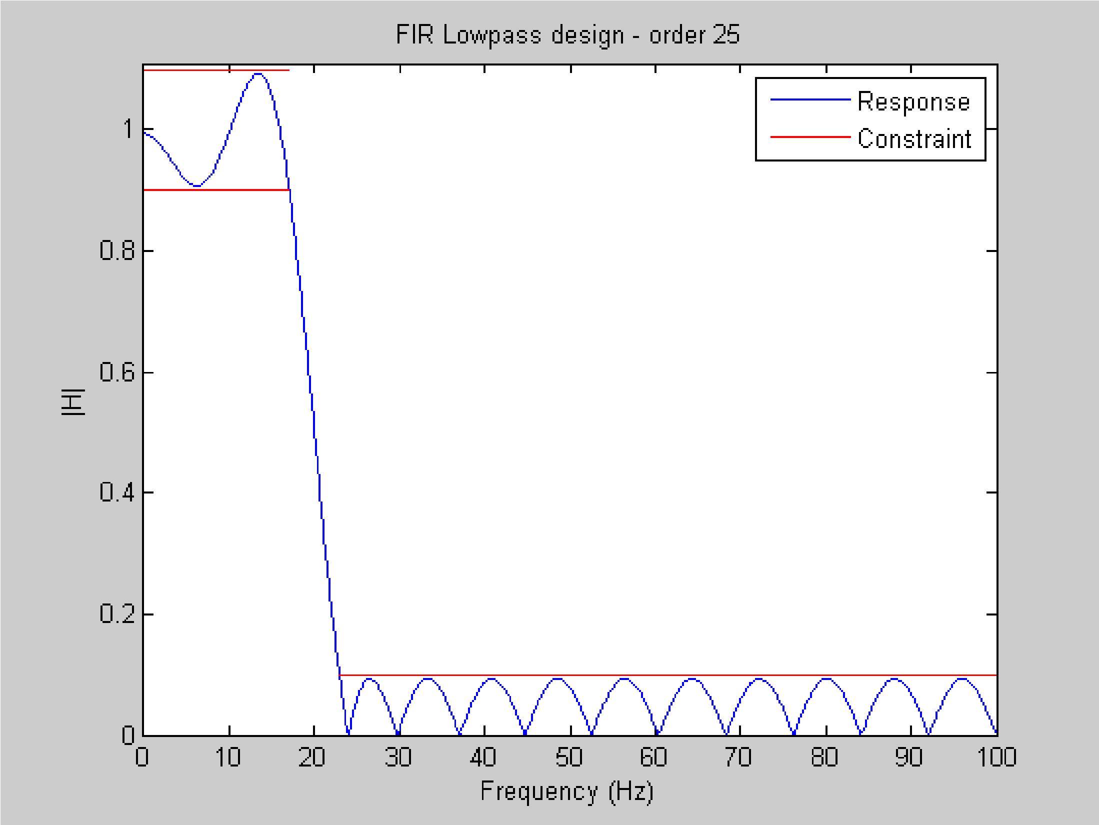
```
Wp =

    0.1700


Ws =

    0.2300


Rp =

    0.9151


Rs =

    20


n =

    10


Wn =

    0.1857


b_iir =

  1.0e-003 *

  Columns 1 through 6

    0.0009    0.0089    0.0401    0.1070    0.1873    0.2247

  Columns 7 through 11

    0.1873    0.1070    0.0401    0.0089    0.0009


a_iir =

  Columns 1 through 6

    1.0000   -6.2735   18.1913  -31.9679   37.5881  -30.8282

  Columns 7 through 11

   17.8286   -7.1684    1.9154   -0.3068    0.0224
```

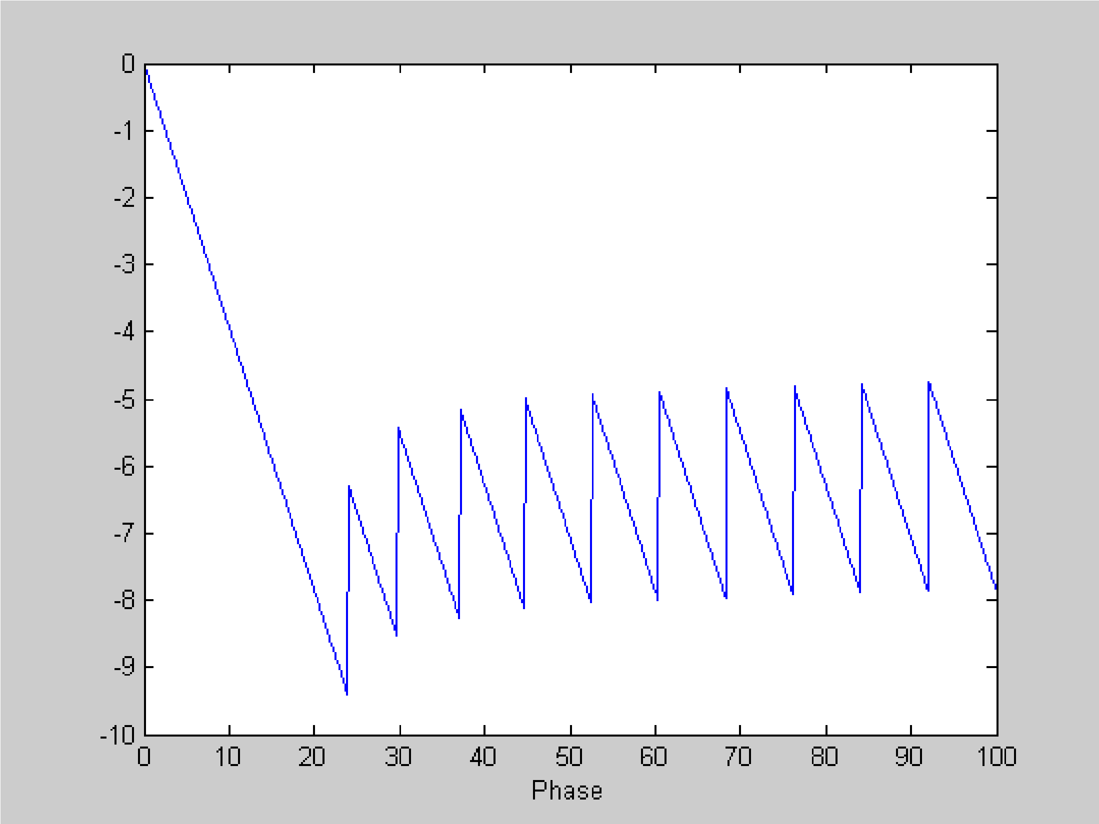


Problem 12.4

FIR design usign parks McClellan design method. We can try designing filters of different order - when the specs are met, we have found a filter of sufficiently high order. This happens at n = 25.

```
fd = [ 0 17/100 23/100 1];
a = [1 1 0 0];
figure
for n = 25
    b_fir = firpm(n,fd,a);
    [h,w] = freqz(b_fir,1,1024,fs);
    plot(w,abs(h))
    hold on
end
plot([0 17], [0.9 0.9],'red', [0 17], [1.1 1.1],'red',[23 100], [0.1 0.1],'red')
axis([0 100 0 1.11])
ylabel('|H|')
xlabel('Frequency (Hz)')
title('FIR Lowpass design - order 25')
legend('Response','Constraint')

figure
plot(w,phase(h))
xlabel('Phase')
```

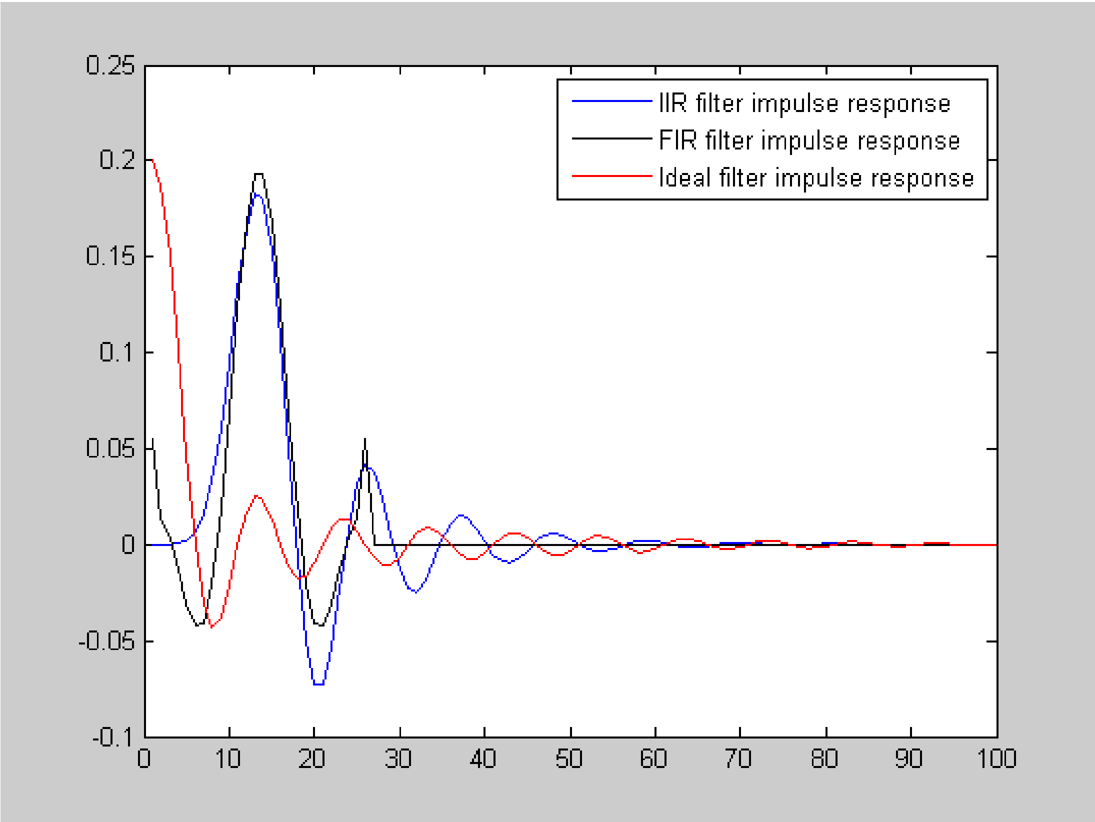




Problem 12.5

The blue plot shows the IIR response, black shows FIR, and red shows the ideal response. Notice the ideal response introduces no delay, while both the iir and fir introduce delay. Also notice the FIR response is identically zero for indices greater than the filter order.

```
imp = [1 zeros(1,199)];
h_iir = filter(b_iir,a_iir,imp);
h_fir = filter(b_fir,1,imp);
h_ideal = filter(fft([ones(1,20) zeros(1,160) ones(1,20)]/200),1,imp);

figure
plot(h_iir(1:100))
hold on
plot(h_fir(1:100),'black')
plot(real(h_ideal(1:100)),'red')
legend('IIR filter impulse response','FIR filter impulse response','Ideal filter impulse re
```

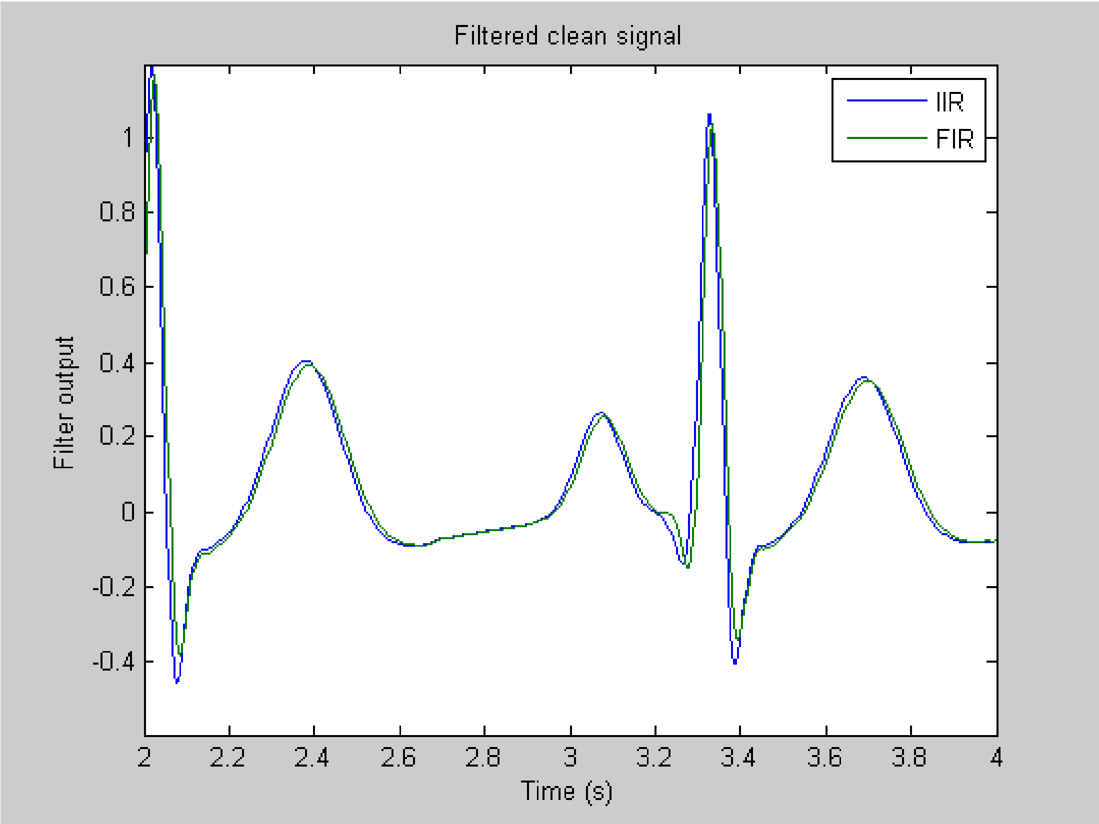


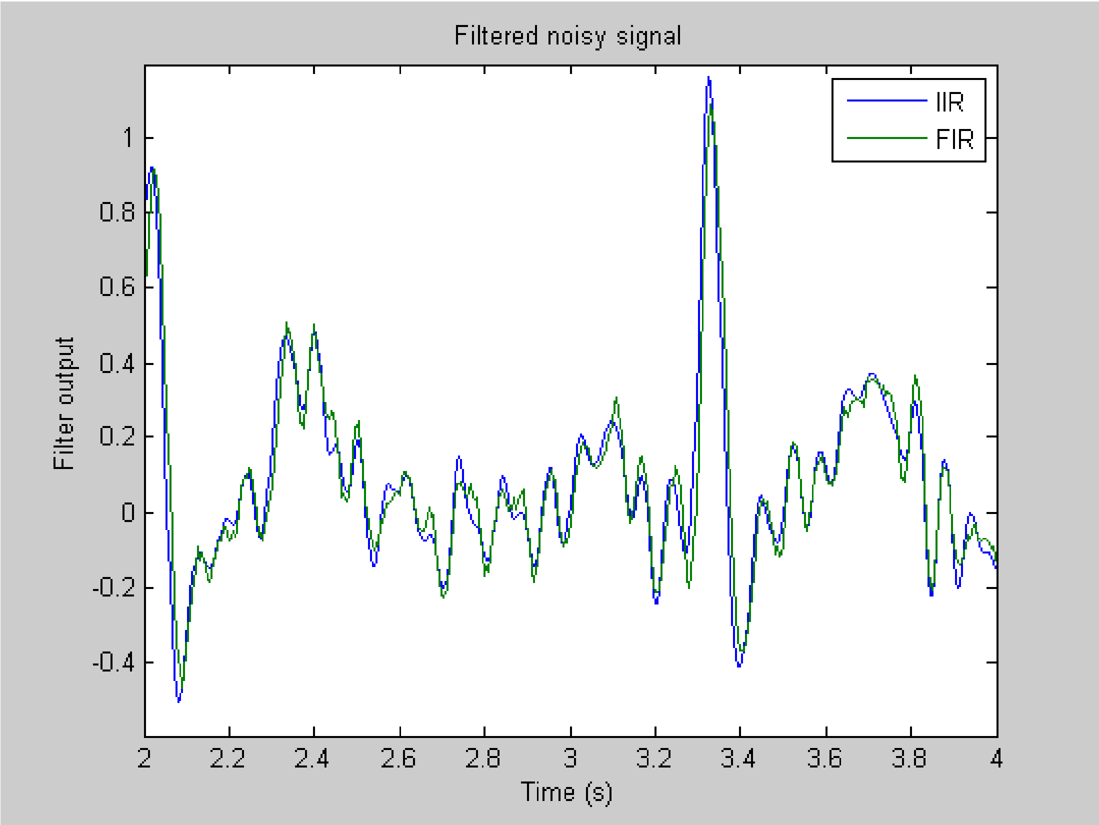
Problem 12.6

The noisy FIR output does not look as clean - this is because of the ripple in pass and stopband of the FIR filter. Since an IIR butterworth is monotonically decreasing, the spec is exactly met at the cut off frequencies, but exceeded elsewhere. Not the case for the FIR filter, where the spec is barely met at many frequencies (hence, has more high frequency noise).

```
yc_iir = filter(b_iir,a_iir,clean_sig);
yc_fir = filter(b_fir,1,clean_sig);

y_iir = filter(b_iir,a_iir,noisy_sig);
y_fir = filter(b_fir,1,noisy_sig);

figure
plot(t,yc_iir,t,yc_fir)
legend('IIR', 'FIR')
xlabel('Time (s)')
ylabel('Filter output')
title('Filtered clean signal')
axis([2 4 -.6 1.2])

figure
plot(t,y_iir,t,y_fir)
```

```
legend('IIR', 'FIR')
xlabel('Time (s)')
ylabel('Filter output')
title('Filtered noisy signal')
axis([2 4 -.6 1.2])
```

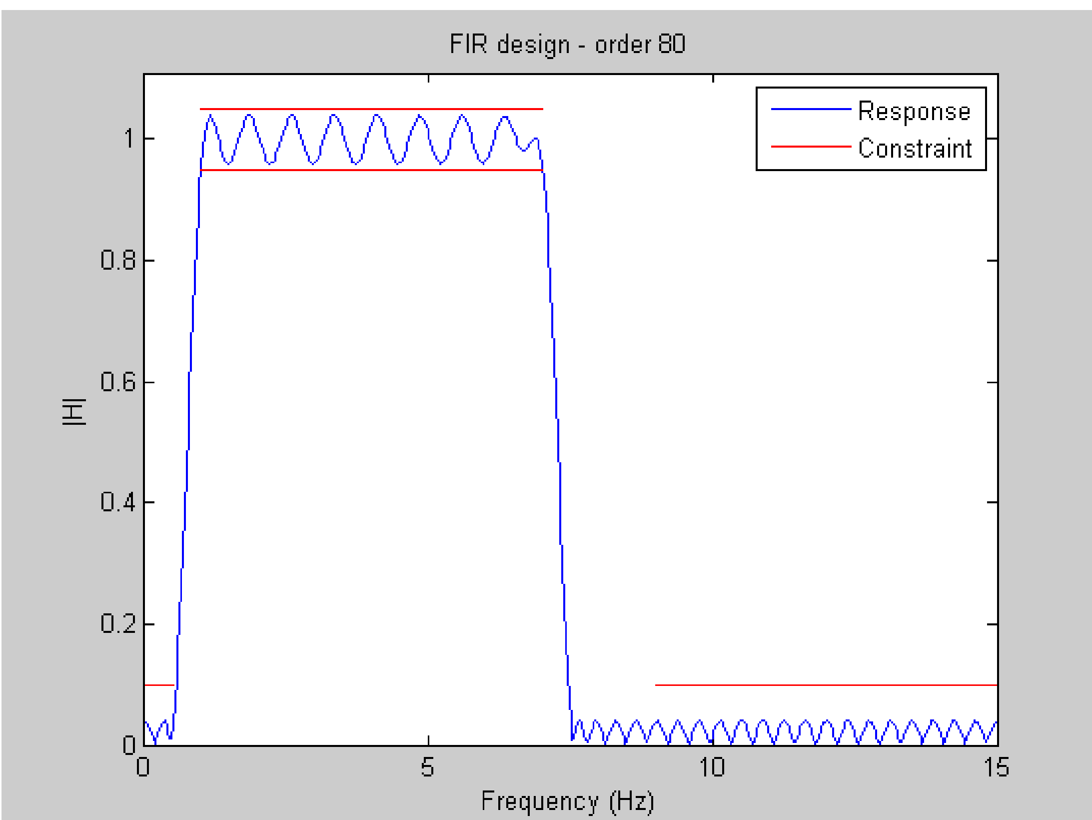


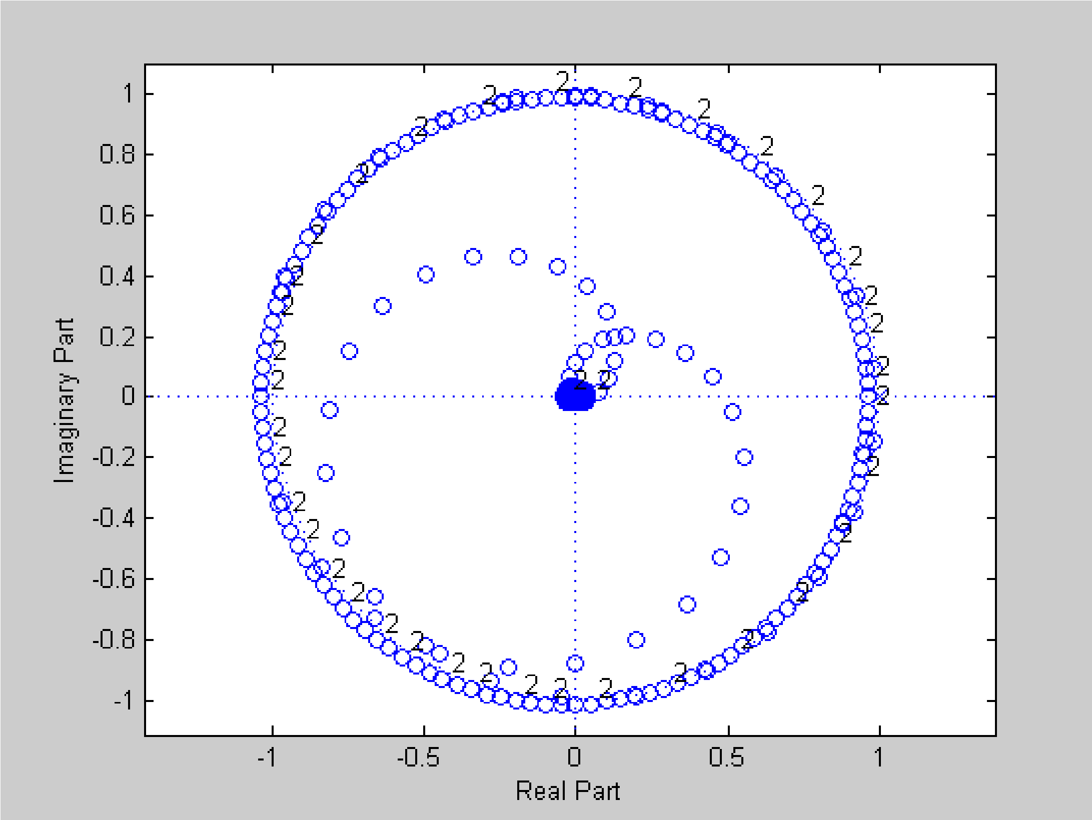


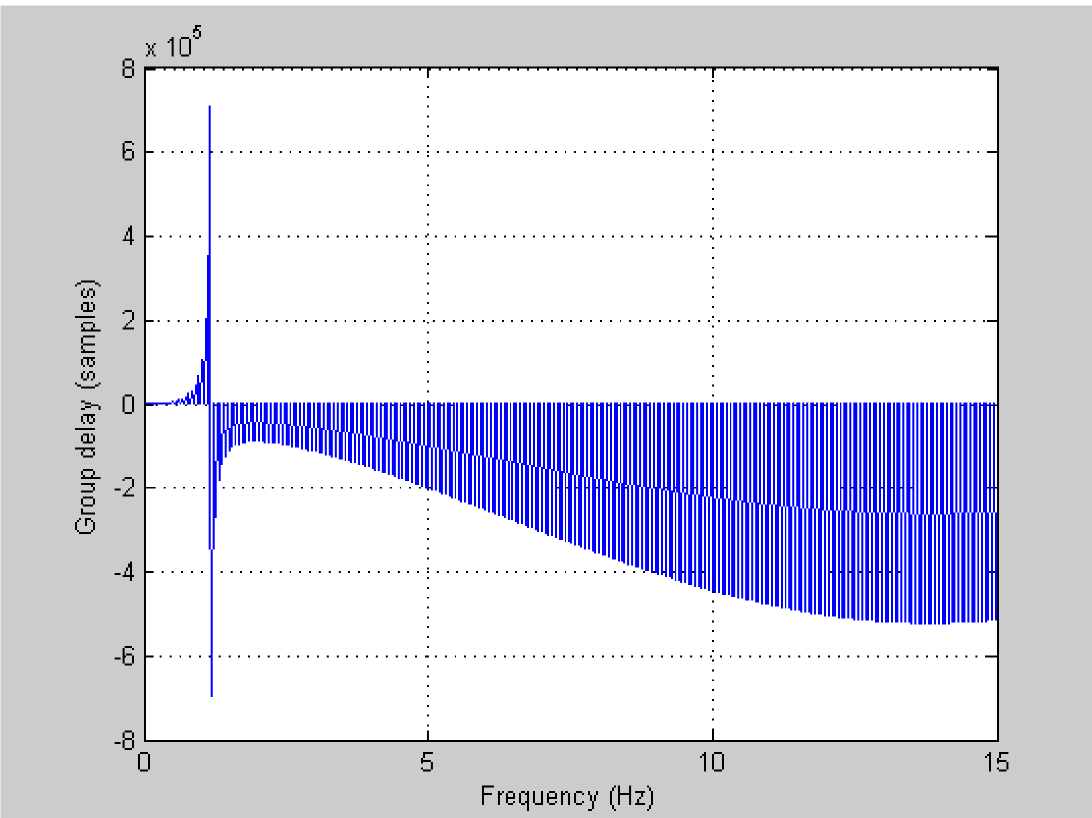
Problem 12.7

Use firpm in to create filter with specified response. Notice that it can be helpful to change where the stop band starts, or you may disign a filter that 'blows-up' in the don't care region. In this case, you can decrease the transition region from 7 - 9 Hz to 7 to 7.5 Hz. A filter order of around 80 meets specifications.

```
clear
clc

fs = 30;
Wp = [1 7]*2*pi/fs/pi;
Ws = [0.5 9]*2*pi/fs/pi;

fd = [0 0.5 1 7 7.5 15]/15;
a =  [0 0   1 1 0 0 ];
figure
for n = 80
    b_fir = firpm(n,fd,a,'pass');
    [h,w] = freqz(b_fir,1,[],fs);
    plot(w,abs(h))
    hold on
end
plot([0 0.5], [0.1 0.1],'red', [1 7], [.95 .95],'red', [1 7], [1.05 1.05], 'red', [9 15], [
axis([0 15 0 1.11])
ylabel('|H|')
xlabel('Frequency (Hz)')
title('FIR design - order 80')
legend('Response','Constraint')

figure
plot(w, phase(h));
zplane(h,1)

figure
grpdelay(h,1,512,fs)
```







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