

## Homework 11 Solution

### Contents

- [Homework 11 problem 1](#)
- [Prob 1a\)](#)
- [Prob 1b\)](#)
- [Prob 1c\)](#)
- [Group Delay Plots](#)
- [Homework 11 problem 2](#)
- [Prob 2a\)](#)
- [Prob 2b\)](#)
- [Prob 2c\)](#)
- [Prob 2d\)](#)

### Homework 11 problem 1

```
close all
clear
clc

fs = 30;
Wp = [1 7]*2*pi/fs/pi;
Ws = [0.5 9]*2*pi/fs/pi;
p = 0.9;
s = 0.1;
Rp = -20*log10(p);
Rs = -20*log10(s);
```

#### Prob 1a)

```
[n, Wn] = buttord(Wp, Ws, Rp, Rs);
display('Butterworth order')
n

display('Butterworth Transfer Function')
[b1,a1] = butter(n,Wn)

figure
freqz(b1,a1,512,fs)
subplot(2,1,1)
axis([0,15,-70,1])
title('Butterworth Response')

figure
zplane(b1,a1)
title('Butterworth Pole-Zero Locations')
```

Butterworth order

n =

7

Butterworth Transfer Function

b1 =

Columns 1 through 9

0.0095            0    -0.0668            0    0.2004            0    -0.3340            0    0.3340

Columns 10 through 15

```
0 -0.2004      0 0.0668      0 -0.0095
```

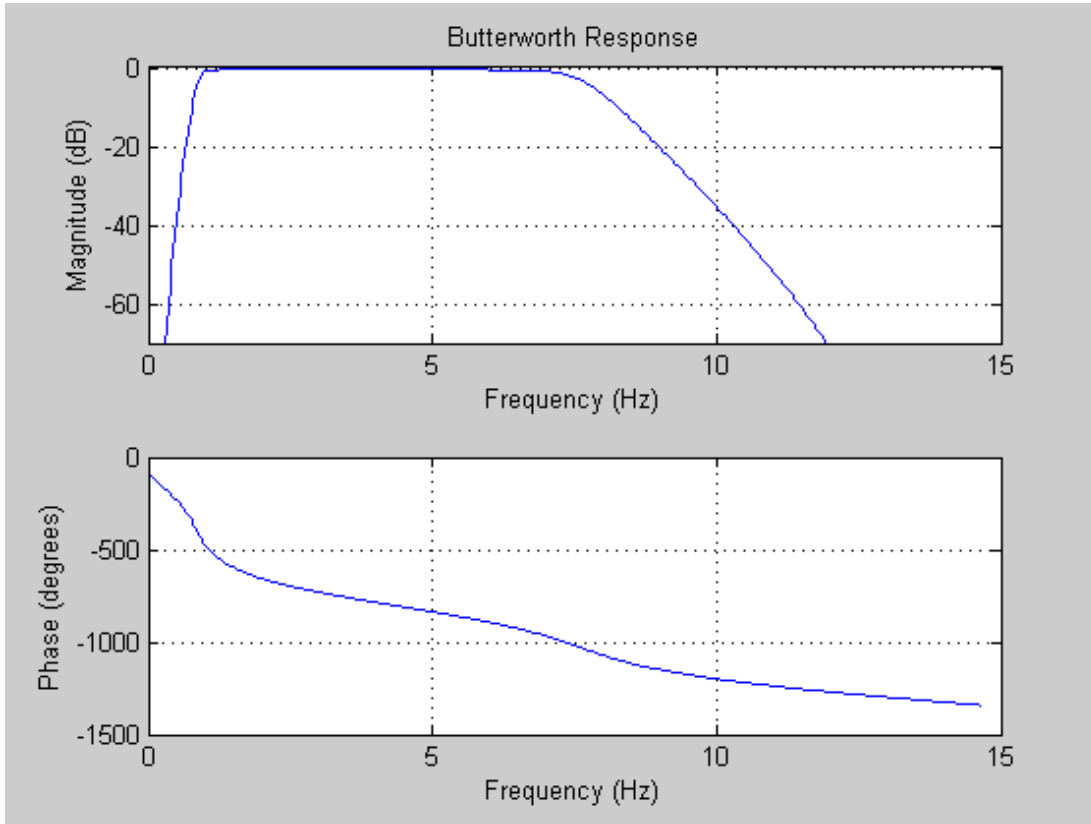
a1 =

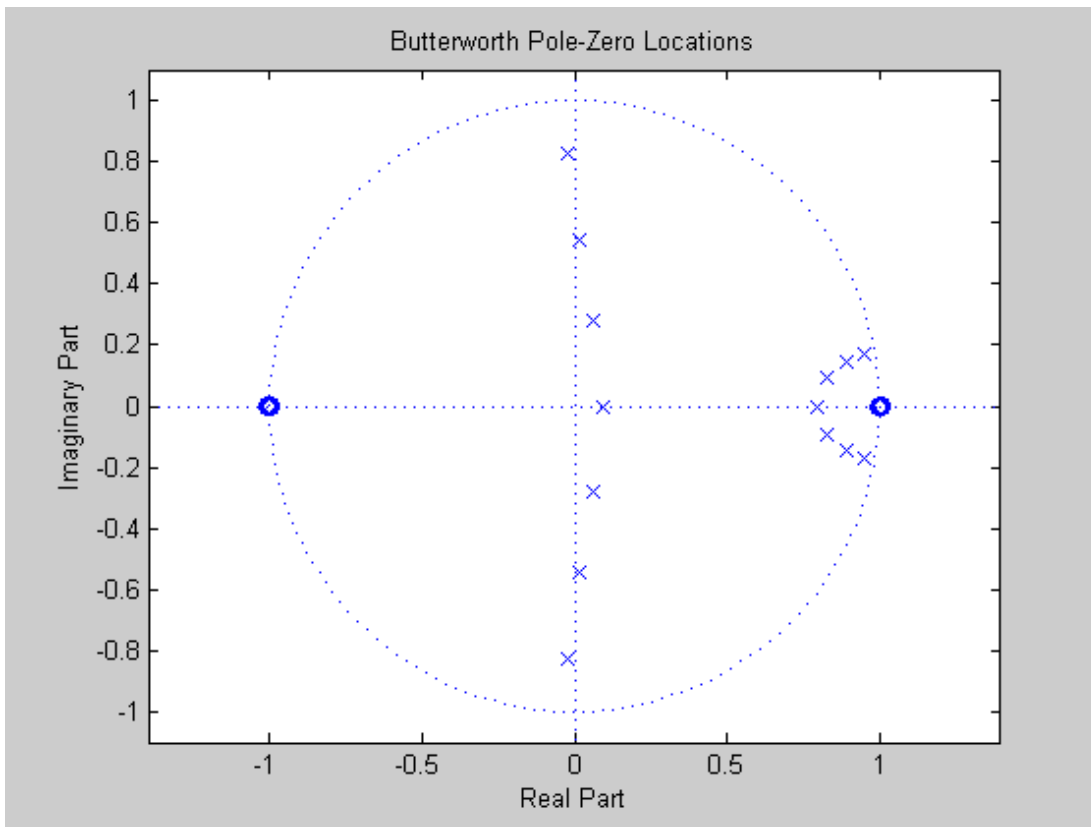
Columns 1 through 9

```
1.0000 -6.3376 18.4940 -33.8465 44.8315 -46.3937 38.5528 -25.7861 13.9191
```

Columns 10 through 15

```
-6.0734 2.0928 -0.5429 0.1025 -0.0132 0.0007
```



**Prob 1b)**

```
[n, Wn] = cheblord(Wp, Ws, Rp, Rs);
display('Chebyshev type 1 order')
n
```

```
display('Chebyshev Type 1 Transfer Function')
[b2,a2] = cheby1(n,Rp,Wn)
```

```
figure
freqz(b2,a2,512,fs)
subplot(2,1,1)
axis([0,15,-70,1])
title('Chebyshev Type 1 Response')
```

```
figure
zplane(b2,a2)
title('Chebyshev type 1 Pole-Zero Locations')
```

Chebyshev type 1 order

n =

4

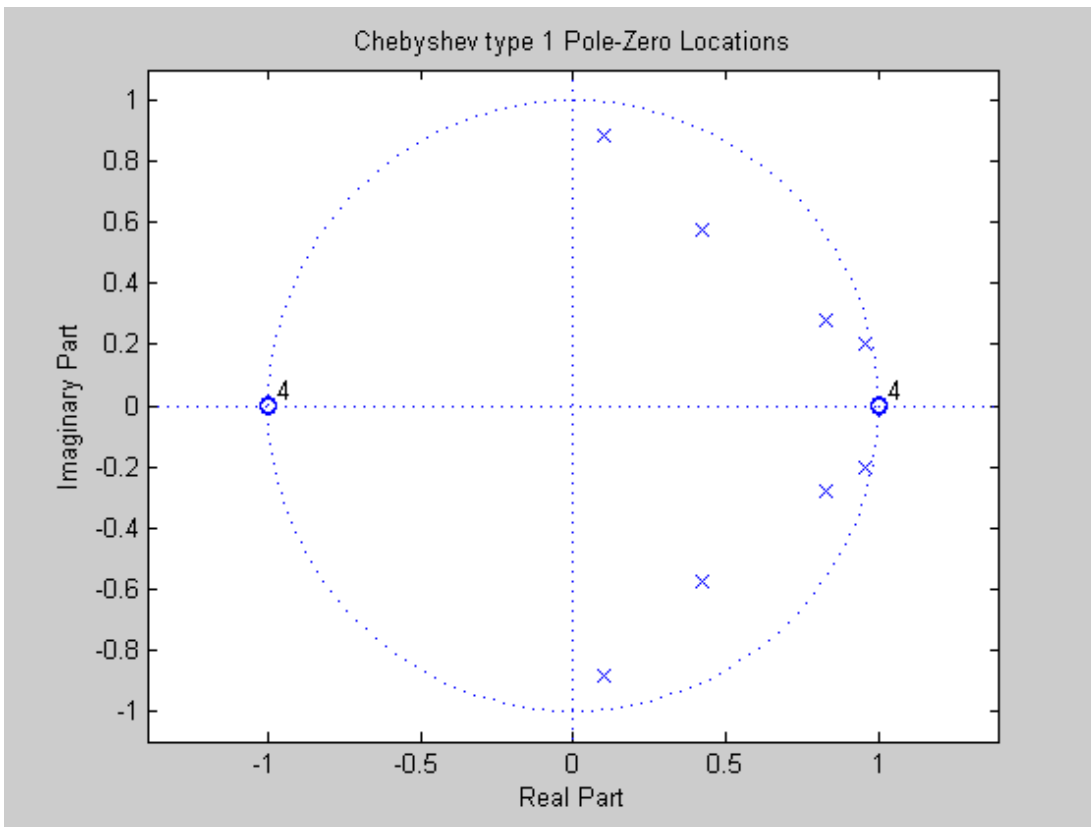
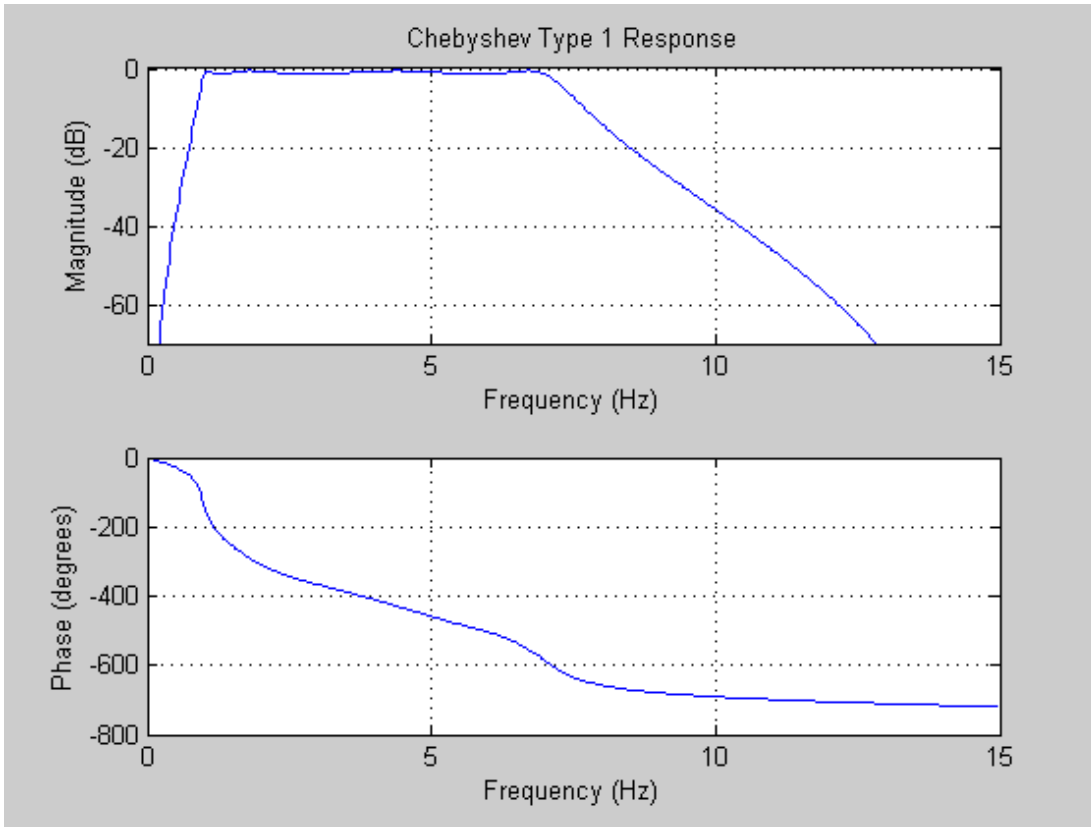
Chebyshev Type 1 Transfer Function

b2 =

0.0250      0    -0.1001      0    0.1501      0    -0.1001      0    0.0250

a2 =

1.0000    -4.6072    10.0666    -14.1457    14.2429    -10.4548    5.4051    -1.7981    0.2960



**Prob 1c)**

```
[n, Wn] = ellipord(Wp, Ws, Rp, Rs);
```

```

display('Elliptical order')
n

display('Elliptical Transfer Function')
[b3,a3] = ellip(n,Rp,Rs,Wn)

figure
freqz(b3,a3,512,fs)
subplot(2,1,1)
axis([0,15,-70,1])
title('Elliptical Response')

figure
zplane(b3,a3)
title('Elliptical Pole-Zero Locations')

```

Elliptical order

n =

3

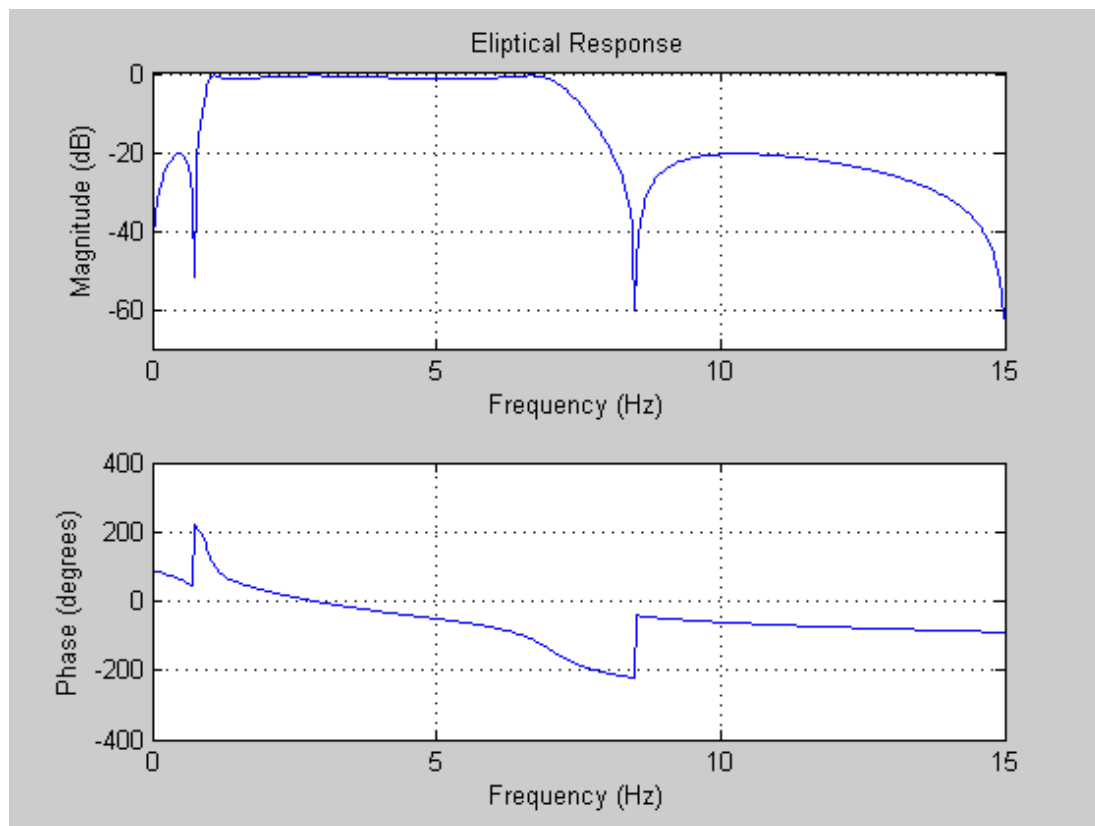
Elliptical Transfer Function

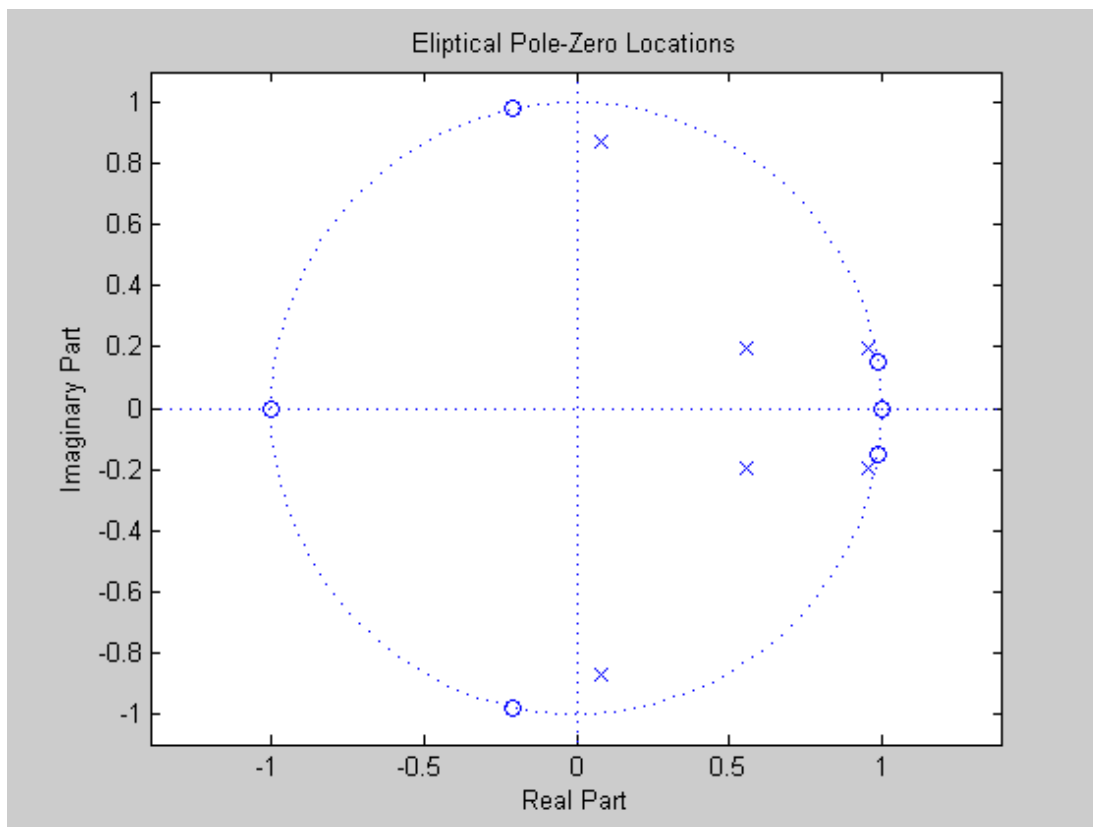
b3 =

0.1888    -0.2946    0.0334    0.0000    -0.0334    0.2946    -0.1888

a3 =

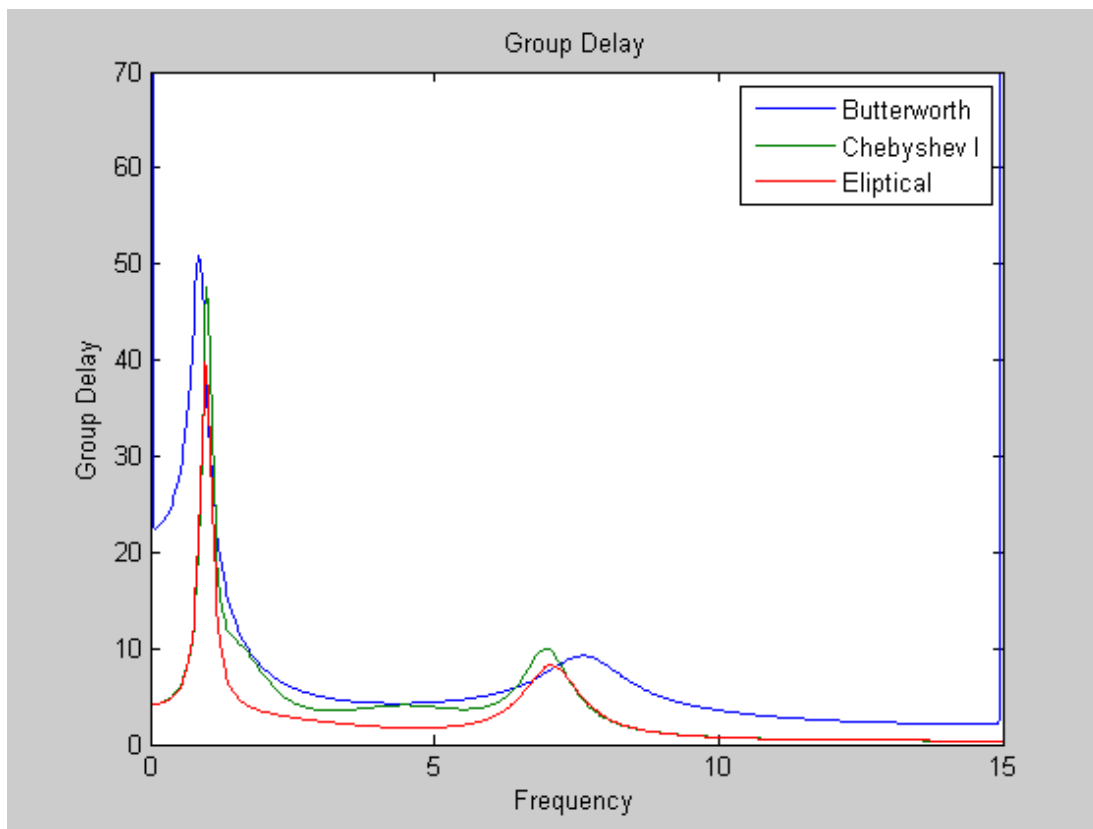
1.0000    -3.1840    4.6819    -4.6008    3.2431    -1.3799    0.2551





### Group Delay Plots

```
[gd1,w1] = grpdelay(b1,a1,512,fs);  
[gd2,w2] = grpdelay(b2,a2,512,fs);  
[gd3,w3] = grpdelay(b3,a3,512,fs);  
plot(w1,gd1,w2,gd2,w3,gd3)  
legend('Butterworth','Chebyshev I','Elliptical')  
title('Group Delay')  
xlabel('Frequency')  
ylabel('Group Delay')  
axis([0 15 0 70])
```



### Homework 11 problem 2

```
close all
clear
clc

fs = 240;
Wp = [57 63]*2*pi/fs/pi;
Ws = [59 61]*2*pi/fs/pi;
p = 0.9;
Rp = -20*log10(p);
Rs = 60;

[n, Wn] = buttord(Wp, Ws, Rp, Rs);
display('Butterworth order')
n
```

Butterworth order

n =

7

### Prob 2a)

```
display('Butterworth Transfer Function')
[b,a] = butter(n,Wn,'stop')

[H W] = freqz(b,a,512,fs);

figure
zplane(b,a)
title('Butterworth Pole-Zero Locations')
```

Butterworth Transfer Function

b =

Columns 1 through 9

```
0.7294 -0.0000 5.1059 -0.0000 15.3176 -0.0001 25.5294 -0.0001 25.5294
```

Columns 10 through 15

```
-0.0001 15.3176 -0.0000 5.1059 -0.0000 0.7294
```

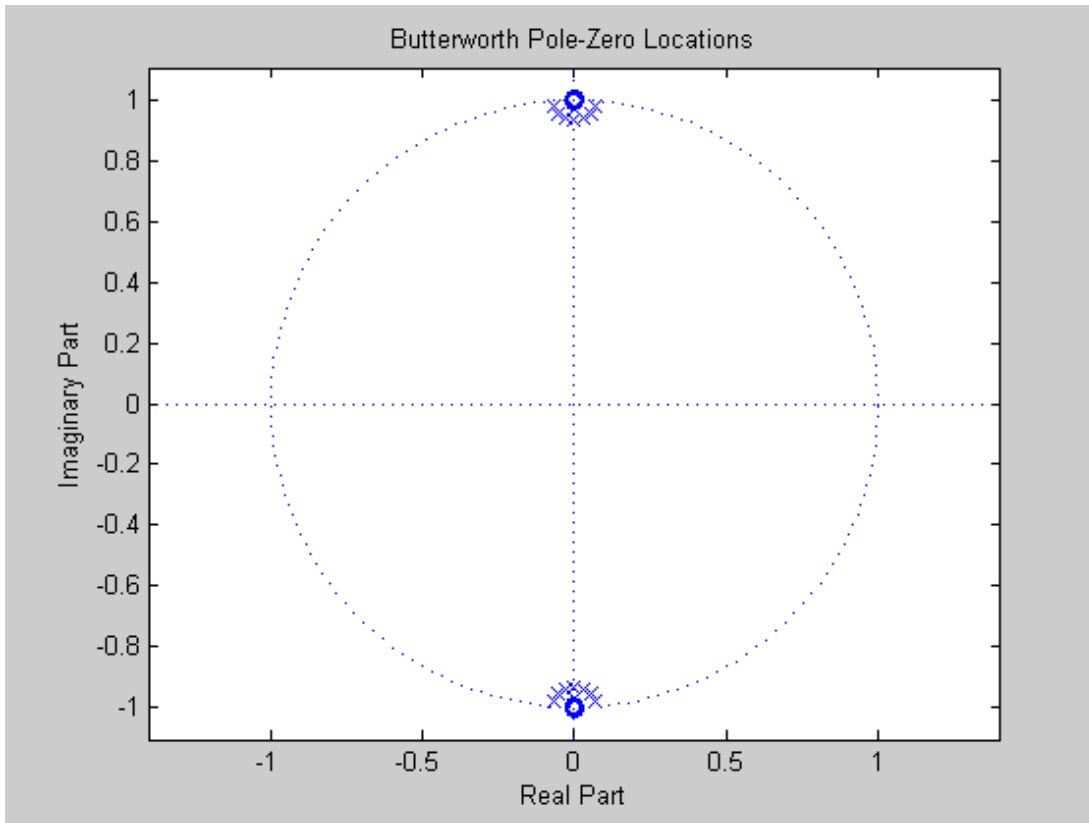
a =

Columns 1 through 9

```
1.0000 -0.0000 6.3697 -0.0000 17.4146 -0.0001 26.4888 -0.0001 24.2080
```

Columns 10 through 15

```
-0.0001 13.2918 -0.0000 4.0596 -0.0000 0.5320
```



### Prob 2b)

```
load ECGExample.mat
%All zero filter
h1 = [0.5 0 0.5];
[H1 W1] = freqz(h1,1,[],240);

%Pole-zero filter
bpz = [1 0 1]*1.81/2;
apz = [1 0 0.81];
[H2 W2] = freqz(bpz,apz,[],240);
```

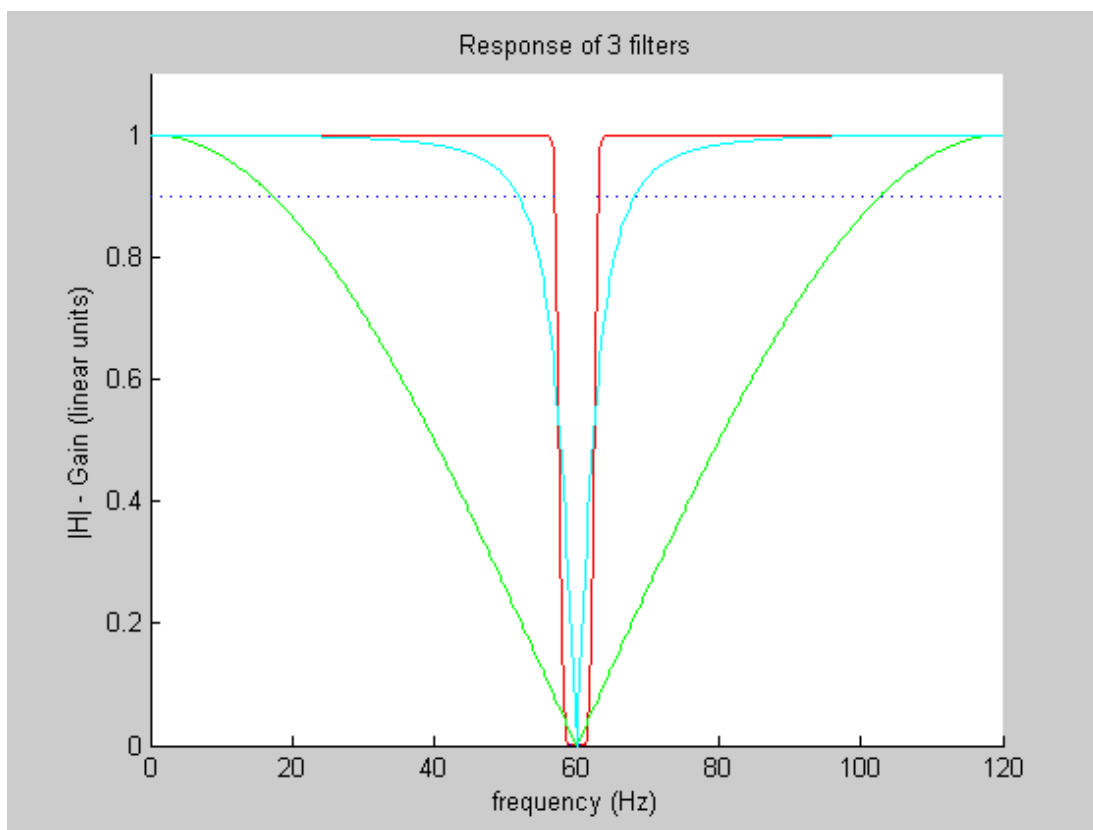


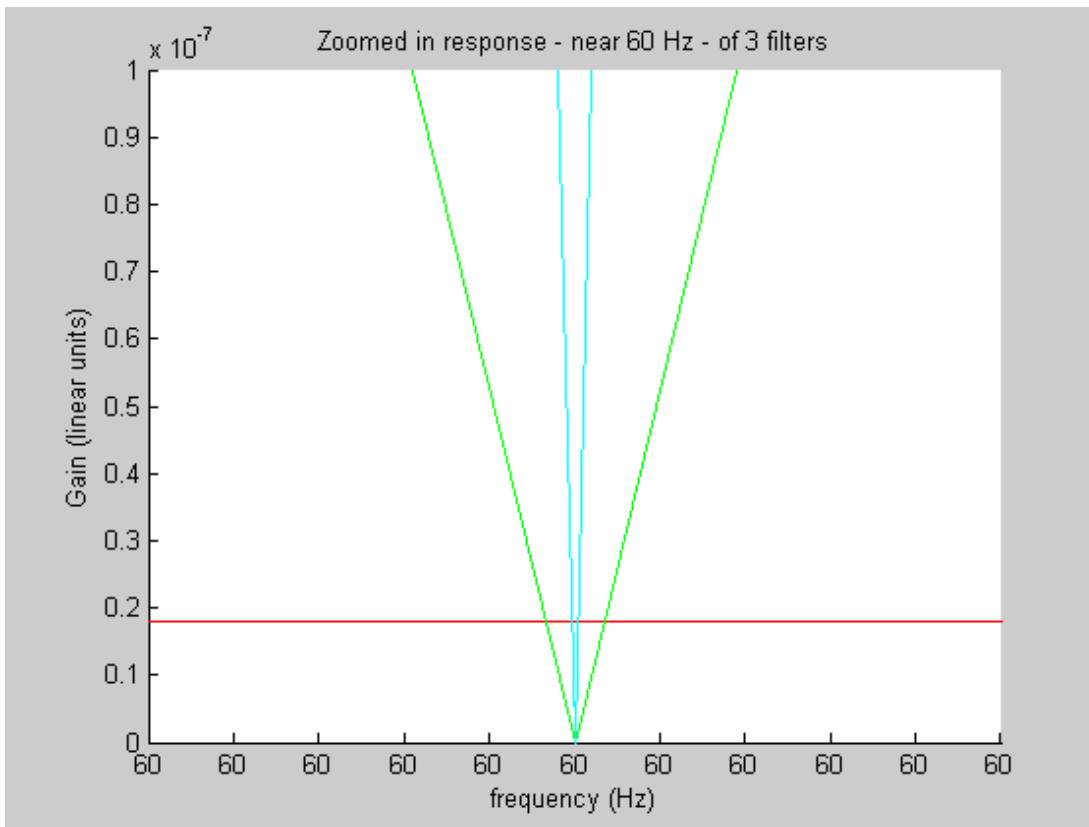
```
%Plot all on same graph for comparison
```

```
figure
hold on
plot(W,abs(H),'red')
plot(W1,abs(H1),'green')
plot(W2,abs(H2),'cyan')
%Plot Specs
plot([0 57],[.9 .9],':')
plot([59 61],[1e-3 1e-3],':')
plot([63 120],[.9 .9],':')
axis([0 120 0 1.1])
title('Response of 3 filters')
xlabel('frequency (Hz)')
ylabel('|H| - Gain (linear units)')
```

```
%Zoom in on 60 Hz
```

```
figure
hold on
plot(W,abs(H),'red')
plot(W1,abs(H1),'green')
plot(W2,abs(H2),'cyan')
%Plot Specs
plot([0 57],[.9 .9],':')
plot([59 61],[1e-3 1e-3],':')
plot([63 120],[.9 .9],':')
axis([0 120 0 1.1])
title('Zoomed in response - near 60 Hz - of 3 filters')
xlabel('frequency (Hz)')
ylabel('Gain (linear units)')
axis([(60-1e-5) (60+1e-5) 0 1e-7])
```



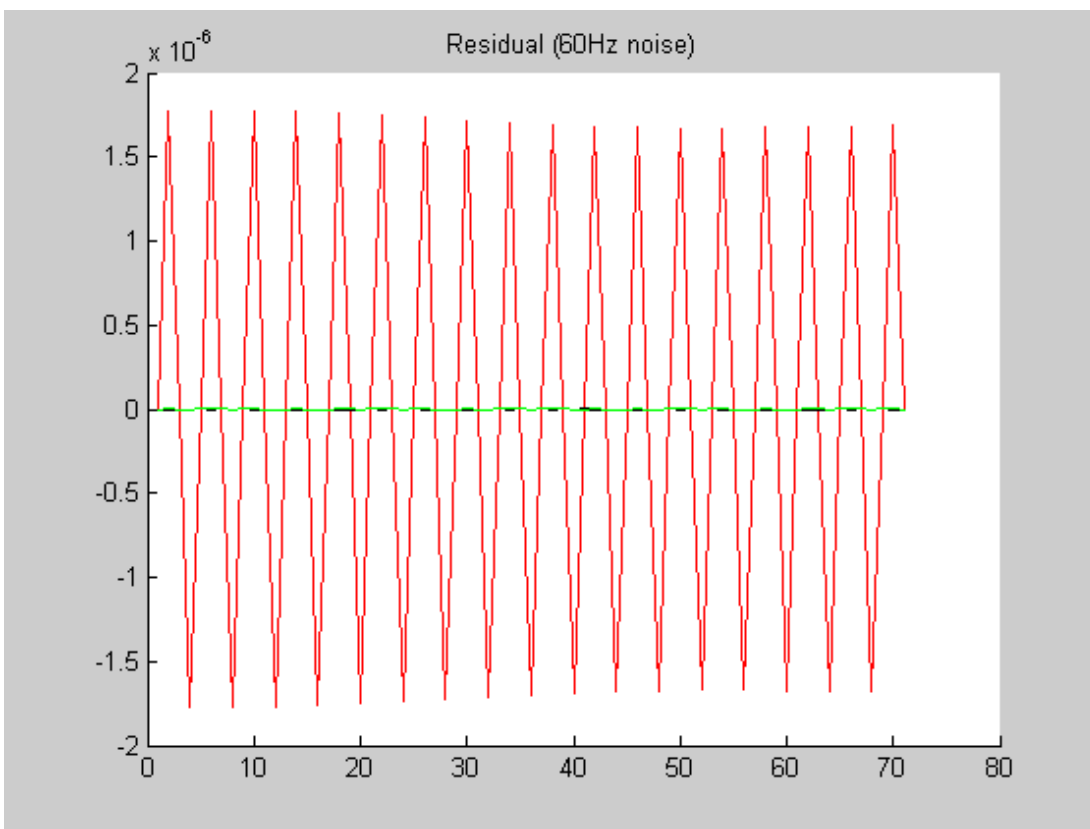
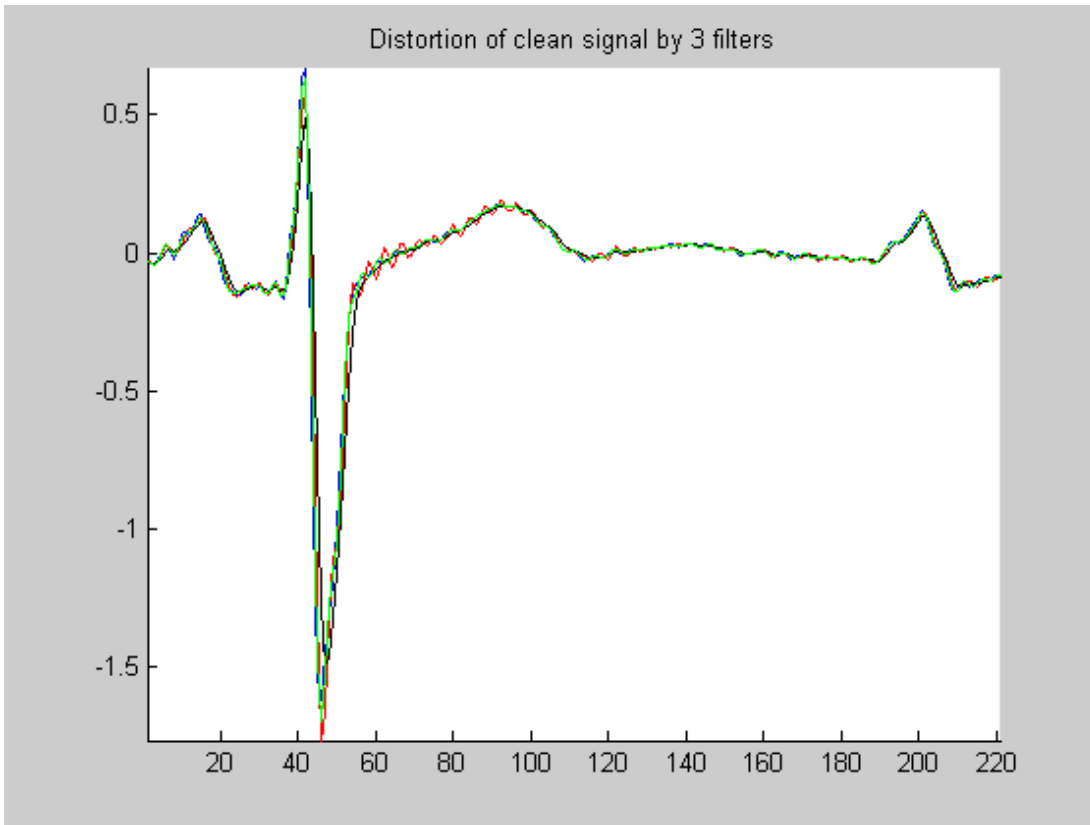
**Prob 2c)**

```
y = filter(b,a,ecgnse);
y1 = filter(h1,1,ecgnse);
y2 = filter(bpz, apz,ecgnse);
```

```
figure
hold on
plot(ecg(680:900))
plot(y(680:900), 'red')
plot(y1(680:900), 'black')
plot(y2(680:900), 'green')
axis tight
title('Distortion of clean signal by 3 filters')
```

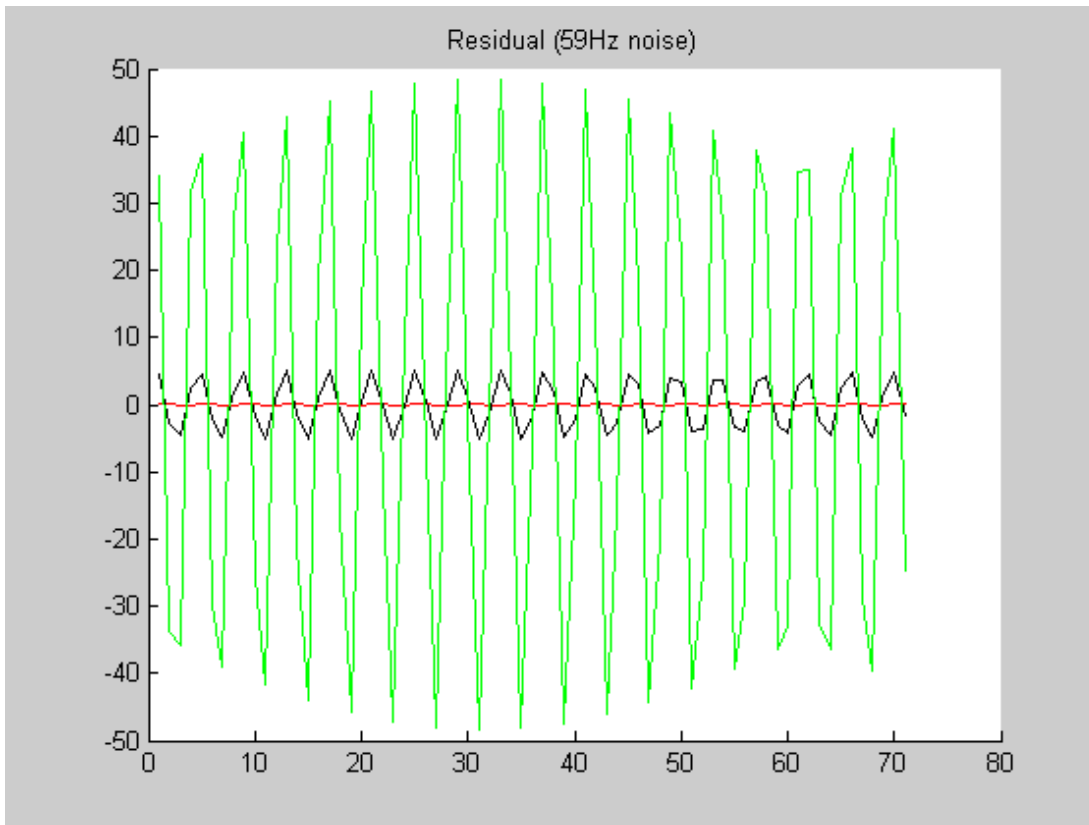
```
noise = ecgnse-ecg;
n = filter(b,a,noise);
n1 = filter(h1,1,noise);
n2 = filter(bpz,apz,noise);
```

```
figure
hold on
plot(n(2680:2750), 'red')
plot(n1(2680:2750), 'black')
plot(n2(2680:2750), 'green')
%axis tight
title('Residual (60Hz noise)')
```

**Prob 2d)**

```
noise2 = 200*sin(2*pi*59*[0:1:length(ecg)-1]/fs);  
ecgnse2 = ecg.'+noise2;  
  
n = filter(b,a,noise2);
```

```
n1 = filter(h1,1,noise2);  
n2 = filter(bpz,apz,noise2);  
  
figure  
hold on  
  
plot(n(2680:2750),'red')  
plot(n1(2680:2750),'black')  
plot(n2(2680:2750),'green')  
title('Residual (59Hz noise)')
```



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