ECE4429 Lab3 Answersheet

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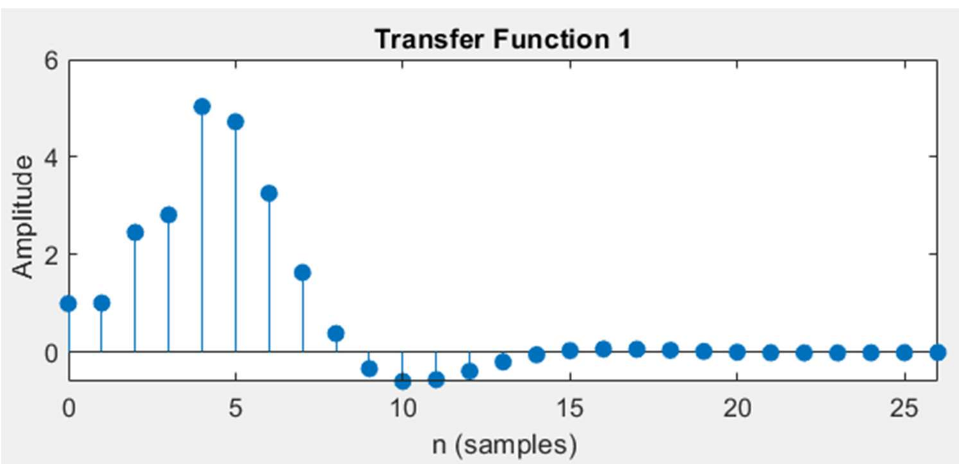
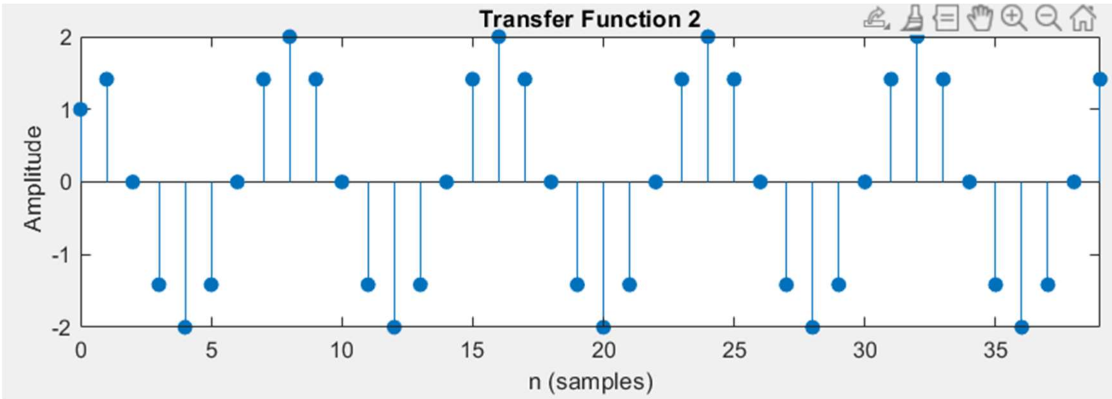
Transfer function synthesis and stability

```
Z1 = [1.4*exp((1i*pi)/3); 1.4*exp(-(1i*pi)/3); 1.2*exp((1i*2*pi)/3);
1.2*exp(-(1i*2*pi)/3)];
P1 = [0.7*exp((1i*pi)/6); 0.7*exp(-(1i*pi)/6); 0; 0];
[num1, den1] = zp2tf(Z1,P1,1);
Tf1 = filt (num1, den1);
subplot(311);
impz(num1, den1);
title('Transfer Function 1');

P2 = [exp(-(1i*pi)/4);exp((1i*pi)/4)];
Z2 = [-1;1];
[num2, den2] = zp2tf(Z2, P2, 1);
Tf2 = filt (num2, den2);
subplot(312);
impz(num2, den2);
title('Transfer Function 2');

P3 = [1;1];
Z3 = [0;0];
[num3, den3] = zp2tf(Z3, P3, 1);
Tf3 = filt (num3, den3);
subplot(313);
impz(num3, den3);
title('Transfer Function 3');
```



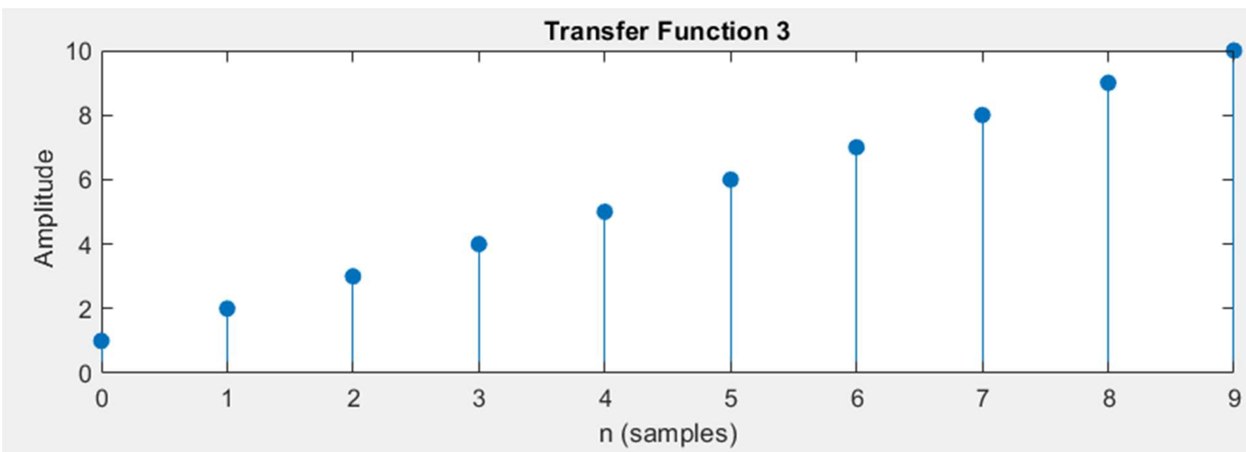

```
1 - 0.2 z^-1 + 1.72 z^-2 + 0.336 z^-3 + 2.822 z^-4
---------------------------------------------------
            1 - 1.212 z^-1 + 0.49 z^-2
```

Transfer Function1 has a increase untill the 4th sample, and decreace to 0. Since all the poles and zeros are with in the unit circle, this is a steady response.



$$\frac{1 - z^{-2}}{1 - 1.414\,z^{-1} + z^{-2}}$$

The transfer function2 has the impulse response as a wave with amplitude equals 2. Since all the poles and zeros are on the margin of unit circle, it is a marginally stable system.



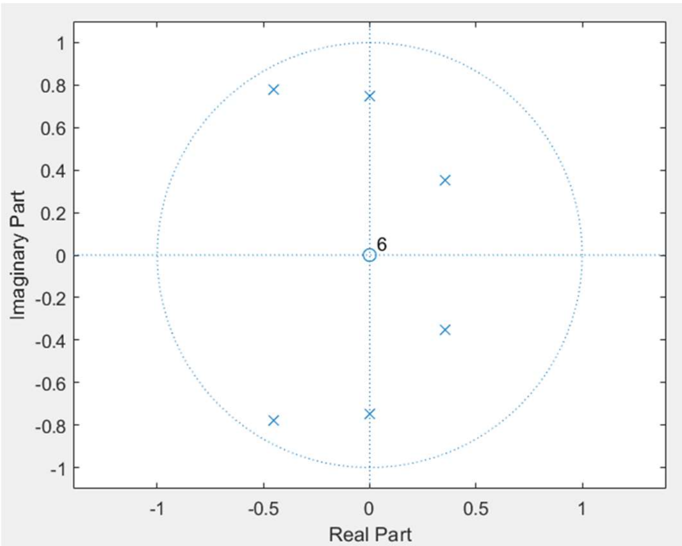
$$\frac{1}{1 - 2\,z^{-1} + z^{-2}}$$

The impulse response of transfer function3 that is costantly increasing. It is unstable because repeated pole on the margin is unstable.

Pole-zero, magnitude, and phase response plots

```
H = [1 0.1929 0.9861 -0.2393 0.4408 -0.1956 0.1139];
zplane(1, H);
figure
impz(1,H);
figure%magnitude and phase response
freqz(1,H); % Plots frequency response
title('The magnitude and phase response');
```

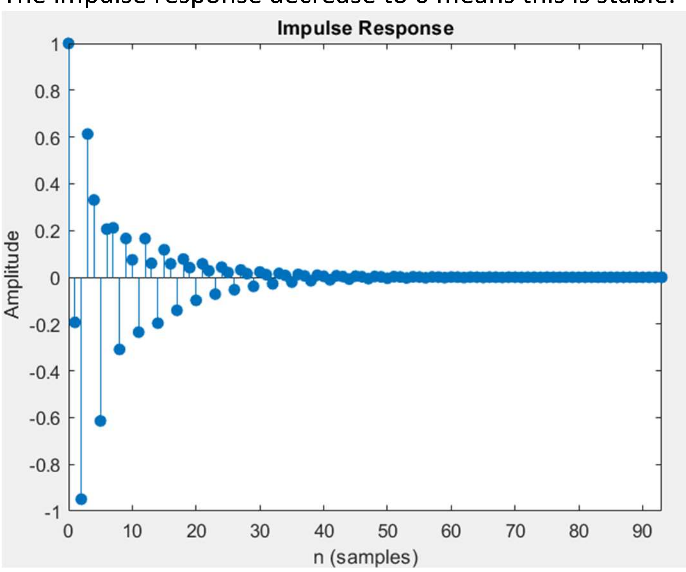
Q1.



Base on the plot, this system is a bandpass filter.
From the plot, the poles are illustrate that the magnitude is at 0.25pi rad/sample, 0.5pi rad/sample, and 0.67pi rad/sample.

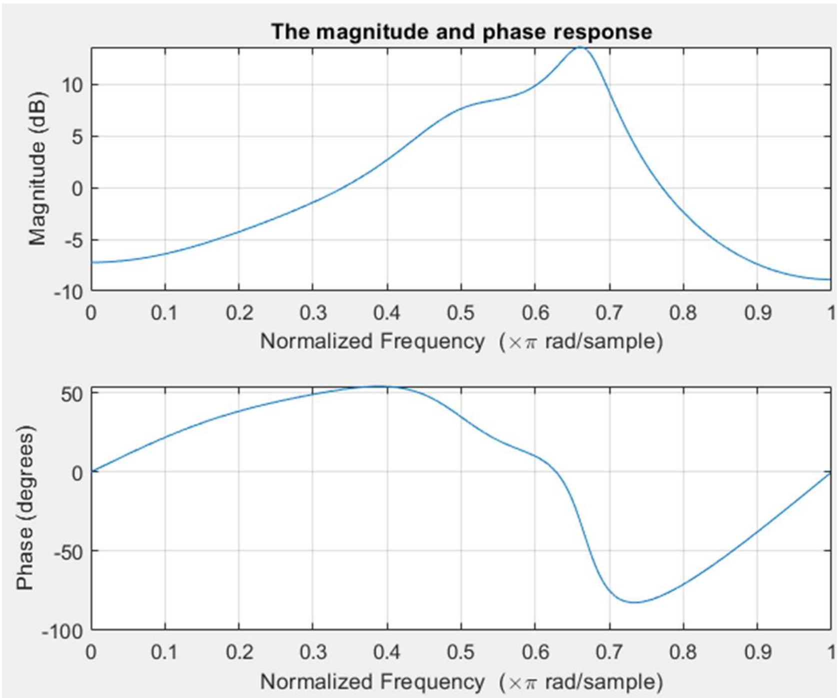
Q2.

This system is stable because all the poles and zeros are within the unit circle.
The impulse response decrease to 0 means this is stable.



Q3.

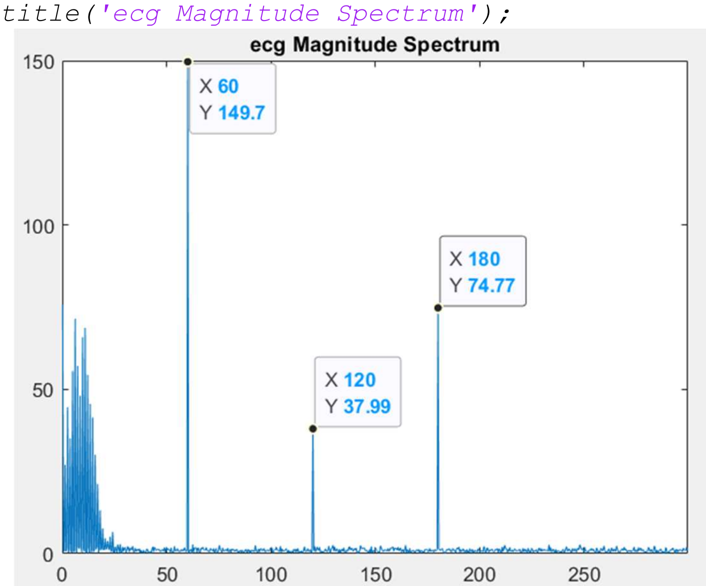
The magnitude and phase response look ike what I expected. The magnitude response shows a bandpass filter, and the phase do react at 0.66pi rad/sample.



Notch filter design & implementation

- **Spectrum analysis**

```
ecg = load('ecgbn.dat');
len = length(ecg);
fs = 600;
t = 1/fs*(0:len-1);
ecg_fft = fft(ecg);
frq = 0 : fs/len : fs/2-fs/len;
figure
plot(frq, abs(ecg_fft(1:len/2)));
title('ecg Magnitude Spectrum');
```



The unwanted frequencies are showed in the plot, with frequency ±60Hz, ±120Hz, ±180Hz.

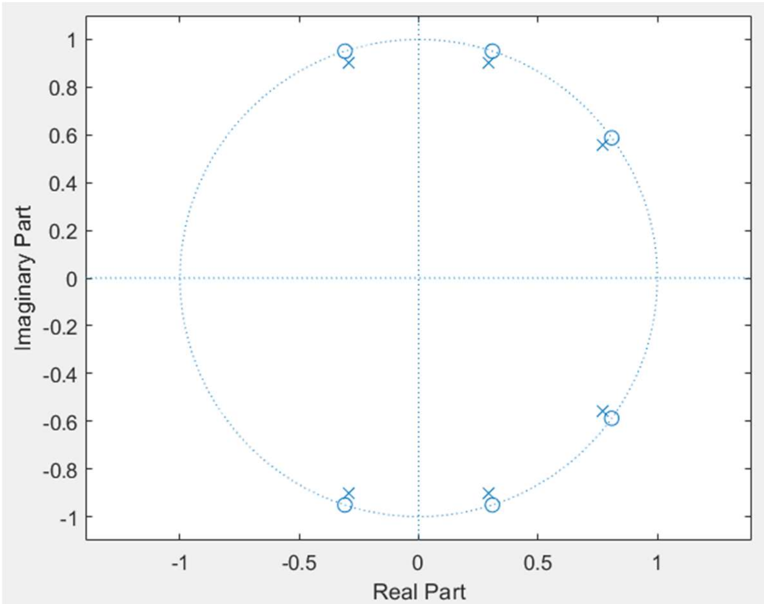
- **Pole and Zero**

Assume pole radii to be 0.95.

```
Z = [exp(-(1i*60*2*pi)/600);exp((1i*60*2*pi)/600);exp(-
(1i*120*2*pi)/600);exp((1i*120*2*pi)/600);exp(-
(1i*180*2*pi)/600);exp((1i*180*2*pi)/600)];
P = [0.95*exp(-(1i*60*2*pi)/600);0.95*exp((1i*60*2*pi)/600);0.95*exp(-
(1i*120*2*pi)/600);0.95*exp((1i*120*2*pi)/600);0.95*exp(-
(1i*180*2*pi)/600);0.95*exp((1i*180*2*pi)/600)];
[num, den] = zp2tf (Z,P,1);
Tf = filt (num, den);
figure
zplane(num, den);
```

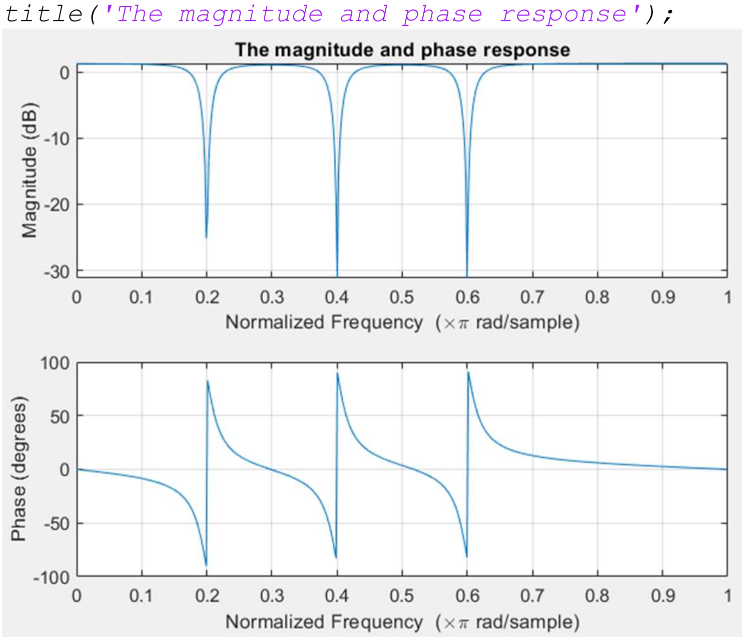
Transfer Function:

```
    1 - 1.618 z^-1 + 2.618 z^-2 - 2.618 z^-3 + 2.618 z^-4 - 1.618 z^-5 + z^-6
  ---------------------------------------------------------------------------
  1 - 1.537 z^-1 + 2.363 z^-2 - 2.245 z^-3 + 2.132 z^-4 - 1.252 z^-5 + 0.7351 z^-6
```



- **Magnitude, and Phase response**

```
figure
freqz(num, den); % Plots frequency response
title('The magnitude and phase response');
```

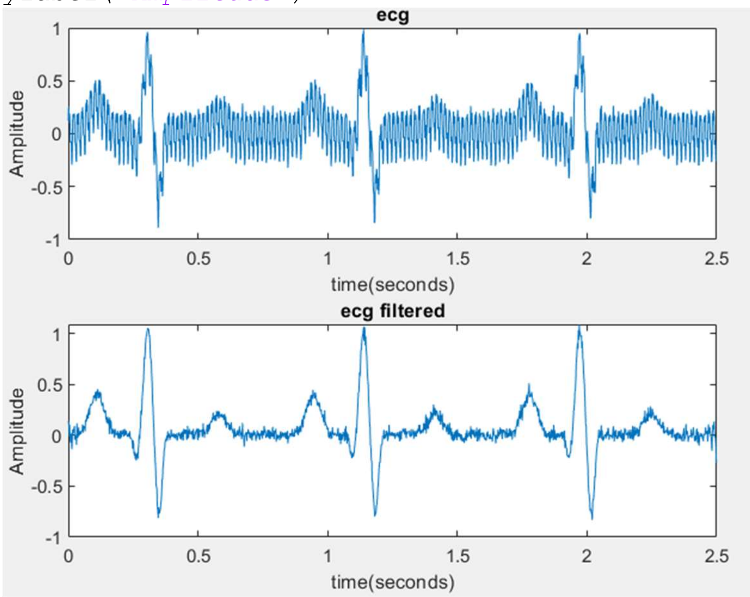


The plots have responds at 0.2pi/sample, 0.4pi/sample and 0.6pi/sample, which matches the frequency ±60Hz, ±120Hz, ±180Hz when sampling frequency is 600Hz. (60*2pi/600 = 0.2pi)

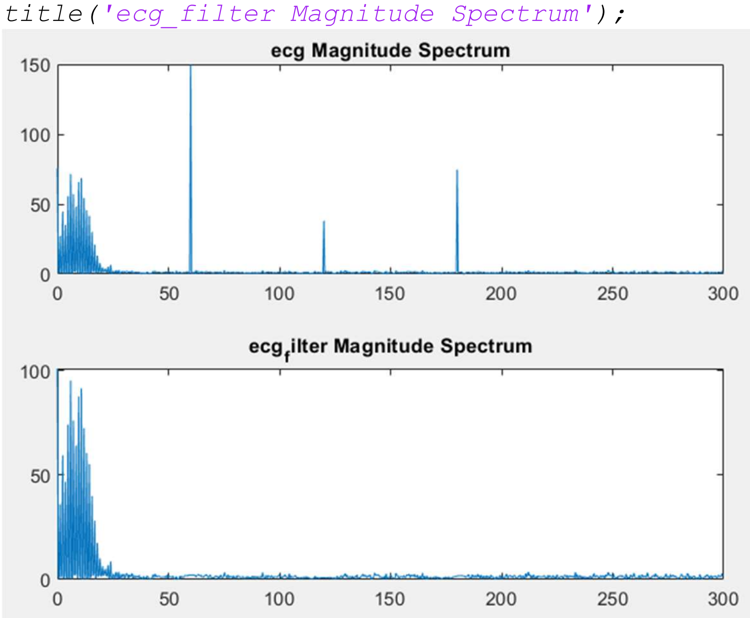
- **ECG filtering**

```
ecg_filter = filtfilt(num, den, ecg);
figure
subplot(211);
plot(t, ecg);
title('ecg');
xlabel('time(seconds)')
ylabel('Amplitude')
```

```
subplot(212);
plot(t, ecg_filter);
title('ecg filtered');
xlabel('time(seconds)')
ylabel('Amplitude')
```




```
figure
subplot(211);
plot(frq, abs(ecg_fft(1:len/2)));
title('ecg Magnitude Spectrum');
subplot(212);
ecg_fft_filter = fft(ecg_filter);
plot(frq, abs(ecg_fft_filter(1:len/2)));
title('ecg_filter Magnitude Spectrum');
```



The plots show that the unwanted frequencies and noises are susseccfully removed by the filter.

Transient response

Transient response of the filter can be seen in the plot of the Filter ECG signal.

Transient response is the response of a system to a change from an equilibrium or a steady state.