DSP Lab Report

Experiment 6

Aim:

1. To design a Butterworth filter according to the given specifications, find its transfer function plot its poles and zeroes and Bode.
2. To use the designed Butterworth filter to filter the given ECG signal.
3. To design a bandpass Butterworth filter to obtain only fundamental frequency component of an instrument.
4. To design Chebyshev1 filter according to the given specifications and plot its Bode.

Codes:

Q1)

```
% a = 3

Fs = 720;

% Finding order and Natural frequency
[N,wn] = buttord(10*2/Fs,20*2/Fs,3,40);
% finding the numerator and denominator coefficients of transfer function
[B,A] = butter(N,wn);
% finding the TF
SYS = tf(B,A,1/Fs);

% plotting poles and zeroes
figure();
pzmap(SYS);

% plotting bode
figure();
h = bodeplot(SYS);
setoptions(h,'FreqUnits','Hz');
title('Bode of Butterworth');
```

Q2)

```
% a = 3
Fs = 720;

% Finding order and Natural frequency
[N,wn] = buttord(10*2/Fs,20*2/Fs,3,40);
% finding the numerator and denominator coefficients of transfer function
[B,A] = butter(N,wn);

% loading ECG data
ECG = load('ECG_Data.txt');
% filtering ECG data
Y = filter(B,A,ECG);

dt = 1/Fs;
n = length(ECG);
T = n/Fs;
t = 0:dt:T-dt;

% plotting the filtered ECG signal
figure();
plot(t,ECG,'r');
hold();
plot(t,Y,'g');
legend(['Original';'Filtered']);
title('Filtering action on ECG');
xlabel('time(s)');
ylabel('ECG');


DFTx = fft(ECG);
DFTy = fft(Y);
N = length(DFTx);
k = 0:N-1;
f = Fs/N .* k;

% plotting the DFT
figure();
subplot(2,1,1);
plot(f,abs(DFTx));
title('DFT of original signal');
xlabel('Frequency(Hz)');
ylabel('DFT(ECG)');
subplot(2,1,2);
```

```
plot(f,abs(DFTy));
title('DFT of filtered signal');
xlabel('Frequency(Hz)');
ylabel('DFT(ECG)');
```

Q3)

```
% importing the wav file
[y,Fs] = audioread('instru3.wav');

% plotting the spectrogram
figure();
spectrogram(y,blackman(500),10,[],Fs);
title('Instru3');

% Designing the butterworth filter
[N,wn] = buttord([700,850]*2/Fs,[690,950]*2/Fs,10,15);
[B,A] = butter(N,wn);

% filtering the wav file
Y = filter(B,A,y);

audiowrite('filtered_instru3.wav',Y,Fs);

% plotting the spectrogram
figure();
spectrogram(Y,blackman(500),10,[],Fs);
title('Filtered Instru3');
```

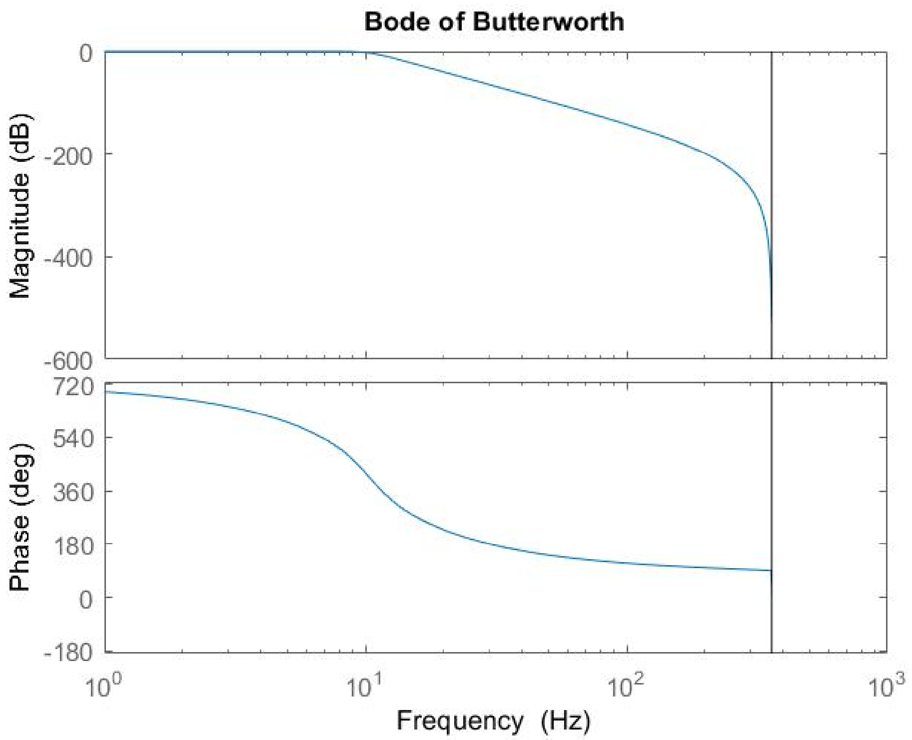
Q4)

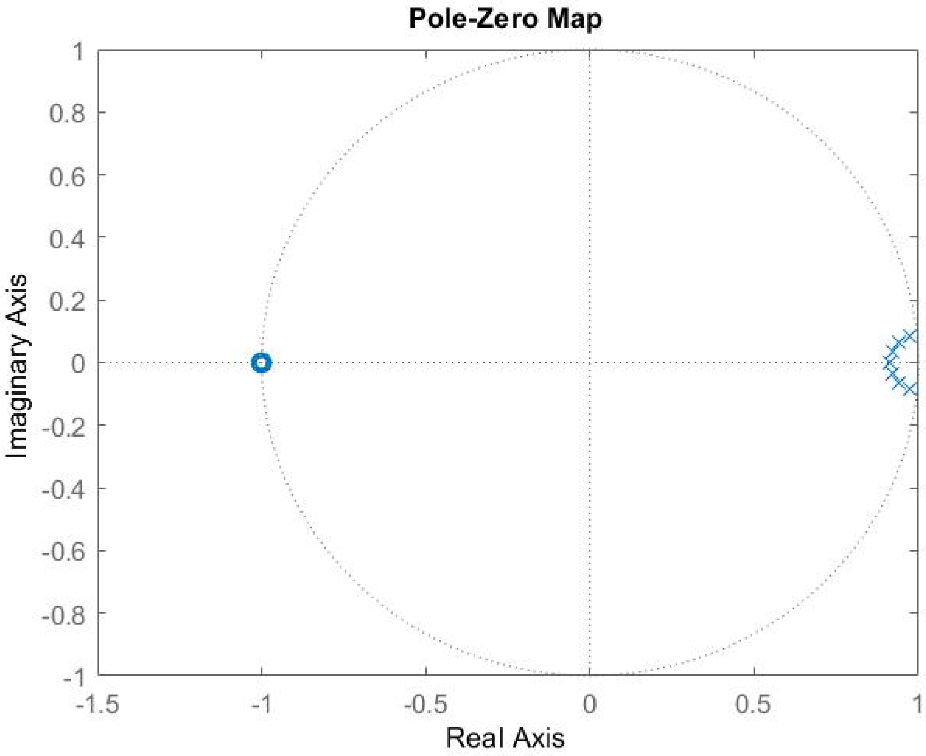
```
% a = 3
Fs = 720;

% designing chebyshev1 filter
[N,wp] = cheb1ord(10*2/Fs,20*2/Fs,3,40);
[B,A] = cheby1(N,0.5,wp);
SYS1 = tf(B,A,1/Fs);

% plotting bode of chebyshev1
figure();
h = bodeplot(SYS1);
setoptions(h,'FreqUnits','Hz');
```

```
title('Bode of Chebyshev1');

% designing butterworth filter
[N,wn] = buttord(10*2/Fs,20*2/Fs,3,40);
[B,A] = butter(N,wn);
SYS2 = tf(B,A,1/Fs);

% finding impulse and step responses of chebyshev1 and butterworth filters
[Y1,T1] = impulse(SYS1,1);
[Y2,T2] = step(SYS1,1);
[Y3,T3] = impulse(SYS2,1);
[Y4,T4] = step(SYS2,1);

% plotting the impulse and step responses
figure();
plot(T1,Y1,'r',T3,Y3,'g',T2,Y2,'y',T4,Y4,'b');
legend('Impulse Chebyshev1','Impulse Butterworth','Step Chebyshev1','Step Butterworth');
title('Time Responses');
xlabel('Time(s)');
ylabel('y(t)');
```

Q1)

Graphs:





Observations:

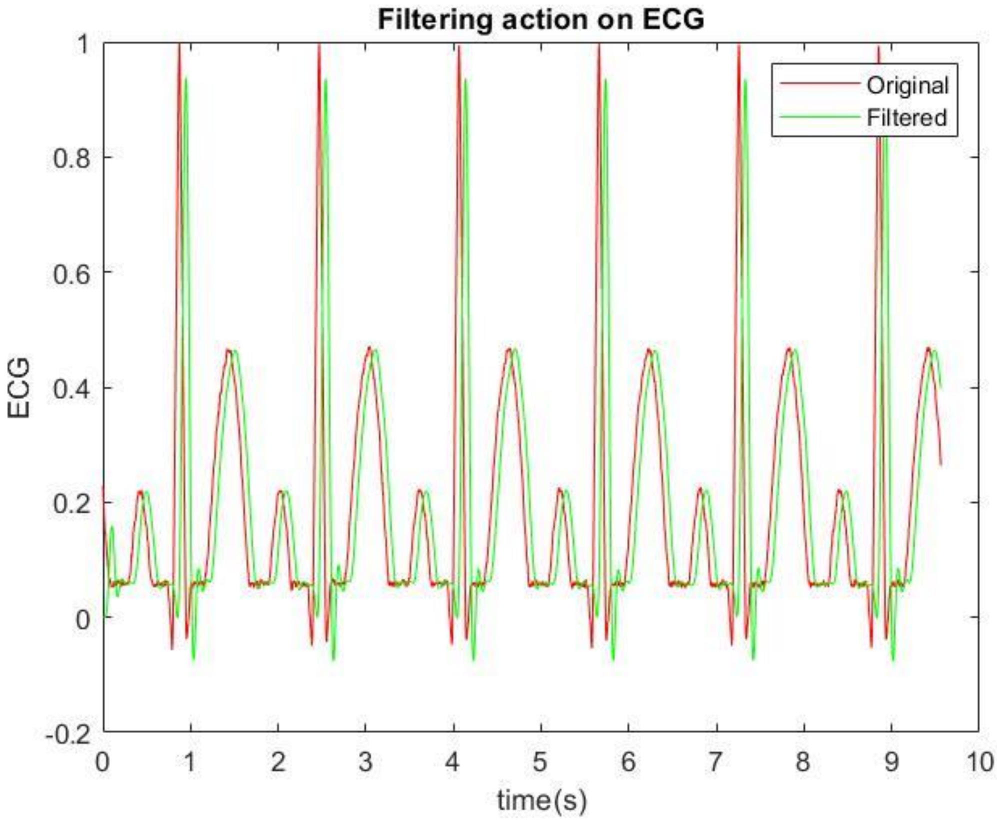
- It can be seen that the poles (X) of the system lie within the unit circle, since it's a causal system, the system is stable.
- Transfer Function:

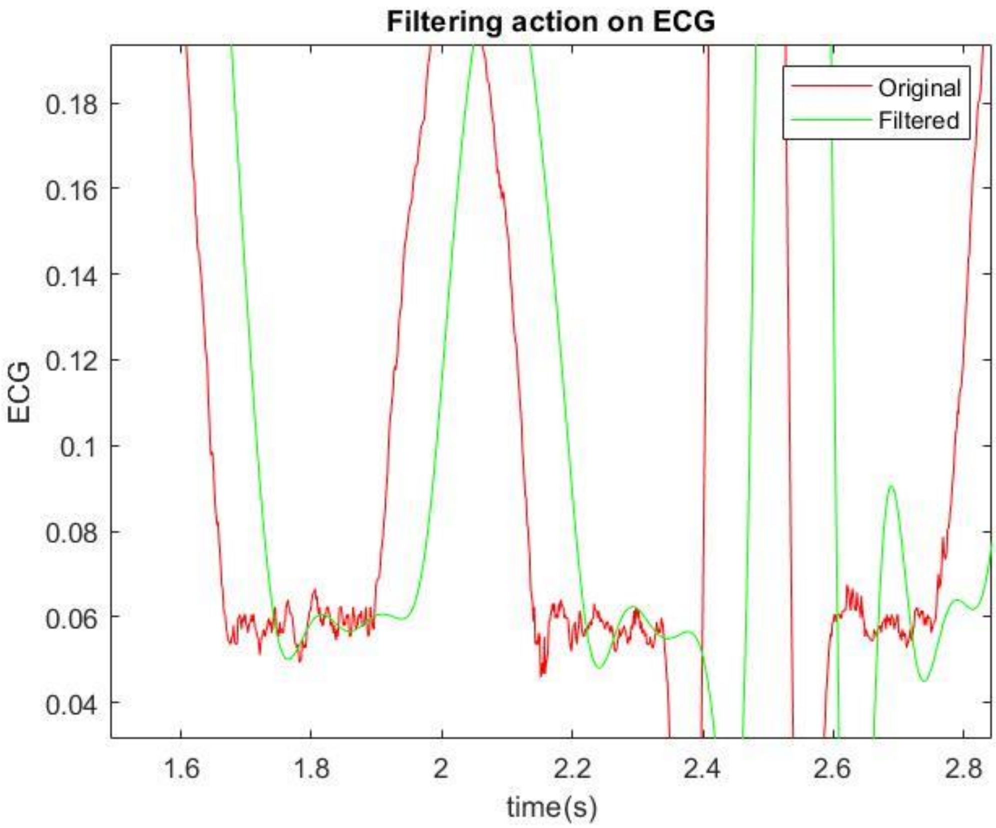
  H (z) =

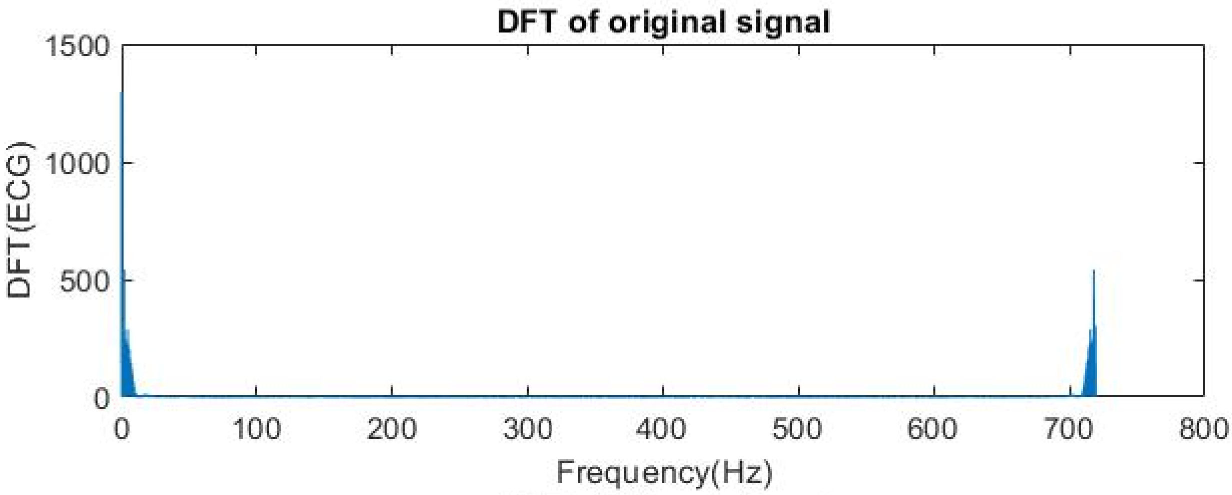
$$H(z) = \frac{10^{-7} * (0.0032 + 0.0224 * z^{-1} + 0.0672 * z^{-2} + 0.112 * z^{-3} + 0.112 * z^{-4} + 0.0672 * z^{-5} + 0.0224 * z^{-6} + 0.0032 * z^{-7})}{(1.0000 - 6.5930 * z^{-1} + 18.6403 * z^{-2} - 29.2957 * z^{-3} + 27.6410 * z^{-4} - 15.6566 * z^{-5} + 4.9295 * z^{-6} - 0.6655 * z^{-7})}$$

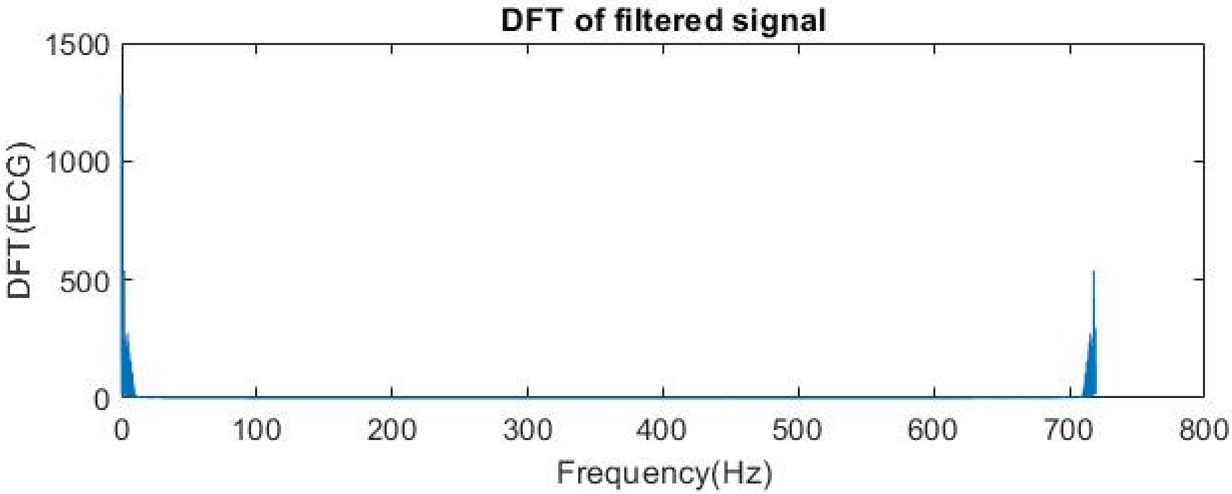
Q2)

Graphs:


Filtering action on ECG
Original
Filtered
ECG
time(s)
1
0.8
0.6
0.4
0.2
0
-0.2
0
1
2
3
4
5
6
7
8
9
10


Filtering action on ECG
Original
Filtered
ECG
time(s)
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
1.6
1.8
2
2.2
2.4
2.6
2.8



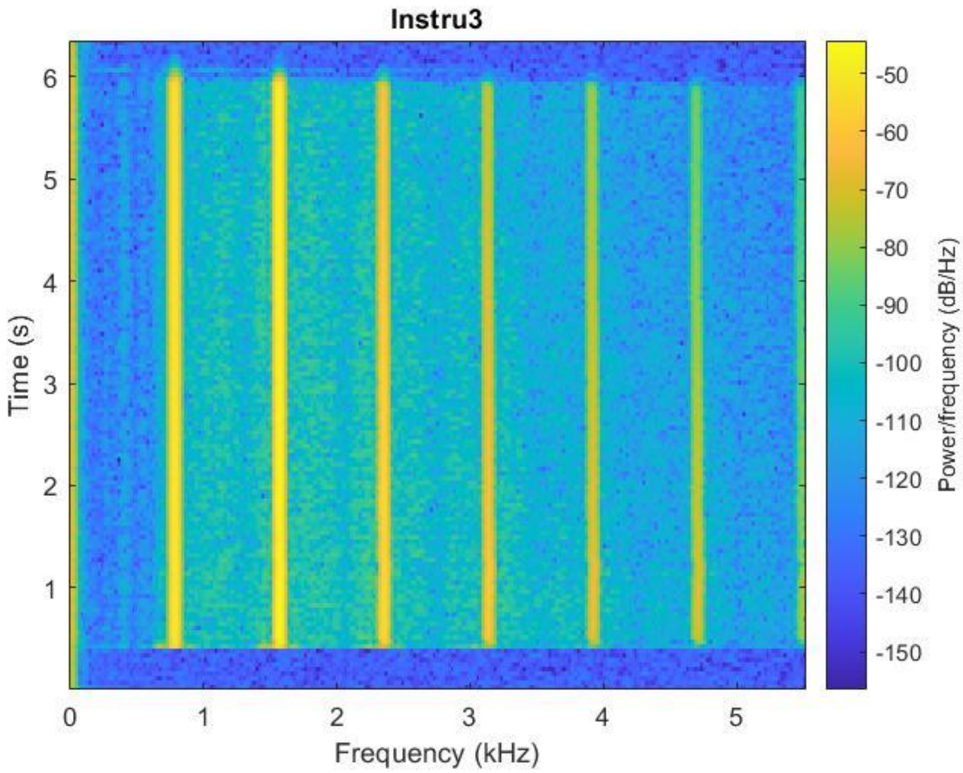


Observations:

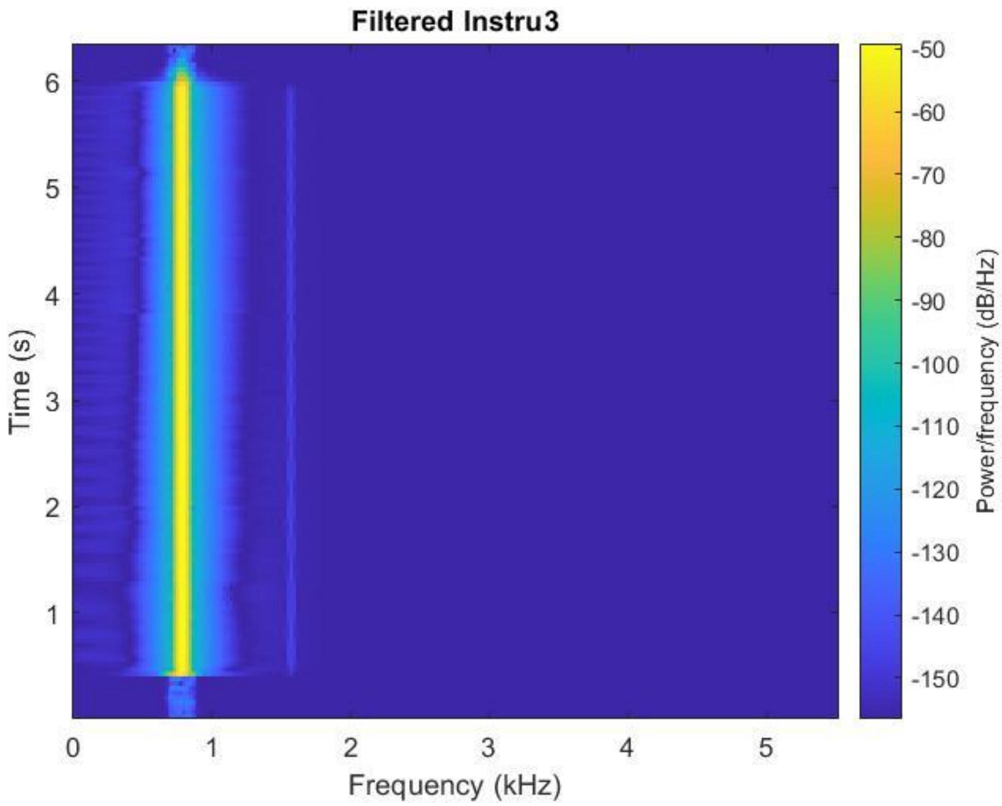
- In the zoomed version of the ECG signal, it can be clearly seen that the high frequency components of the ECG signal are filtered out.

Q3)

Graphs:



Instru3
Time (s)
Frequency (kHz)
Power/frequency (dB/Hz)
0
1
2
3
4
5
6
-50
-60
-70
-80
-90
-100
-110
-120
-130
-140
-150



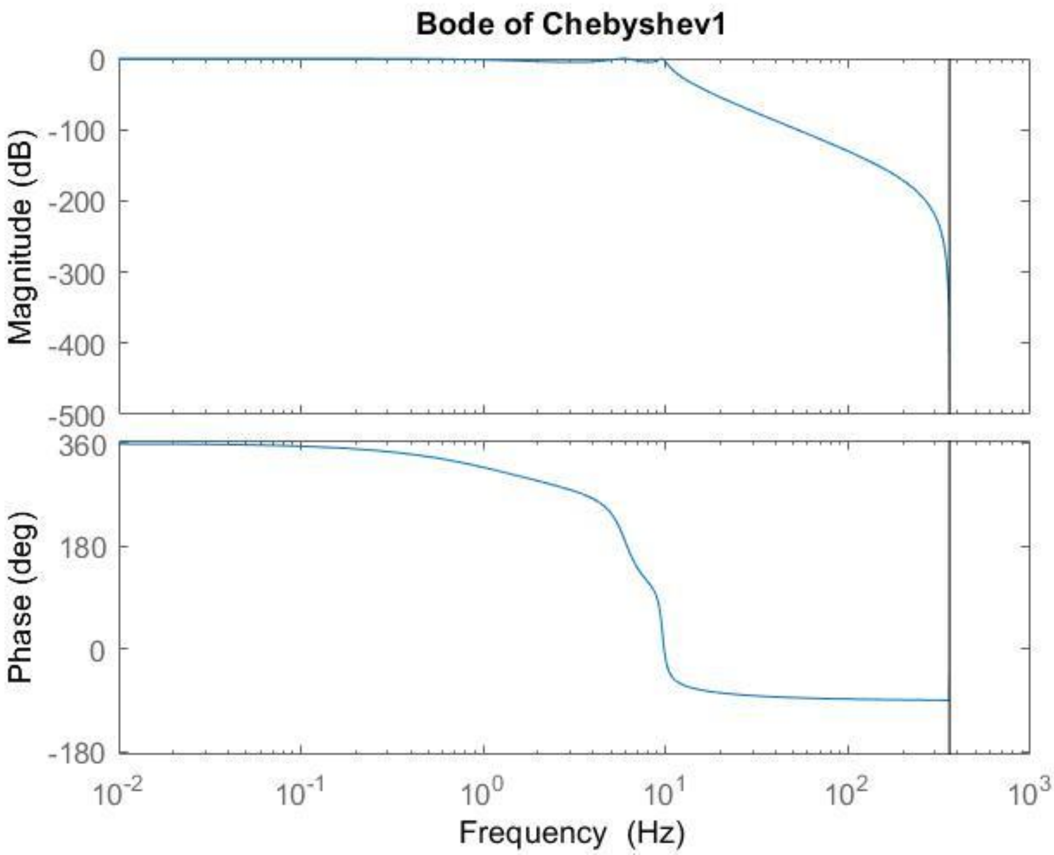
Filtered Instru3
Time (s)
Frequency (kHz)
Power/frequency (dB/Hz)
0
1
2
3
4
5
6
-50
-60
-70
-80
-90
-100
-110
-120
-130
-140
-150

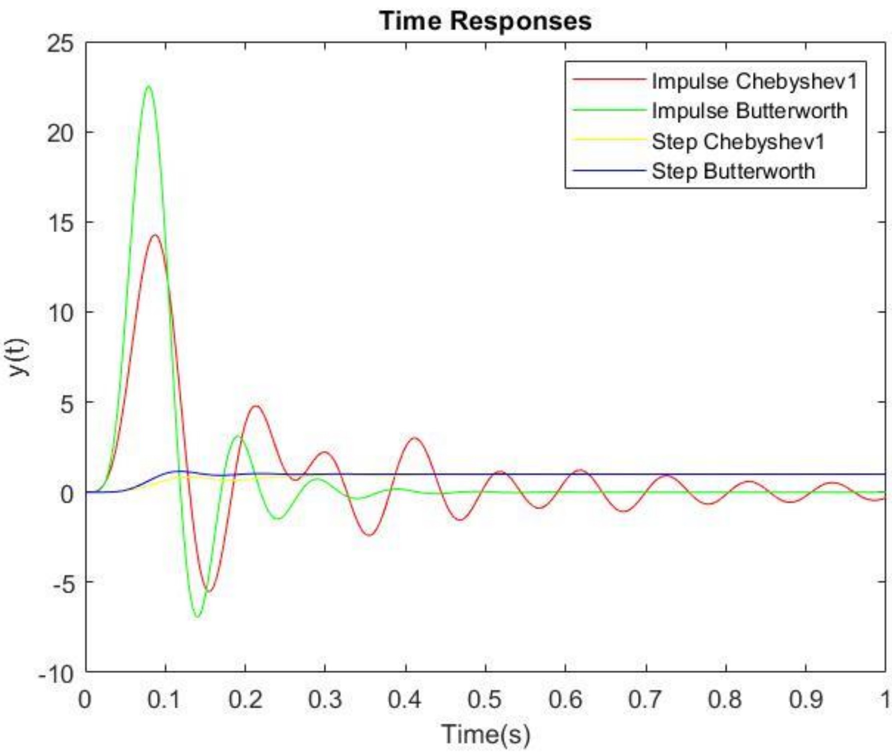
Observations:

- The fundamental frequency was found to be close to 778 Hz.
- The bandpass Butterworth filter was designed to filter out rest of the frequencies. It has the following specifications:
  - Passband frequencies: 700 – 850 Hz
  - Stopband frequencies: 0 – 690 and 950 – INF
  - Maximum passband ripple: -10 dB
  - Stopband attenuation: 15 dB
- From the spectrogram of the filtered signal, it can be observed that only a small pass band around 778 Hz exists.
- When converted to wav file, it can be observed that the sound has become soft.

Q4)

Graphs:





Observations:

- The order of the both the Chebyshev1 and Butterworth is 7.
- From bode of Chebyshev1, it can be seen that Chebyshev1 has a better drop rate in both the magnitude and phase plot when compared to Butterworth filter.
- From the step response plots, both the filters reach steady state almost at the same time.
- From the impulse response plots, it can be seen that, Chebyshev1 takes a long time to reach steady state than Butterworth filter. So settling time is more in Chebyshev1 filter.
- Also the percentage overshoot is more in Butterworth than in Chebyshev1 filter.

Conclusions:

- The Butterworth filter of given specification was implemented and was used to filter an ECG signal.
- A Butterworth filter was designed to extract only the fundamental frequency component of an instrument recording.
- A Chebyshev1 filter was designed and compared to a Butterworth filter of similar specification on the lines of their responses to Impulse and Step input.