DSP LAB Experiment 6
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GITHUB LINK: https://github.com/ramyashri1887/DSP-LAB

Problem 1. (Butterworth filter design)

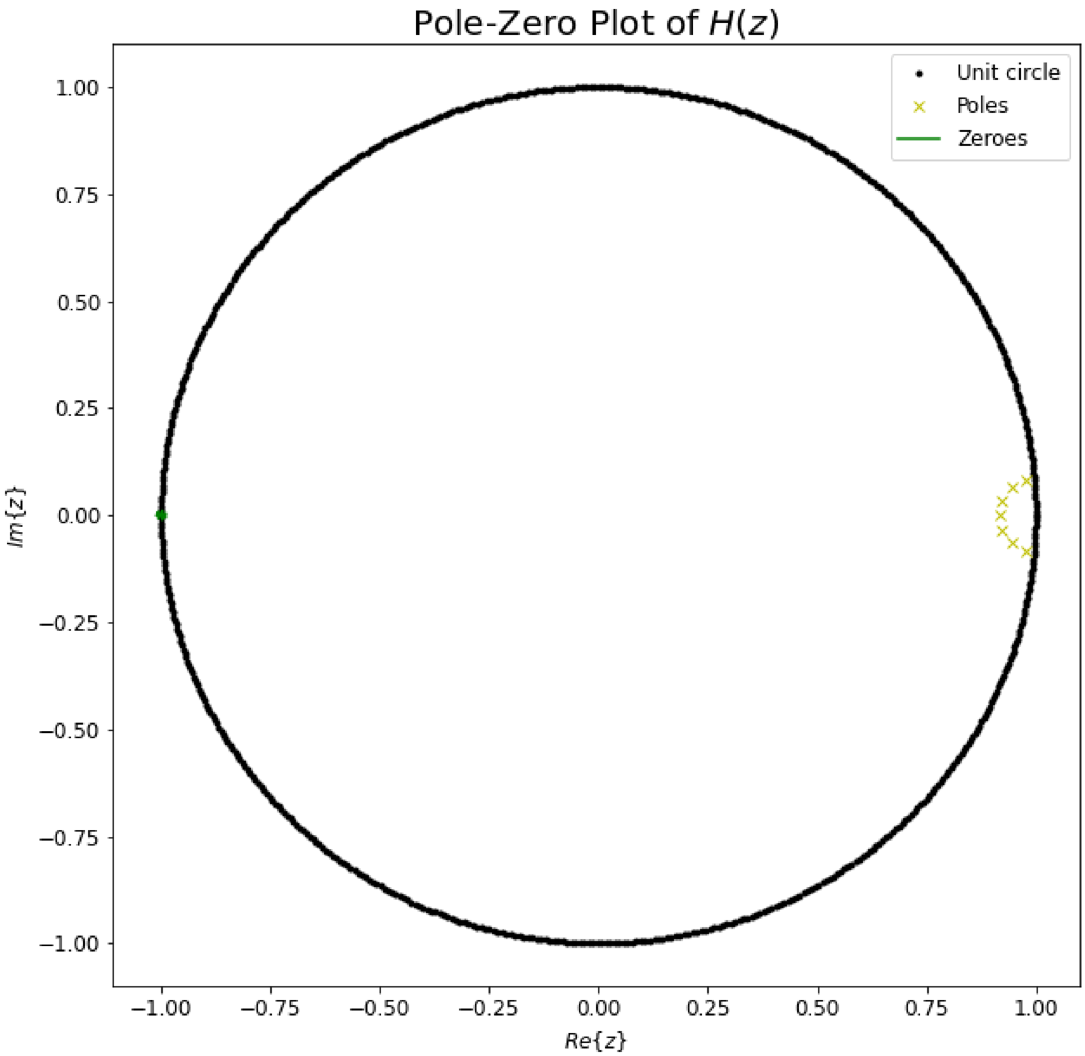
1. Find the transfer function of the filter.
7th order function
Zero at 0.
And 6 complex poles ($a1^{½}$, $a2^{½}$, $a3^{½}$)and 1 real positive pole(a4).
Transfer function:
$a0/(s^2-a1)(s^2-a2)(s^2-a3)(s-a4)$

$$H(j\omega) = 1/\sqrt{\{1 + \varepsilon^2 (\omega/\omega_C)^{2n}\}}$$

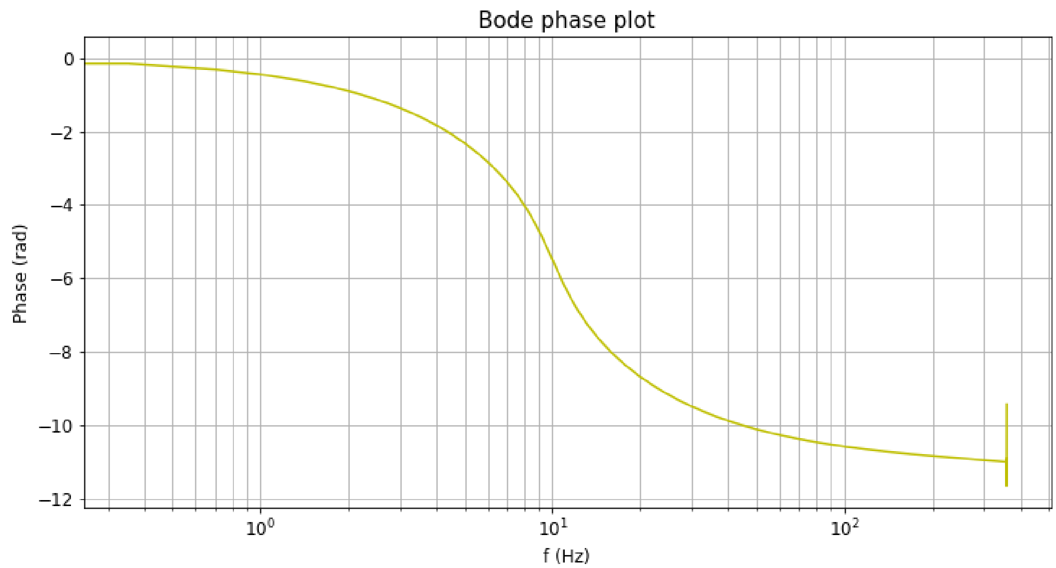
Where n is the order of the filter:7
ω is the radian frequency and it is equal to 2πf: f=10Hz
And ε is the maximum passband gain: 40dB

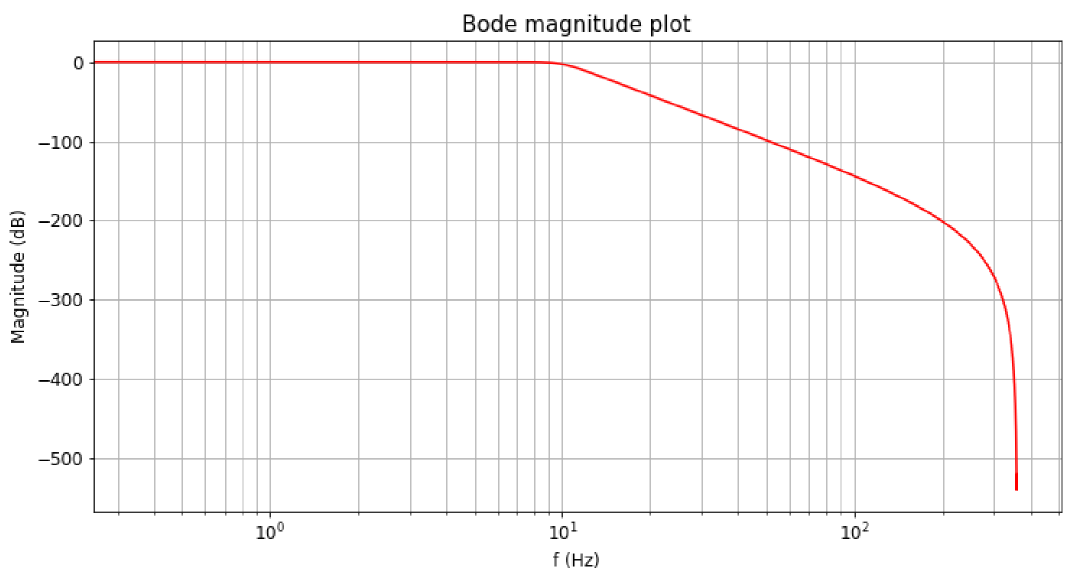
$H(jw)= 1/sqrt(1+40^2(\omega /(20\ pi\ ))^{14})$

2. Plot its pole-zero plot. Comment on the system stability from the plot.
Unstable system because poles lie on the right half of the cartesian plane


Pole-Zero Plot of $H(z)$
Unit circle
Poles
Zeroes
1.00
0.75
0.50
0.25
0.00
−0.25
−0.50
−0.75
−1.00
$Im\{z\}$
−1.00
−0.75
−0.50
−0.25
0.00
0.25
0.50
0.75
1.00
$Re\{z\}$

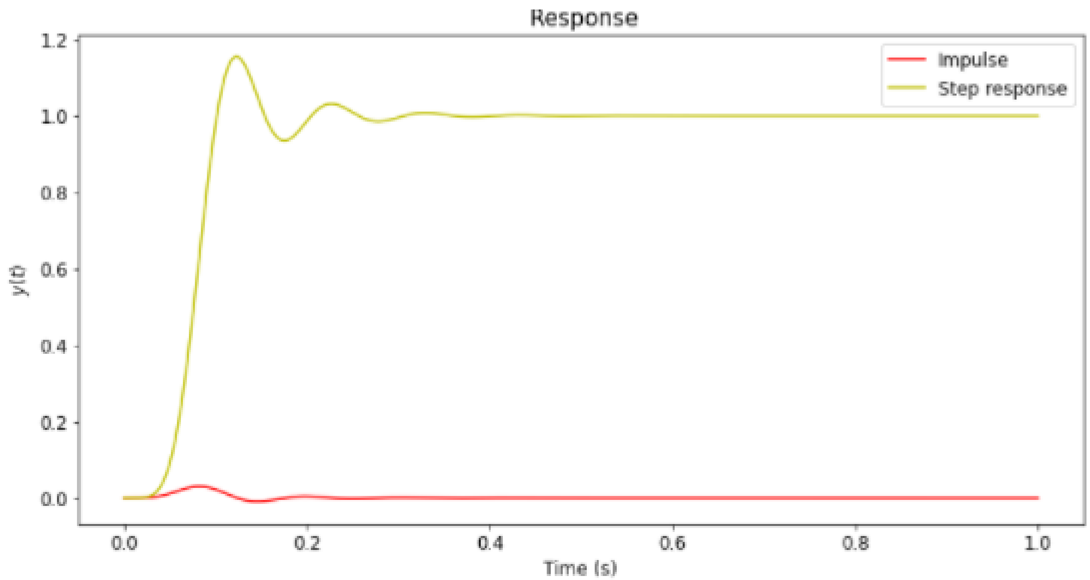
3. Plot also the bode plot (with respect to frequency in Hz).

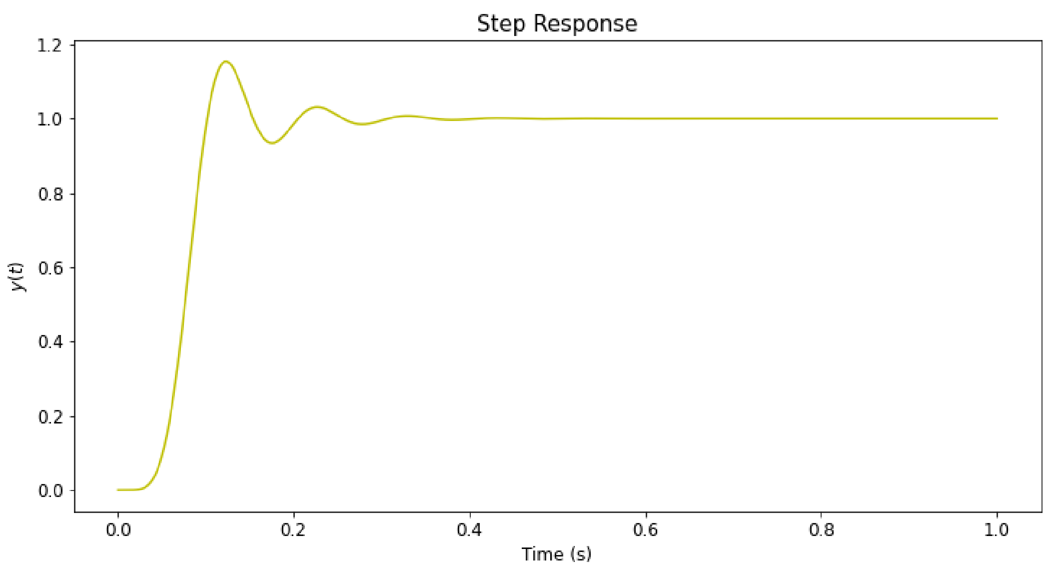


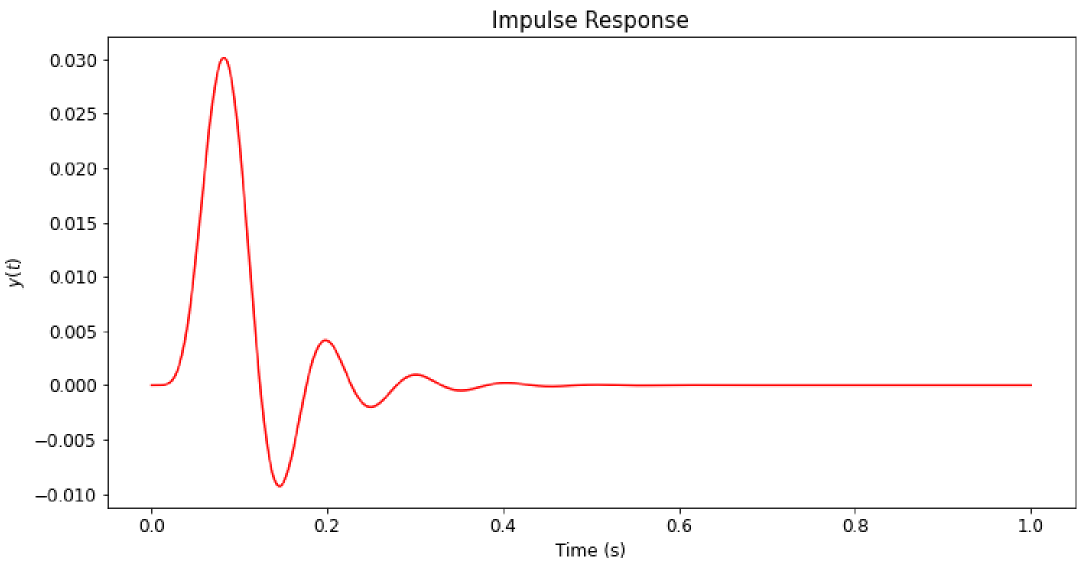


Compare (plot on the same graph with legends) the impulse response and step response of the two filters for a duration of 1 sec. Write down your observations.

Answer: Step response has to be the integral of the impulse response. It's an infinite impulse response filter.

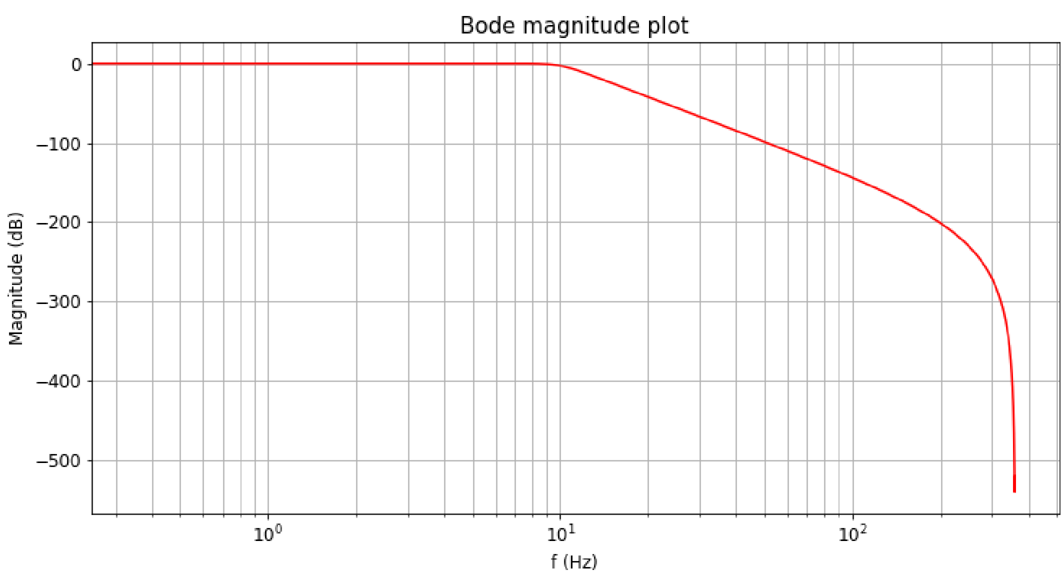

Response
Impulse
Step response
y(t)
Time (s)
0.0
0.2
0.4
0.6
0.8
1.0
1.2

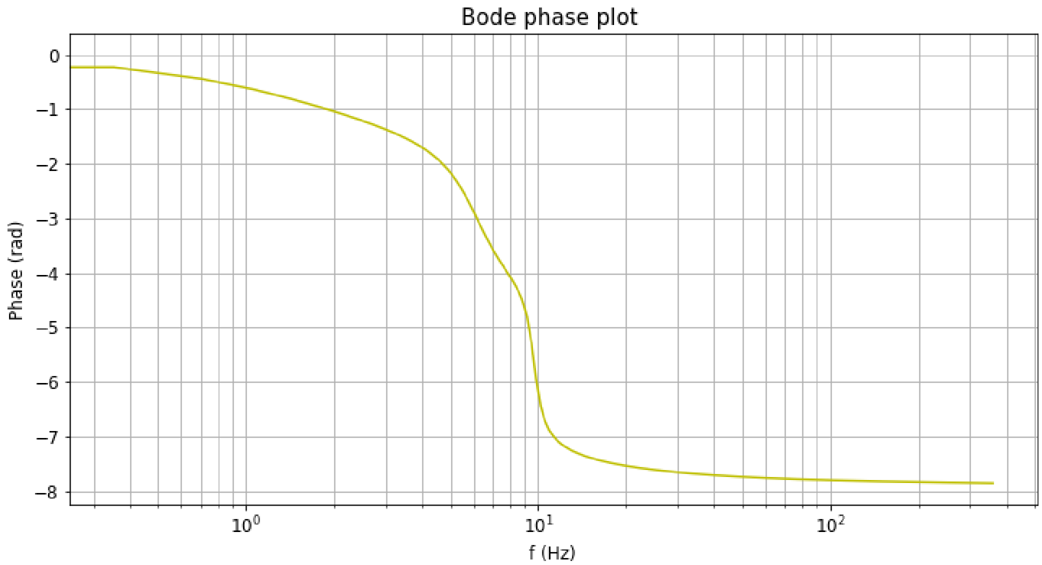

Step Response
y(t)
Time (s)
0.0
0.2
0.4
0.6
0.8
1.0
1.2



Problem 4. (Chebyshev filter design)
Try the lowpass filter specifications used in Problem 1 with Type I Chebyshev's filter. Compare the system order, w.r.t Butterworth.

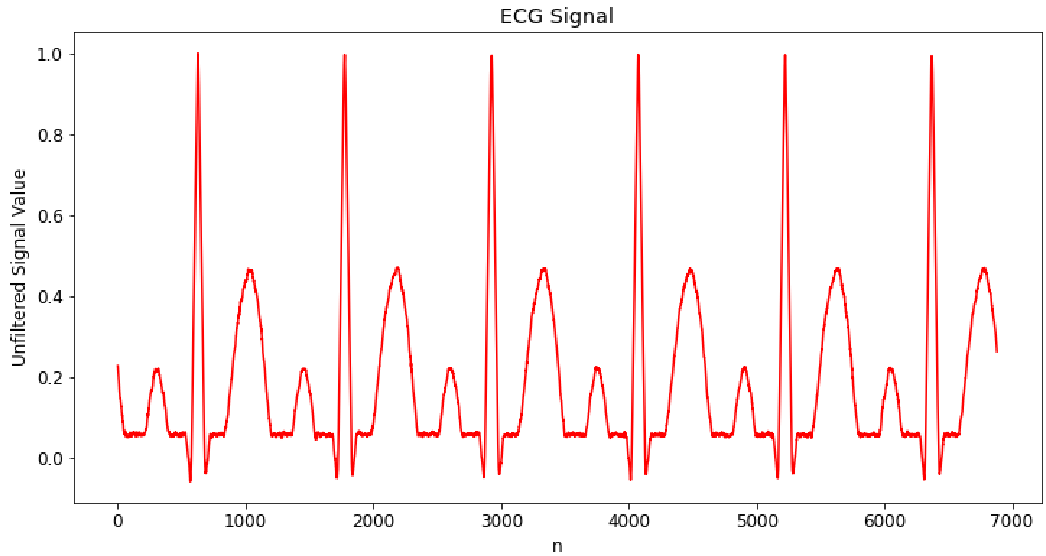
Plot the Bode.

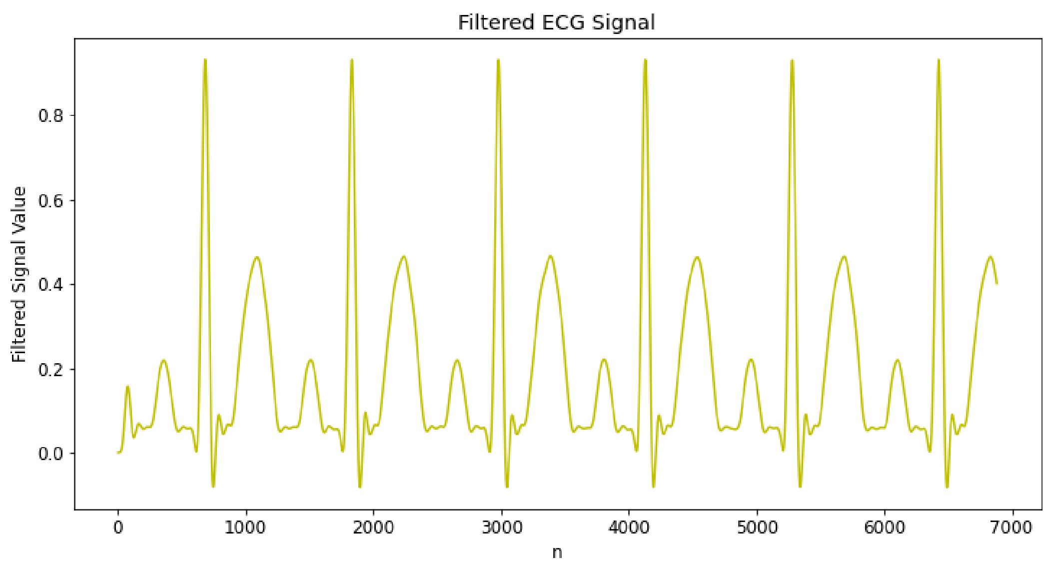


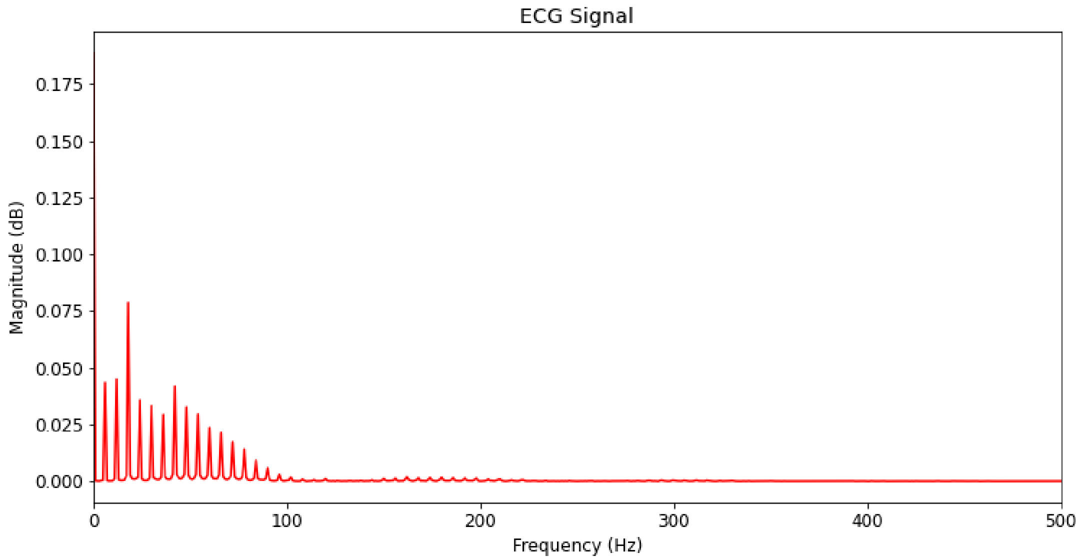


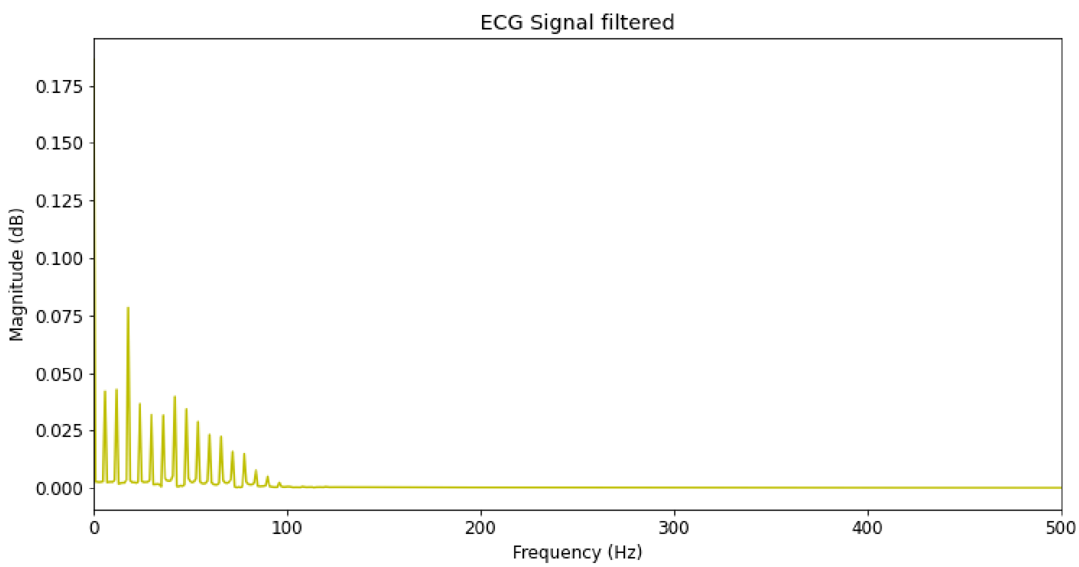
Conclusions:
Chebyshev’s filter order: 5
Butterworth filter order: 7
Compared with a Chebyshev Type I filter, the Butterworth filter has a slower roll-off and thus will require a higher order to implement a particular stopband specification, but Butterworth filters have a more linear phase response in the pass-band than Chebyshev Type I can achieve.

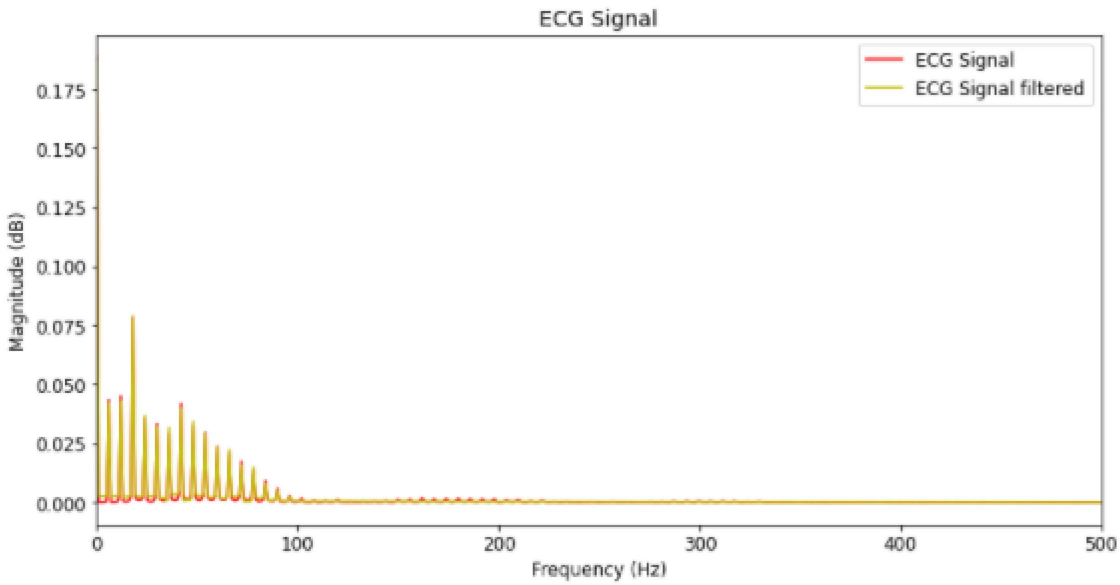
Problem 2. (Filtering)
Use the Butterworth filter to filter the ECG data (FS = 720 Hz) stored in the text file. Plot the filtered output and compare it with the original signal in the same figure.


ECG Signal
Unfiltered Signal Value
1.0
0.8
0.6
0.4
0.2
0.0
0
1000
2000
3000
4000
5000
6000
7000
n


Filtered ECG Signal
Filtered Signal Value
0.8
0.6
0.4
0.2
0.0
0
1000
2000
3000
4000
5000
6000
7000
n

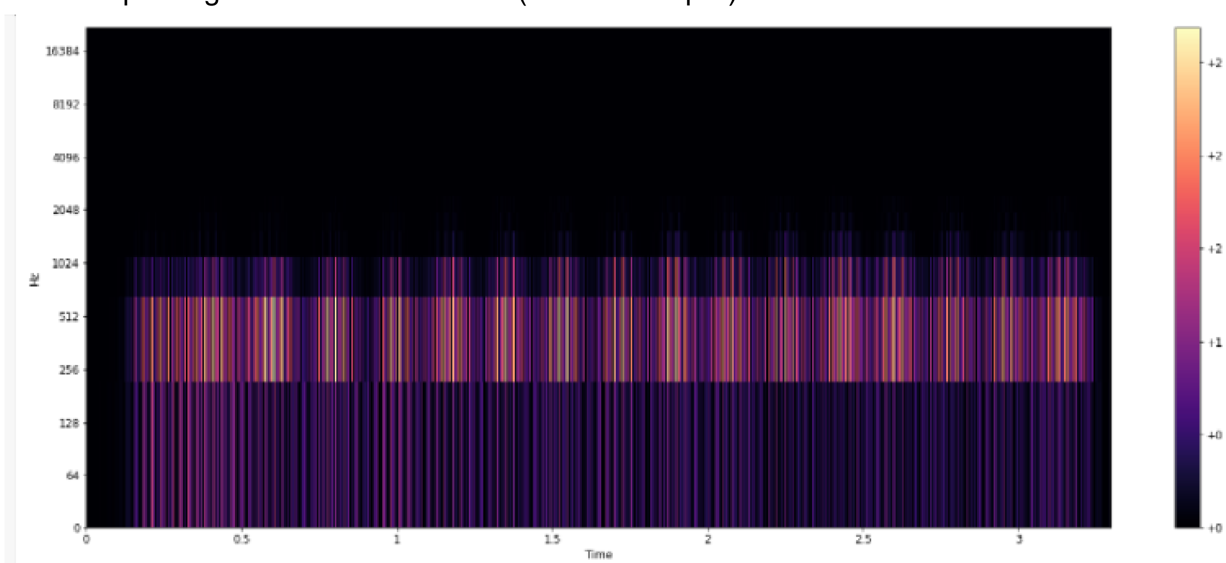

ECG Signal
Magnitude (dB)
0.175
0.150
0.125
0.100
0.075
0.050
0.025
0.000
0
100
200
300
400
500
Frequency (Hz)


ECG Signal filtered
Magnitude (dB)
0.175
0.150
0.125
0.100
0.075
0.050
0.025
0.000
0
100
200
300
400
500
Frequency (Hz)



Observations:
Butterworth lowpass filter with, higher frequencies filtered out of the signal. Filtered signal or noise-free signal can be further used to extract features from the ECG data. We are not using the Butterworth high pass filter for ECG data because it creates more distortion in our signal after applying it.

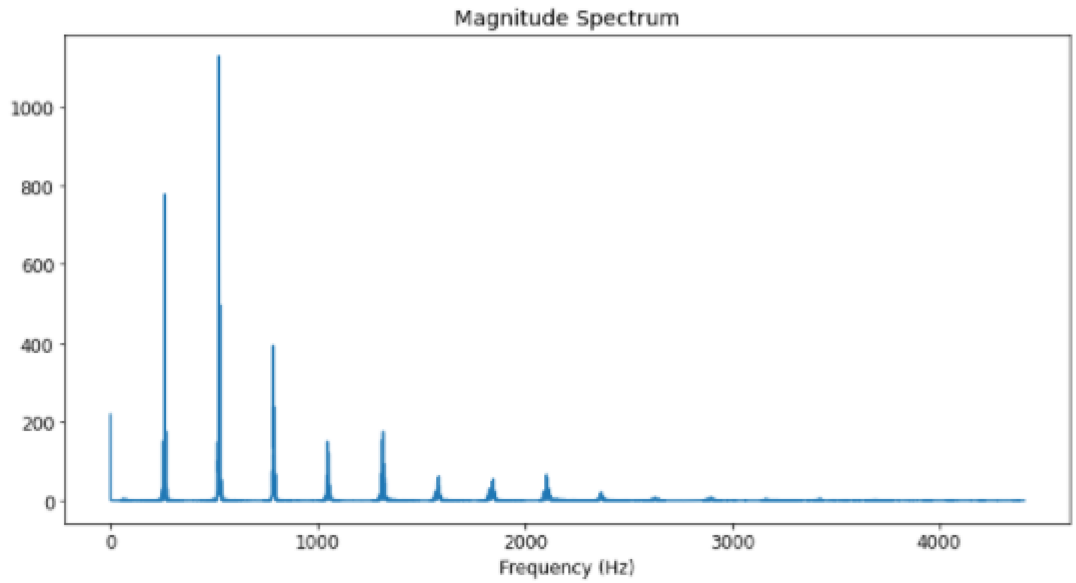
Problem 3. (Filtering — Time-Frequency Analysis)
Plot the spectrogram of the instruα.wav (Same as Exp-5).

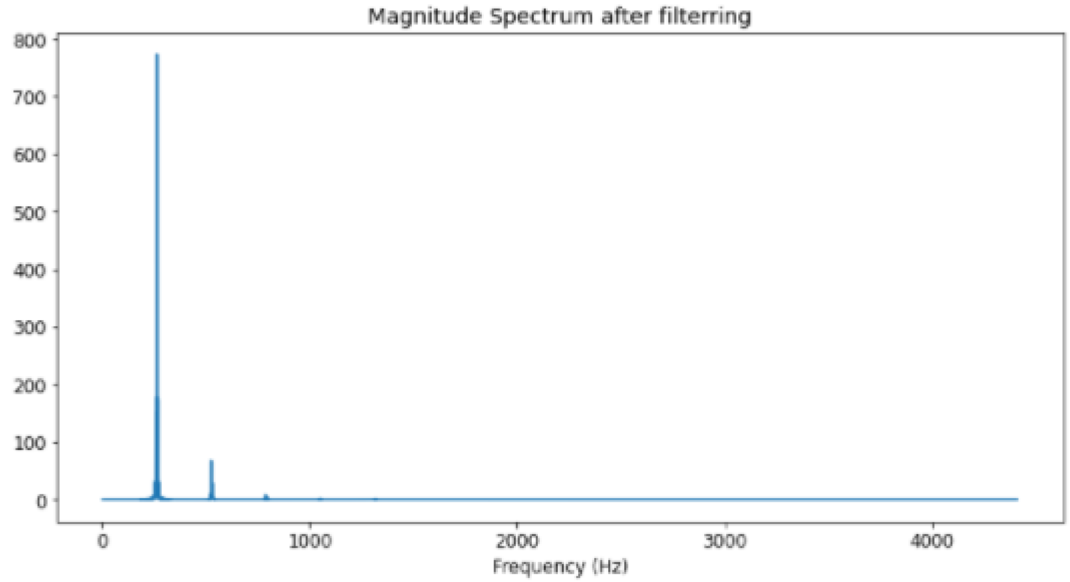


4.1 Spectrogram of instru3

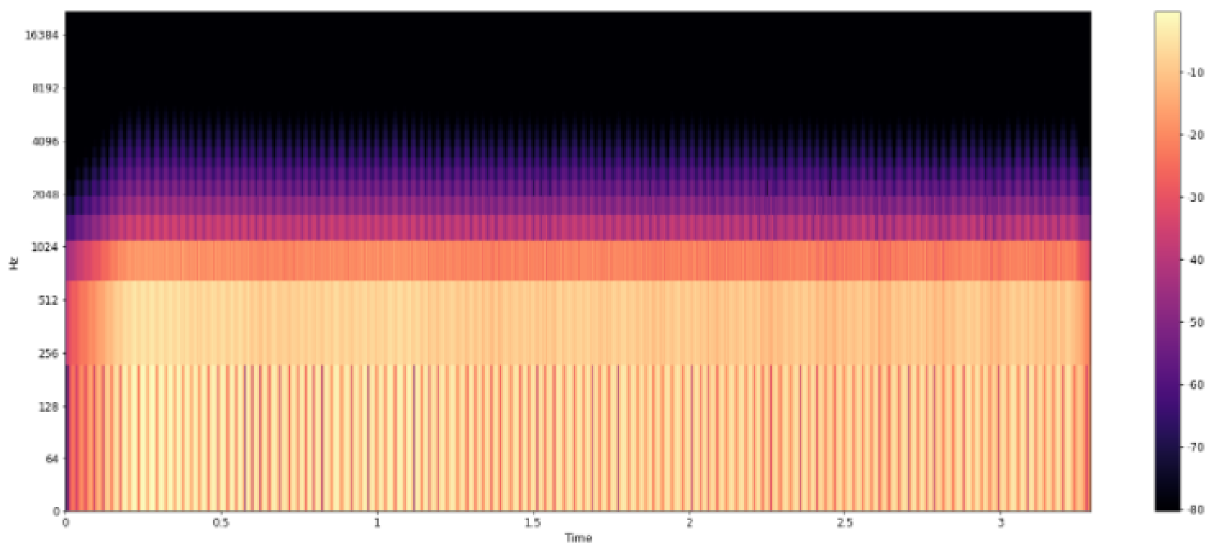
Design a digital Butterworth bandpass filter to only extract the fundamental (The first major peak after DC) and remove the rest including the DC.
Answer:

Steps to choose the passband. Plot a DFT and look for the first harmonic. Since the first harmonic likes close to 250 Hz. the passband chosen is [200,300].





4.3



4.4 Spectrogram of the filtered signal

Time-frequency analysis of filtered signal: The higher weighting parts localize the regions which are expected to be the signal components, and the lower weighting parts attenuate the noise in the time-frequency domain.