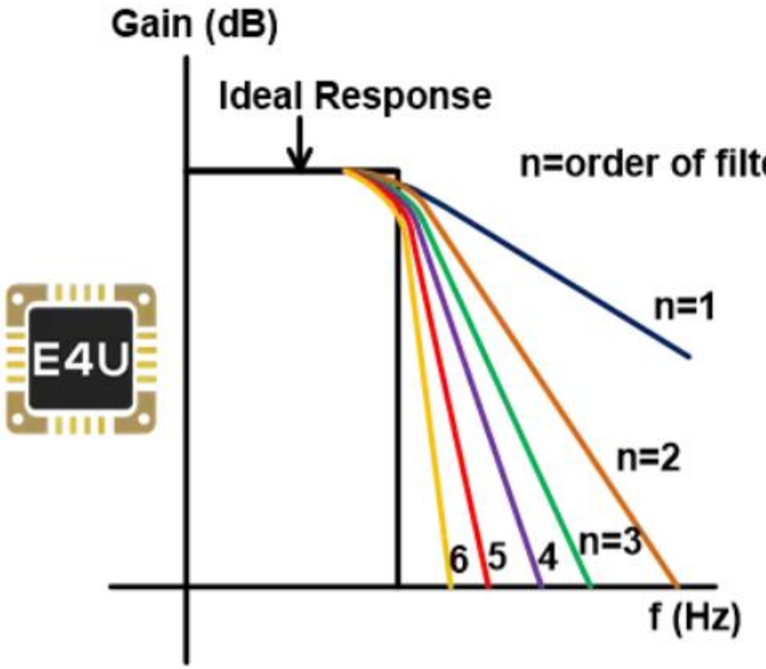
Design and Simulation of Different Types of Infinite Impulse Response (IIR) Filters

Experiment no#3

- Butterworth Filter
- Chebyshev Filter : Type -1 and Type-2
- Elliptic Filter

Various order of Butterworth filter

The below figure shows the frequency response of the Butterworth filter for various orders of the filter.



Frequency Response of Butterworth Filter

- Design a 10th order band pass (BP) Butterworth filter with a passband from 100 to 200 Hz and plot both impulse response and frequency response.

Impulse response and frequency response

```
Fs=1000;% Fs=1000 i.e. sampling frequency
n=10; %order of the filter
Wn=[100 200]/500; %normalized by Fs/2
% Normalized frequency Wn can vary between 0 and 1
%Normalization is done by Fs/2, here Wn = 0.2 to 0.4
[b,a]=butter(n,Wn);
figure(1)
[y,t]=impz(b,a,101); % 101 samples of impulse response
plot(t,y)
title('Impulse Response') grid on
figure(2) freqz(b,a,512, Fs)
title('Frequency Response')
```

- Step response??
- For the above mentioned problem
- Step response <<- >> Impulse response

Step Response

- **Fs=1000;% Fs=1000 i.e. sampling frequency**
- **n=10; %order of the filter**
- **Wn=[100 200]/500; %normalized by Fs/2**
- **[b,a]=butter(n,Wn);**
- **stepz(b,a)**
- **grid on**

Differences between Butterworth and Chebyshev filter

	Butterworth Filter	Chebyshev Filter
Order of Filter	The order of the Butterworth filter is higher than the Chebyshev filter for the same desired specifications.	The order of the Chebyshev filter is less compared to the Butterworth filter for the same desired specifications.
Hardware	It requires more hardware.	It requires less hardware.
Ripple	There is no ripple in passband and stopband of frequency response.	There is either ripple in passband or stopband.
Poles	All poles lie on a circle having a radius of the cutoff frequency.	All poles lie on ellipse having major axis R, ξ, minor axis r.
Transition band	The Butterworth filter has a wider transition band compared to the Chebyshev filter.	The Chebyshev filter has a narrow transition band compared to the Butterworth filter.
Types	It doesn't have any types.	It has two types; type-1 and type-2.
Cutoff Frequency	The cutoff frequency of this filter is not equal to the passband frequency.	The cutoff frequency of this filter is equal to the passband frequency.

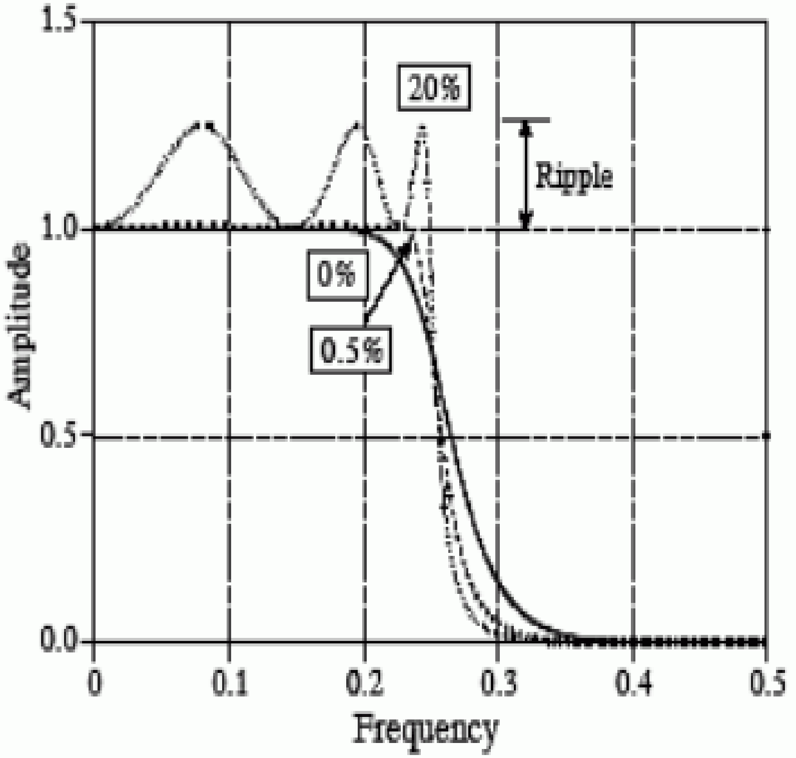
Question 2

- Design a 10th order BP Chebyshev filter of type-I with a passband from 100 to 200 Hz and plot the impulse response and frequency response. Consider 25dB ripple in passband.

```
Fs=1000;
n=10;
Rp=25;
Wn=[100 200]/(Fs/2);
[b,a]=cheby1(n,Rp,Wn);   % For stop band
[b,a]=cheby1(n,Rp,Wn,’stop’);
[y,t]=impz(b,a,101);
figure(1)
plot(t,y)
grid on
title('Impulse Response')
figure(2)
freqz(b, a, 512, Fs)
title('Frequency Response')
```

Chebyshev Filter

FIGURE 20-1
The Chebyshev response. Chebyshev filters achieve a faster roll-off by allowing ripple in the passband. When the ripple is set to 0%, it is called a *maximally flat* or *Butterworth* filter. Consider using a ripple of 0.5% in your designs; this passband unflatness is so small that it cannot be seen in this graph, but the roll-off is much faster than the Butterworth.

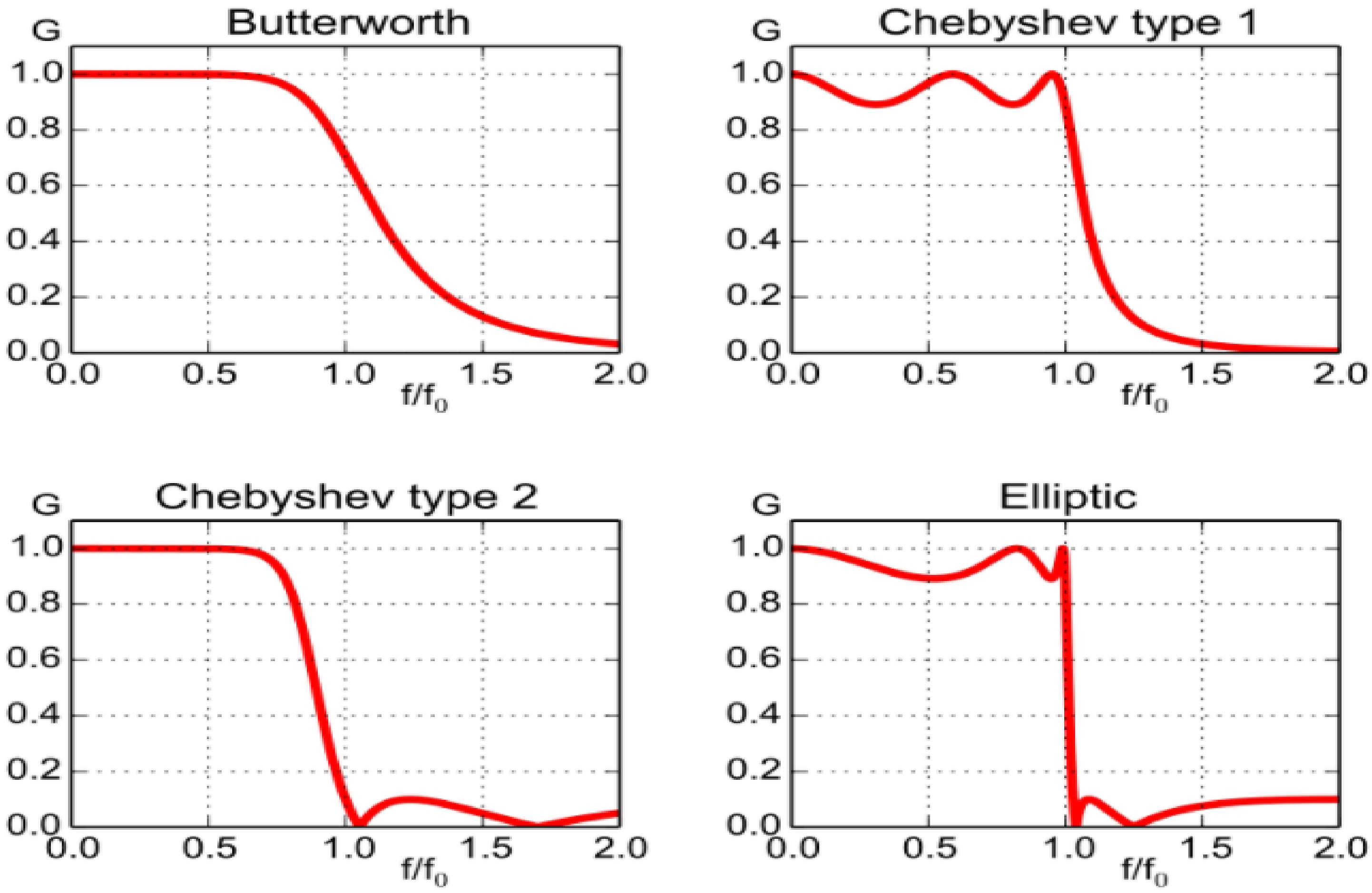


Elliptic Filter: Question 3

3. **Design a 10th order BP elliptic filter with passband in the range of 100 to 200 Hz. Plot the frequency response and impulse response of the filter. Consider 5dB ripple in passband and 20dB attenuation in stopband.**

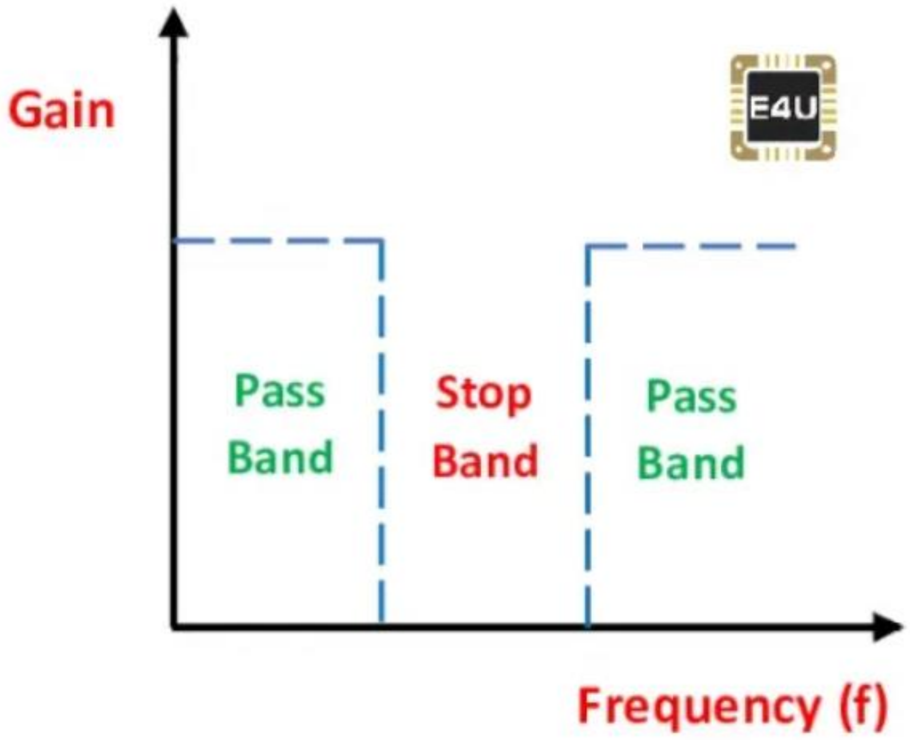
```
Fs=1000; %Sampling Frequency

n=10;
Rp=5;
Rs=20; % Rs dB down from peak value in pass-band
Wn=[100 200]/(Fs/2);
[b,a]=ellip(n,Rp,Rs,Wn);
figure(1);
freqz(b,a,512,Fs); %512 samples
title('Frequency Response')
figure(2);
[y,t]=impz(b, a, 500); % here 500 means number of
samples
plot(t,y)
grid on
title('Impulse response of Elliptic filter')
```

Comparison

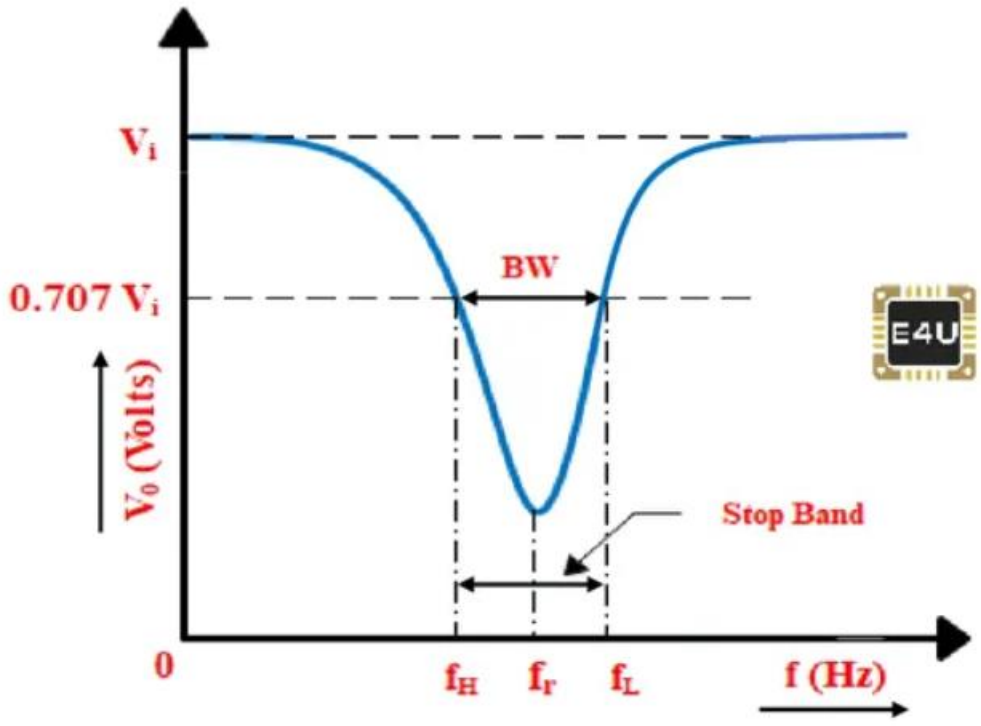


Butterworth
Chebyshev type 1
Chebyshev type 2
Elliptic
G
1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.5
1.0
1.5
2.0
f/f0

Notch filter (Bandstop)



Frequency Response



Characteristics of a Notch Filter

Question 4

A bandpass IIR filer has the transfer function of, $H(z) = \dfrac{z^2 - 1}{z^2 + 0.877}$; determine poles and zeros of the filter and frequency response taking sampling frequency $Fs = 500\text{Hz}$.

The transfer function of the filter, $H(z) = \dfrac{z^2 - 1}{z^2 + 0.877} = \dfrac{1 - z^{-2}}{1 + 0.877z^{-2}}$.

P =

0 + 0.9365i

0 - 0.9365i

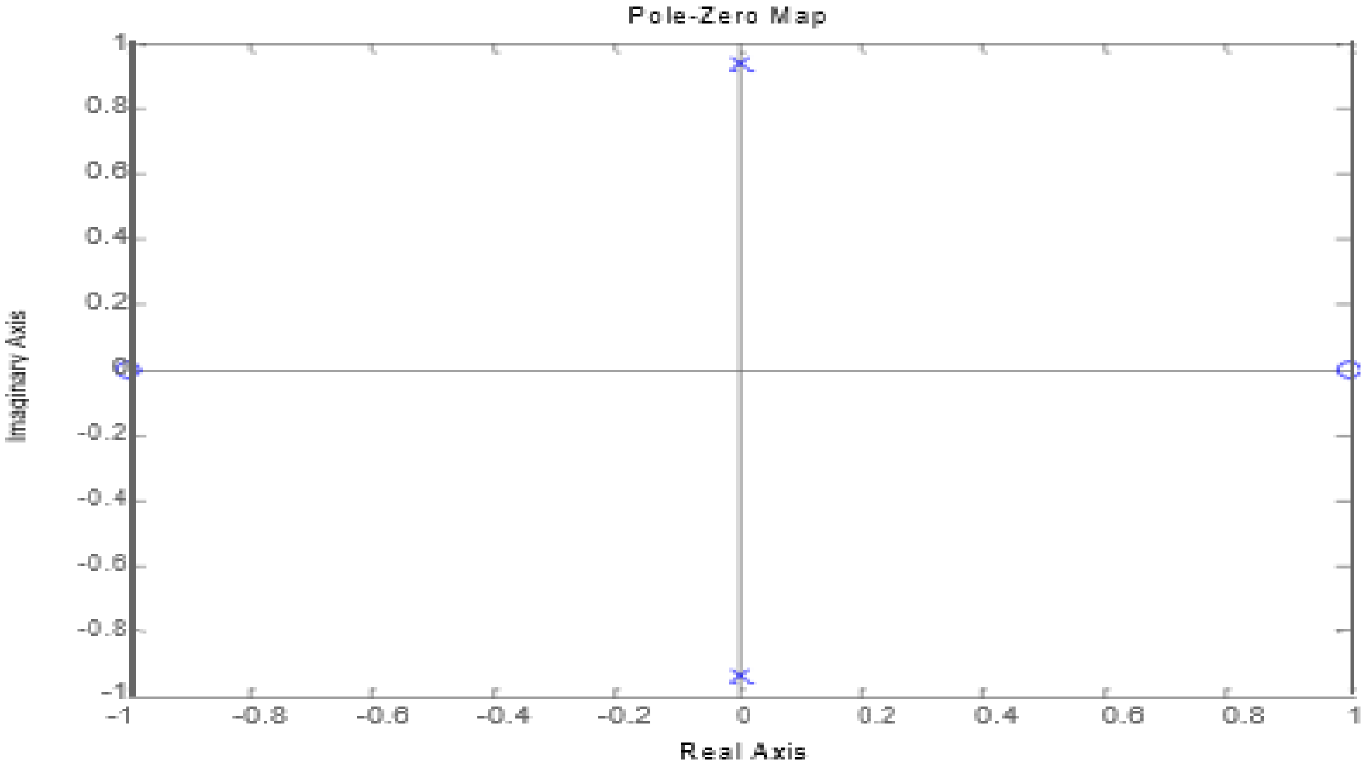
Z. =

-

1

1

Pole-zero diagram



Solution

```
b=[1, 0, 1]; %numerator
a=[1, 0, 0.877];% denominator
Fs=500;
freqz(b, a, 512, Fs); %512 samples
```

Question 5

Observe the frequency response of, $H(z) = \dfrac{1 - z^{-2}}{1 - 0.877z^{-2}}$ and comment on the result.

```
b=[1, 0, 1]; %numerator
a=[1, 0, -0.877];% denominator
Fs=500;
freqz(b, a, 512, Fs); %512 samples
```