Introduction:

In signal processing, filter are essential to perform specific task such as removal of noise, bypass certain frequency, pass certain frequency. Analog filter and digital filter are two main categories in filter design.

Typical examples of frequency function are:

- A low-pass filter is used to cut unwanted high-frequency signals.
- A high-pass filter passes high frequencies fairly well; it is helpful as a filter to cut any unwanted low-frequency components.
- A band-pass filter passes a limited range of frequencies.
- A band-stop filter passes frequencies above and below a certain range. A very narrow band-stop filter is known as a notch filter.

IIR filters have infinite-duration impulse responses, and hence they can be matched to analog filters, all of which generally have infinitely long impulse responses. Therefore, the basic technique of IIR filter design transforms well-known analog filters into digital filters using complex-valued mappings.

Discussion:

Below are some technical terms that are commonly used when describing filter response curves:

- -3dB Frequency (f_{3dB}). This term, pronounced "minus 3dB frequency", corresponds to the input frequency that causes the output signal to drop by -3dB relative to the input signal. The -3dB frequency is also referred to as the cutoff frequency, and it is the frequency at which the output power is reduced by one-half (which is why this frequency is also called the "half-power frequency"),
- Center frequency (f_0). The center frequency, a term used for band-pass and notch filters, is a central frequency that lies between the upper and lower cutoff frequencies.
- Bandwidth. The bandwidth is the width of the passband, and the passband is the band of frequencies that do not experience significant attenuation when moving from the input of the filter to the output of the filter.
- Stopband frequency (f_s). This is a particular frequency at which the attenuation reaches a specified value.
    - For low-pass and high-pass filters, frequencies beyond the stopband frequency are referred to as the stopband.
    - For band-pass and notch filters, two stopband frequencies exist. The frequencies between these two stopband frequencies are referred to as the stopband.

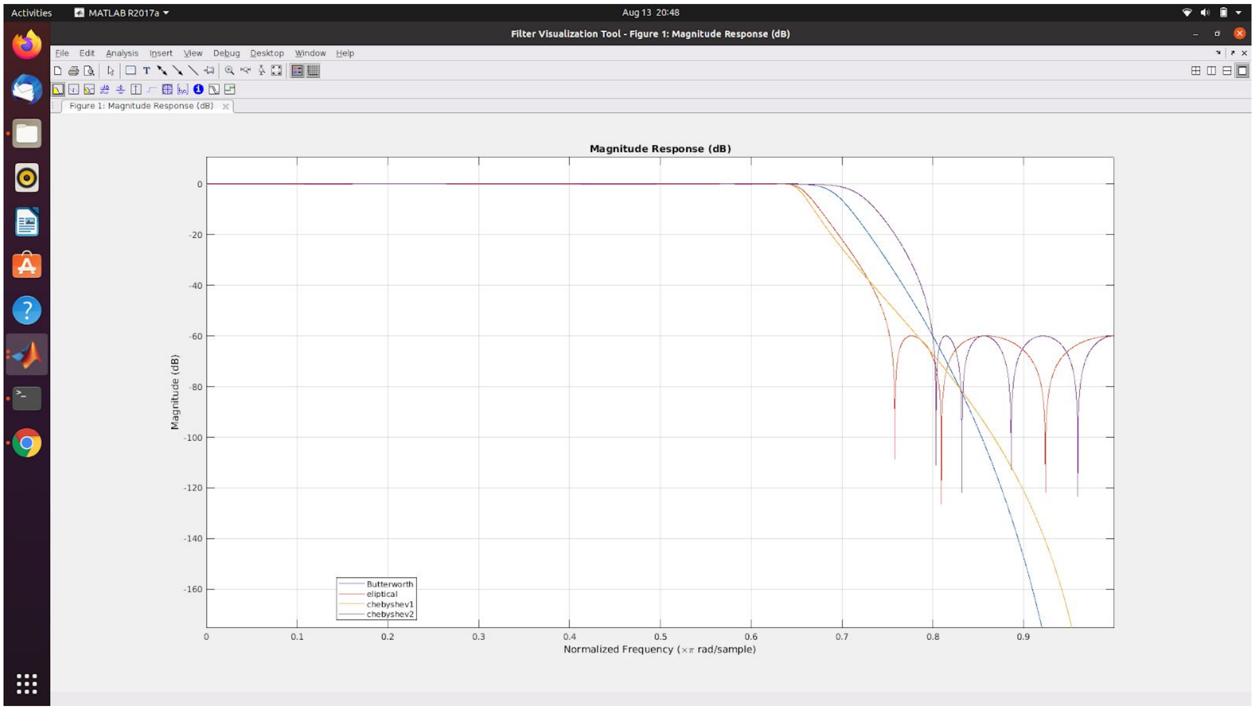
Matlab Code:

Main code:

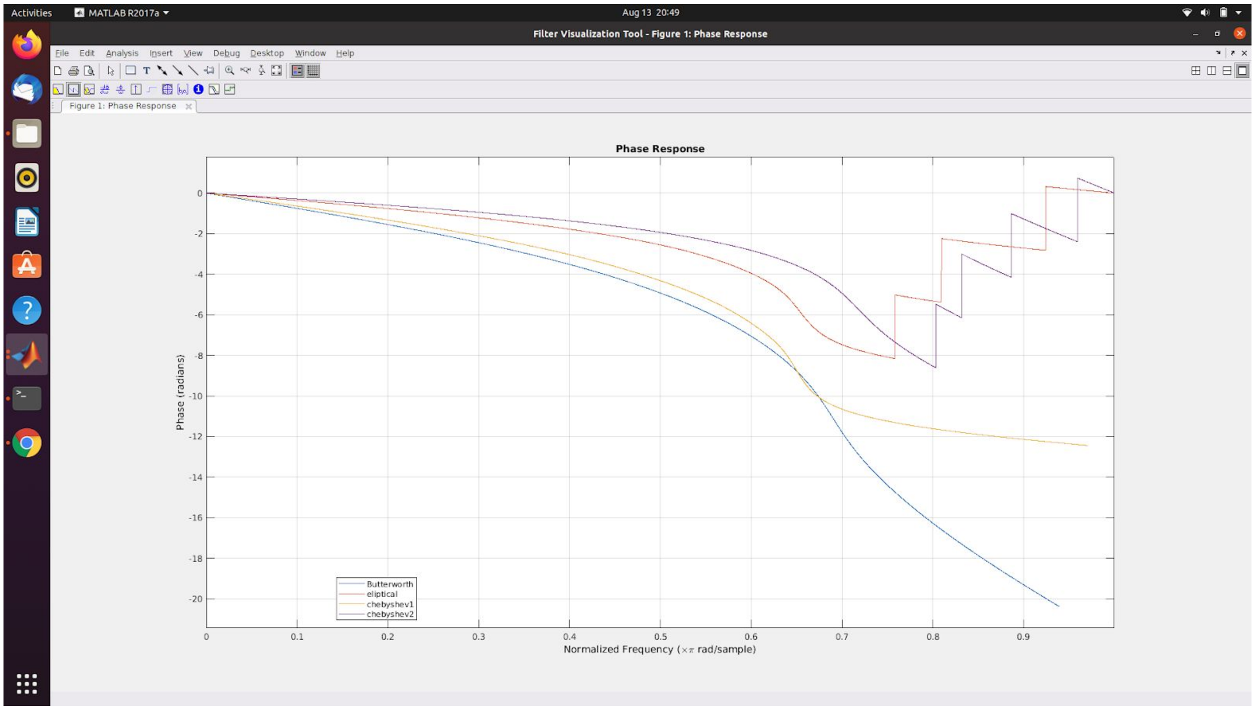
```
clc;close all; clear all;
wp=0.64; ws = 0.8;Rp=0.1;As=60;
% Wp = passband-edge frequency in rad/sec; Wp > 0
% Ws = stopband-edge frequency in rad/sec; Ws > Wp > 0
% Rp = passband ripple in +dB; (Rp > 0)
% As = stopband attenuation in +dB; (As > 0)
[N1,wn1]=buttord(wp,ws,Rp,As);
[b1,a1] = butter(N1,wn1)
[N2,wn2]=ellipord(wp,ws,Rp,As);
[b2,a2] = ellip(N2,Rp,As,wn2)
[N3,wp] = cheb1ord(wp,ws,Rp,As);
[b3,a3] = cheby1(N3,Rp,wp);
[N4,wn] = cheb2ord(wp,ws,Rp,As);
[b4,a4] = cheby2(N4,As,wn);
hvft=fvtool(b1,a1,b2,a2,b3,a3,b4,a4);
legend(hvft,'Butterworth','eliptical','chebyshev1','chebyshev1');

%-------uncomment below lines to obtain state-space
model.------------------
%d = designfilt('lowpassiir', 'FilterOrder', 14, 'HalfPowerFrequency', ...
 %              .5, 'DesignMethod', 'butter')
%[w, x, y, z]=ss(d);
```

Graph:

Magnitude Response:



Phase response:



Analysis:

From the magnitude response, We can say that the butterworth filter has the smoothest response, but it has the highest order among all, which is 14.
One more important thing to mention that, chebyshev1 filter has smooth response which also meets requirement of stopband and passband. So it is best filter as it has low order-6 and it will be cost-efficient also.