

a.)

Pass band freq  $f_p = 6 \text{ kHz}$ Stop band freq  $f_s = 15.5 \text{ kHz}$ 

\* Graph in images

b.)

(i)

Butterworth filter: The obtained order of the filter is  $N > 1$   
and  $\omega_p > \omega_c$ 

$$\text{Transfer function is } |H(j\omega)| = \frac{0.653}{\sqrt{1 + \left(\frac{\omega}{1200\pi}\right)^2}}$$

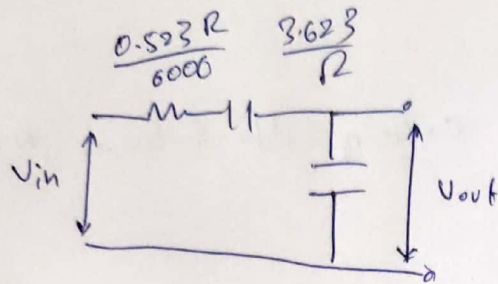
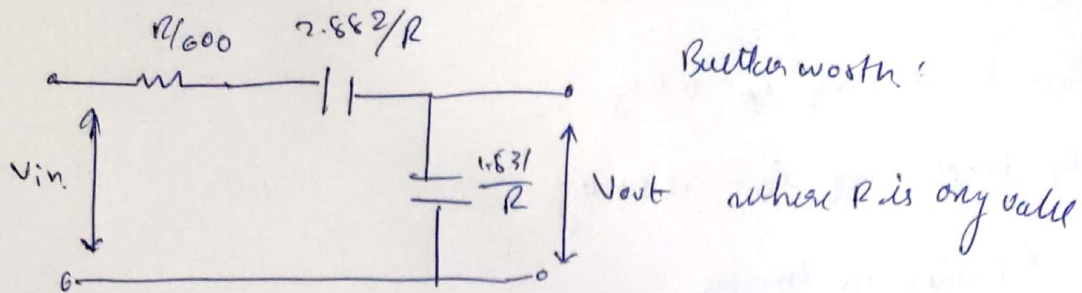
Ideally maximum gain must be 1. But in this case the maximum gain obtained was 0.653. Hence an offset factor of 0.653

Chebyshev filter: The obtained order of the filter is  $N > 1$ ,  
and ripple  $\epsilon = 0.027 \text{ dB}$

$$\therefore \text{Transfer fn } |H(j\omega)| = \frac{0.653}{\sqrt{0.8631 + 0.2788 \left(\frac{\omega}{1200\pi}\right)^2}}$$

(similarly offset factor of 0.653)

c.)



Chebyshev:-  
where R is any value

d.) For a sq wave as input;

At low freq (for  $f \leq 3000 \text{ Hz}$ ): The shape of output wave is the same as input signal and the variation in the gain is same as for a sinusoid.

At higher freq: The shape of the output signal gets peaky and close to triangular wave

At  $f \geq \omega_p$ : The shape of output wave is completely distorted. This is because for fourier series of square wave

$$f(t) = \sum_{n=-\infty}^{\infty} C_n e^{-nj\omega t}$$

The output is

$$f_{out}(t) = \sum_{n=-\infty}^{\infty} |H(nj\omega)| c_n e^{-nj\omega t}$$

So higher freq components are attenuated and thus the obtained Fourier series of the output signal mimics a triangular wave.

a) At stop band freq

a) Output:-

is as shown in fig

At pass band

b) output

c) Measuring the phase:

To measure the phase difference, one can measure the delay in time between output and input.

eg. we have  $\Delta t = -32 \mu\text{sec}$

$$\Delta\phi = 2\pi f \Delta t = -0.179 \text{ rad (for } f = 1300 \text{ Hz)}$$



