TITLE:

DESIGN AND IMPLEMENTATION OF ANTI-ALIASING FILTER FOR ACTIVE POWER FILTERS

THEORY:

This project presents the design and implementation of anti-aliasing filter for active power filters using eSim software. Filters are electronic circuits that allow certain frequencies to pass through while attenuating others. Based on components we have Active and Passive filters. Based on frequency, filters are classified as Low Pass filter, High Pass filter, Band Pass filter, Band Stop filter and All Pass filter. Based on design approach there are Butterworth, Chebyshev, Elliptic and Bassel filters. A filter experiences harmonic suppression caused by insufficient sampling rate leading to overlapping of frequency components and deterioration of power quality.

To overcome this suppression, the anti-aliasing filter is implemented using 4th order Low-pass Butterworth filter. The filter uses multiple-feedback architecture by placing the resistors and capacitors to meet established specifications. This anti-aliasing filter plays a critical role in solving spectral aliasing and heightening the accuracy of data acquisition in harmonic suppression. A fourth order low pass Butterworth filter was chosen as it provides maximally flat response in the pass-band with a good balance of smooth response and effective attenuation.

The design specifications of the anti-aliasing filter are:

Pass-band Edge Frequency (F_p): 2.5 kHz (ensuring harmonic detection up to 50th order)
Maximum Pass-band Attenuation (A_p): 0.5 dB (to minimize distortion in useful signals)
Stop-band Edge Frequency (F_s): 6.4 kHz (as per Nyquist condition)
Minimum Stop-band Attenuation (A_s): 20 dB (to effectively remove unwanted frequencies)

Calculating the order of the filter (N):

$$k_{ps} = \sqrt{(10^{0.1\,A_p} - 1)/(10^{0.1\,A_s} - 1)} = 0.035$$

$$\lambda_{ps} = F_p / F_s = 0.391$$

$$N >= log_{10} k_{ps} / log_{10} \lambda_{ps} = 3.57$$

The order of the filter is taken as 4.

Cutoff frequency (F_c):

$$F_c = F_p \Big/ \sqrt[2N]{10^{0.1\,A_p} - 1} = 6756.625\ \pi\ rad/s$$

$$f_c = F_c / 2\pi = 3.38\ kHz$$

Transfer function:

For a fourth order LPF, the transfer function is given as,

Normalized transfer function, $G(p) = 1 / [(p^2 + 0.7654\,p + 1)\,(p^2 + 1.8478\,p + 1)]$

Transfer function after substituting p by s / F_c, $H(s) = 1/ [(k_1^2 s^2+k_2 s+1) (k_1^2 s^2+k_3 s+1)]$

with $k_1 = 4.7111*10^{-5}$, $k_2 = 3.6059*10^{-5}$ and $k3 = 8.7051*10^{-5}$

Setting C_{11}=1200 pF and C_{12}=1500 pF,

$R_1 = k_2 /3C_{11} = 10.02\ k\Omega$

$R_2 = k_3 /3C_{12} = 19.34\ k\Omega$

Therefore, choose $R_{11} = R_{21} = R_{31} = R_1 = 10k\Omega$ and $R_{12} = R_{22} = R_{32} = R_2 = 20k\Omega$

$C_{21} = 3k_1^2 / (k_2 R_1) = 0.018\ \mu F$

$C_{22} = 3\ k_1^2 / (k_3 R_1) = 3824\ pF$

Consequently, choose $R_{41} = 15k\Omega$ and $R_{42} = 30k\Omega$

Values of the components are taken in the schematic diagram as calculated above.

The graphs obtained after simulation in eSim is given below. The plot Vout shows the frequency vs magnitude plot where magnitude is taken as $20*\log_{10}$(Vout / Vin) where Vin is 3V. Further, a phase plot is also showing the frequency vs phase plot where phase is taken as Vphase*(180/π).

CIRCUIT DIAGRAM:

BLOCK DIAGRAM:

The circuit diagram of the Fourth-order low-pass Butterworth anti-aliasing filter circuit in eSim is as shown in Figure 1:

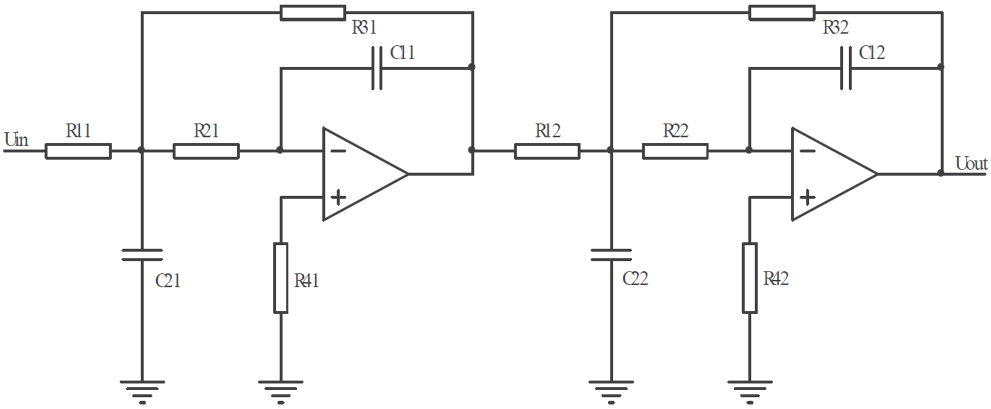

Fig1: Fourth-order low-pass Butterworth anti-aliasing filter circuit

SCHEMATIC DIAGRAM:

The circuit schematic of the Fourth-order low-pass Butterworth anti-aliasing filter circuit in eSim is as shown in Figure 2:

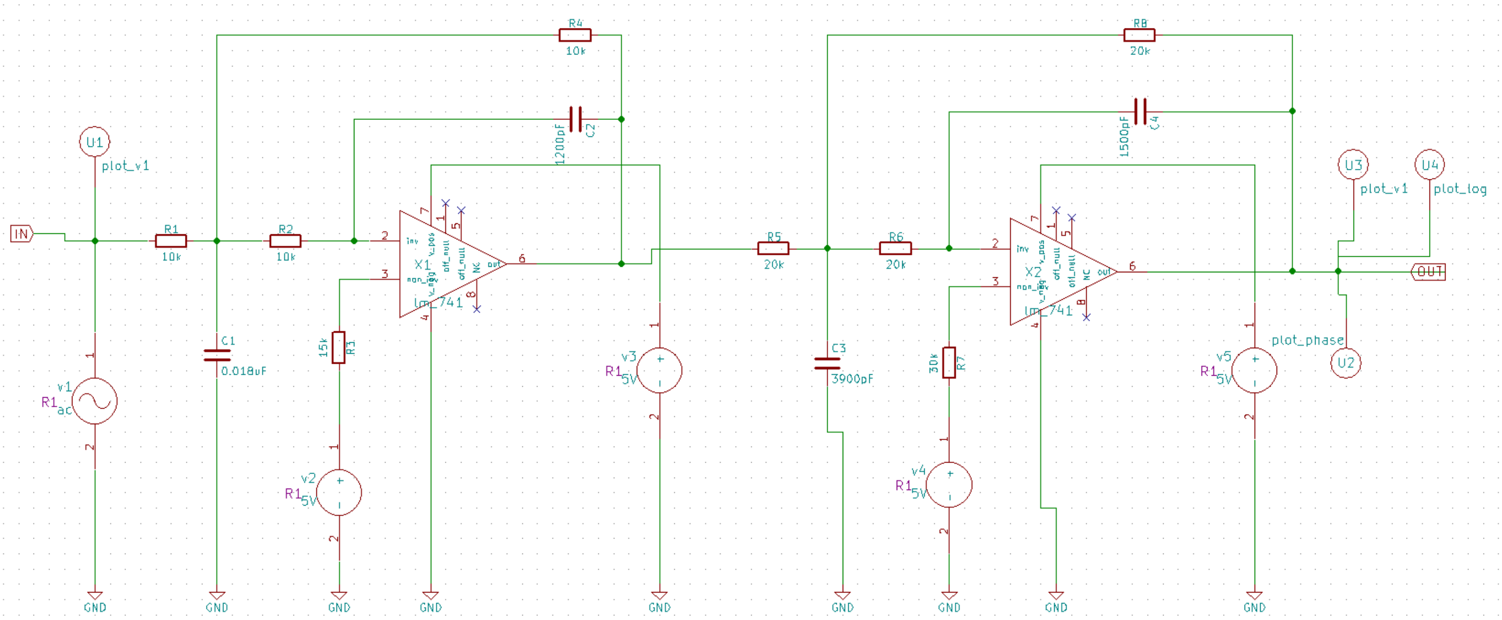

Fig2: Fourth-order low-pass Butterworth anti-aliasing filter schematic circuit

RESULTS:

The Simulation results of the Fourth-order low-pass Butterworth anti-aliasing filter circuit in eSim

1. **NGSPICE PLOTS**

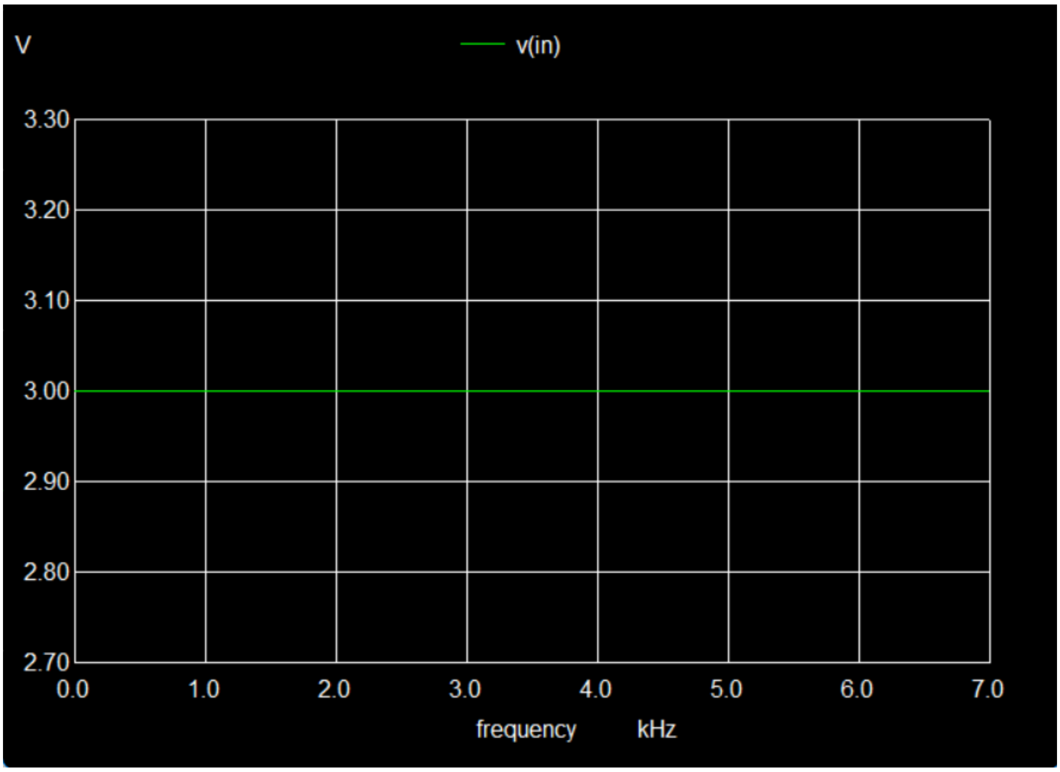

Fig3: Ngspice Input plot with Vin=3V

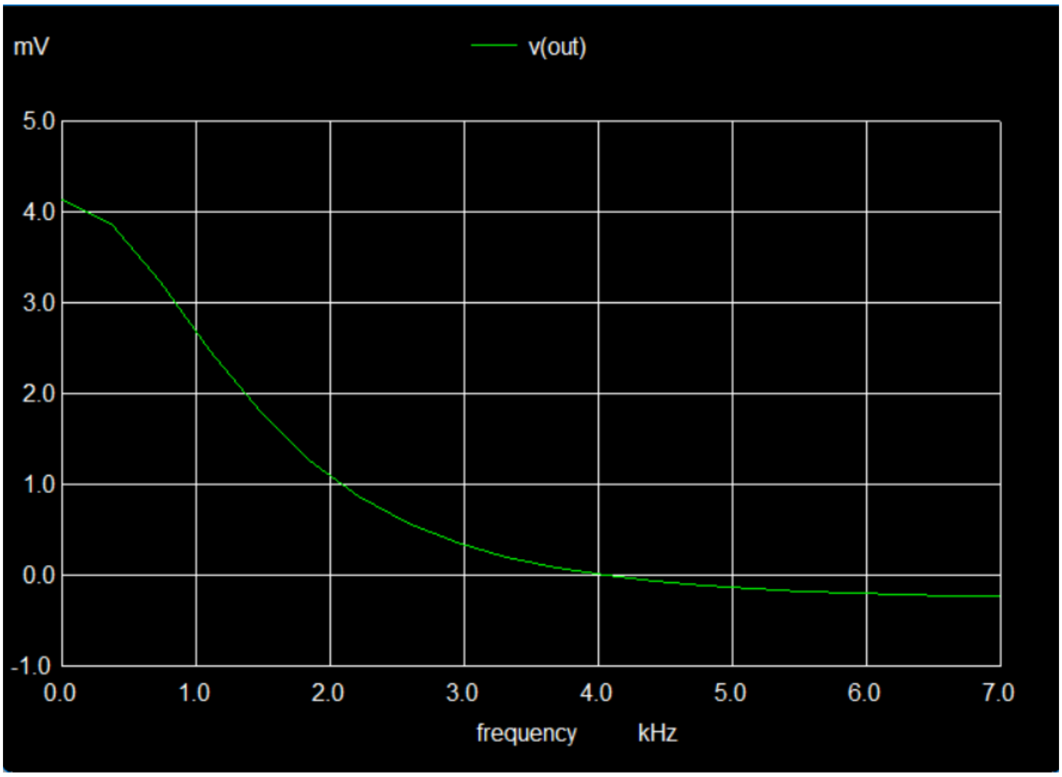

Fig4: Ngspice Output plot Vout

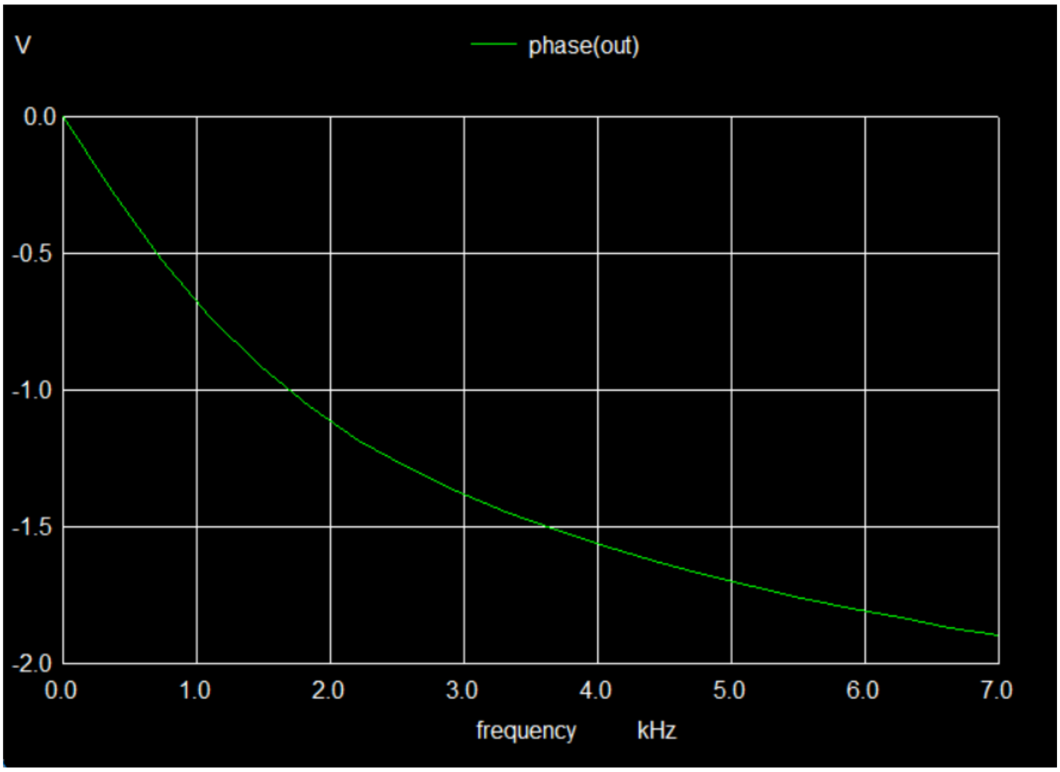

Fig5: Ngspice Phase plot

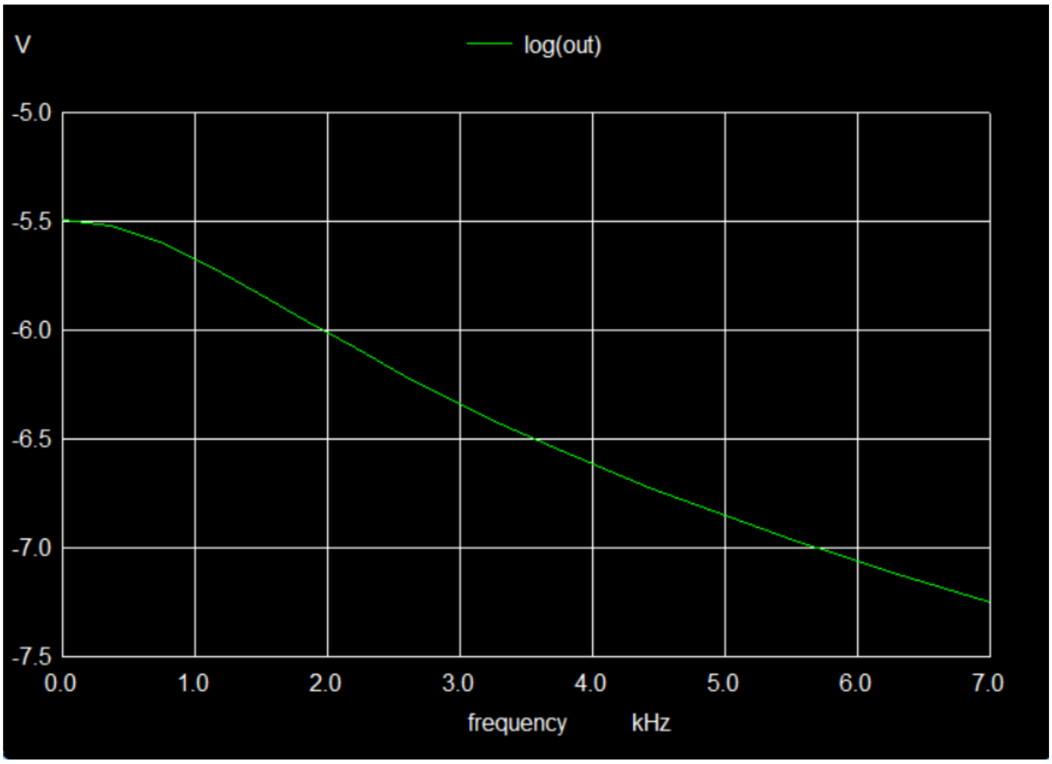

Fig6: Ngspice log plot

2. PYTHON PLOTS:

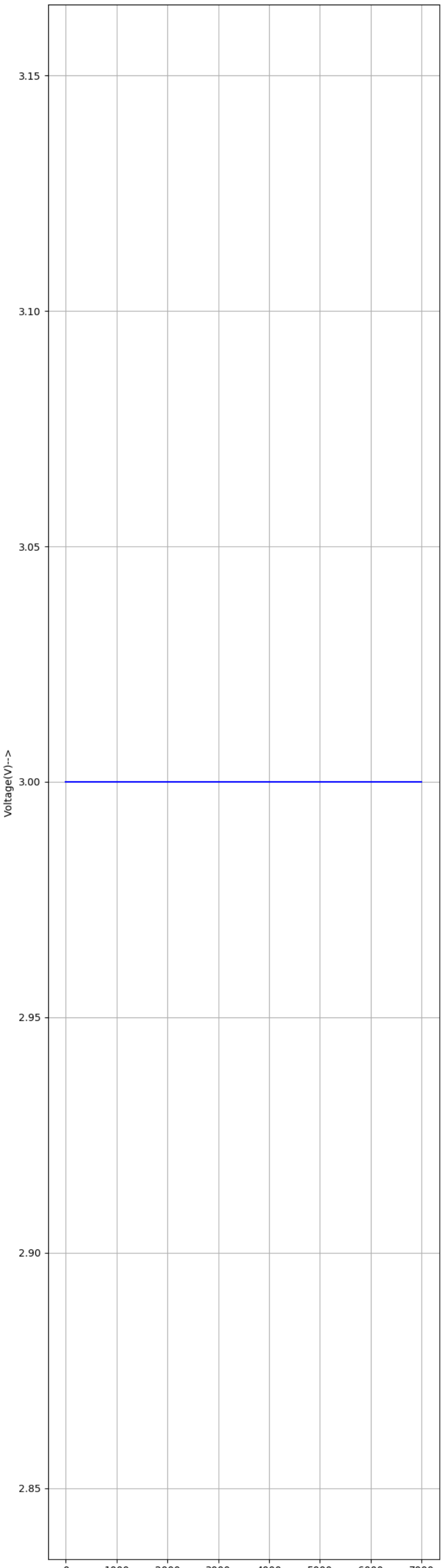

Fig7: Python plot input

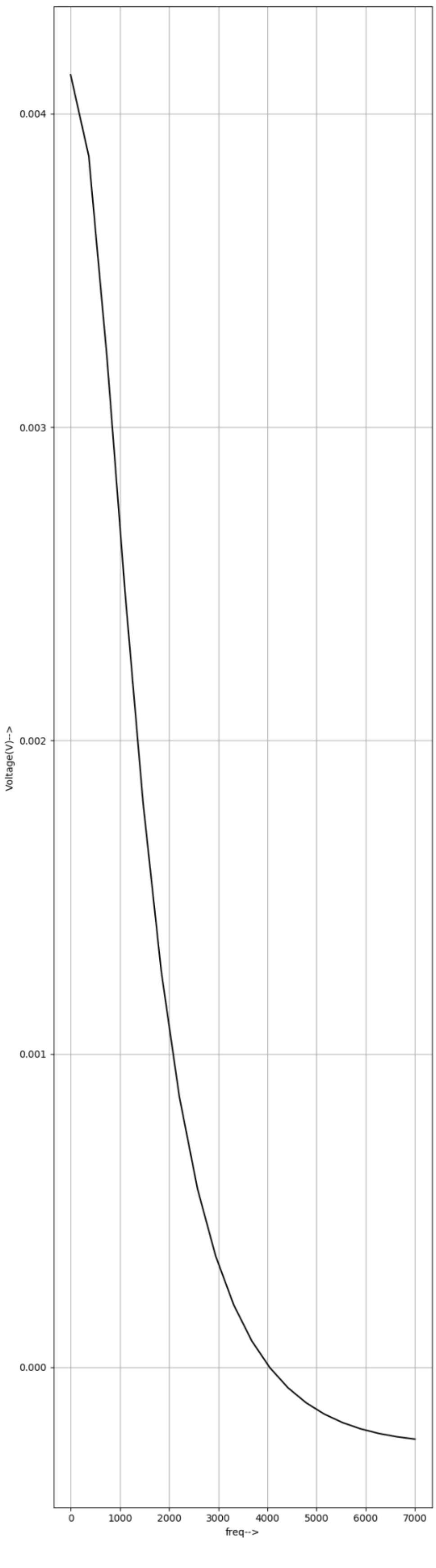

Fig8: Python plot output

CONCLUSION:

The fourth order Butterworth low-pass anti-aliasing filter circuit was designed and implemented using eSim software. The results obtained were analysed and following observations made. The Vin plot shows a flat response as expected. The Vout plot starts to attenuate as frequency increases and reduces to a flat line after the stop band frequency i.e., 6 kHz. The log plot gives a smooth roll-off and attenuates at the cut-off frequency which perfectly aligns with the characteristics of Butterworth filter. The phase plot shows a phase shift increasing gradually as frequency increases which is typical for Butterworth filters.

REFERENCES:

1. https://www.computer.org/csdl/proceedings-article/ihmsc/2010/4151a147/12OmNrkBwyh
2. https://electronics.stackexchange.com/questions/274696/anti-aliasing-filter-design