Experiment 5

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1 Aim of the experiment

To familiarise with the concept of Chebyshev filter and Butterworth filter

2 Results/Graphs

2.1 Question 1

Low pass digital Butterworth filter

Code : task1.m

a) Transfer function

```
Transfer function 'sys1' from input 'u1' to output ...

      1.37e-11 z^8 + 1.096e-10 z^7 + 3.836e-10 z^6 + 7.672e-10 z^5 + 9.59e-10 z^4 + 7.672e-10 z^3 + 3.836e-10 z^2 + 1.096e-10 z + 1.37e-11
 y1:  ---------------------------------------------------------------------------------------------------------------------------------
                        z^8 - 7.537 z^7 + 24.87 z^6 - 46.91 z^5 + 55.33 z^4 - 41.79 z^3 + 19.73 z^2 - 5.328 z + 0.6296

Sampling time: 0.00138889 s
```

Figure 1: Butterworth filter transfer function

b) Graph

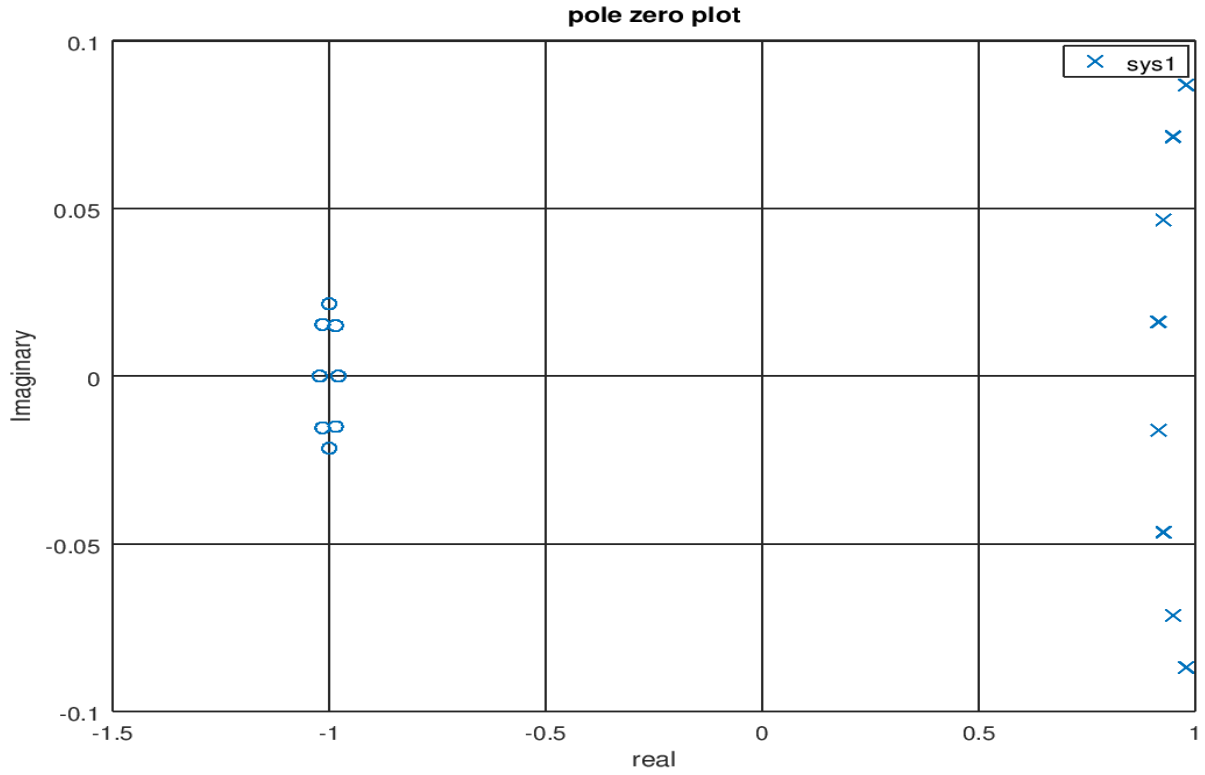

Figure 2: Pole Zero plot of Butterworth filter

c) Graph

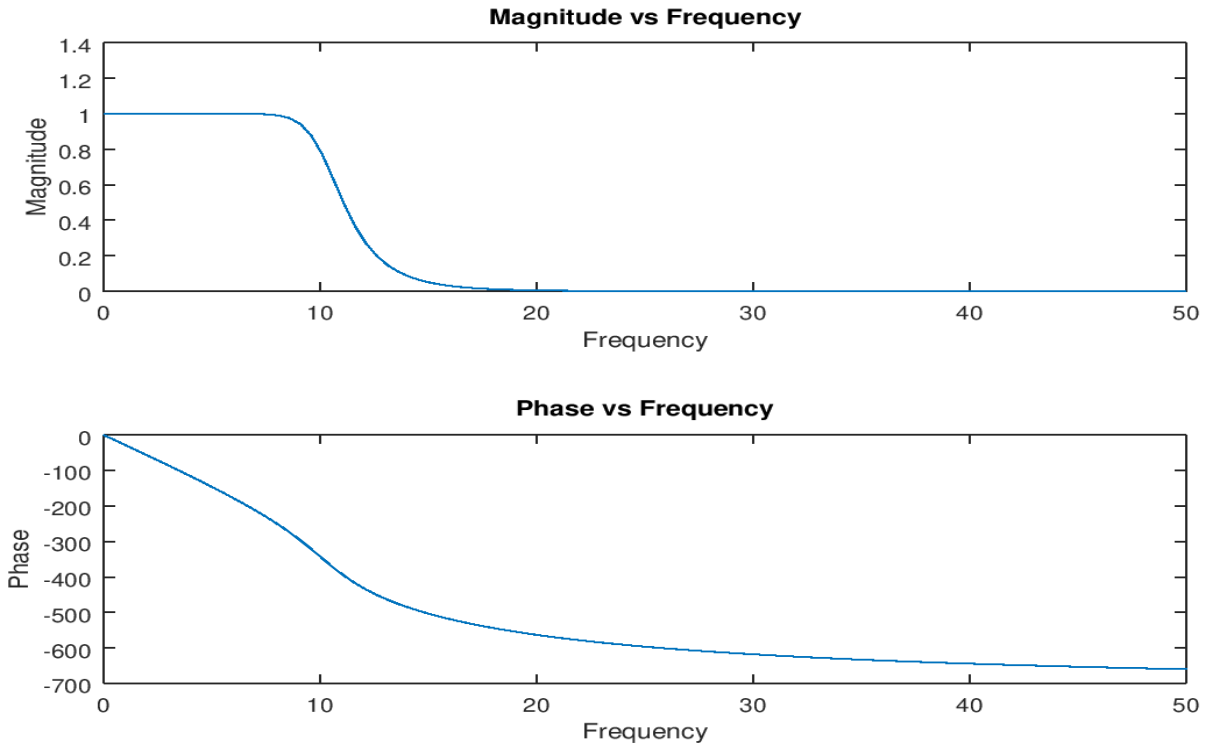

Figure 3: Bode plot of Butterworth filter

Observations

- The transfer function of the filter is of order 8.
- The poles of the transfer function lie on a circle.
- The bode plots are mostly flat in their pass and stop bands.

Conclusion

- The Butterworth filter has a slow transition from passband to stopband.
- The ripples in passband and stopband are almost nonexistent.
- The magnitude response of Butterworth filter decreases monotonically as the frequency (angular frequency-) increases from 0 to infinity.

2.2 Question 2

Low pass digital Type I Chebyshev filter

Code : task2.m

a) Transfer function

```
Transfer function 'sys1' from input 'u1' to output ...

      1.254e-08 z^5 + 6.271e-08 z^4 + 1.254e-07 z^3 + 1.254e-07 z^2 + 6.271e-08 z + 1.254e-08
 y1:  ---------------------------------------------------------------------------------------
                    z^5 - 4.929 z^4 + 9.727 z^3 - 9.608 z^2 + 4.75 z - 0.9402

Sampling time: 0.00138889 s
```

Figure 4: Type I Chebyshev filter transfer function

b) Graph

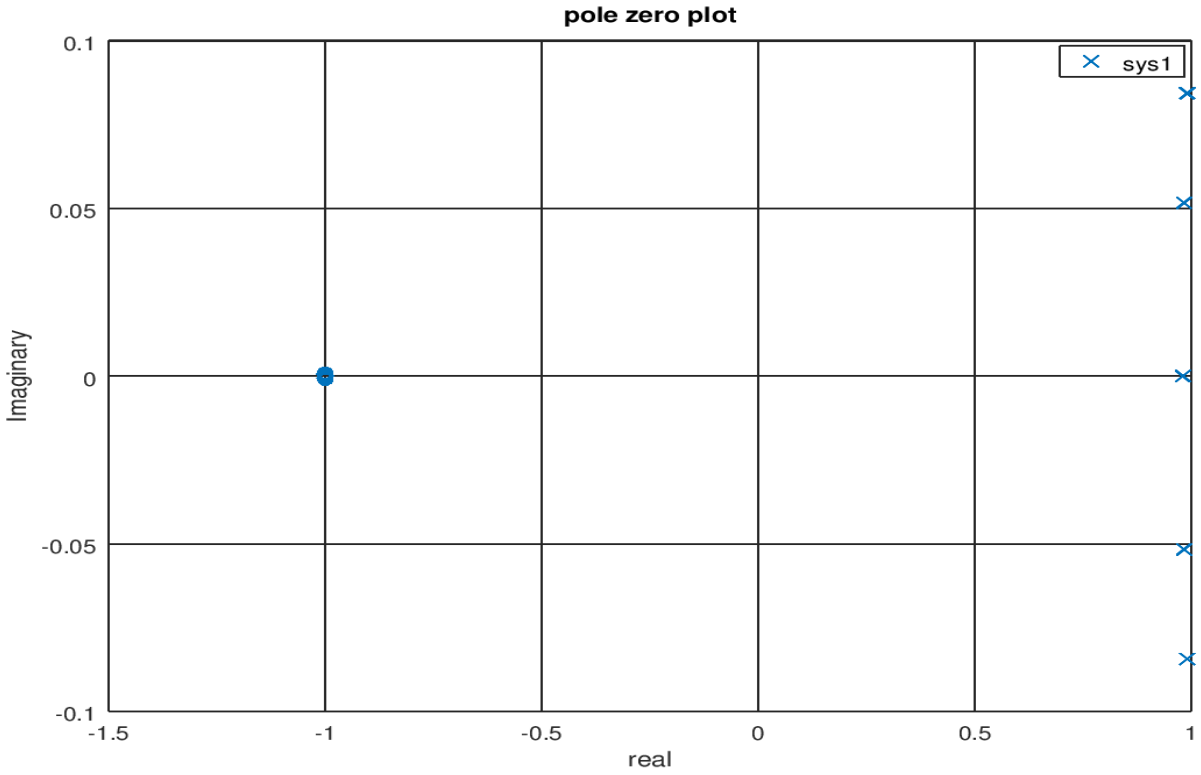

Figure 5: Pole Zero plot of Type I Chebyshev filter

c) Graph

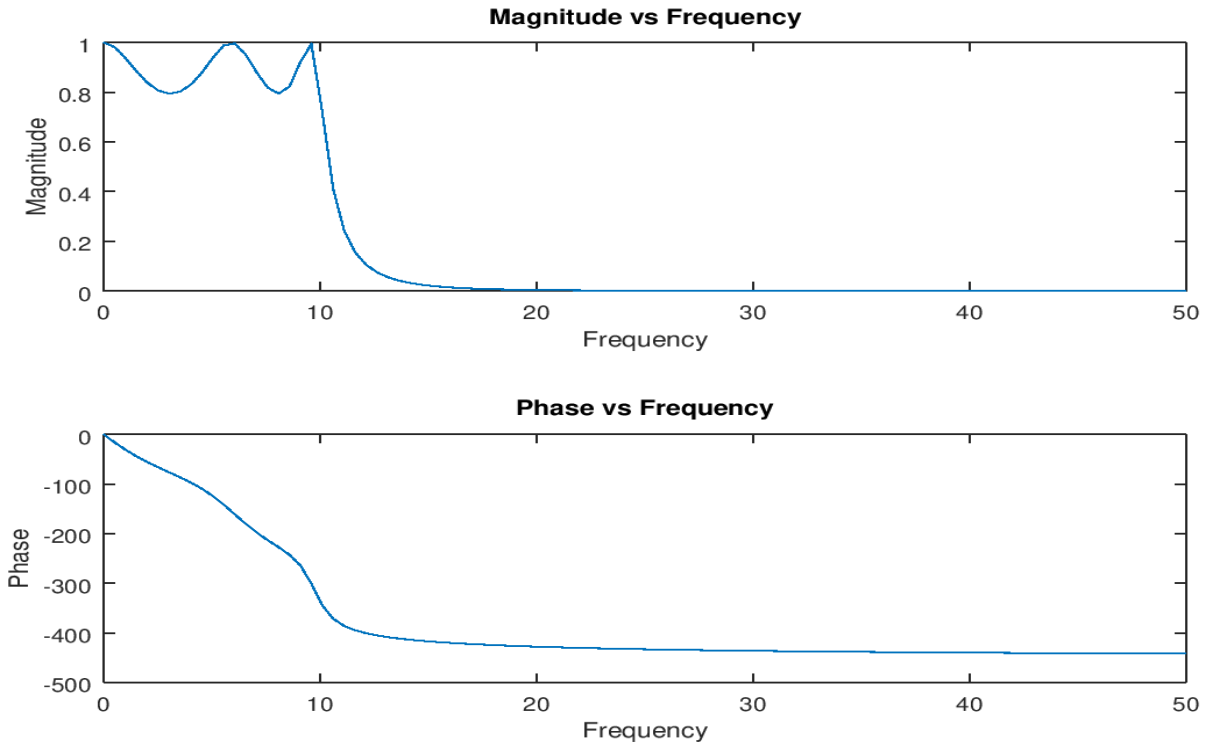

Figure 6: Bode plot of Type I Chebyshev filter

Observations

- The transfer function is of order 5 while the order in Butterworth was 8.
- The poles of the transfer function lie on an ellipse, a vertical ellipse.
- The bode plots had ostensible ripples in the passband.

Conclusion

- The Chebyshev filter has a relatively faster transition from passband to stopband due to sharper frequency cutoffs.
- There are ripples in the passband but very little in the stop band-a salient feature of the Type 1 Chebyshev Filter.
- For the same specifications, the number of poles in Butterworth are more when compared to the Chebyshev filter i.e., the order of the Chebyshev filter is less than that of Butterworth. This is a great advantage because less discrete components will be necessary to construct the filter.

2.3 Question 3

Comparison of Impulse response and step response of the 2 filters.

Code : task3.m

a) Graph

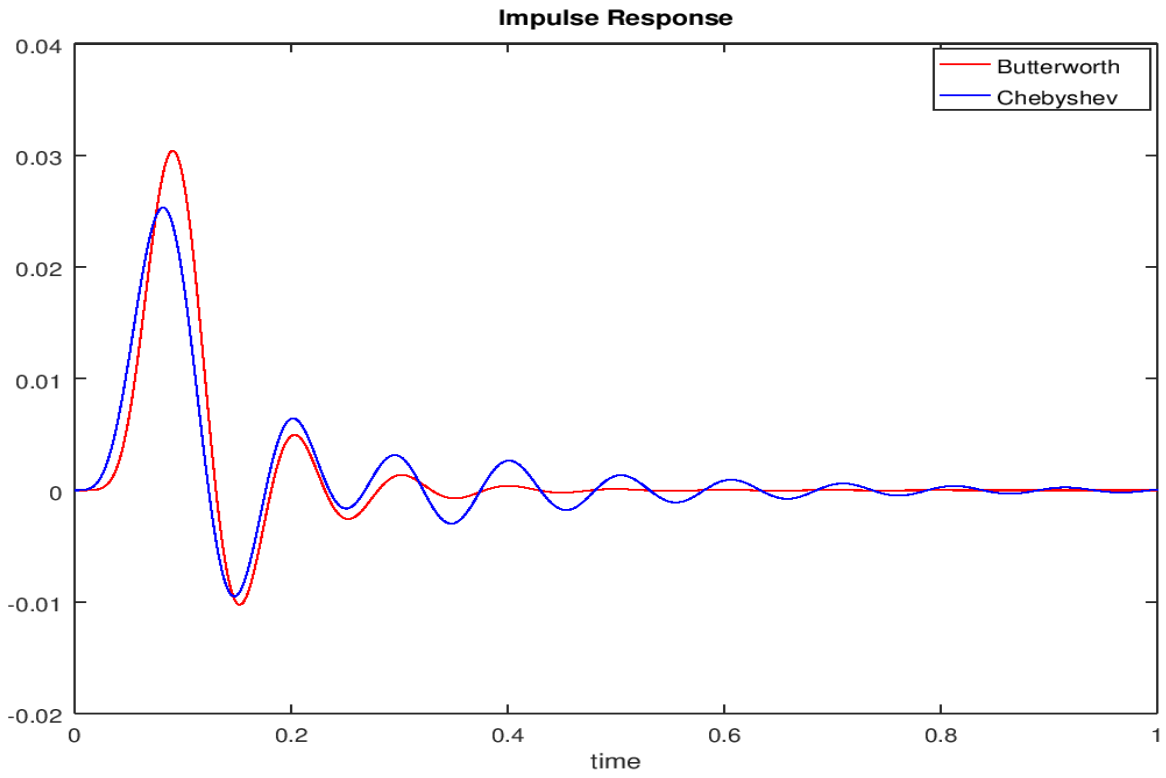

Figure 7: Impulse Response

b) Graph

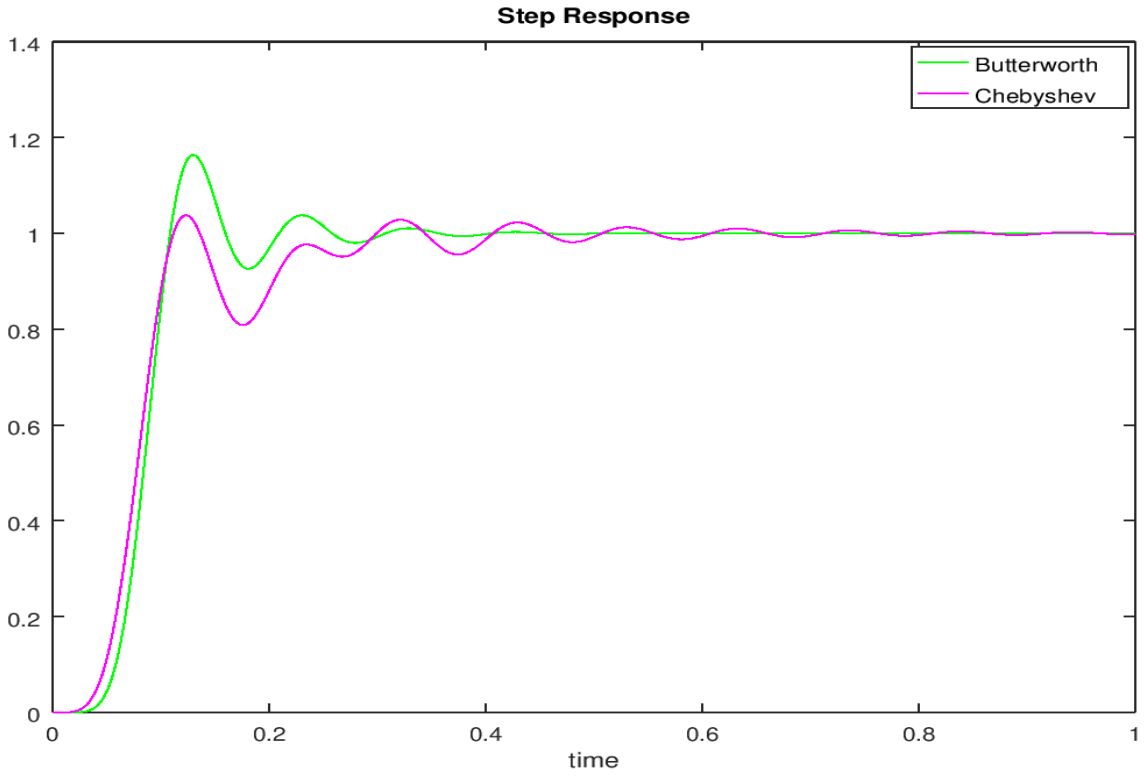

Figure 8: Step Response

Observations

- The magnitude response of low pass Butterworth filter is more stable in the lower frequencies(in the long run or after some time) compared to low pass Chebyshev filter which fluctuates or has much more ripples.
- Considerable overshoot and ringing in step response is present in Butterworth Filters which is more in it compared to Chebyshev.
- Butterworth filter has almost no ripples in its step response once it response stabilizes while Chebyshev does.

Conclusion

- Chebyshev filters are sharper than the Butterworth filter, but show ripples.
- The Butterworth filter rolls off more slowly around the cutoff frequency than the Chebyshev filter, but without ripple.
- Considerable overshoot and ringing is present in the step response of Butterworth Filter, which worsens with increasing order.
- As ripple increases in the Chebyshev filter the roll off becomes sharper. The Butterworth filter is designed to have as flat a frequency response as possible and is referred to as maximally flat magnitude filter.
- Butterworth filters are also used for Anti-aliasing applications. Chebyshev filters are used where the frequency content of a signal is more important than having a constant amplitude.
- If we require a sharper roll-off and can deal with some ripple in the passband, then Chebyshev is the winner or else if we require a smooth passband and can deal with a slower roll-off, then Butterworth would be a better choice.