Thulasihan Sivarajah

Introduction/Objective

To analyze, design, implement and test an Active Low Pass Filter (LPF) design to meet specifications (outlined in the following Table) based on the use of Butterworth and Chebyshev type filter designs utilizing 2nd Order Sallen-Key circuit blocks for the implementation. Specifically, the aim is to explore the filter design process and contrast these two types of filter responses.

Specifications

Lab Station	**Ap** (Passband Attenuation)	**As** (Stopband Attenuation)	**fp** (Passband frequency)	**fs** (Stopband frequency)
12	3 dB	70 dB	2kHz	18kHz

Results

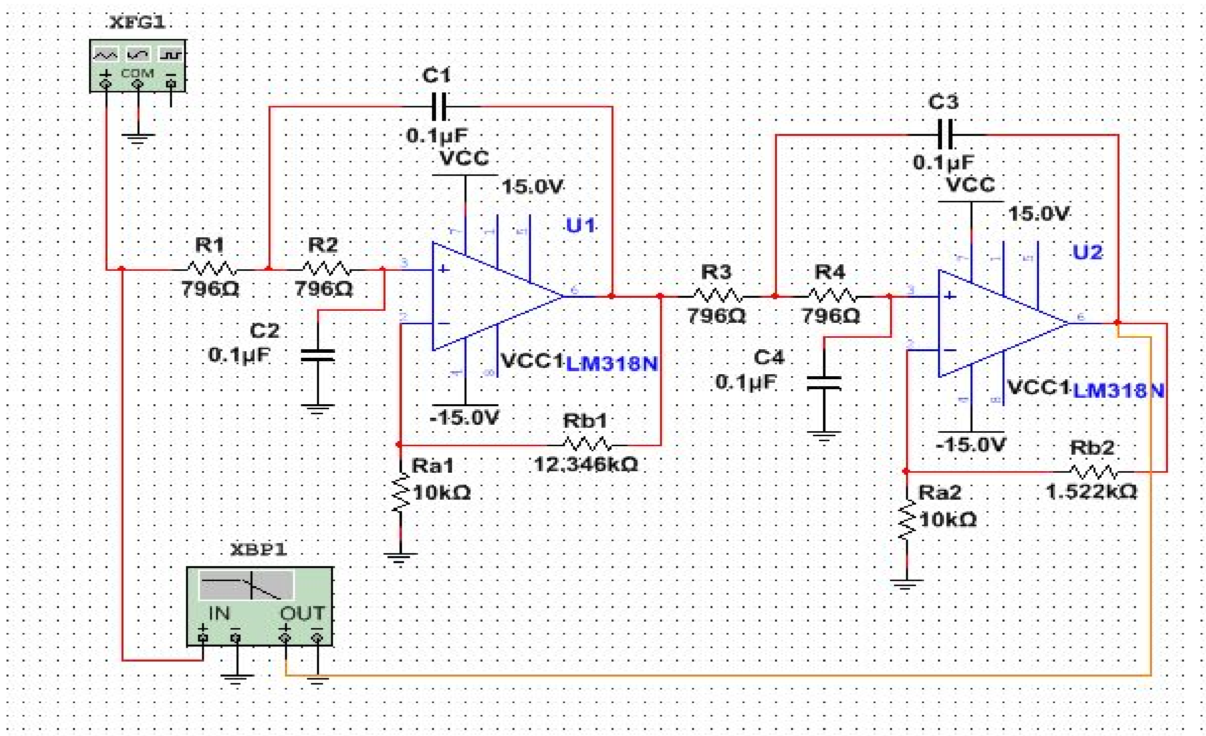

Figure 1: This is the designed Butterworth filter circuit under test. The overall order of this circuit is n=4.

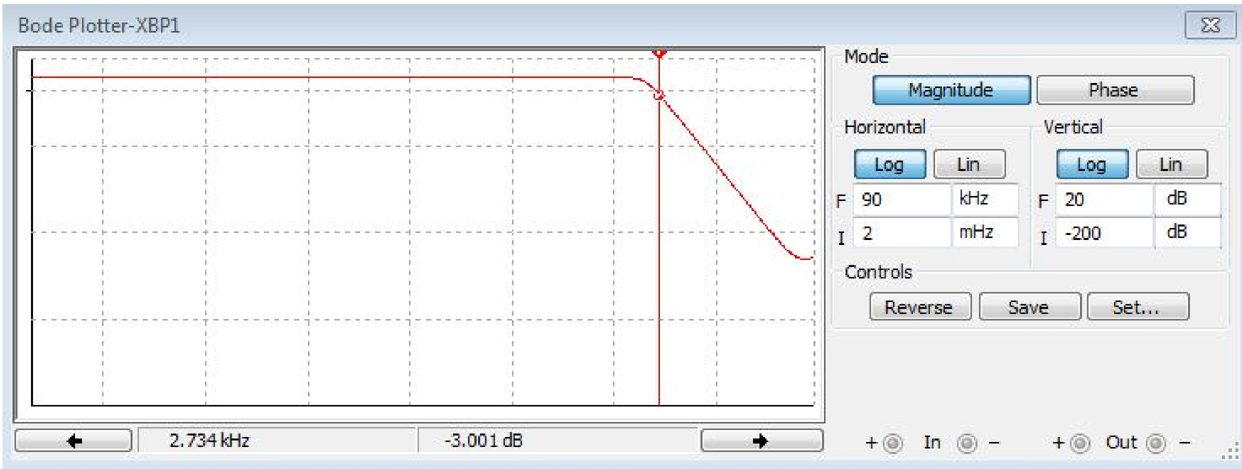

Figure 2: This is the frequency response of the Butterworth circuit. At approximately -3.00 dB which is the passband attenuation (Ap), the passband frequency (fp) is 2.734 kHz.

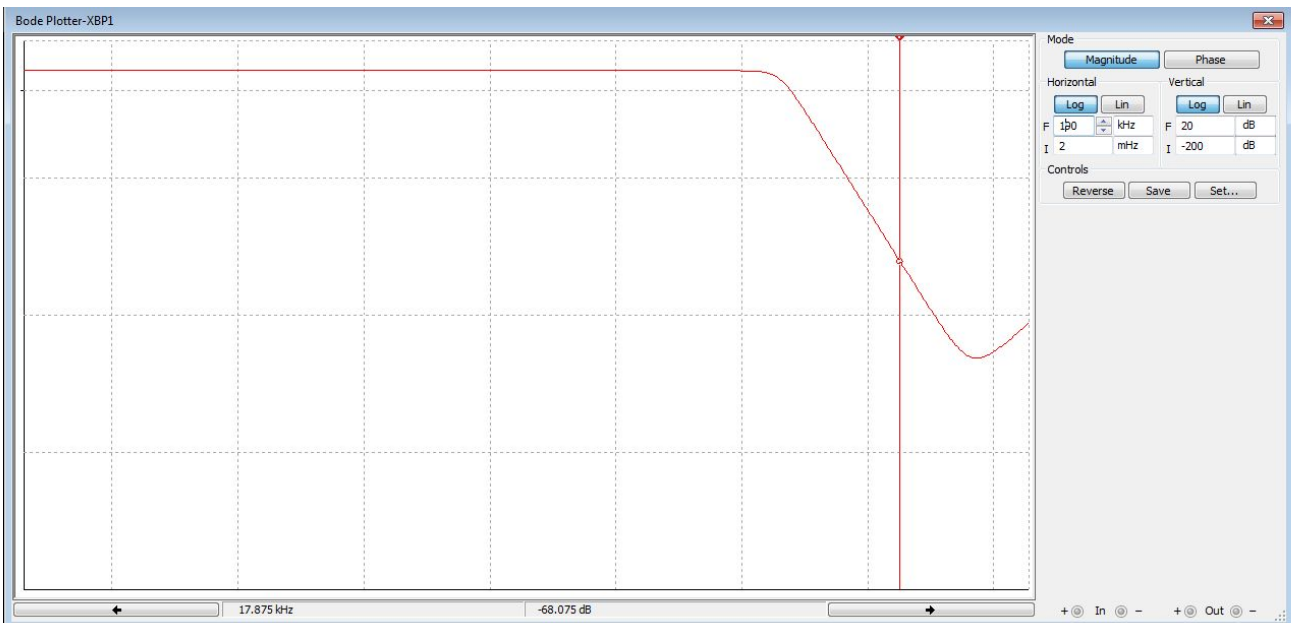

Figure 3: This is the frequency response of the Butterworth circuit. At approximately 18kHz which is the stopband frequency (fs), the stopband attenuation (As) is 68.075dB.

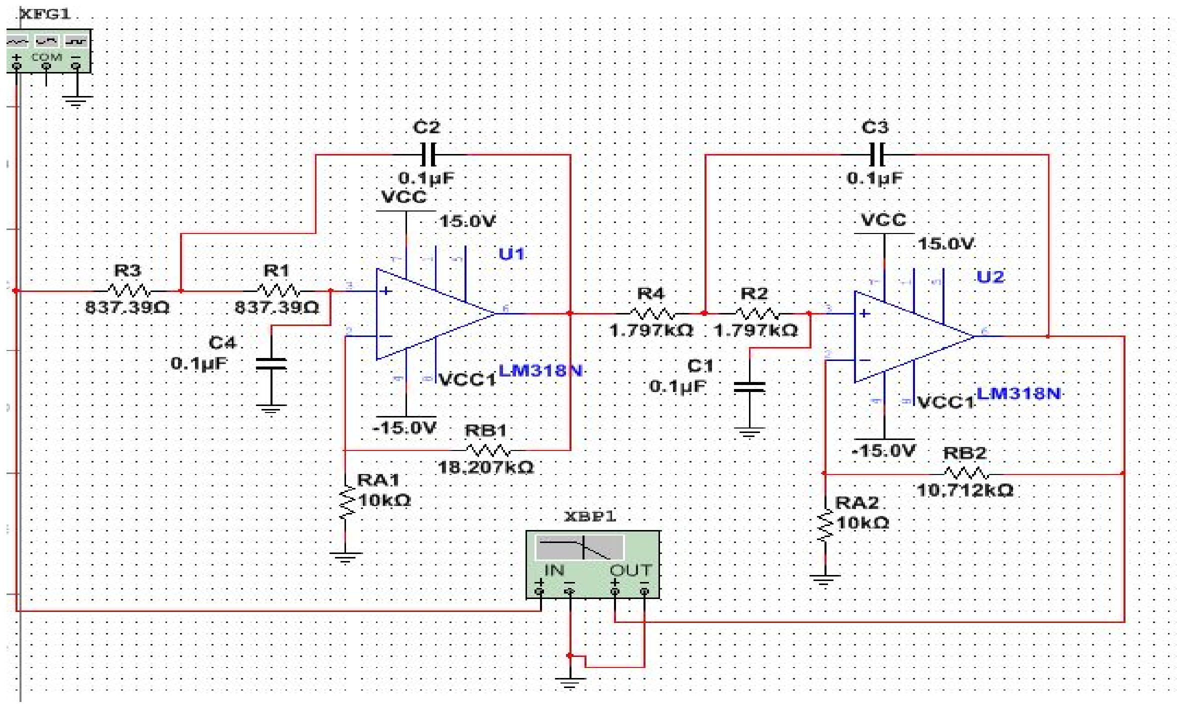

Figure 4: This is the designed Chebyshev filter circuit under test. The overall order of this circuit is n=4.

Figure 5: This is the frequency response of the Chebyshev circuit. At approximately -3.00 dB which is the passband attenuation (Ap), the passband frequency (fp) is 2.653 kHz.

Figure 6: This is the frequency response of the Chebyshev circuit. At approximately 18kHz which is the stopband frequency (fs), the stopband attenuation (As) is 75.805dB.

Conclusion

When comparing the Chebyshev filter and the Butterworth filter designs, I noticed that the expected value of the stopband Attenuation (As) for the chebyshev is 94.27 dB while the Butterworth is 76.317 dB. This clearly signifies that the Chebyshev filter gives a much steeper gain than the butterworth circuit as the frequency increased. Compared to the Butterworth filter design, the Chebyshev filter can achieve a sharper transition between the passband and the stopband. When observing the frequency response of the Butterworth and Chebyshev designs, the Butterworth circuit contains a “flat response” or no ripple while the Chebyshev circuit contains a ripple within the frequency response. Both the Chebyshev and Butterworth contain different design approaches for the same specifications based on their different normalized transfer functions. The values of the simulation is what we expected with a slight amount of percent error. The reason for this is because when designing the chebyshev and butterworth circuits, the design practise is to have your specifications to be met, which means that over designing is required in order to meet the requirement. When overdesigning is required by having an increase expected attenuation stopband can cause variation between the simulation and the theoretical design analysis. Also based on the resistor values not being standard resistor values from the E24 series can deviate from the required filter response since sensitivity is a major impact within filter designs.

Formula used for %Error/Sample Calculation

$$\%Error = \frac{|Experimental - Expected|}{Expected} * 100\%$$

$$\%Error = \frac{3.001-3}{3.0} * 100\% = 0.03\%$$

Table 1: Comparison between expected value and experimental value for the Butterworth design circuit.

Parameters	Expected Value	Experimental Value	% Error
Ap (Passband Attenuation)	3.0 dB	3.001dB	0.03%
As (Stopband Attenuation)	76.317 dB	68.075 dB	10.7%
fp (Passband frequency)	2 kHz	2.734 kHz	36.7%
fs (Stopband frequency)	18 kHz	17.875 kHz	0.69%

Table 2: Comparison between expected value and experimental value for the Chebyshev design circuit.

Parameters	Expected Value	Experimental Value	% Error
Ap (Passband Attenuation)	3.0 dB	3.035dB	1.167%
As (Stopband Attenuation)	94.27 dB	75.805 dB	19.5%
fp (Passband frequency)	2 kHz	2.653 kHz	32.65%
fs (Stopband frequency)	18 kHz	17.924 kHz	0.42%