ECEN303 Lab 5 - Filters

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1 VCSC Filters

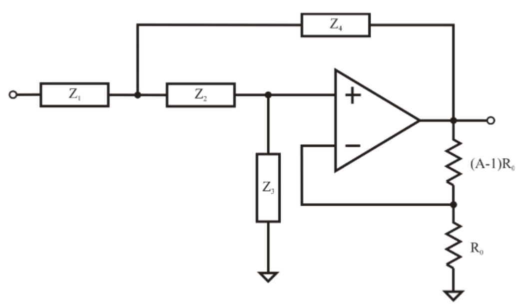

Figure 1: VCSC Filter

For this section, the gain and phase response of Bessel and Chebyshev filters will be analysed. These filters will take the form of the low pass filter circuit in Figure 1. The quality factor, Q, has a distinct value for each filter. Q can be described by the equation

$$Q = \frac{1}{3-A}$$

1.1 Bessel Filter

For a Bessel filter, $Q = \frac{1}{\sqrt{3}}$. Using this, A and subsequently R_0 can be found.

$$\frac{1}{3-A} = \frac{1}{\sqrt{3}}$$

$$3 - A = \sqrt{3}$$

$$A = 3 - \sqrt{3} = 1.265$$

$$(1-A)R_0 = 0.265R_0$$

$$Picking \quad R_0 = 3.9K\Omega$$

$$0.265R_0 = 1043.25\Omega \simeq 1k\Omega + 47\Omega$$

The Bessel filter is designed as follows:

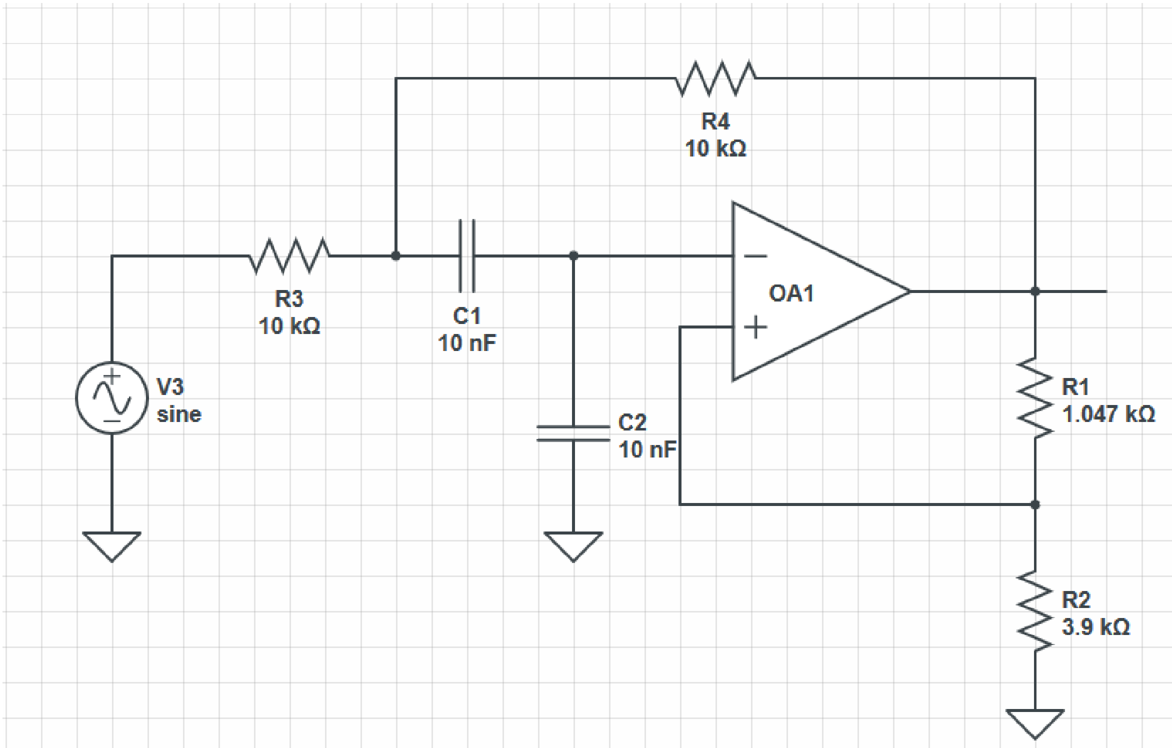

Figure 2: Bessel Filter

The gain and phase responses were found by looking at the output of the circuit as the input signal from a function generator had its frequency increased.

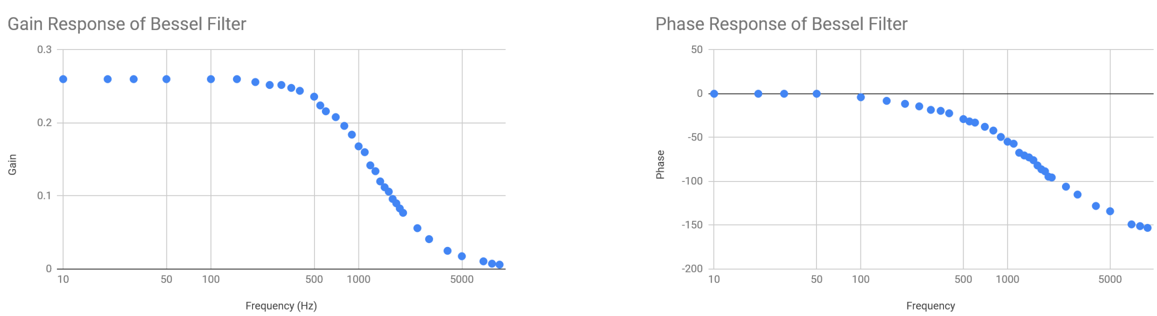

Figure 3: Gain and Phase Response of Bessel Filter

In Figure 3 it can be seen that the cutoff frequency is around 1kHz. At this point the phase also decreases and tends towards -180 degrees (instability).

1.2 Chebyshev Filter

A Chebyshev filter has $Q = 0.9564$. The resistances can be found from this:

$$3 - A = \frac{1}{0.9564}$$
$$A = 3 - 1.04559$$
$$A = 1.954$$

$$(1 - A)R_0 = 0.954R_0$$
$$Picking \quad R_0 = 3.9K\Omega$$
$$0.954R_0 = 3722.2\Omega \simeq 2.7k\Omega + 1k\Omega$$

The Chebyshev filter is as designed as followed:

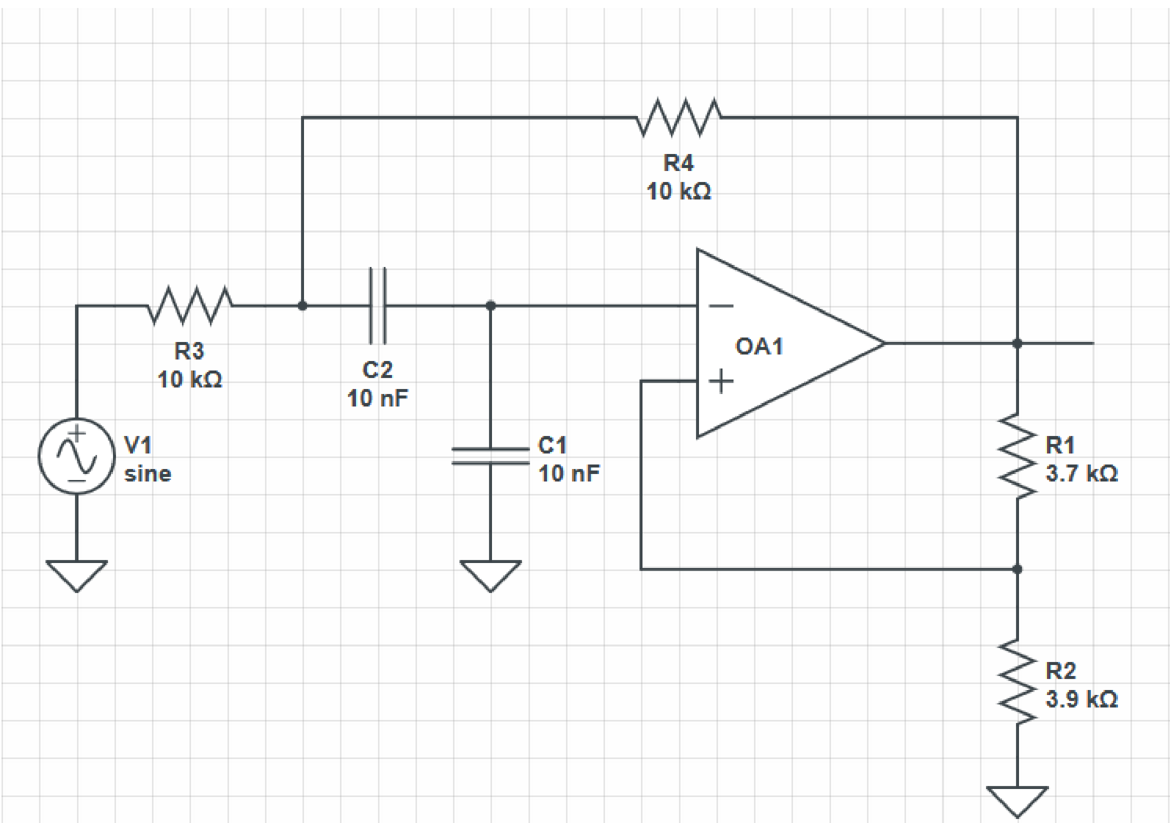

Figure 4: Chebyshev Filter

The responses found (in comparison with the Bessel filter) can be seen in Figure 5.

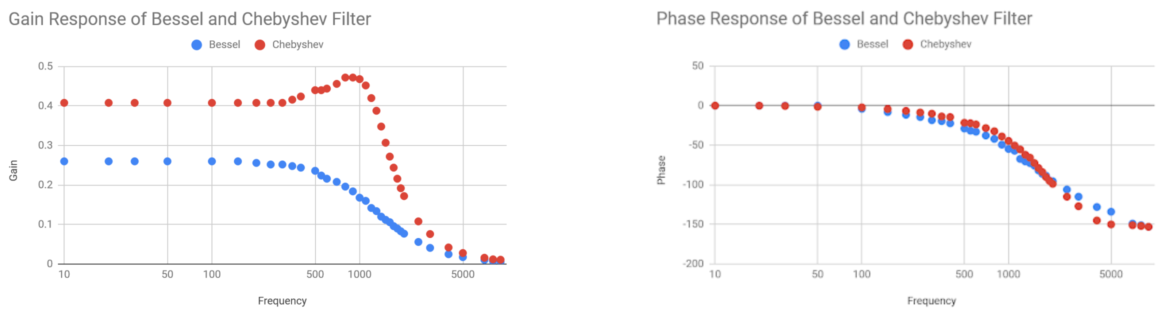

Figure 5: Gain and Phase Response of Chebyshev and Bessel Filter

It can be seen that the Chebyshev filter has the same cut off frequency as the Bessel filter at around 1kHz. The gain of the Chebyshev filter is higher than that of the Bessel. However it can be seen that the Chebyshev filter has a ripple just before the cut-off frequency. The Bessel filter is more reliable in frequencies nearer the cutoff frequency.

The Chebyshev filter has a smaller phase response for frequencies before the cutoff frequency and a larger phase response after the cutoff frequency.

1.3 Frequency Scaling Factor (FFS)

The FFS can be described via the equation

$$\omega_0 = \frac{1}{FSF}\frac{1}{RC}$$

Both the filters have the same cut-off frequency $2\pi \cdot 1000$, so will have the same FSF.

$$2\pi \cdot 1000 = \frac{10000}{FSF}$$

$$FSF = 1.59$$

2 Filter Design and Simulation Tools

The Butterworth filter has $Q = \frac{1}{\sqrt{2}}$.

$$3 - A = \sqrt{2}$$

$$A = 3 - \sqrt{2}$$

$$A = 1.586$$

$$(1 - A)R_0 = 0.586R_0$$
$$Picking \quad R_0 = 3.9K\Omega$$
$$0.954R_0 = 2284.6\Omega \simeq 2.2k\Omega + 82\Omega$$

The Butterworth filter is designed as follows:

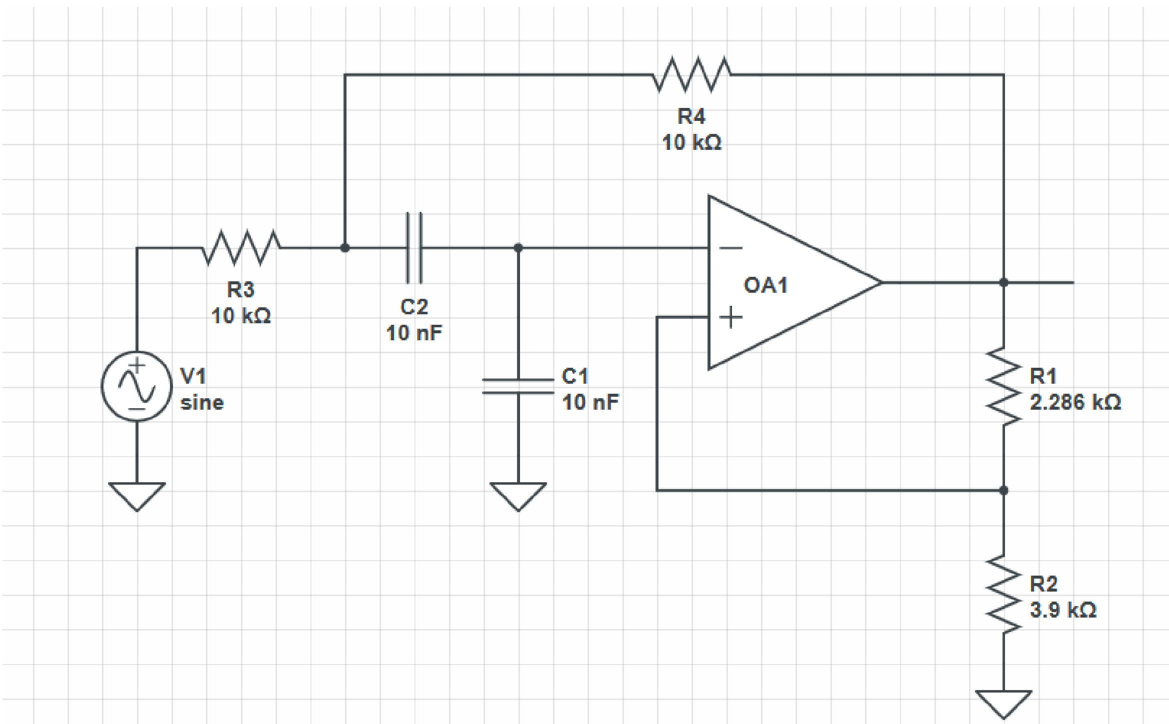

Figure 6: Chebyshev Filter

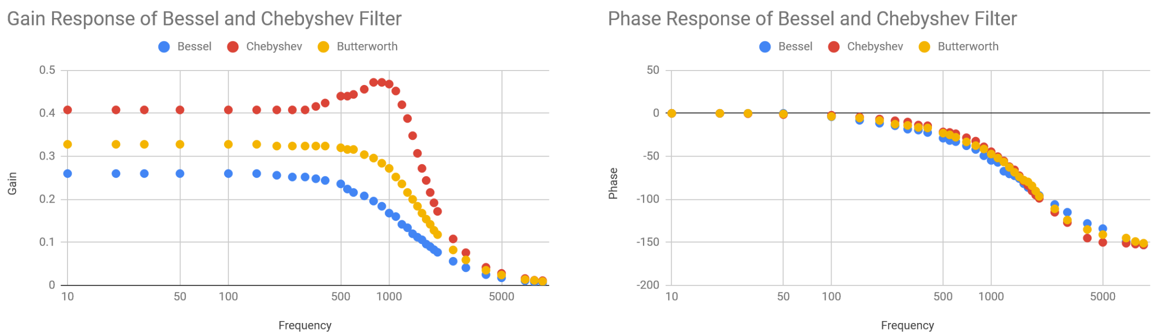

Figure 7: Gain and Phase Response of Butterworth, Chebyshev and Bessel Filter

3 Discussion

3.1 Merits of Different Filters

3.2 Sampling Rate and Bandwidth