

assignment 1

by Sean Jones

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Assignment 1

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Active filter design

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1. Introduction, aims and objectives

Due to the many variations of an electronic filter, an investigation will be taken place to find out the effects of changing the style of filter or the order of a filter. The values will all be calculated and tested on multisim to prove the cut off frequency of the high and low pass filters. The cut off frequency that will be aimed to archive in this investigation is 70kHz

Research will need to be done to find out information on the different types of filters and their characteristics.

When the circuits have all been simulated and fine-tuned then then an evaluation of the different types of filters will be made and a conclusion of the report will determine which filter is best and what the number of orders does to the filter.

2. Research into filter design

Active Filters are used in electronic circuits to eliminate unwanted frequencies in a circuit. When a filter reaches a certain frequency then the filter doesn't allow anything passed. (Gergely, 2002) states "an electrical filter is a circuit which is used to separate some components of an electrical signal from others"

Filters can filter different types of frequencies; these are low pass, high pass, bandpass and band-stop. These are shown in Figure 1

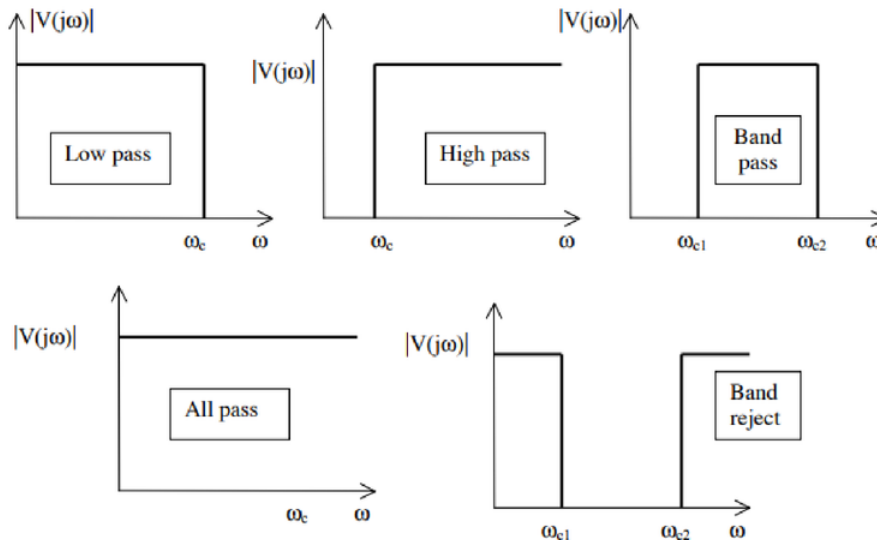


Figure 1 Types of filters

Low pass

(ece, 2018) States that "A low pass filter is a circuit whose amplitude function decreases as ω increases, that is, the circuit passes low frequencies and rejects high frequencies". A circuit of a 1st order low pass circuit is shown below in Figure 2.

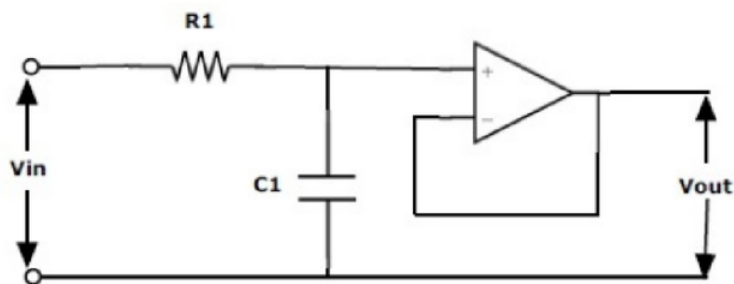


Figure 2 circuit of a 1st order low pass filter

Shown on a graph in Figure 3 is the cut off frequency of a low pass filter. The cut off frequency is 3dB after the initial roll off on a 1st order circuit the roll off is increased by 3dB per order of the filter. The gradient of the slope after this will be -20dB per decade per order of the filter Figure 4. The steeper the gradient, the better as the cut off frequency will be more precise. The higher the order of the filter the better it filters frequency but the cost of the filter is increased as more components are used.

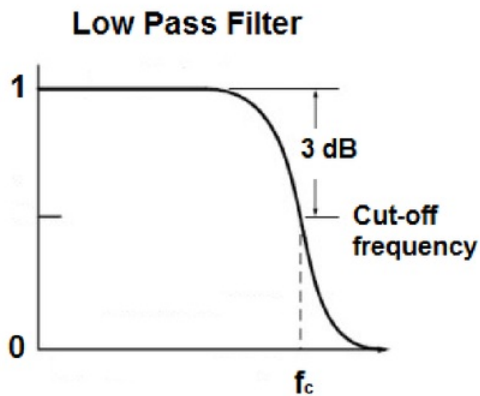


Figure 3 example of a low pass filter cut off

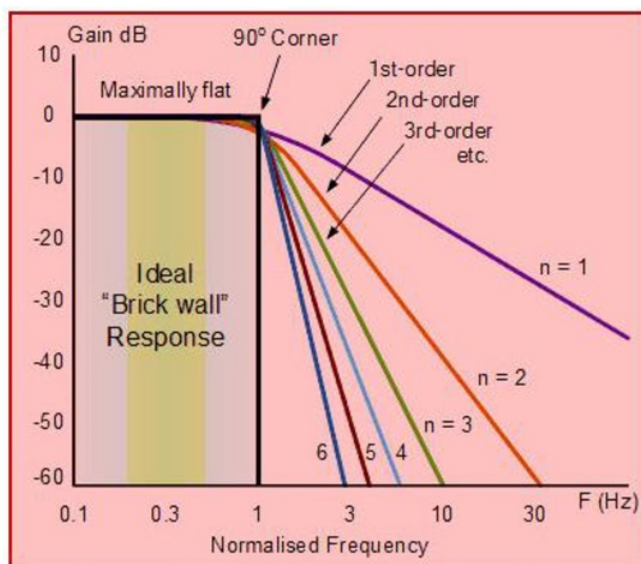


Figure 4 example of the effect of multiple order filter

High pass

(ece, 2018) Suggests that the magnitude increase along with frequency and after the cut off frequency is met then the circuit allows the signal to pass. If the frequency is lower than the cut off then it is rejected. A 1st order high pass circuit is shown below in Figure 5. The capacitor and the resistor have swapped places which changes the type of filter.

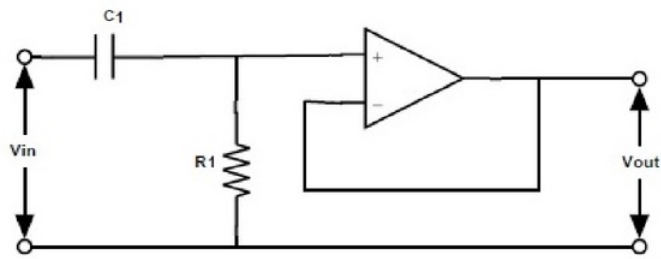


Figure 5 1st order high pass circuit

The frequency response looks the same as a low pass filter other than it is inverted as cuts a different frequency off. This is displayed in Figure 6.

High Pass Filter

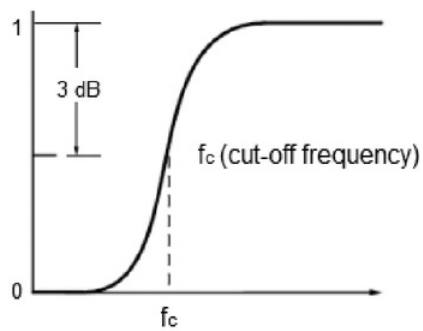


Figure 6 high pass frequency response

Band pass

(electronicshub, 2018) Suggests A band pass allows a certain frequency range to pass through the filter put not anything else. This range is called the band width. The band width is like a high pass and a low pass put together on a frequency response graph Figure 7. The filter allows the signal through at the 1st cut off frequency and blocks at the second cut off frequency. The circuit for a 1st order band pass is shown below In Figure 8.

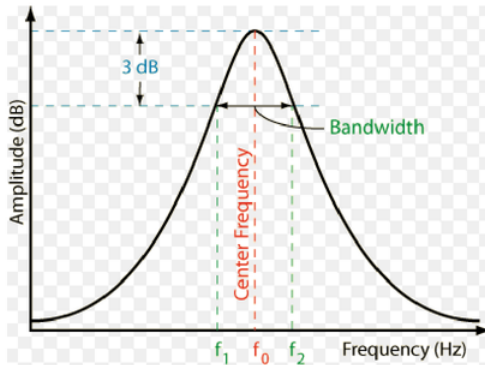


Figure 7 band pass frequency response

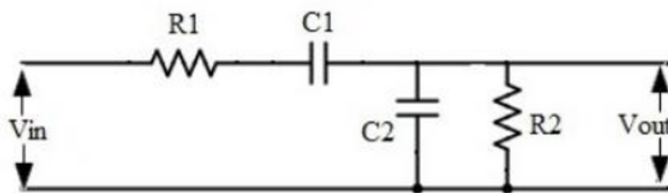


Figure 8 1st order band pass circuit

Band stop

(ece, 2018) Suggests A band stop filter works exactly like a band pass but blocks the signal within a certain frequency range. The frequency response for this type of filter is shown below in Figure 9.

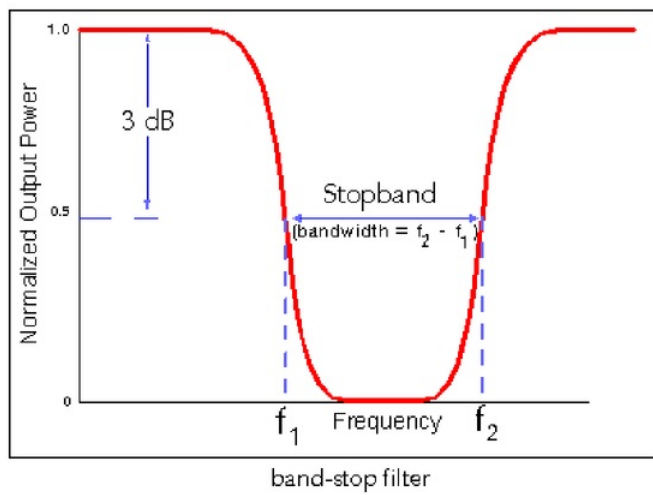


Figure 9 band stop frequency response

Below shows the circuit of a 1st order band stop circuit in Figure 10

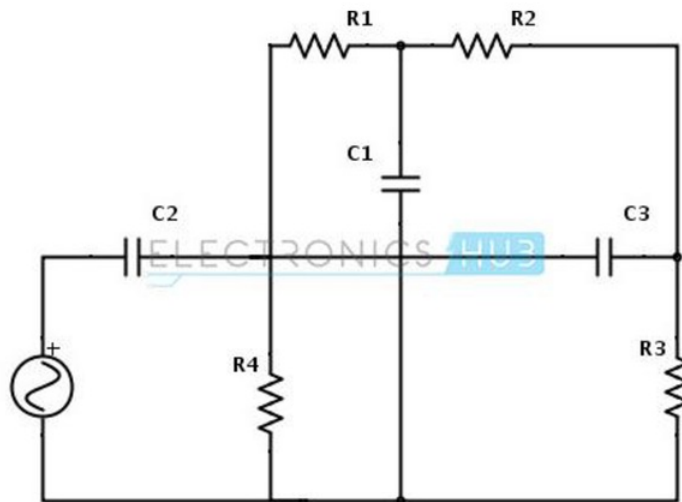


Figure 10 1st order band stop circuit

Looking into the low pass filter there are 3 main types of filters that can be used. These are Butterworth, Bessel and Tschebyscheff.

(Storey, 2017) States that “The Butterworth is optimised to produce a flat response within its pass band” it’s suggested that this flatness is in sacrifice to the sharp knee and phase performance. The Butterworth gives the flattest response.

(Storey, 2017) also states that “ the Bessel filter is optimised for a linear phase response” this is because even though the Bessel filter has a poor knee sharpness the phase response is better than the other types of filters and (Storey, 2017) suggests it’s ideal for pulse waveforms. The phase shift is a constant with the Bessel filter unlike the other filters so it doesn’t distort the waveform.

(Storey, 2017) Suggests that Tschebyscheff has the sharpest change from pass band to stop band but its phase response is very poor which means it distorts the output largely.

All the filter types are good for their own purposes but the best average is the Butterworth as its performance is in the middle of the Tschebyscheff and the Bessel for usability. The Bessel has the best phase performance and the Tschebyscheff has the best transition from band stop to band pass. Figure 11 shows how the gain and phase response compare against the filter types.

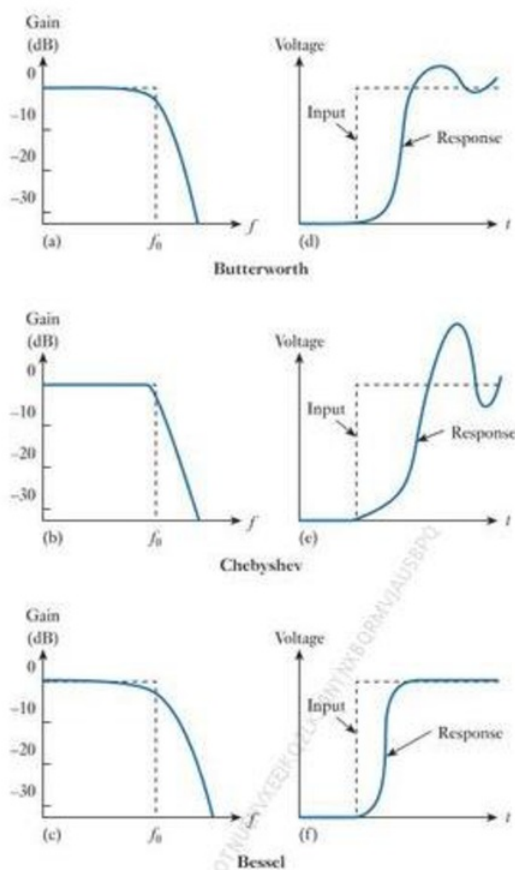


Figure 11 Comparison against filter types

(Gergely, 2002) Says that “filters can be found in radio and TV receivers where the wanted station is selected by filtering out its wanted frequency from all the ones received by the aerial” it’s also suggested that filters are used in analogue to digital and digital to analogue conversions.

(elprocus, 2018)Says that “Active filters are used in communication systems for suppressing noise, to isolate a communication of signal from various channels to improve the unique message signal from a modulated signal.”

3. Design method, choices and calculations

All the filter that will be designed is going to have a cut off frequency of 70kHz.

This report will compare and contrast the differences between filter designs. The first type of comparison will be comparing having the same order of filters but using different filter types such as Bessel, Butterworth and Tschebyscheff. The filters will all be 5th order low pass circuit.. This investigation will highlight the difference in the roll off and gradient after roll off by just changing the filter type.

The 5th order filters will be made up from 3 stages 1 1st order and 2 2nd order. The output of the first stage will connect to the input of the second order and the output of the 2nd stage will connect to the input of the 3rd stage and the output of the 3rd stage will be measured to find out the result of the test.

The first stage of the filter design is too chose the type and find the coefficients related to that type for the certain order of filter. The coefficients for this Butterworth filter are in the table below.

Butterworth		
Stage number	a _i	b _i
1	1	0
2	1.6180	1
3	0.6180	1

Now the values for stage 1 can be calculated. Stage 1's circuit is as below in Figure 12

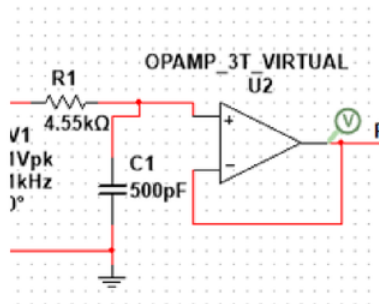


Figure 12 stage 1 low pass Butterworth

The resistor will be called R1 and the capacitor will be called C1 for the calculations. The formula to work out R1 is:

$$R1 = \frac{a_1}{2\pi f_c C_1}$$

C1 needs to be selected to complete the calculation. The value of C1 is going to be 500pF.

The value of f_c is 70kHz

$$R1 = \frac{1}{2\pi(70000)(500 * 10^{-12})}$$

$$R1 = 4.55K\Omega$$

The ideal resistance is between $1k\Omega$ and $10k\Omega$ so an $R1$ value of $4.55k\Omega$ is perfect. If the value was below or above the ideal bracket then the value of $C1$ may need to be changed and adjusted to make the best filter.

So for stage one of the filter the values are

$$R1 = 4.55k\Omega$$

$$C1 = 500pF$$

Now the first stage is complete stages 2. Stage 2 is a second order and is as below in Figure 14.

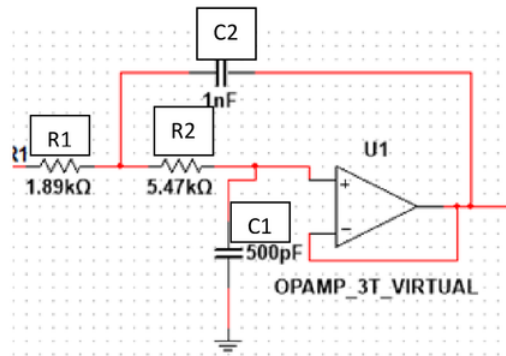


Figure 13 stage 2 low pass filter

Like the stage 1 part of the filter $C1$ will be chosen. $R1$, $R2$ and $C2$ will need to be calculated from this. $C2$ will be the first to be calculated as it's required in the equation to calculate the two resistors.

$$C1 = 500pF$$

The equation for $C2$ is:

$$C2 \geq C1 \frac{4b_1}{a_1^2}$$

So

$$C2 \geq (500 * 10^{-12}) \frac{4(1)}{(1.6180)^2}$$

$$C2 = 1nF$$

Now a value for $C2$ has been found $R1$ & $R2$ can be found using the equation:

$$R_{1,2} = \frac{a_1 C_2 \pm \sqrt{a_1^2 C_2^2 - 4b_1 C_1 C_2}}{4\pi f_c C_1 C_2}$$

$$R1 = \frac{(1.6180)(1 * 10^{-9}) + \sqrt{(1.6180)^2 (1 * 10^{-9})^2 - 4(1)(500 * 10^{-12})(1 * 10^{-9})}}{4\pi(70000)(500 * 10^{-12})(1 * 10^{-9})}$$

$$R1 = 1.89k\Omega$$

$$R2 = \frac{(1.6180)(1 * 10^{-9}) - \sqrt{(1.6180)^2(1 * 10^{-9})^2 - 4(1)(500 * 10^{-12})(1 * 10^{-9})}}{4\pi(70000)(500 * 10^{-12})(1 * 10^{-9})}$$

$$R2 = 5.47k\Omega$$

The values from the stage 2 of this filter are

$$R1 = 1.89k\Omega$$

$$R2 = 5.47k\Omega$$

$$C1 = 500pF$$

$$C2 = 1nF$$

For the 3rd stage of the filter another 2nd order will be used. All the calculations will be the same but with different values of a and b coefficients which change the resistor values and C2 value.

$$C1 = 500pF$$

The equation for C2 is:

$$C2 \geq C1 \frac{4b_1}{a1^2}$$

So

$$C2 \geq (500 * 10^{-12}) \frac{4(1)}{(0.6180)^2}$$

$$C2 = 5.5nF$$

Now a value for C2 has been found R1 & R2 can be found using the equation:

$$R1,2 = \frac{a1C2 \pm \sqrt{a1^2C2^2 - 4b1C1C2}}{4\pi f_c C1C2}$$

$$R1 = \frac{(0.6180)(5.5 * 10^{-9}) + \sqrt{(0.6180)^2(1 * 10^{-9})^2 - 4(1)(500 * 10^{-12})(5.5 * 10^{-9})}}{4\pi(70000)(500 * 10^{-12})(5.5 * 10^{-9})}$$

$$R1 = 1.1k\Omega$$

$$R2 = \frac{(0.6180)(5.5 * 10^{-9}) - \sqrt{(0.6180)^2(1 * 10^{-9})^2 - 4(1)(500 * 10^{-12})(5.5 * 10^{-9})}}{4\pi(70000)(500 * 10^{-12})(5.5 * 10^{-9})}$$

$$R2 = 1.71k\Omega$$

The values from the 3rd stage of this filter are

$$R1 = 1.1k\Omega$$

$$R2 = 1.71k\Omega$$

$$C1 = 500pF$$

$$C2 = 5.5nF$$

Now that all stages of the filter are completed they can all be put together and simulated to check the calculations are correct. A simulated signal is put on the input of the filter to test the filter. The constructed circuit is shown below in Figure 15

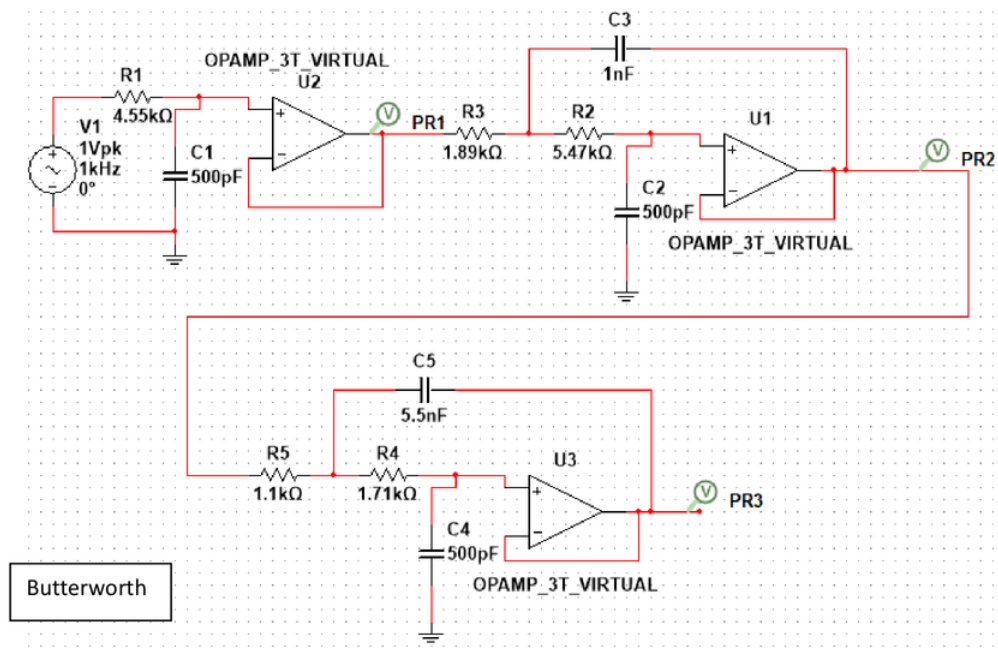


Figure 15 Butterworth 5th order circuit

The next filter that will be looked at is the Thschebyscheff.

Thschebyscheff		
Stage number	a_i	b_i
1	3.5711	0
2	1.1280	2.4896
3	0.1872	1.0814

Stage 1 (1st order)

$$R1 = \frac{a_1}{2\pi f_c C_1}$$

The value of C1 is going to be 2nF.

The value of f_c is 70kHz

$$R1 = \frac{3.5711}{2\pi(70000)(2 * 10^{-9})}$$

$$R1 = 4.55K\Omega$$

Stage 2 (2nd order)

Like the stage 1 part of the filter C1 will be chosen. R1, R2 and C2 will need to be calculated from this. C2 will be the first to be calculated as it's required in the equation to calculate the two resistors.

$$C1 = 200\text{pF}$$

The equation for C2 is:

$$C2 \geq C1 \frac{4b_1}{a1^2}$$

So

$$C2 \geq (200 * 10^{-12}) \frac{4(2.4896)}{(1.1280)^2}$$

$$C2 = 2\text{nF}$$

Now a value for C2 has been found R1 & R2 can be found using the equation:

$$R1,2 = \frac{a1C2 \pm \sqrt{a1^2C2^2 - 4b1C1C2}}{4\pi f_c C1C2}$$

$$R1 = \frac{(1.1280)(2 * 10^{-9}) + \sqrt{(1.1280)^2(2 * 10^{-9})^2 - 4(2.4896)(200 * 10^{-12})(2 * 10^{-9})}}{4\pi(70000)(200 * 10^{-12})(2 * 10^{-9})}$$

$$R1 = 2.66\text{k}\Omega$$

$$R2 = \frac{(1.1280)(2 * 10^{-9}) - \sqrt{(1.1280)^2(2 * 10^{-9})^2 - 4(2.4896)(200 * 10^{-12})(2 * 10^{-9})}}{4\pi(70000)(200 * 10^{-12})(2 * 10^{-9})}$$

$$R2 = 7.31\text{k}\Omega$$

The values from the stage 2 of this filter are

$$R1 = 2.66\text{k}\Omega$$

$$R2 = 7.31\text{k}\Omega$$

$$C1 = 200\text{pF}$$

$$C2 = 2\text{nF}$$

Stage 3 (2nd order)

$$C1 = 200\text{pF}$$

The equation for C2 is:

$$C2 \geq C1 \frac{4b_1}{a1^2}$$

So

$$C2 \geq (200 * 10^{-12}) \frac{4(1.0814)}{(0.1872)^2}$$

$$C2 = 2.47\text{nF}$$

Now a value for C2 has been found R1 & 2 can be found using the equation:

$$R_{1,2} = \frac{a_1 C_2 \pm \sqrt{a_1^2 C_2^2 - 4b_1 C_1 C_2}}{4\pi f_c C_1 C_2}$$

R1

$$= \frac{(0.1872)(2.47 * 10^{-9}) + \sqrt{(0.1872)^2(2.47 * 10^{-9})^2 - 4(1.0814)(200 * 10^{-12})(2.47 * 10^{-9})}}{4\pi(70000)(200 * 10^{-12})(2.47 * 10^{-9})}$$

$$R1 = 1.97k\Omega$$

R2

$$= \frac{(0.1872)(2.47 * 10^{-9}) - \sqrt{(0.1872)^2(2.47 * 10^{-9})^2 - 4(1.0814)(200 * 10^{-12})(2.47 * 10^{-9})}}{4\pi(70000)(200 * 10^{-12})(2.47 * 10^{-9})}$$

$$R2 = 8k\Omega$$

The values from the 3rd part of this filter are

$$R1 = 1.97k\Omega$$

$$R2 = 8k\Omega$$

$$C1 = 200pF$$

$$C2 = 2.47nF$$

These stages are combined and look the same as the Butterworth but with different values. This is shown in Figure 16

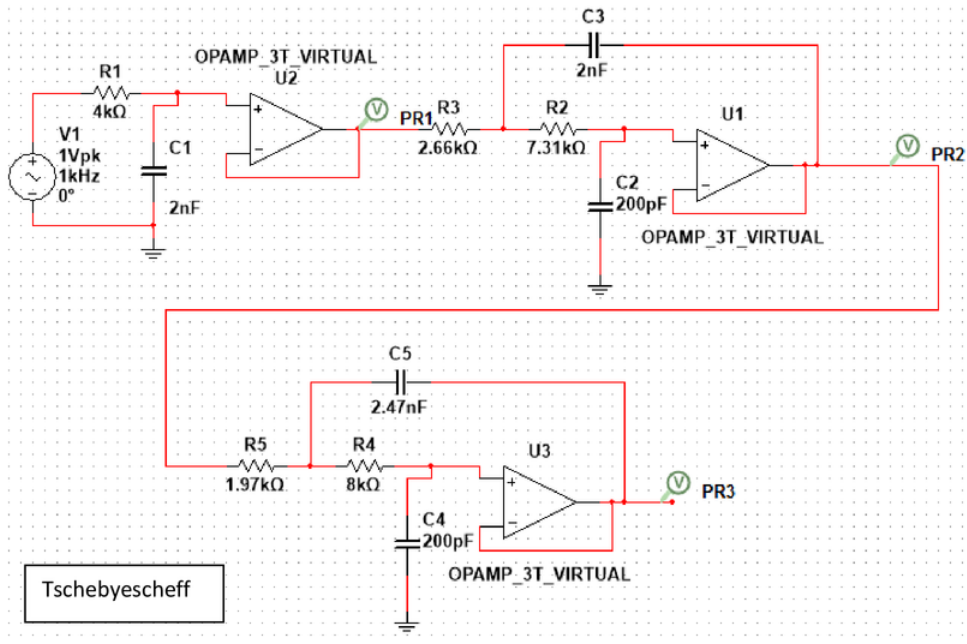


Figure 16 Tschebyscheff 5th order low pass

The next filter is a Bessel filter

Bessel		
Stage number	a _i	b _i
1	0.6656	0
2	1.1402	0.4128
3	0.6216	0.3245

Stage 1 (1st order)

$$R1 = \frac{a_1}{2\pi f_c C_1}$$

The value of C1 is going to be 200pF.

The value of f_c is 70kHz

$$R1 = \frac{0.6656}{2\pi(70000)(200 * 10^{-12})}$$

$$R1 = 7.57K\Omega$$

Stage 2 (2nd order)

Like the stage 1 part of the filter C1 will be chosen. R1, R2 and C2 will need to be calculated from this. C2 will be the first to be calculated as it's required in the equation to calculate the two resistors.

$$C1 = 200pF$$

The equation for C2 is:

$$C2 \geq C1 \frac{4b_1}{a_1^2}$$

So

$$C2 \geq (200 * 10^{-12}) \frac{4(0.4128)}{(1.1402)^2}$$

$$C2 = 290nF$$

Now a value for C2 has been found R1 & R2 can be found using the equation:

$$R_{1,2} = \frac{a_1 C_2 \pm \sqrt{a_1^2 C_2^2 - 4b_1 C_1 C_2}}{4\pi f_c C_1 C_2}$$

R1

$$= \frac{(1.1402)(290 * 10^{-12}) + \sqrt{(1.1402)^2 (2 * 10^{-12})^2 - 4(0.4128)(200 * 10^{-12})(290 * 10^{-12})}}{4\pi(70000)(200 * 10^{-12})(290 * 10^{-12})}$$

$$R1 = 4.21k\Omega$$

$$R2 = \frac{(1.1402)(290 * 10^{-12}) - \sqrt{(1.1402)^2(2 * 10^{-12})^2 - 4(0.4128)(200 * 10^{-12})(290 * 10^{-12})}}{4\pi(70000)(200 * 10^{-12})(290 * 10^{-12})}$$

$$R2 = 8.75k\Omega$$

The values from the stage 2 of this filter are

$$R1 = 4.21k\Omega$$

$$R2 = 8.75k\Omega$$

$$C1 = 200pF$$

$$C2 = 290pF$$

Stage 3 (2nd order)

$$C1 = 200pF$$

The equation for C2 is:

$$C2 \geq C1 \frac{4b_1}{a1^2}$$

So

$$C2 \geq (200 * 10^{-12}) \frac{4(0.3245)}{(0.6216)^2}$$

$$C2 = 800pF$$

Now a value for C2 has been found R1 & 2 can be found using the equation:

$$R1,2 = \frac{a1C2 \pm \sqrt{a1^2C2^2 - 4b1C1C2}}{4\pi f_c C1C2}$$

R1

$$= \frac{(0.6216)(800 * 10^{-12}) + \sqrt{(0.6216)^2(800 * 10^{-12})^2 - 4(0.3245)(200 * 10^{-12})(800 * 10^{-12})}}{4\pi(70000)(200 * 10^{-12})(800 * 10^{-12})}$$

$$R1 = 2.12k\Omega$$

R2

$$= \frac{(0.6216)(800 * 10^{-12}) - \sqrt{(0.6216)^2(800 * 10^{-12})^2 - 4(0.3245)(200 * 10^{-12})(800 * 10^{-12})}}{4\pi(70000)(200 * 10^{-12})(800 * 10^{-12})}$$

$$R2 = 4.95k\Omega$$

The values from the 3rd part of this filter are

$$R1 = 12.12k\Omega$$

$$R2 = 4.95k\Omega$$

$$C1 = 200pF$$

$$C2 = 800pF$$

The final circuit is shown below in Figure 17

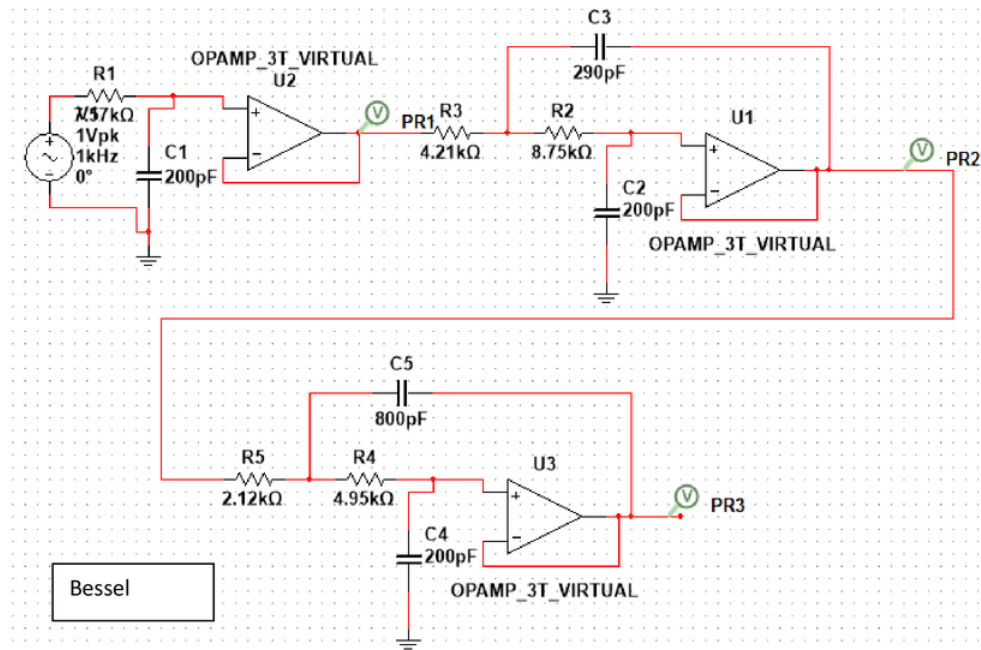


Figure 17 Bessel 5th order low pass

To compare the difference in different order filters, the type of filter will now remain the same and the number of orders will change. The filter will be a high pass Butterworth and 3rd order, 6th order and 9th order will be compared to see if the gradient of roll off is affected by 20dB per decade per order. Also the sharpness at the top of the roll off will be investigated to see if it gets sharper as the orders are increased.

The filter design of a high pass is similar to that of a low pass but the resistors and the capacitor change places. Coefficients are used just like the low pass filter as in the table below.

Butterworth 3 rd order		
Stage number	a _i	b _i
1	1	0
2	1	1

Now the values for stage 1 can be calculated. Stage 1's circuit is as below in Figure 18

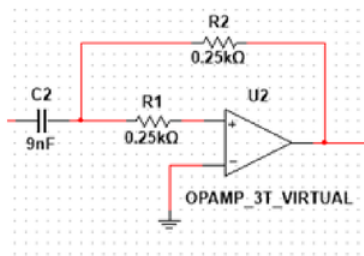


Figure 18 stage 1 3rd order high pass filter

C1 is estimated in a highpass filter.

$$C1 = 9\text{nF}$$

$$R1 = \frac{1}{2\pi f_c a_1 C_1}$$

The value of f_c is 70kHz

$$R1 = \frac{1}{2\pi(70000)(1)(9 \times 10^{-9})}$$

$$R1 = 0.25\text{k}\Omega$$

$$R2 = R1$$

Stage 2 (3rd order)

Like the stage 1 part of the filter C1 will be chosen. R1, R2 and C2 will need to be calculated from this. C2 will be the first to be calculated as it's required in the equation to calculate the two resistors.

$$C1 = 500\text{pF}$$

The circuit for stage 2 of the 3rd order filter is as below in Figure 19

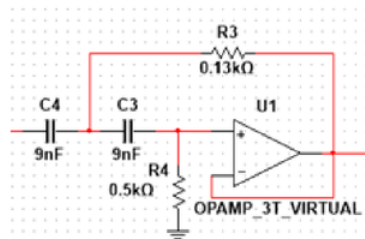


Figure 19 stage 2 of 3rd order high pass filter

C1 is chosen for second order.

$$C2 = C1$$

$$C1 = 9\text{nF}$$

Now a value for C2 has been found R1 & R2 can be found using the equation:

$$R1 = \frac{1}{\pi f_c C a1}$$

$$R1 = \frac{1}{\pi(70000)(9 * 10^{-9})(1)}$$

$$R1 = 0.5k\Omega$$

$$R2 = \frac{a1}{4\pi f_c C b1}$$

$$R1 = \frac{(1)}{\pi(70000)(9 * 10^{-9})(1)}$$

$$R2 = 0.13k\Omega$$

Now that all stages of the filter are completed they can all be put together on simulate them and to check the calculations are correct. A simulated signal is put on the input of the filter.

The constructed circuit is shown below in Figure 21

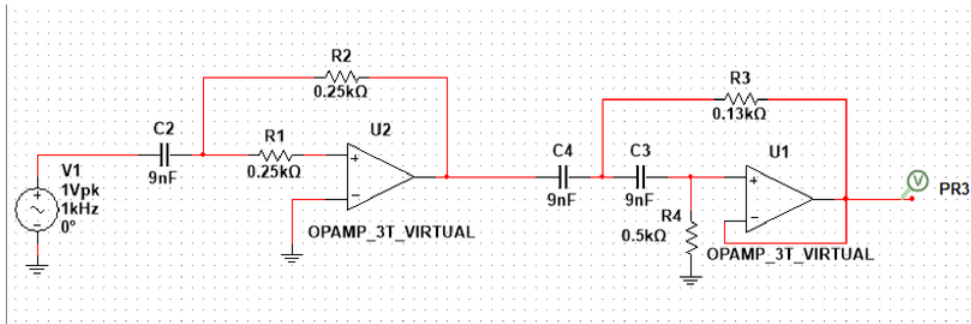


Figure 20 3rd order low pass filter

6th order high pass filter

Butterworth 6 th order		
Stage number	a _i	b _i
1	1.9319	0.676
2	1.4142	1
3	0.5176	1.479

1st stage (2nd order)

C1 is chosen for second order.

$$C2=C1$$

$$C1 = 2\text{nF}$$

Now a value for C2 has been found R1 & R2 can be found using the equation:

$$R1 = \frac{1}{\pi f_c C a1}$$

$$R1 = \frac{1}{\pi(70000)(2 * 10^{-9})(1.9319)}$$

$$R1 = 1.176\text{k}\Omega$$

$$R2 = \frac{a1}{4\pi f_c C b1}$$

$$R1 = \frac{(1.9319)}{\pi(70000)(2 * 10^{-9})(0.676)}$$

$$R2 = 1.098\text{k}\Omega$$

2nd stage (2nd order)

C1 is chosen for second order.

$$C2=C1$$

$$C1 = 2\text{nF}$$

Now a value for C2 has been found R1 & R2 can be found using the equation:

$$R1 = \frac{1}{\pi f_c C a1}$$

$$R1 = \frac{1}{\pi(70000)(2 * 10^{-9})(1.4142)}$$

$$R1 = 1.607\text{k}\Omega$$

$$R2 = \frac{a1}{4\pi f_c C b1}$$

$$R1 = \frac{(1.4142)}{\pi(70000)(2 * 10^{-9})(1)}$$

$$R2 = 0.803k\Omega$$

3rd stage (2nd order)

C1 is chosen for second order.

$$C2=C1$$

$$C1 = 2nF$$

Now a value for C2 has been found R1 & R2 can be found using the equation:

$$R1 = \frac{1}{\pi f_c C a1}$$

$$R1 = \frac{1}{\pi(70000)(2 * 10^{-9})(0.5176)}$$

$$R1 = 4.392k\Omega$$

$$R2 = \frac{a1}{4\pi f_c C b1}$$

$$R1 = \frac{(0.5176)}{\pi(70000)(2 * 10^{-9})(1.479)}$$

$$R2 = 0.294k\Omega$$

The stages are then put together on multisim and is shown below in Figure 22

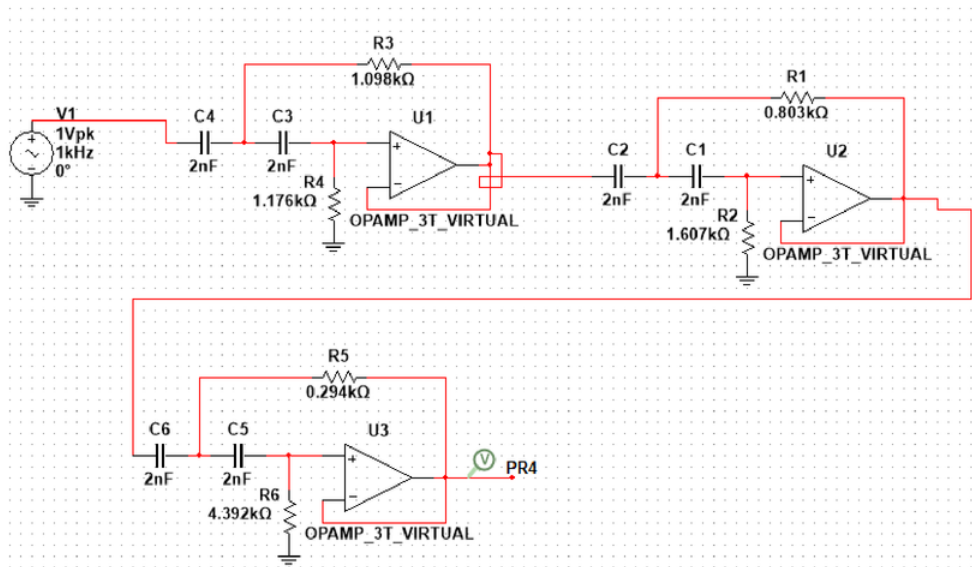


Figure 21 6th order high pass

9th order high pass filter

Butterworth 9 th order		
Stage number	a _i	b _i
1	1	0
2	1.8794	1
3	1.5321	1
4	1	1
5	0.3473	1

C 1 is estimated in a highpass filter.

$$C1 = 2\text{nF}$$

$$R1 = \frac{1}{2\pi f_c a_1 C_1}$$

The value of f_c is 70kHz

$$R1 = \frac{1}{2\pi(70000)(1)(2 * 10^{-9})}$$

$$R1 = 3.248K\Omega$$

$$R2 = R1$$

2nd stage (2nd order)

C1 is chosen for second order.

$$C2 = C1$$

$$C1 = 2\text{nF}$$

Now a value for C2 has been found R1 & R2 can be found using the equation:

$$R1 = \frac{1}{\pi f_c C a_1}$$

$$R1 = \frac{1}{\pi(70000)(700 * 10^{-12})(1.8794)}$$

$$R1 = 3.456k\Omega$$

$$R2 = \frac{a_1}{4\pi f_c C b_1}$$

$$R1 = \frac{(1.8794)}{\pi(70000)(700 * 10^{-12})(1)}$$

$$R2 = 3.056k\Omega$$

3rd stage (2nd order)

C1 is chosen for second order.

$$C2=C1$$

$$C1 = 2\text{nF}$$

Now a value for C2 has been found R1 & R2 can be found using the equation:

$$R1 = \frac{1}{\pi f_c C a1}$$

$$R1 = \frac{1}{\pi(70000)(700 * 10^{-12})(1.5321)}$$

$$R1 = 4.24\text{k}\Omega$$

$$R2 = \frac{a1}{4\pi f_c C b1}$$

$$R1 = \frac{(1.5321)}{\pi(70000)(700 * 10^{-12})(1.479)}$$

$$R2 = 2.488\text{k}\Omega$$

4th stage (2nd order)

C1 is chosen for second order.

$$C2=C1$$

$$C1 = 2\text{nF}$$

Now a value for C2 has been found R1 & R2 can be found using the equation:

$$R1 = \frac{1}{\pi f_c C a1}$$

$$R1 = \frac{1}{\pi(70000)(700 * 10^{-12})(1)}$$

$$R1 = 6.496\text{k}\Omega$$

$$R2 = \frac{a1}{4\pi f_c C b1}$$

$$R1 = \frac{(1)}{\pi(70000)(700 * 10^{-12})(1)}$$

$$R2 = 1.624\text{k}\Omega$$

5th stage (2nd order)

C1 is chosen for second order.

$$C2=C1$$

$$C1 = 2\text{nF}$$

Now a value for C2 has been found R1 & R2 can be found using the equation:

$$R1 = \frac{1}{\pi f_c C a1}$$

$$R1 = \frac{1}{\pi(70000)(700 * 10^{-12})(0.3473)}$$

$$R1 = 18.704k\Omega$$

$$R2 = \frac{a1}{4\pi f_c C b1}$$

$$R1 = \frac{(0.3473)}{\pi(70000)(700 * 10^{-12})(1.479)}$$

$$R2 = 0.564k\Omega$$

Below shows the 9th order filter circuit in Figure 22

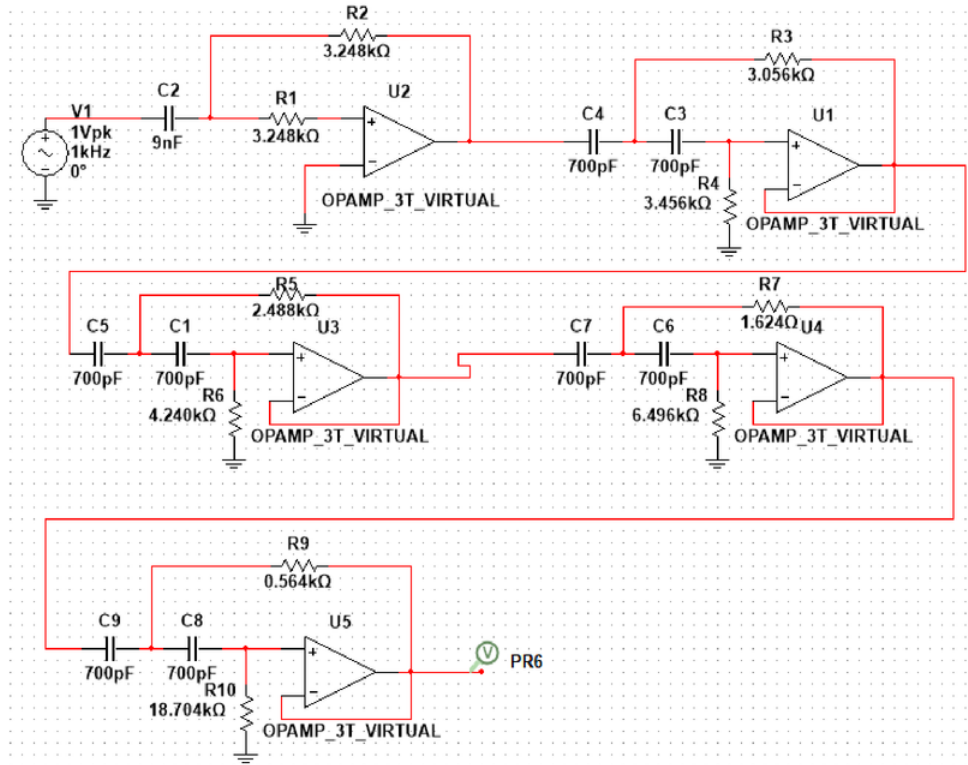


Figure 22 9th order filter circuit

4. Testing and improving the design

to prove the theory behind the behaviour characteristics of filters, all the circuits that have been designed will now be tested. The circuit will be tested using multisim's ac sweep simulation function. This will simulate the circuit with real life characteristics. Voltage probes have been placed on the circuits to test the circuit.

Starting with the Butterworth shown below in Figure 24. The has the gradient of -100dB per decade which is expected for a 5th order filter. The roll of isn't the best but the slope down is very flat which was expected from the research.

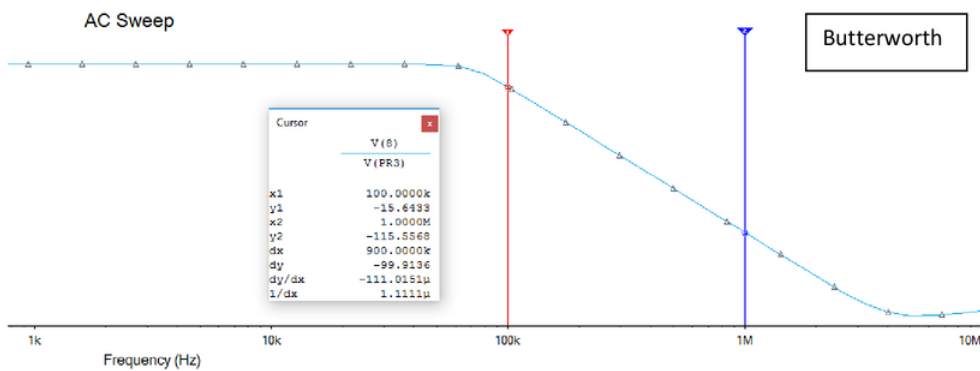


Figure 23 Butterworth simulation

Thschebyscheff is in Figure 25 below. This has a very sharp roll off but the signal is very distorted on the pass band which was pointed out when researched. The gradient is very close to 100dB per decade which is very good.

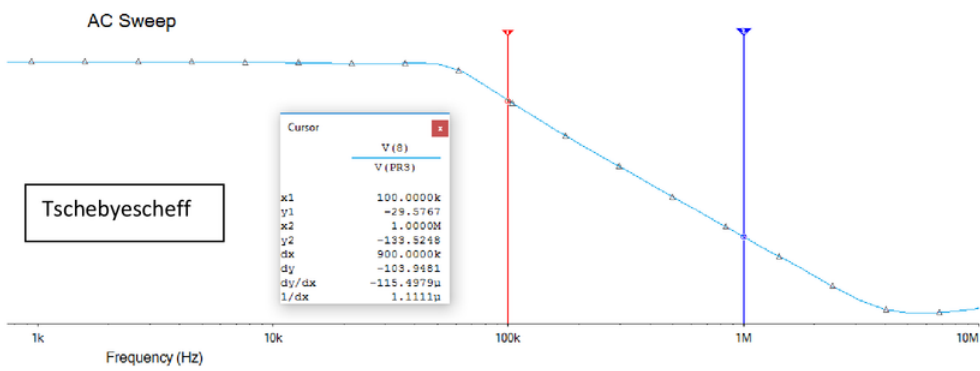


Figure 24 Thschebyscheff simulation

Bessel is in Figure 26 below. The Bessel's gradient is also very close to 100dB per decade. The roll off is very slow on this but there is very little distortion in band pass.

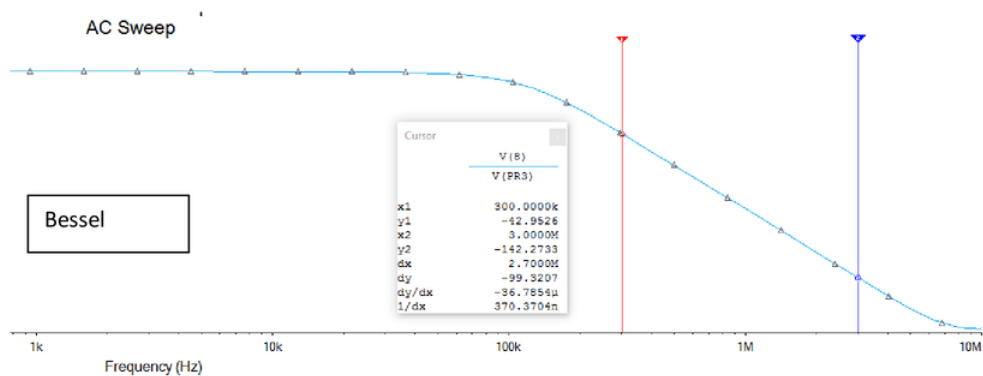


Figure 25 Bessel simulation

Now the effect of increasing the order needs to be compared.

3rd order will be the first circuit to test.

The 3rd order Figure 27 is a very long gradual incline which has a gradient of 60 dB per decade which isn't very good Figure 28. The roll off isn't sharp at all and there's also a lot of distortion on the band

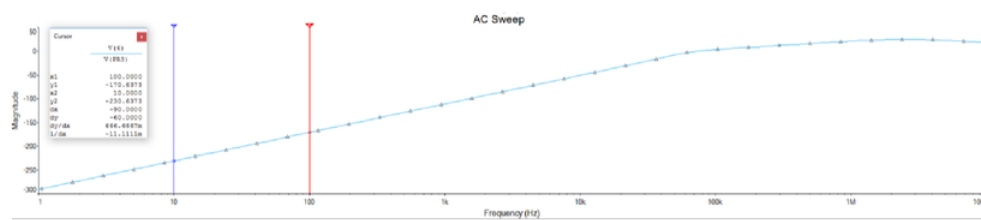


Figure 26 3rd order simulation

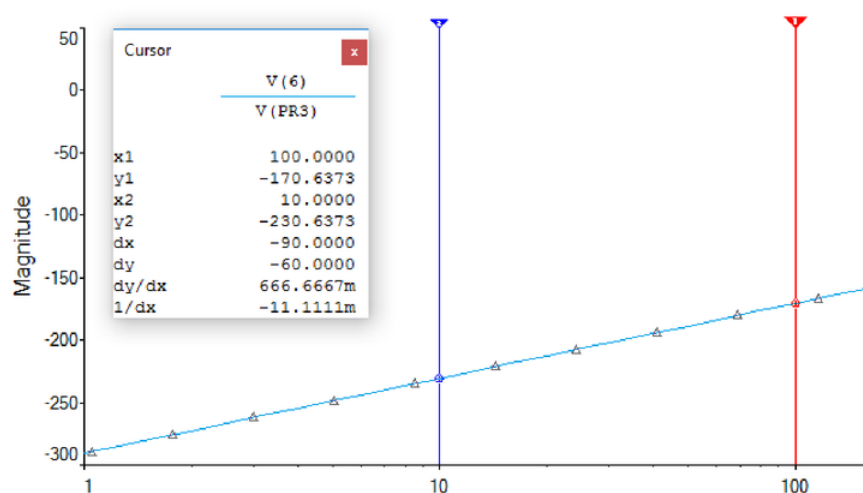


Figure 27 3rd order gradient

The 6th order filter shows a much greater gradient at 120dB per decade. This filter is also a lot less distorted and has a sharp roll off. Figure 29 shows the simulation.

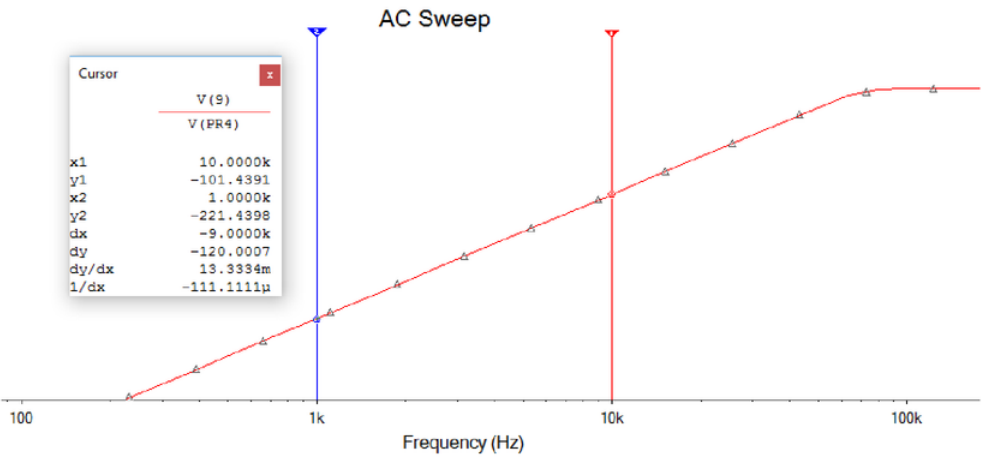


Figure 28 6th order simulation

The 9th order shows a very steep gradient at 180 dB per decade with a very sharp roll off on the top. This proves that increasing the order of a filter largely improves the performance of that filter. 9th order is shown in Figure 30

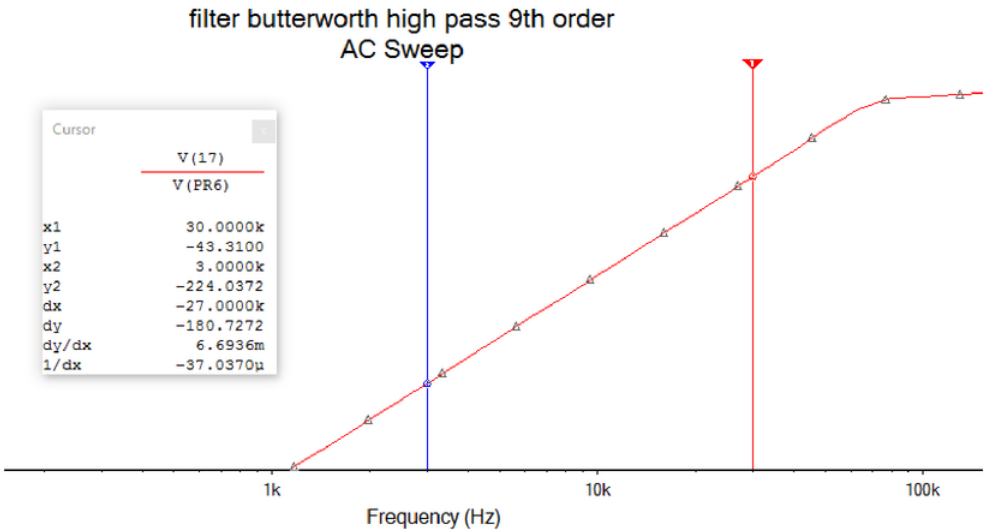


Figure 29 9th order simulation

5. Conclusions

The aim of this report was to test what affects a filter when designing a filter. The two types of variables whilst testing was the type of filter and the number of orders a filter was.

It was found that the type of filter affected the waveform of the circuit such as the sharpness of the roll off and the distortion of the waveform. Butterworth had the most average characteristics where as Thschebyscheff had a really sharp roll off but was distorted whereas Bessel had no distortion but a bad roll off.

Increasing the orders of the filters showed that the order controlled the gradient of the roll off and the sharpness of the band pass to band stop transition. The more the orders were increased the closer the circuit came to the brick wall effect where the roll off almost matches a digital waveform.

The calculations were fairly easy to do but were time consuming on the Thschebyscheff filter. High pass filter was very easy to do the calculation as they were quite simple.

6. Reference list and bibliography

Bibliography

ece. (2018, 01 02). *www.ece.rutgers.edu*. Retrieved from *www.ece.rutgers.edu*:
<http://www.ece.rutgers.edu/~psannuti/ece224/PEEII-Expt-2-07.pdf>

electronicshub. (2018, 01 02). *www.electronicshub.or*. Retrieved from *www.electronicshub.or*:
<https://www.electronicshub.org/passive-band-pass-rc-filter/>

elprocus. (2018, 01 03). *www.elprocus.com*. Retrieved from *www.elprocus.com*:
<https://www.elprocus.com/types-active-filters-and-applications/>

Gergely, D. I. (2002). *Analog electronics: circuits, systems and signal processing*.

Storey, N. (2017). *Electronics: A Systems Approach*. Pearson Education.

assignment 1

GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

Instructor

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GRADING FORM: CSG-RUBIC

SEAN JONES

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RESEARCH-INFORMED LITERATURE



There was evidence of further reading and research and appropriate in text referencing. Your interpretation and understanding of the additional research was satisfactory. Your references were appropriate to the task, the reference list was short and should increase the breadth of your research for future assignments.

6

KNOWLEDGE AND UNDERSTANDING



The knowledge and understanding of the subject demonstrated by this assignment was generally very

21

good. There were very few gaps in your knowledge of the basic principles and your understanding of the higher level concepts was very good. Your research and explanation was particularly good and extended your knowledge well beyond that contained in the course notes.

ANALYSIS



Your analysis of the task was brief and lacked a lot of the required detail. You have demonstrated reasonable analytical skills and your approach to the task was logical. You carried out a reasonable evaluation of the results, but the conclusions were very brief.

10

PRACTICAL APPLICATION AND DEP.



Your application of practical skills for this task was generally very good. You used the resources available in MultiSim appropriately when designing the circuit and you used appropriate options for testing and evaluating the circuit performance. You managed to design an efficient circuit that functioned within the specification and achieved this by only asking for assistance when appropriate. Your results were comprehensive and allowed for a good conclusion to be attempted.

21

SKILLS FOR PROFESSIONAL PRAC.



In this assignment you have demonstrated skills in working individually and also collaboratively. Your written report was of an appropriate length, you could however be more efficient with your word count. The report was well presented, with good

7

diagrams in appropriate places, good sentence/paragraph structure and clear calculations.