

assignment 1 5009

by Sean Jones

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Assignment 1

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Analysis, Simulation and
Evaluation of Electrical Circuits
and Electronic Systems

HNC electrical and electronic
engineering

PSDE5009

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1. Introduction

The purpose of this report is to critically analyse the differences between first and second order filter circuits and first and second order electronic filter circuits. High pass and low pass circuits will be used to test a wide range of circuits. On one circuit different resistor values will be used to see how the resistance value affects the filter circuit.

The values of the circuit will need to be chosen and some will need to be calculated. The end design of each circuit will be put into mat lab to be able to gain a graphical support in the comparison of the types of the circuit. Data such as the gradient and the cut off frequency will need to be marked on the graphs. When comparing two graphs the graphs may be combined for an easy visual analysis.

Laplace transfer functions will be used to put the data of the circuit into a format that can be inputted into mat lab.

This report will need to be concluded to determine which types of circuits are best for a filter and which where the most affective.

2. Analysis of First Order Electric Circuits

The difference between a RL circuit and a RC circuit will be analysed first. These circuits will both be first order circuits. The RL circuit will be the first to be created and tested. Firstly suitable values must be given for R and L.

$$R = 10\Omega$$

$$L = 0.01\text{H}$$

These values will be inputted to the circuit and used for all the calculations. Below is what a RL circuit in Figure 1. The positioning of the two components makes it a low pass. If the resistor was swapped with the inductor then it would be a high pass.

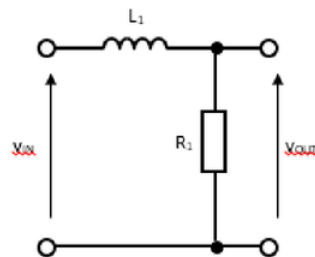


Figure 1 RL circuit

This circuit then has the Laplace transform applied to it. Below in Figure 2 shows the circuit after Laplace transform.

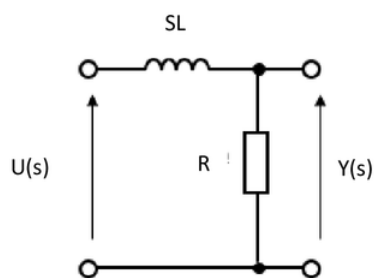


Figure 2 RL Laplace transforms

The calculations chosen for this circuit can now be placed on the circuit. This is shown below in Figure 3.

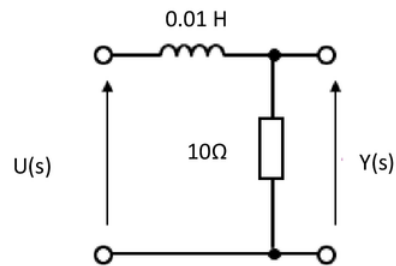


Figure 3 RL circuit with values

The time constant will now need to be calculated. This is as below.

$$t = L/R$$

With the chosen values of R and L inserted

$$t = 0.01/10$$

$$t = 0.001$$

Transfer function

$$H(s) = \frac{1}{ts+1}$$

$$H(s) = \frac{1}{0.001s+1}$$

The transfer function is placed into mat lab to prove the calculations. The graph shows an exponential rise which is expected with an inductor. after 0.632 of the final value the time taken is the same as the time constant. Although the value differs by 0.000001 this is close enough to prove the results. This graph is shown in Figure 4.

```

1 % First Order RL Exponential Rise
2 num=[1];
3 dem=[0.001 1];
4 step(num,dem);
5 xlabel('time,secs');
6 ylabel('Inductor voltage, volts');
7 grid

```

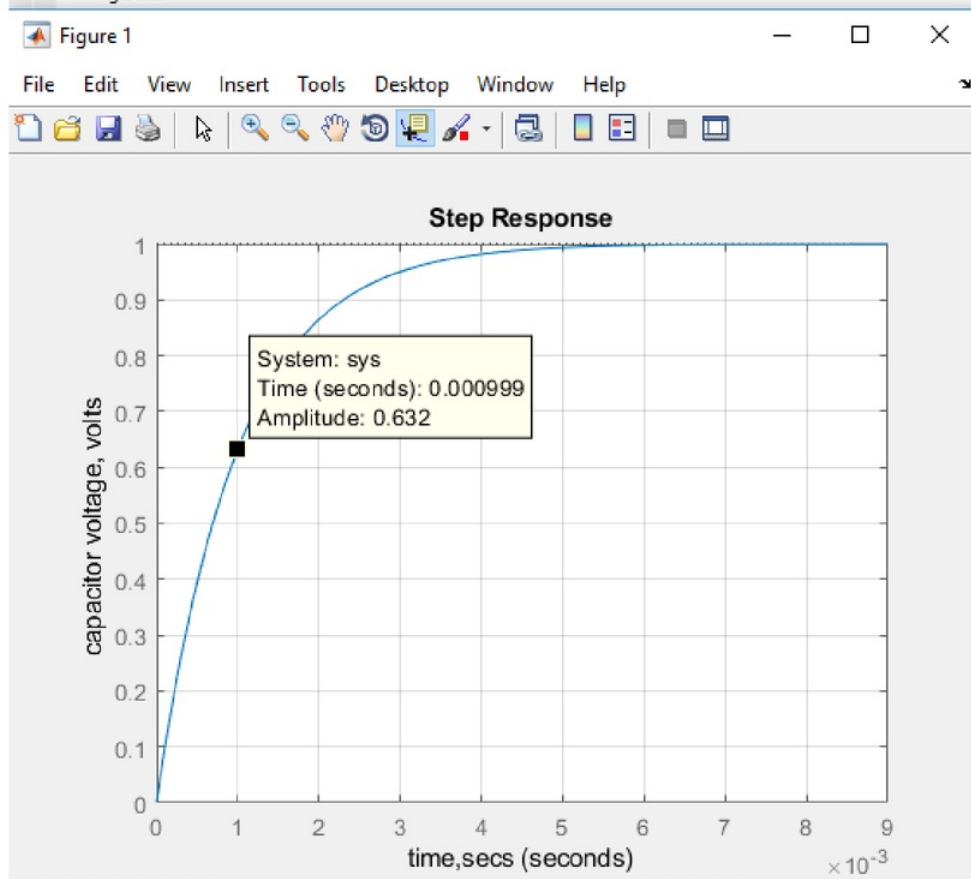


Figure 4 RL exponential

The cut off frequency now needs to be calculated. The cut off frequency is the unusable frequency for the circuit so if it goes below 3db then it cuts the frequency off in a low pass circuit.

$$\omega C = R/L$$

$$\omega C = 10/0.01$$

$$\omega C = 10/0.01$$

$$\omega C = 1000$$

$$H(j\omega) = \frac{\omega C}{s + \omega C}$$

$$H(j\omega) = \frac{1000}{s + 1000}$$

This is then proven in mat lab using the “bode” function instead of the “step” function. The results from Mat lab are Shown in Figure 5 . The results show that the 3db cut off occurs at nearly 1k rad/s. after 3db the drop occurs at 19db/decade which is close to the expected drop off.

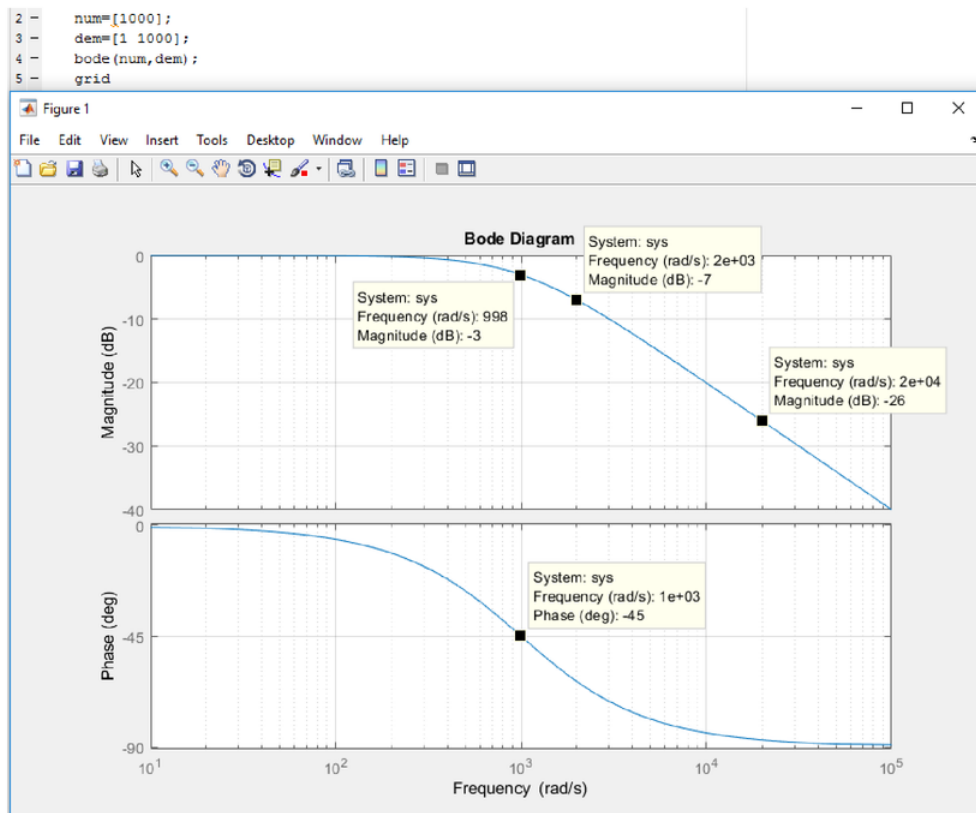


Figure 5 RL bode diagram

RC high pass filter

Below in Figure 6 shows the circuit of the high pass RC circuit. Even though it looks the same as an RL with the inductor swapped with a capacitor its characteristics change into a high pass instead of a low pass. Just like a RL if the capacitor and resistor are swapped then the circuit will be a low pass.

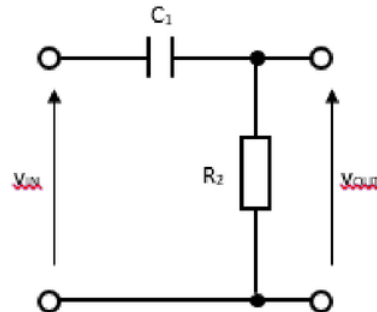


Figure 6 RC circuit

This circuit will now have the Laplace transforms applied to it as in Figure 7.

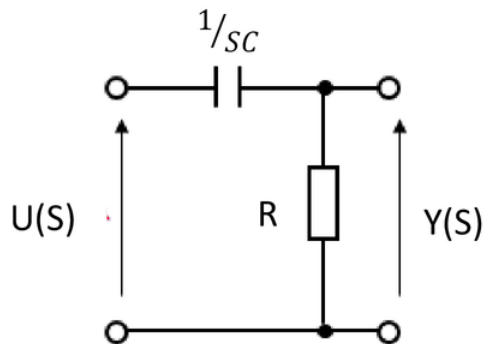


Figure 7 RC Laplace transforms

Suitable values must be chosen for the circuit to perform the calculations. These values are:-

$$R = 1.6K\Omega$$

$$C = 4\mu F$$

these values are then substituted into the circuit as in Figure 8.

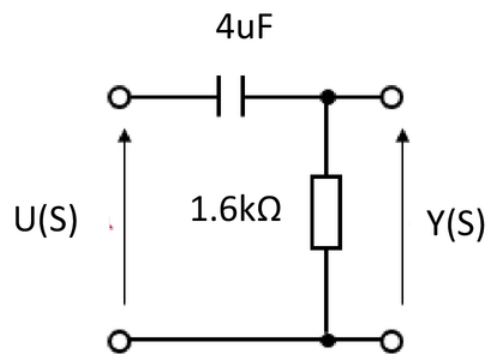


Figure 8 RC final circuit

Now the circuit is complete the transfer function needs to be calculated to put the results into mat lab. The time constant needs to be calculated first as it is needed in the transfer function. Time constant is calculated below.

$$t = RC$$

$$t = 1600 \times (4 \times 10^{-6})$$

$$t = 6.4\text{ms}$$

Now the time constant is obtained it can be put into the transfer function below.

$$H(s) = \frac{ts}{ts+1}$$

$$H(s) = \frac{6.4\text{ms}}{6.4\text{ms} + 1}$$

The transfer function is converted into mat lab to give a graph of the exponential decay of the high pass filter. This proves the calculations, as the time after 0.368 of the final value the time is the same as the calculated time constant. This graph is displayed in Figure 9

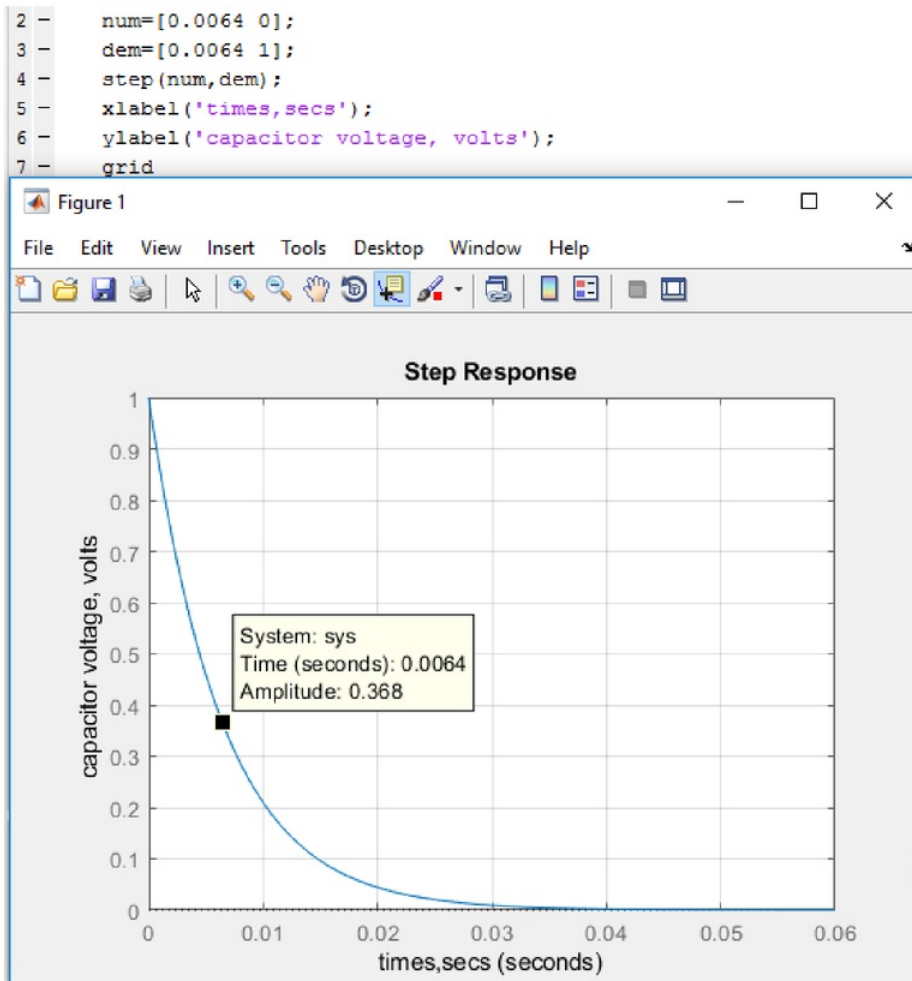


Figure 9 RC exponential decay

The next part of the test is to find the cut off frequency of the filter. The first thing is to calculate the cut off frequency to have a judging point when simulating the circuit in mat lab. Below is the calculations for the cut off frequency.

$$\omega_c = \frac{1}{RC}$$

$$\omega_c = \frac{1}{6.4 \times 10^{-3}}$$

$$\omega_c = 156.25 \text{ RADS/s}$$

below is the transfer function for the cut off frequency.

$$H(j\omega) = \frac{RCS}{RCS+1}$$

$$H(j\omega) = \frac{6.4*10^{-3}s}{6.4*10^{-3}+1}$$

Now inserted into mat lab in Figure 10. The graph shows the cut off frequency to be very close to the calculated value which was 156.25. The gradient is 18.53 dB/decade which is slightly more gradual incline but the cut off frequency is more accurate.

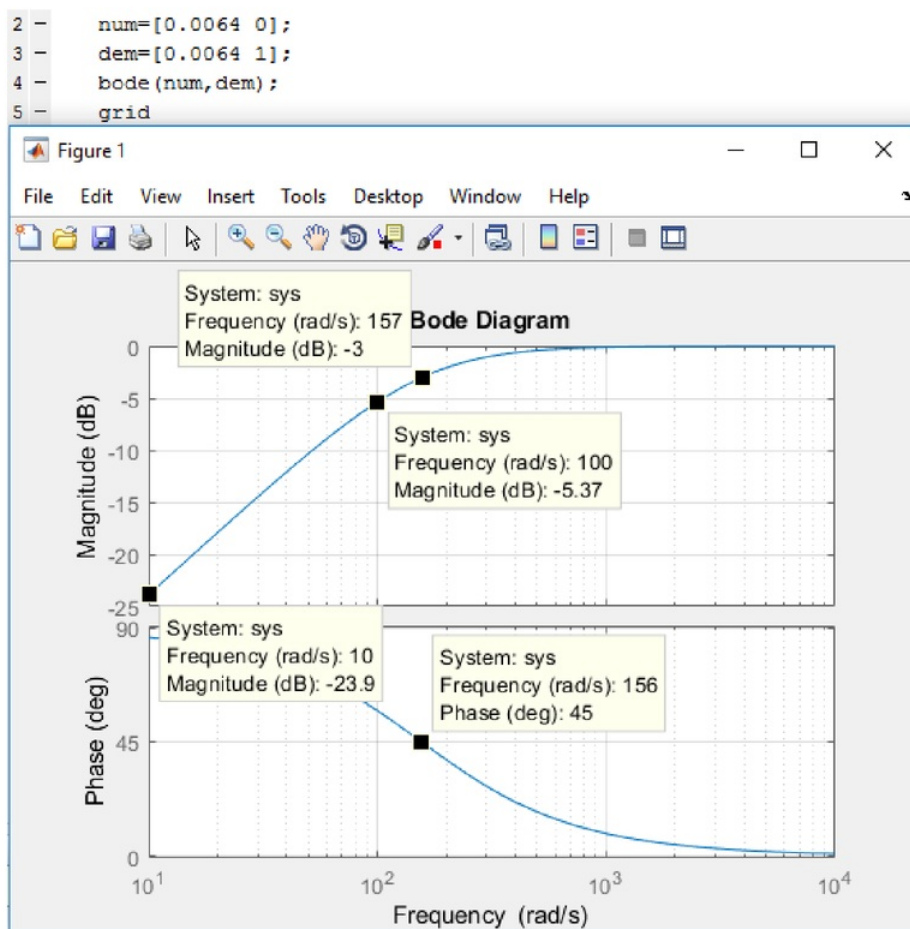


Figure 10 RC bode diagram

3. Analysis of Second Order Electric

The second order electric filters consist of a resistor capacitor and an inductor. A low pass circuit is shown below in Figure 11.

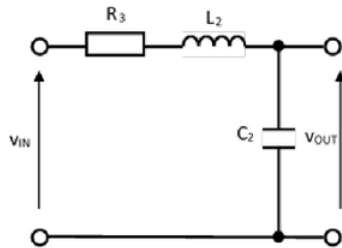


Figure 2(a): Low Pass Filter

Figure 11 2nd order low pass circuit

The values for the components must be chosen. The resistor value must be changed 4 times to show over damped, critically damped, under damped and no damping.

$$R = 10$$

$$C = 50\mu\text{F}$$

$$L = 0.2\text{H}$$

For the other scenarios of the value of R. R will equal

$$R = 0$$

$$R = 400$$

$$R = \text{critical}$$

$$\omega_n = \frac{1}{\sqrt{LC}}$$

$$\omega_n = 316.23 \text{ rad/s}$$

$$H(s) = \frac{\frac{1}{LC}}{s^2 + \frac{R}{L}s + \frac{1}{LC}}$$

$$H(s) = \frac{1}{s^2 + \frac{10}{0.2}s + \frac{1}{(0.2(50 * 10^{-6}))}}$$

$$H(s) = \frac{100000}{s^2 + 50s + 100000}$$

The response diagram for this on mat lab shows that this is under damped. This is shown in Figure 12

```
1 - hold off
2 - % under damped
3 - num=[100000];
4 - dem=[1 50 100000];
5 - step(num,dem);
6 - ylabel("V out (volts)");
7 - xlabel("time in seconds");
8 - grid on
9 -
```

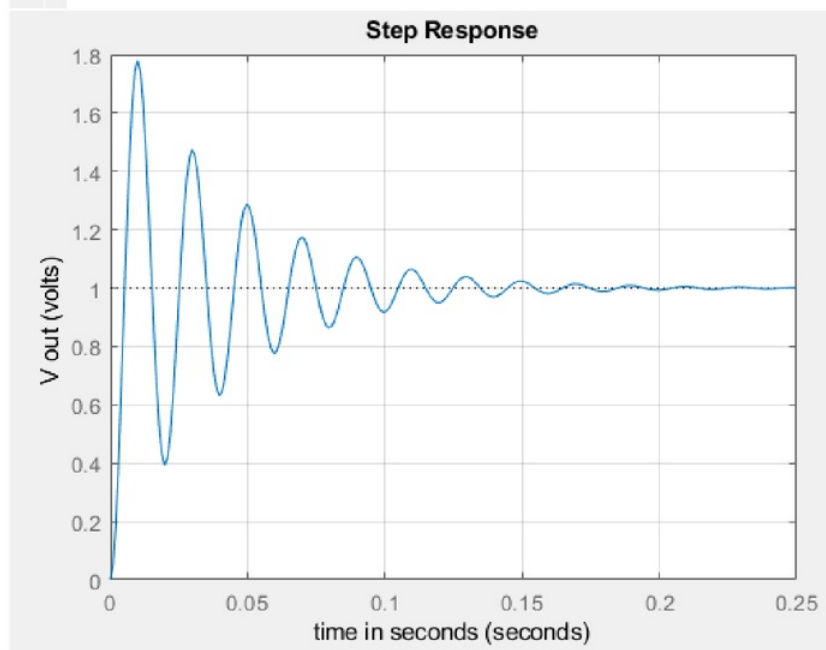


Figure 12 2nd order electric filter step response

$$H(s) = \frac{1}{s^2 + \frac{0}{0.2}s + \frac{1}{(0.2(50 * 10^{-6}))}}$$

$$H(s) = \frac{100000}{s^2 + 0s + 100000}$$

Below in Figure 13 shows the no damping circuit.

```

1 - hold off
2 - % no damping
3 - num=[100000];
4 - dem=[1 0 100000];
5 - step(num,dem);
6 - ylabel("V out (volts)");
7 - xlabel("time in seconds");
8 - grid on

```

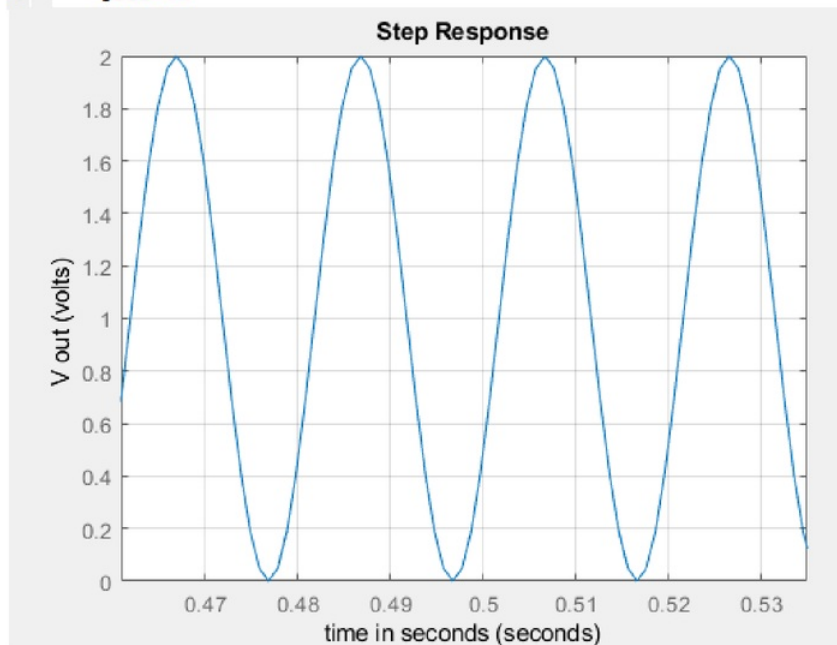


Figure 13 over damped 2nd order

$$H(s) = \frac{1}{s^2 + \frac{200}{0.2}s + \frac{1}{(0.2(50 * 10^{-6}))}}$$

$$H(s) = \frac{100000}{s^2 + 1000s + 100000}$$

This over damped circuit is in Figure 14

```

1 - hold off
2 - % over damping
3 - num=[100000];
4 - dem=[1 2000 100000];
5 - step(num,dem);
6 - ylabel("V out (volts)");
7 - xlabel("time in seconds");
8 - grid on

```

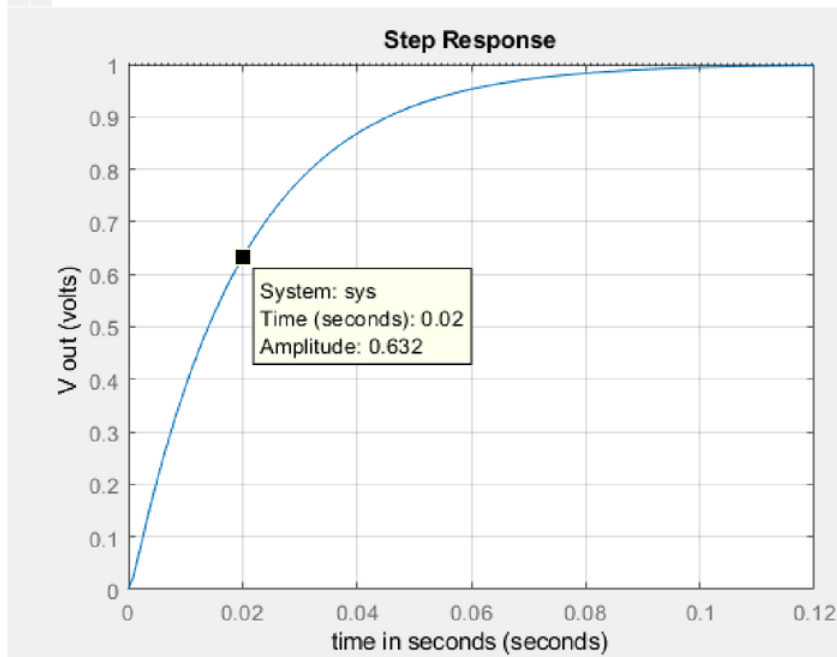


Figure 14 over damped 2nd order

$$R = 2 \sqrt{\frac{L}{C}} = 126.49$$

$$H(s) = \frac{1}{s^2 + \frac{126.49}{0.2}s + \frac{1}{(0.2(50 * 10^{-6}))}}$$

$$H(s) = \frac{100000}{s^2 + 632.46s + 100000}$$

Figure 15 shows the critical damping graph.

```

1 - hold off
2 - % critical damping
3 - num=[100000];
4 - den=[1 632.46 100000];
5 - step(num,den);
6 - ylabel("V out (volts)");
7 - xlabel("time in seconds");
8 - grid on

```

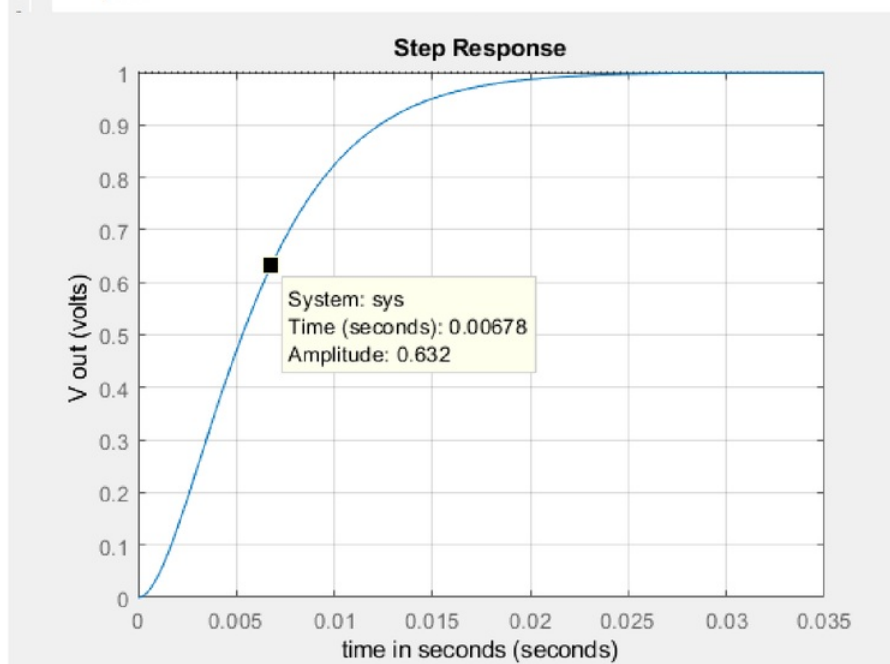


Figure 15 critical damping of 2nd order

Below Figure 16 compares the frequency response of these different resistance levels on a filter.

```

1 - hold off
2 - % under damped
3 - num=[100000];
4 - dem=[1 50 100000];
5 - bode(num,dem);
6 - grid on
7 - hold on
8 - %critical damping
9 - num=[100000];
10 - dem=[1 632.46 100000];
11 - bode(num,dem);
12 - %over damping
13 - num=[100000];
14 - dem=[1 2000 100000];
15 - bode(num,dem);
16 - %no damping
17 - num=[100000];
18 - dem=[1 0 100000];
19 - bode(num,dem);

```

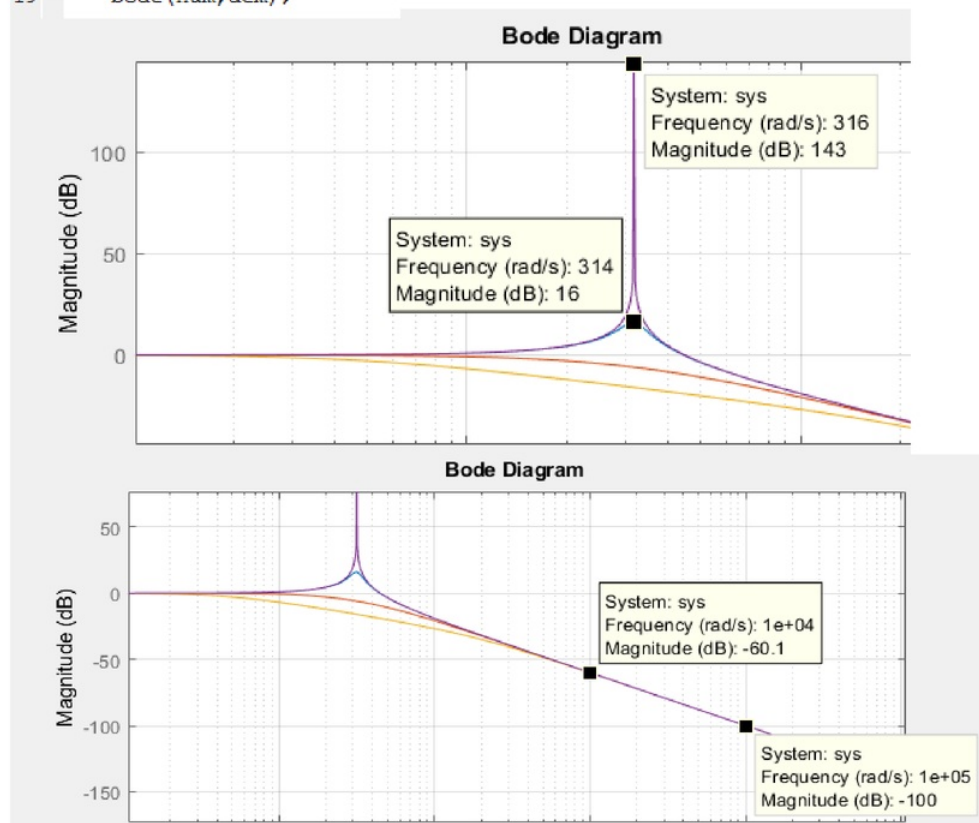


Figure 16 bode diagram

4. Task 3 First Order Electronic Systems

A first order electronic filter circuit has similarities to a normal filter circuit but doesn't rely on the resistance of the output for the cut off frequency. It is a completely independent circuit that can have a gain in some instances if required.

Below in Figure 17 Figure 24 shows the 1st order low pass filter circuit. The difference between a low pass and a high pass in a 1st electronic filter circuit is the positioning of the capacitor. If the capacitor is in parallel with the second resistor then it's a low pass. If it's in series between the 1st resistor and the negative of the op amp then it's a high pass.

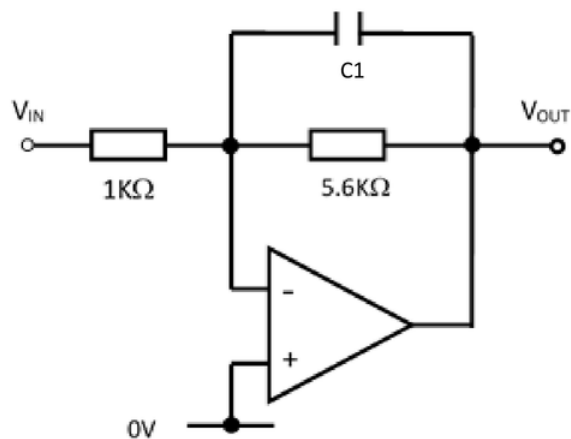


Figure 17 1st order electronic low pass filter circuit

The value for $R1$ and $R2$ have already been given so:

$$R1 = 1k\Omega$$

$$R2 = 5.6k\Omega$$

For this circuit ω_c is chosen so:

$$\omega_c = 700\text{rad/s}$$

The values for the filter can now be calculated

$$K = \frac{R2}{R1}$$

$$K = \frac{5600}{1000}$$

$$K = 5.6$$

$$Wc = \frac{1}{C * R2}$$

$$C = \frac{1}{Wc * R2}$$

$$C = \frac{1}{700 * 5600}$$

$$C = 255nF$$

$$H(s) = -K\left(\frac{Wc}{s + Wc}\right)$$

$$H(s) = -5.6\left(\frac{700}{s + 700}\right)$$

This is then put onto a graph on mat lab to check the calculations shown in Figure 18.

The maximum magnitude will be K in dB

$$20 \log_{10} 5.6 = 14.96 \text{ dB}$$

The cut off frequency should be at 12.96dB which is -3dB of the maximum value and the frequency at this point should be 700rad/s.

This graph has a gradient of 19.62/decade which is normal for a 1st order filter as 20dB/decade / order is usual for a filter

The maximum magnitude is 15dB which is probably caused by rounding in the software of matlab.

The cut off frequency was exactly -3dB from that at 12dB and a frequency of 700rad/s which is spot on to the calculations.

```

1 - num=[-3920];
2 - dem=[1 700];
3 - bode(num,dem);
4 - grid on
5

```

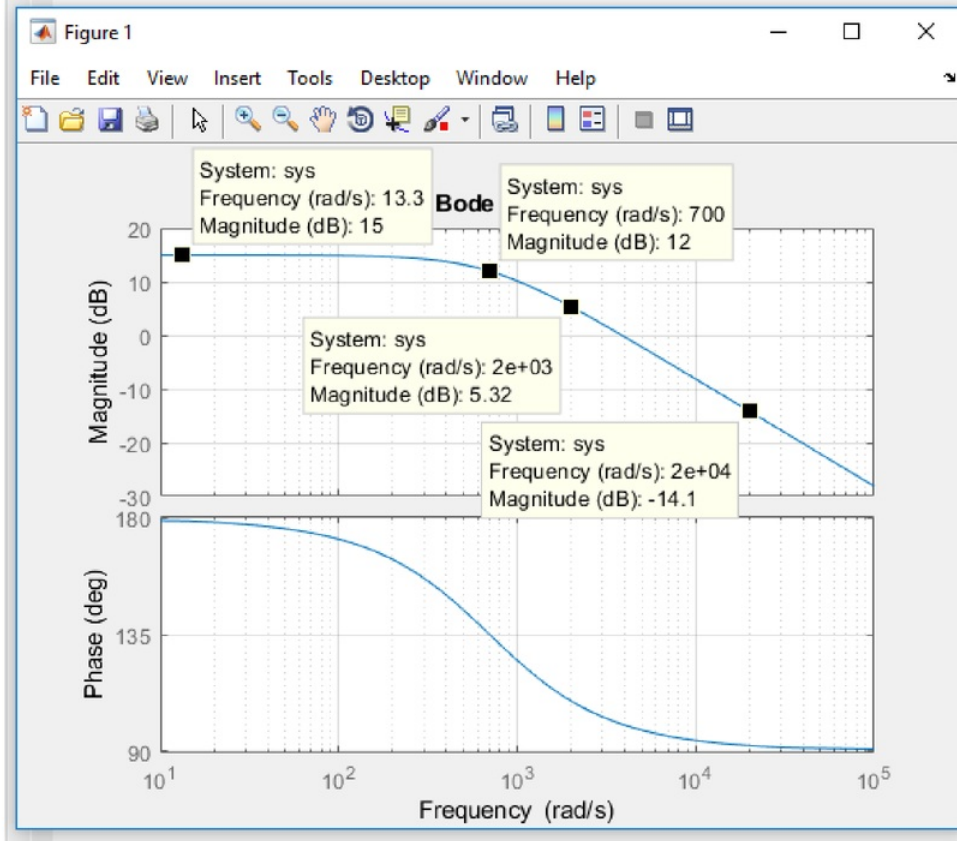


Figure 18 bode diagram 1st order electronic low pass

Below is a 1st order high pass electronic filter circuit. This is similar to the low pass circuit with just the capacitor in a different position.

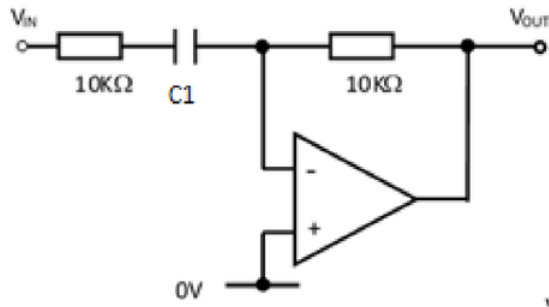


Figure 19 1st order high pass electronic filter circuit

The value for R1 and R2 have already been given so:

$$R1 = 10k\Omega$$

$$R2 = 10k\Omega$$

For this circuit W_c is chosen so:

$$W_c = 700\text{rad/s}$$

The values for the filter can now be calculated

$$K = \frac{R2}{R1}$$

$$K = \frac{10000}{10000}$$

$$K = 1$$

$$W_c = \frac{1}{C * R1}$$

$$C = \frac{1}{W_c * R1}$$

$$C = \frac{1}{700 * 10000}$$

$$C = 143\text{nF}$$

$$H(s) = -K\left(\frac{s}{s + W_c}\right)$$

$$H(s) = -1\left(\frac{s}{s + 700}\right)$$

The maximum magnitude will be K in dB

$$20 \log_{10} 1 = 0 \text{ dB}$$

The cut off frequency will be -3dB of this value which is -3dB.

The gradient should be around 20dB/decade

Figure 20 shows the graph given from matlab. The graph shows a gradient of 19.3 which was expected.

The cut off frequency whilst on 700rad/s the magnitude is 3.01 which is close enough to the expected value that there's no suspected discrepancies.

```

1 - num=[-1 0];
2 - dem=[1 700];
3 - bode(num,dem);
4 - grid on
5

```

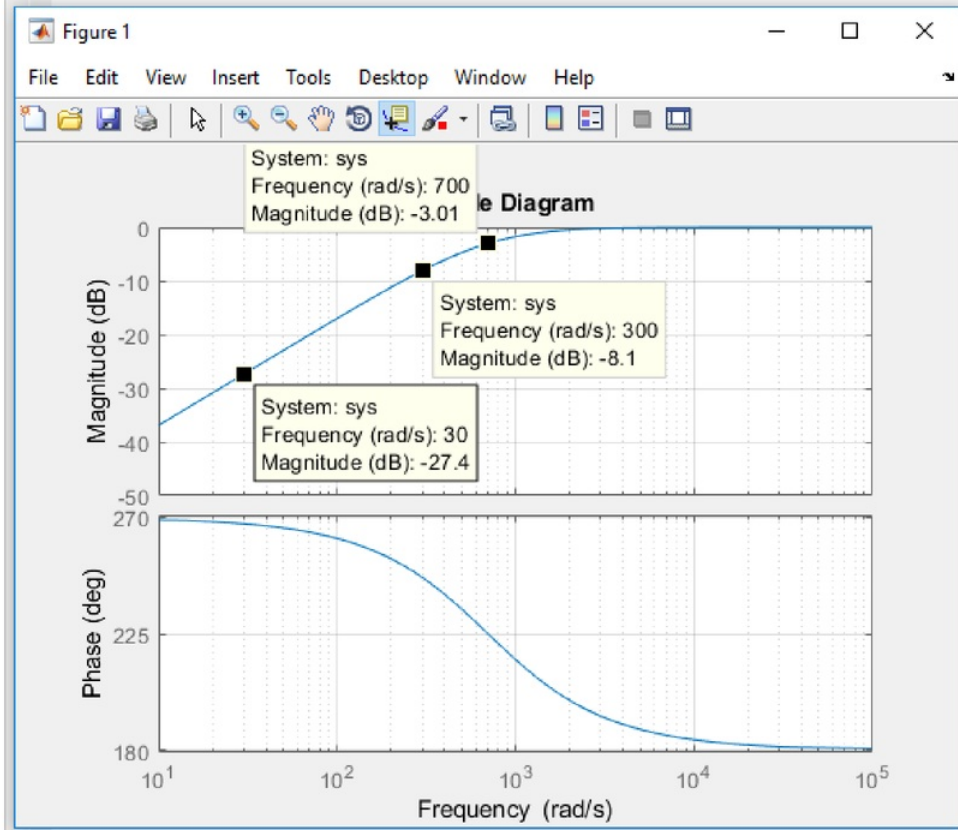


Figure 20 bode diagram 1st order high pass electronic filter

5. Task 4 – Second Order Electronic Systems

Sallen & key low pass filter

Below in Figure 21 is the circuit for low pass electronic second order filter. This circuit doesn't use inductors only the use of capacitors unlike the other second order circuit looked at previously in this report. Just like the other filters on the other hand if the capacitors swap places with the resistors then it will cause the filter to be a high pass instead of a low pass which will be looked into in this section of the report.

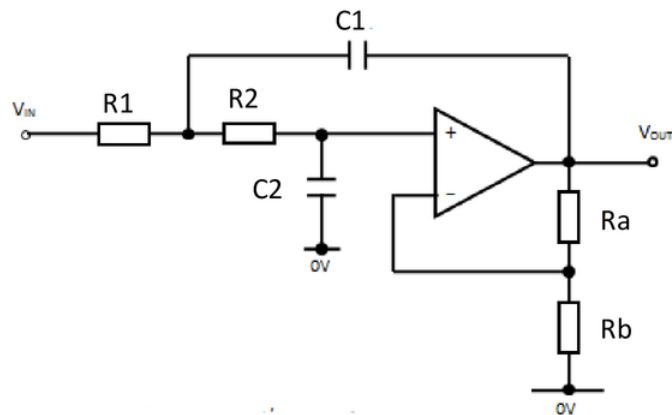


Figure 21 low pass sallen & key circuit

The value for the cut off frequency and the capacitor values will now be chosen.

$$\omega c = 100 \text{ rad/s}$$

$$c = 1 \mu\text{F}$$

The resistor values can now be calculated from this using the equation:

$$R = \frac{1}{\omega c * C}$$

With the values substituted in:

$$R = \frac{1}{100 * (1 * 10^{-6})} = 10 \text{ K}\Omega$$

For this circuit:

$$K = 1.586$$

$$\frac{wc}{Q} = (3 - K)wc$$

$$\frac{wc}{Q} = (3 - 1.586)100 = 141.4$$

The resistor R_b is now chosen

$$R_b = 10K\Omega$$

With this value the resistor R_a can be calculated

$$R_a = (K - 1) * R_b$$

$$R_a = (1.586 - 1)(10 * 10^3)$$

$$R_a = 5.86K\Omega$$

These values are represented in Figure 22 in the circuit diagram.

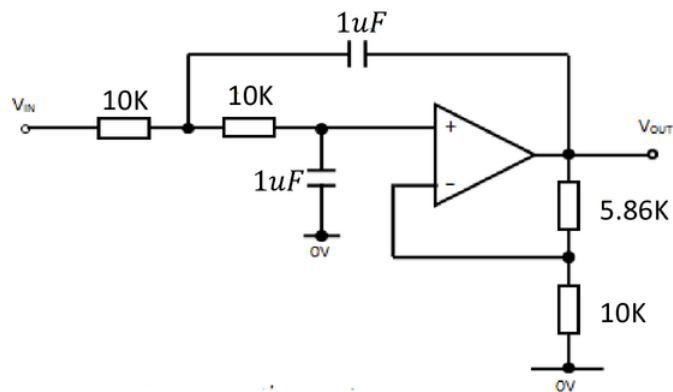


Figure 22 low pass sallen & key finished circuit

All of these values can be used for the transfer function.

$$H(s) = \frac{K * wc^2}{s^2 + (\frac{wc}{Q})s + wc^2}$$

$$H(s) = \frac{1.586 * 100^2}{s^2 + 141.4s + 100^2}$$

$$H(s) = \frac{15860}{s^2 + 141.4s + 10000}$$

This is then put into mat lab to give a graph of the frequency response. Figure 23

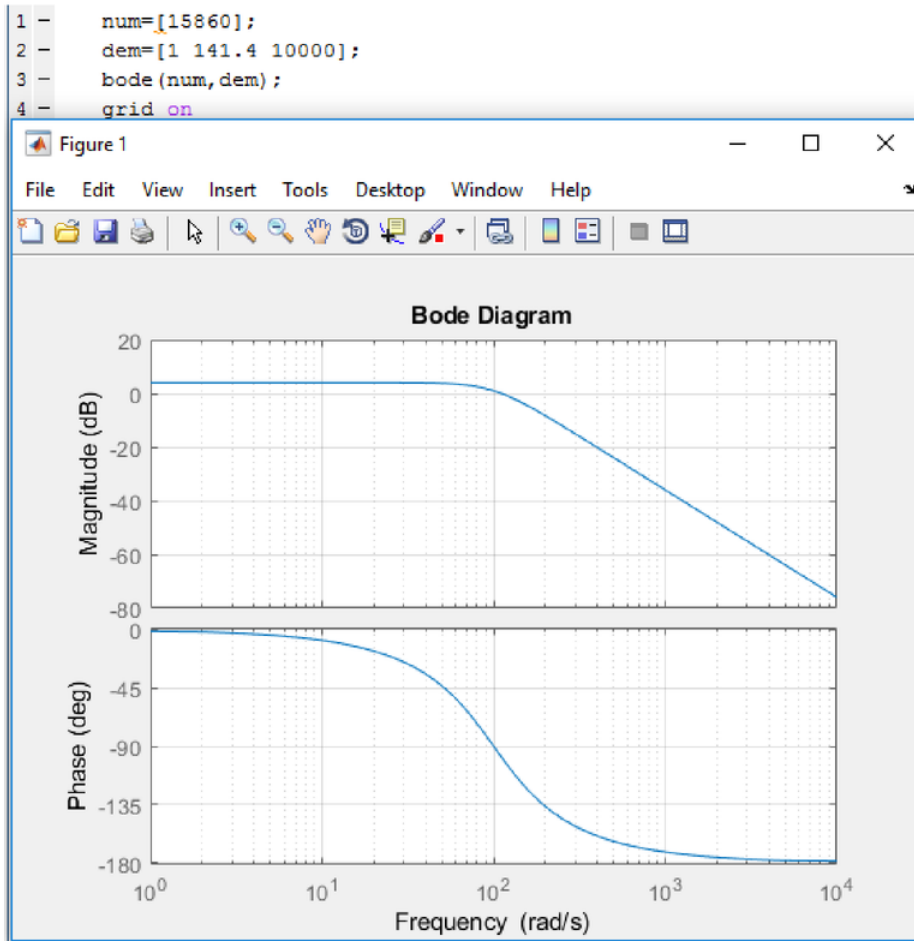


Figure 23 frequency response diagram

Sallen & key high pass filter

Below in Figure 24 is the circuit for a high pass sallen & key high pass second order filter. The difference between this filter and the low pass is that the capacitors and resistors have swapped.

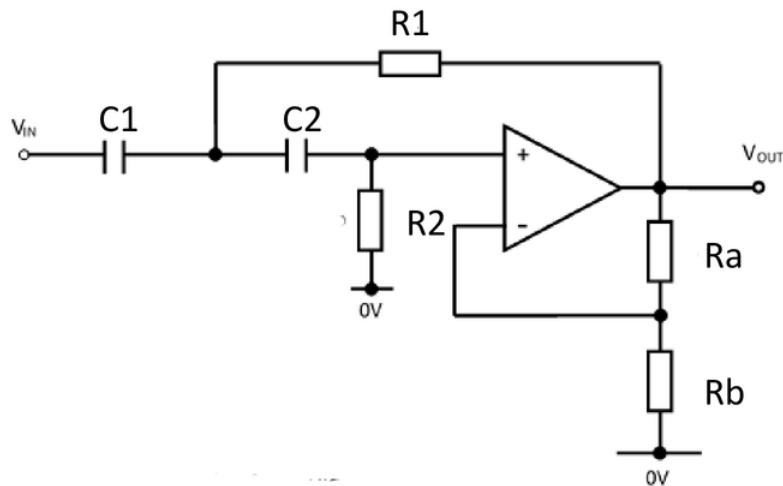


Figure 24 sallen & key high pass circuit

The values for ω_c , $C1$, $C2$, $R1$ and $R2$ are chosen values for this circuit.

$$R1 = 1K\Omega$$

$$R1 = R2$$

$$R2 = 1K\Omega$$

$$C1 = 1\mu F$$

$$C1 = C2$$

$$C2 = 1\mu F$$

$$\omega_c = 100\text{rad/s}$$

for a second order filter:

$$K=1.586$$

$$\frac{\omega_c}{Q} = (3 - K)\omega_c$$

$$\frac{wc}{Q} = (3 - 1.586)100 = 141.4$$

The resistor R_b is now chosen

$$R_b = 10K\Omega$$

With this value the resistor R_a can be calculated

$$R_a = (K - 1) * R_b$$

$$R_a = (1.586 - 1)(10 * 10^3)$$

$$R_a = 5.86K\Omega$$

Now all the values have been calculated the transfer function can be completed to allow the circuit to be put into matlab.

$$H(s) = \frac{KS^2}{S^2 + (\frac{wc}{Q})S + wc^2}$$

$$H(s) = \frac{1.586S^2}{S^2 + 141.4S + 10000}$$

This is then put into matlab as shown in Figure 25

```

1 - num=[1.586 0 0];
2 - dem=[1 141.4 10000];
3 - bode(num,dem);
4 - grid on
5

```

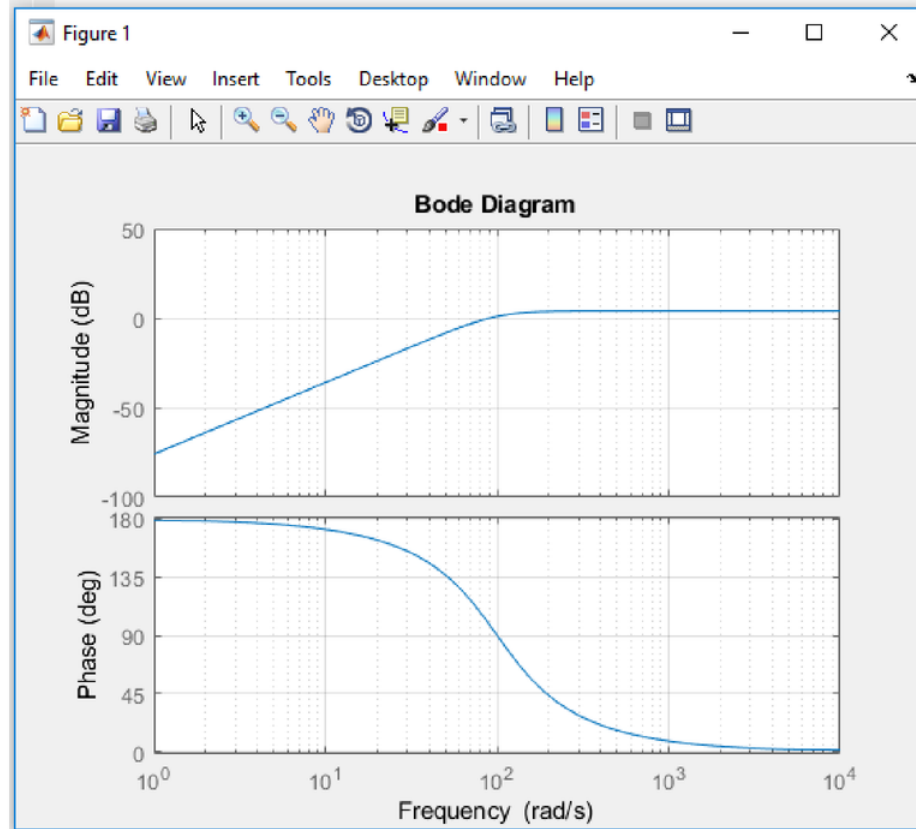


Figure 25 frequency response diagram

6. Conclusions and recommendations

This report shows the difference between first and second order filters. It also shows the differences between electric and electronic filters. The report shows a large difference between first and second order as second order largely improves the sharpness of transition from band pass to band stop and a steeper gradient.

Electronic over electric shows a great difference in performance and when using a second order electronic circuit the filtration is very good and if there were more orders used then very good results could be obtained.

assignment 1 5009

GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

Instructor

54/100

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GRADING FORM: CSG-RUBIC

SEAN JONES

54

RESEARCH-INFORMED LITERATURE



N/A

KNOWLEDGE AND UNDERSTANDING



Sections 2, 3: Explanations for Electric Circuits – .
Some explanations offered with good diagrams.
However part b of task 2 is missing altogether and
further marks were available for your derivations of
your transfer functions. (5/10) Sections 4, 5:
Explanations for Electronic Systems – Some
explanations given with clear diagrams. (5/10)

10

ANALYSIS



Sections 2, 3: Analysis, Modelling and Testing of Electric Circuits - some analysis in evidence with annotated graphs showing transients and frequency responses with cut-offs and roll-offs identified. However, task 2b is missing and further marks were available for a more detailed analysis including the calculations of damping factor etc . (10/20) Sections 4, 5: Analysis, Modelling and Testing of Electronic Systems - Some evidence of analysis but very little offered for task 4, graphs could have been annotated. (10/20) Section 6: Conclusions and recommendations – .Briefly stated but lacking in detail. (3/10)

23

PRACTICAL APPLICATION AND DEP.



Sections 2,3,4,5: Use of Matlab – Good, programmes shown . (8/10) Sections 2,3,4,5: Accuracy and Presentation Quality of Results – Good quality but cursor information should be contained on all graphic results . (6/10)

14

SKILLS FOR PROFESSIONAL PRAC.



Section 1: Introduction: Good introduction setting out the main themes, aims and objectives. (4/5) All sections: Overall Report Quality - Good structure, well presented (3/5)

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