THE UNIVERSITY OF BRITISH COLUMBIA

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Mini Project 4

University of British Columbia

Electrical and Computer Engineering

ELEC 301

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1 Introduction

For this project, we will be using Multisim to simulate active filters and oscillators.

2 Part A

2.0.1 Part 1

For this part, we will be designing a 2nd order Butterworth low pass active filter using the UA741 operational amplifier. Here is the circuit that we will be using for this part:

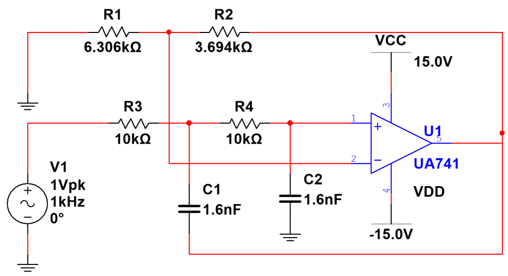

Figure 1: Second Order Butterworth Filter

The calculations to find the resistance R_1,R_2 and capacitance C, we will be using the formulas from the class notes [1]. The formulas can also be found from no. 1 in the Appendix. From the formulas, we can see that

$$\boxed{R_1 = 6.306k\Omega, R_2 = 3.694k\Omega, C = 1.6nF, A_m = 1.59\frac{V}{V}}$$

Below is the phase and magnitude plot for our filter:

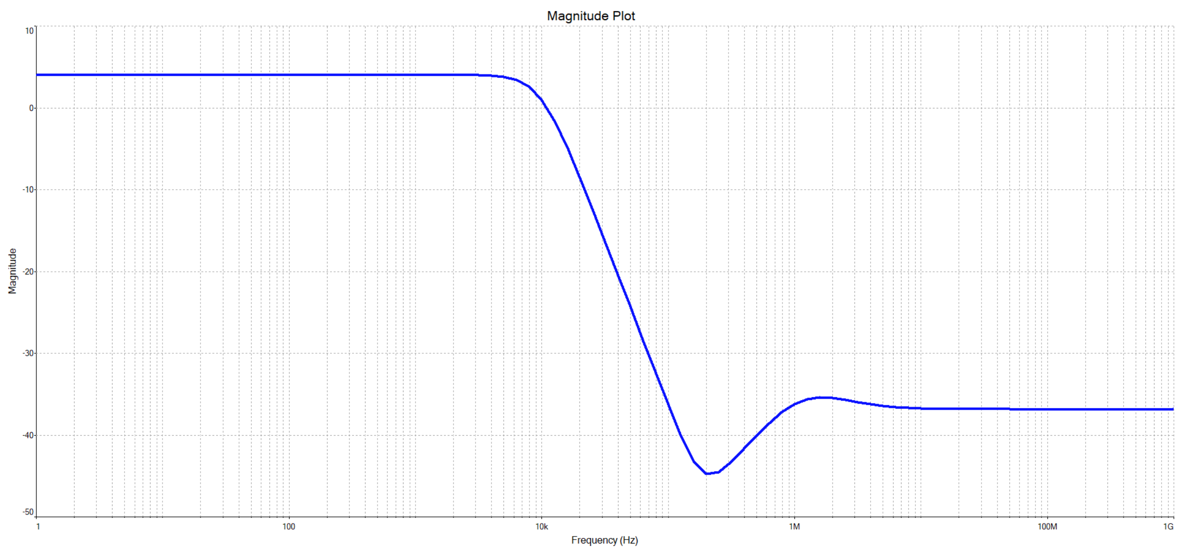

Figure 2: Bode Magnitude Plot

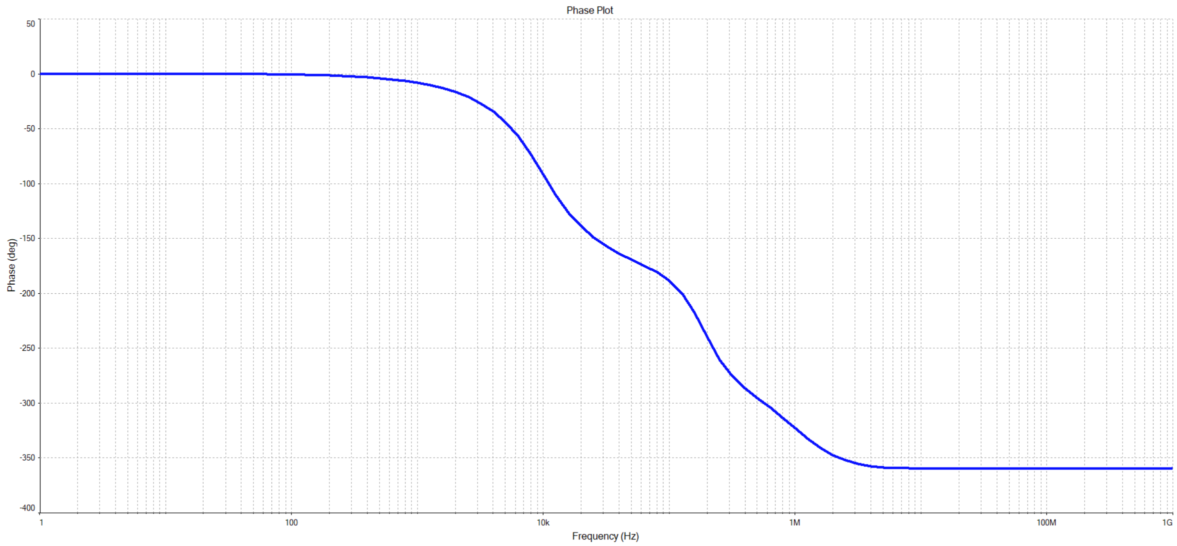

Figure 3: Bode Phase Plot

2.0.2 Part 2

For this part, we will be grounding the input, and measuring the output of the OpAmp. To determine the value of A_m when the circuit begins to oscillate, we need the transfer fucntion. The function is shown below, where R = $10k\Omega$ and C is the value found previously:

$$H(s) = A_M \frac{\frac{1}{(RC)^2}}{s^2 + s\frac{3-A_M}{RC} + \frac{1}{(RC)^2}}$$

Changing the values of the resistances, we find that the oscillations occour when $R_1 = 3k\Omega$ and $R_2 = 7k\Omega$. The oscillation is shown below:

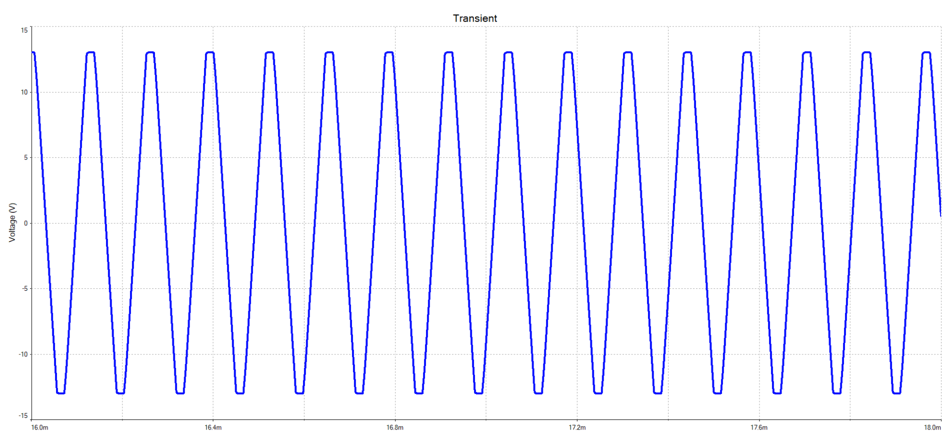

Figure 4: Oscillating Output

Below is the root locus plot:

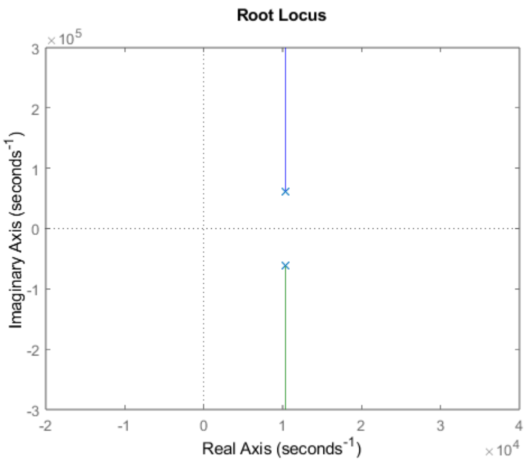

Figure 5: Unstable Root Locus Plot

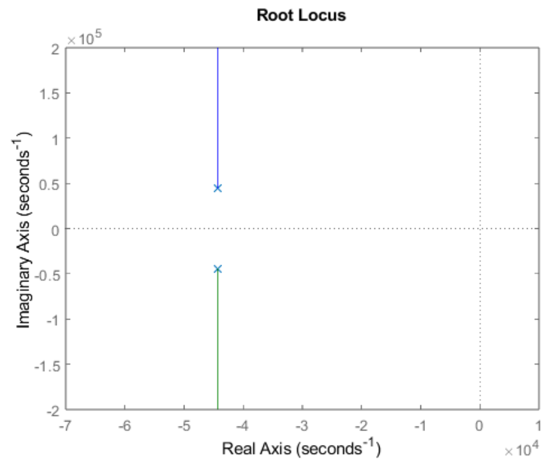

Figure 6: Stable Root Locus Plot

The root locus plot where $A_M > 3$ and $A_M < 3$ is Figure 5 and Figure 6 respectively. We can see from the plot that when the oscillations occour, A_M is greater than 3. This would then cause the system to be unstable as shown in Figure 5, since the poles are on the right side on the jw axis. When the poles are on the other side of the jw axis, the system is stable, and doesn't cause the output to oscillate. This happens when $A_M < 3$. The reason why it has to be less than 3 for the system to be stable is because of the characteristic equation in the transfer function. If A_M is greater than 3, it causes one of the coefficients in the characteristic equation to be negative, causing instability in the system and thus, the oscillations occour.

3 Part B

4 Part C

5 Appendix

$$k = 3 - \sqrt{(2)} \tag{1}$$

(2)

6 References

1. ELEC 301 Class notes
2. Mini Project 4 Document
3. Standard Resistor and Capacitor Values (Canvas)
4. Circuit Maker SPICE Model