



# THE UNIVERSITY OF BRITISH COLUMBIA

Martin Alejo

#75296665

December 9, 2022

Mini Project 4

University of British Columbia

Electrical and Computer Engineering

ELEC 301

Instructor: Nicolas Jaeger

A handwritten signature in black ink, appearing to read "Martin".

# Contents

<b>0</b>	<b>Introduction</b>	<b>1</b>
<b>1</b>	<b>Part A</b>	<b>1</b>
1.0.1	Part 1 . . . . .	1
1.0.2	Part 2 . . . . .	2
<b>2</b>	<b>Part B</b>	<b>3</b>
<b>3</b>	<b>Part C</b>	<b>3</b>
<b>4</b>	<b>Appendix</b>	<b>3</b>
<b>5</b>	<b>References</b>	<b>3</b>

## List of Figures

1	Second Order Butterworth Filter . . . . .	1
2	Bode Magnitude Plot . . . . .	1
3	Bode Phase Plot . . . . .	2
4	Oscillating Output . . . . .	2
5	Unstable Root Locus Plot . . . . .	3
6	Stable Root Locus Plot . . . . .	3

## List of Tables

# 0 Introduction

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

## 1 Part A

### 1.0.1 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:

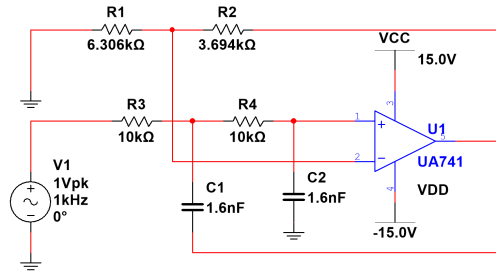


Figure 1: Second Order Butterworth Filter

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

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

Below is the phase and magnitude plot for our filter:

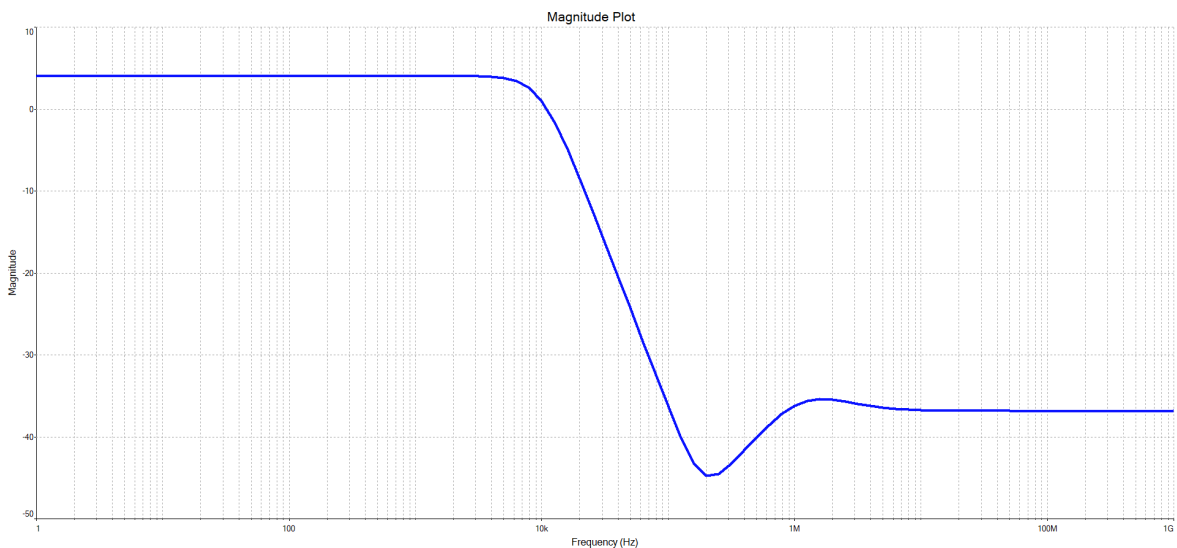


Figure 2: Bode Magnitude Plot

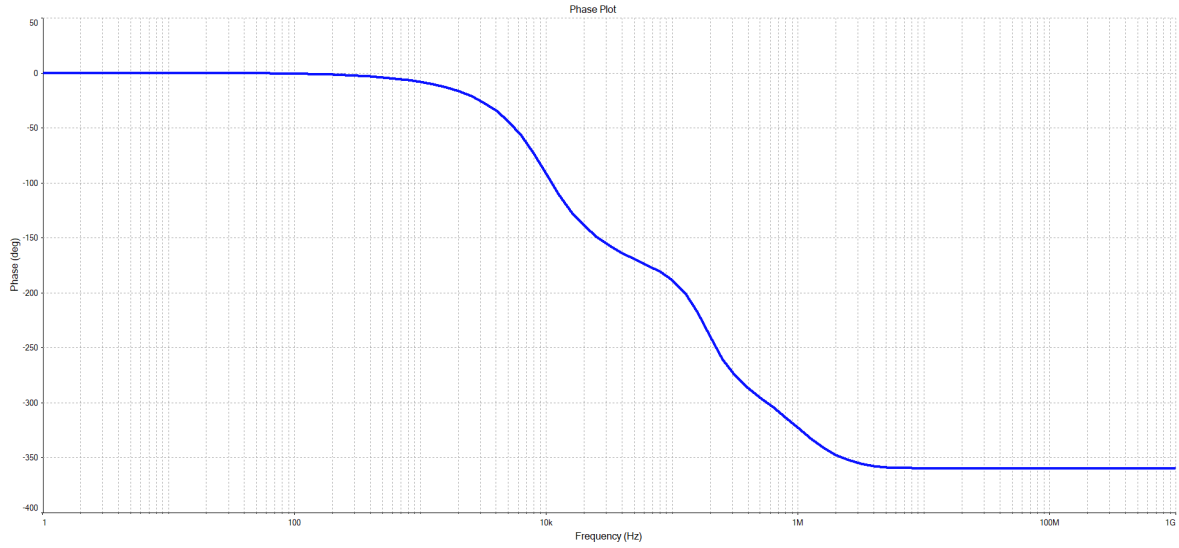


Figure 3: Bode Phase Plot

### 1.0.2 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 function. 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 occur when the resistor values are around  $R_1 = 3k\Omega$  and  $R_2 = 7k\Omega$ . The oscillation is shown below:

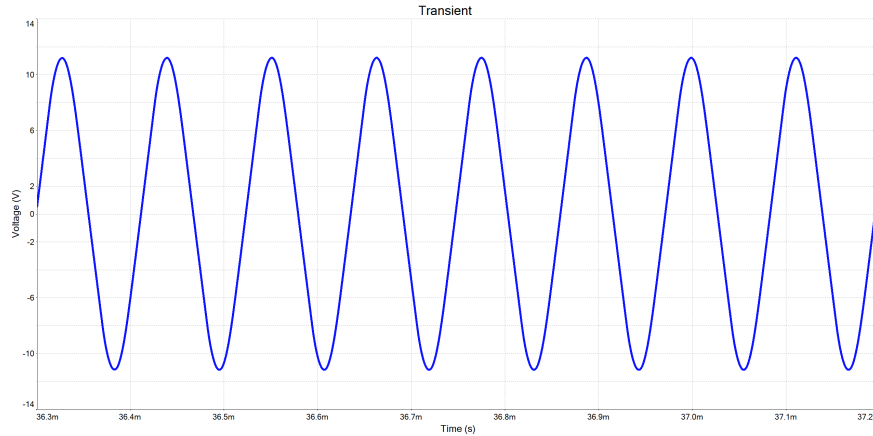


Figure 4: Oscillating Output

Using the cursors and measuring the differences between the crests of the plot, we find that the oscillating frequency is  $f_o = 8.93kHz$ . Below is the root locus plot:

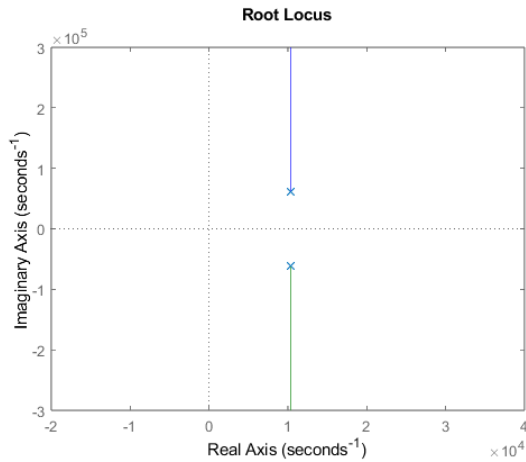


Figure 5: Unstable Root Locus Plot

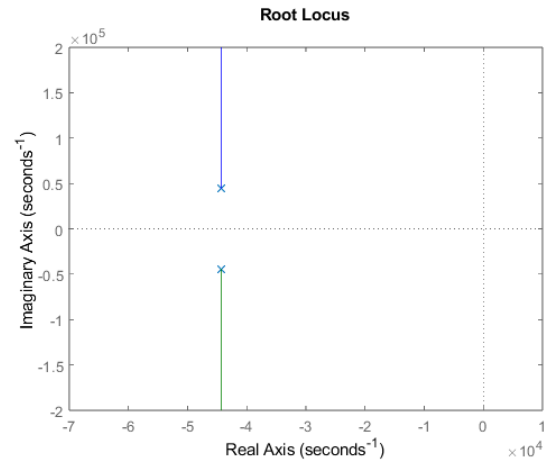


Figure 6: Stable Root Locus Plot

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 occur,  $A_M$  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 occur.

## 2 Part B

## 3 Part C

## 4 Appendix

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

(2)

## 5 References

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