

## **Circuit Theory and Electronics Fundamentals**

### **Lab 5 - Bandpass Filter using OP-AMP**

#### **Aerospace Engineering**

Laboratory Report

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# 1 Introduction

This report is being made for the subject of Circuit Theory and Electronics Fundamentals and is related to the fifth laboratory being its objective to develop a Bandpass Filter using an Operational Amplifier (OP-AMP). In this laboratory there are some specifications that are followed such as a central frequency of 1kHz and a gain at central frequency of 40dB. There are also limited number of the different components. All in all, the circuit that was implemented is shown in figure 1 and it has three different stages. This stages are the High Pass Stage, the Amplication Stage and a Low Pass Stage and they will be explored on the extend of this report.

In Section 2 a theoretical analysis will be made . Secondly, in Section 3 it will be simulated the circuit using ngspice tools. Following with both results from Section 2 and Section 3 being compared and commented in Section ??.

Also, it is important to notice that the NGSpice simulation was made using the provided OPAMP model

Finally, the conclusions of this study are outlined in Section 4.

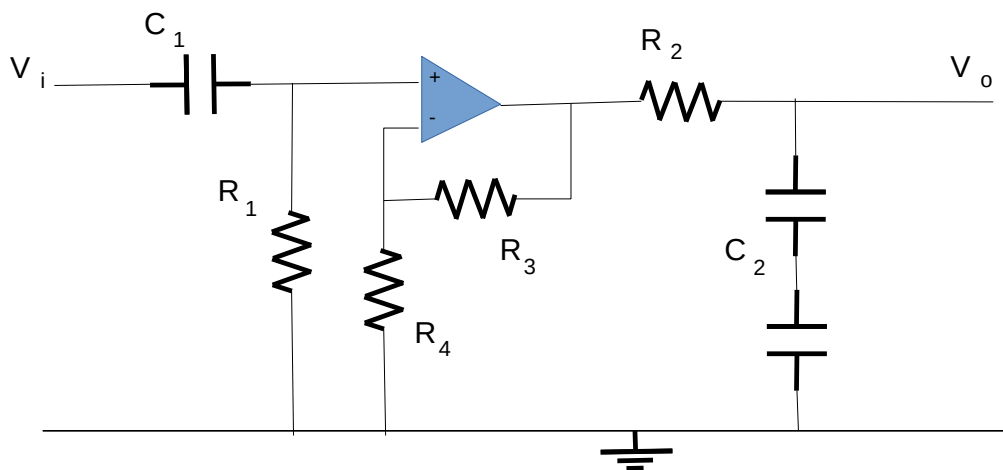


Figure 1: Bandpass Filter using an OP-AMP

## 2 Theoretical Analysis

In this section, the circuit shown in Figure 1 will be analysed theoretically. The constants used for the resistors and capacitors can be seen below.

$$R_1 = 1k\Omega$$

$$R_2 = 1k\Omega$$

$$R_3 = 100k\Omega$$

$$R_4 = 1k\Omega$$

$$C_1 = 220nF$$

$$C_2 = 110nF$$

In order to fully understand the analysis that will be made, it is necessary to bear in mind that there are three stages in this circuit: the High Pass Stage, the Amplification Stage and the Low Pass Stage.

The first one lets the high frequency signals pass, and cuts the ones with lower frequencies. It is made with  $C_1$  and  $R_1$ .

The second stage is used for amplify the signal, being its main component the Operational Amplifier. It's easy to understand that it's on this stage that the gain is maximum. The components of this stage are the OP-AMP,  $R_3$  and  $R_4$ .

The third stage, works essentially for cutting high frequency signals and letting the lower ones pass. It is made by the remaining components,  $R_2$  and  $C_2$ .

All in all, we build a Band Pass Filter by cutting the higher and the lower frequencies and letting pass a specific band of signals.

Name	Value [Ohm/F]
Resistor 1	1.000000e+03 Ohm
Resistor 2	1.000000e+03 Ohm
Resistor 3	1.000000e+05 Ohm
Resistor 4	1.000000e+03 Ohm
Capacitor 1	2.200000e-07 F
Capacitor 2	1.100000e-07 F

Table 1: TITULO

Name	Value [Ohm/F]
Input Impedance	1.000000e+03
Output Impedance	1.000000e+00

Table 2: TITULO

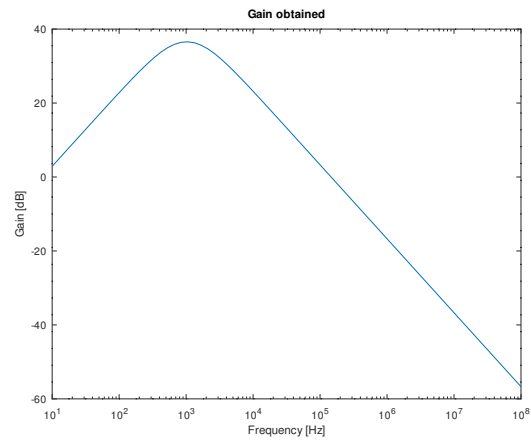


Figure 2: TITULO

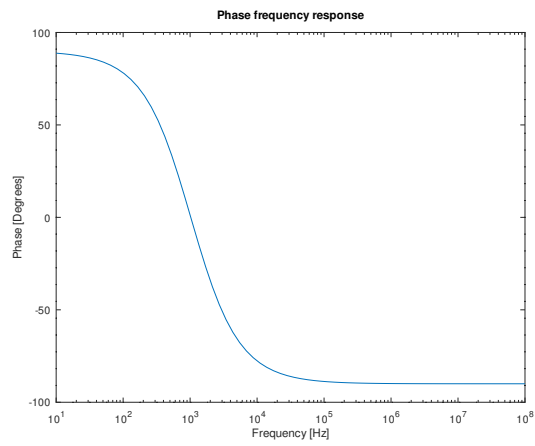


Figure 3: TITULO

### 3 Simulation Analysis

This section covers the bandpass filter simulation (using OP-AMP) in NGSpice. As asked we started by using the provided model of the OP-AMP and then the circuit was improved by doing incremental modifications with suitable parameters. In the next tables it is presented the values asked in the lab assignment: output voltage gain, the central frequency and the input and output impedances at this frequency.

Name	Value
Output Voltage Gain	36.5331
Central Frequency	1013.91

Table 3: Gain and Central Frequency

Following with the analysis, below it is presentend the output and input impedances.

Name	Value
Input Impedance	999.999 + -69087.2 j

Table 4: Input Impedance

Name	Value
Output Impedance	680.05 + -466.901 j

Table 5: Output Impedance

The graphics below show the frequency response of the output voltage gain in the pass-band.

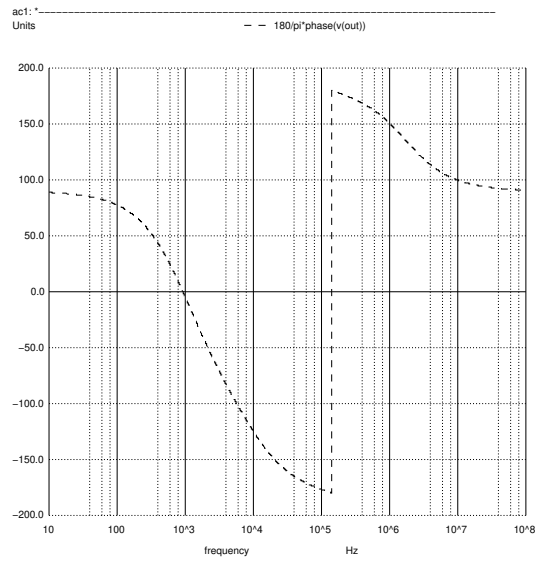


Figure 4: Simulation gain response in phase degree

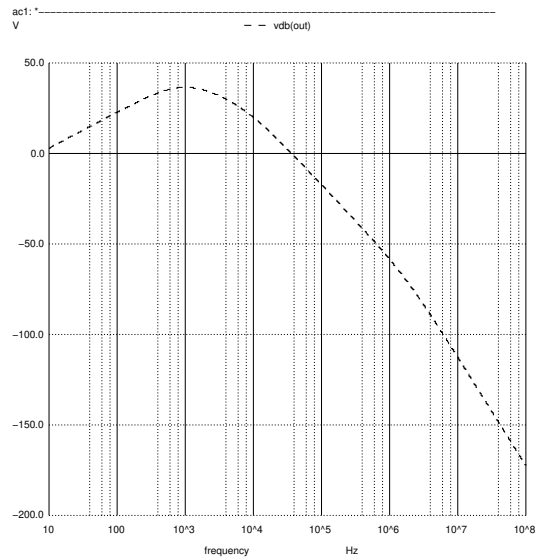


Figure 5: Simulation gain response in dB

Finally, the merit obtained by the group is presentend in the following table. It can be consider that the results were good.

Name	Value
Gain Deviation	32.9164
Frequency Deviation	13.911

Table 6: Gain and frequency deviation

Name	Value
Cost	13426.8
Merit	1.59048E-06

Table 7: Merit



## 4 Conclusion

The objective of this laboratory assignment was to develop a Bandpass Filter and the main goal was achieved.

However by observing analysis and simulation results side by side it can be seen a difference between the two, the results aren't equal and exactly the same comparing both NGSpice and Octave.

Although, we believe that the differences are not that significant and they can be explained by how NGSpice solves the circuit compared to how it was done in the theoretical analysis, considering that NGSpice uses a model with more parameters for the Operational Amplifier that Octave this can be the main reason for the differences.

Regarding this fact, the results obtained are reasonable and it was a successful analysis of the circuit.

Nevertheless the results were achieved not having the best merit. The merit of the circuit was obtained by trial and error, a method that is not perfect and does not result in the best possible results. In this way, we concluded that in order to obtain good results, we were obliged to "yield" part of the merit.

This way, the objective should have never been to have equal results, but rather, have results that seemed reasonable, which we believe it was achieved. The merit obtained was xxx, with a cost of xxxxx.