Circuit Theory and Electronics Fundamentals

T5

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Contents

1 Introduction

The aim of this laboratory is to design a BandPass Filter (BPF) and to implement it using and Operational Amplifier (OpAmp) that has a central frequency of 1kHz and a gain at that central frequency of 40dB. In this assignment there were constraints in the number of components, specifically in resistors and capacitors, that could be used. The figure of Merit shown below quantifies the quality of the BPF.

$$Merit = \frac{1}{Cost \cdot (GainDeviation + CentralFrequecyDeviation + 10^{-6})}$$

The circuit designed by the group is presented as follows:

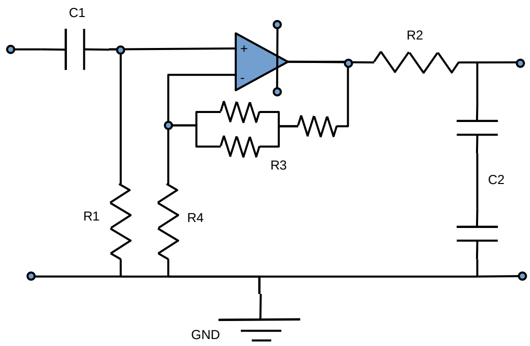


Figure 1: Studied Circuit

The table below has the values of the different components in the previous circuit. The units are V, Ω and F.

C_1	2.2e-07 μF
C_2	1.8033e-07 μF
R_1	1000 Ω
R_2	1000 Ω
R_3	150000 Ω
R_4	1000 Ω

Table 1: Output Stage

The component R_3 is the equivallent to the association of two 100kOhm resistor in parallel with another 100kOhm resistor in series. The component C_2 is the equivallent to the association of one 220nF capacitor and one 1 μF in series.

In Section 2, a theoretical analysis of the circuit is presented. In Section 3, the circuit is analysed by simulation using NGSpice, with its results being compared to the theoretical results obtained in Section 2 in the Section 4, while also outlining in this section the conclusions of this study.

2 Theoretical Analysis

In this section, the circuit is analyzed in theory through Octave calculations. The BPF circuit shown in the introduction basically consists of a high pass filter in series with a low pass filter and a signal amplifier. To be able to make calculations, the OpAmp characteristics are assumed to be ideal, that means its impedance is infinite for the input and null for output.

With the values for the components given in table 1, it is possible to calculate the following values:

$\|Z_{in}\|$	1234.241962 Ω
$\|Z_{out}\|$	661.715694 Ω
Gain	38.164961 dB

Table 2: Values for Gain, Input and Output impedances calculated thgrouh Octave

Finally the frequency response $V_0(f)/V_i(f)$ is ploted for the gain:

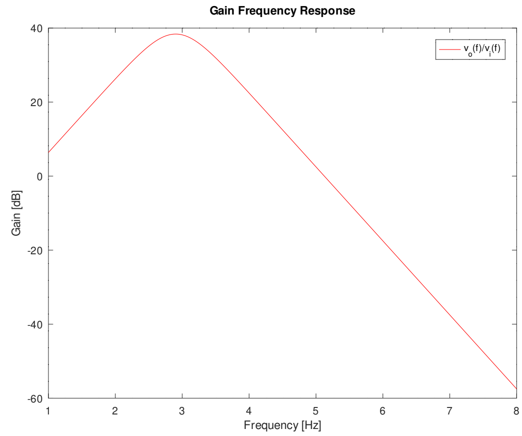


Figure 2: Gain plot - $\frac{V_o(f)}{V_i(f)}$

And for the phase:

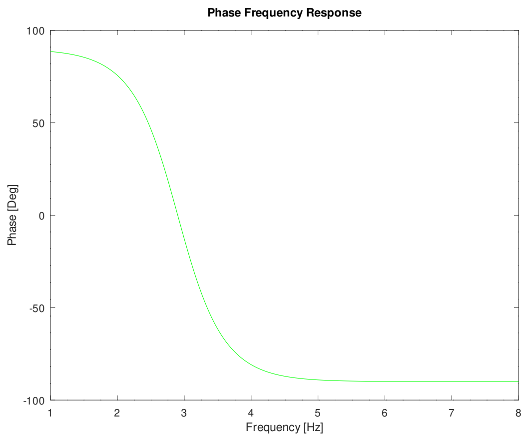


Figure 3: Phase plot

3 Simulation Analysis

In this section the circuit is analyzed in NGSpice.

Given that the model for the OpAmp was already provided, it was only necessary to insert the circuit from the Introduction. The main focus was to analyze and optimize the components within the limits stipulated by the professor in order to obtain the best results possible.

The group settled for a model that outputted the following data:

Zin	999.979 + -723.585 j Ohm
Abs(Zin)	1234.31 Ohm
Zout	441.013 + -497.08 j Ohm
Abs(Zout)	664.516 Ohm
Gain	38.3325 dB
Low Frequency	330.743 Hz
High Frequency	1848.85 Hz
Central Frequency	781.981 Hz

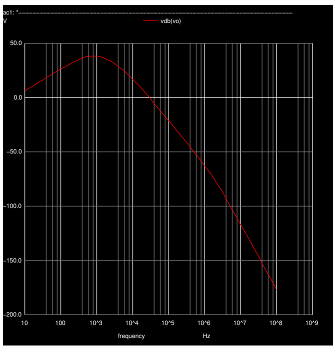
Table 3: Simulation Analysis Values

The merit in this situation is calculated with expression 4:

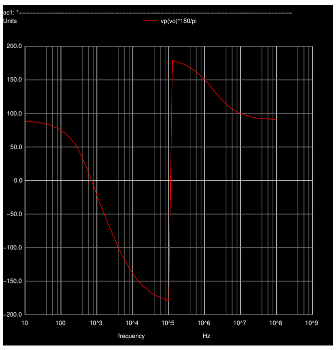
Cost	304.44
Gain deviation	1.66751
Central frequency deviation	218.019
Merit	1.49519E-05

Table 4: Merit Value

The graphs for the frequency response of the gain and phase, that will be compared to the theoretical ones in the following section are represented as follows:



(a) Theoretical Analysis



(b) Simulation Analysis

4 Conclusion

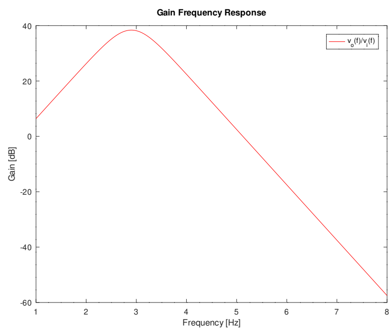
Starting the conclusion with a comparison between Octave and NGSpice values, the results are as follows:

Z_{in}	1000 + -723.432i Ω
$\lvert Z_{in} \rvert$	1234.241962 Ω
Z_{out}	437.868 + -496.125i Ω
$\lvert Z_{out} \rvert$	661.715694 Ω
Gain	38.164961 dB
Low Frequency	326.222201 Hz
High Frequency	1924.350975 Hz
Central Frequency	792.316862 Hz

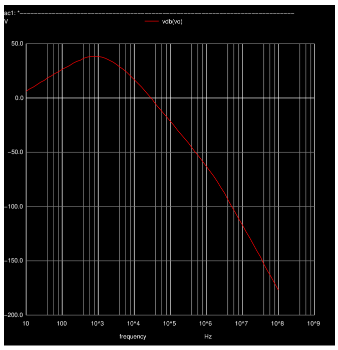
Table 5: Theoretical Analysis

Zin	999.979 + -723.585 j Ohm
Abs(Zin)	1234.31 Ohm
Zout	441.013 + -497.08 j Ohm
Abs(Zout)	664.516 Ohm
Gain	38.3325 dB
Low Frequency	330.743 Hz
High Frequency	1848.85 Hz
Central Frequency	781.981 Hz

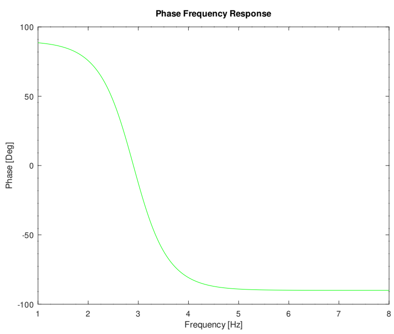
Table 6: Simulation Analysis



(a) Theoretical Analysis



(b) Simulation Analysis



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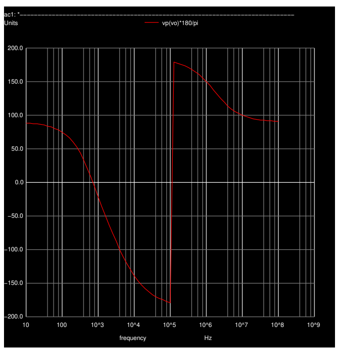

(b) Simulation Analysis

It is clear just from looking at the information above that the model done is fairly accurate in both scenarios, with every aspect being very similar with the exception of both plots, more noticeably for the frequency response phase. This particular discrepancy can be explained by the non-linearity of the circuit, a problem present in every lab assignment with components with that behaviour, or the fact that the OpAmp used in the theoretical analysis was an ideal one with no output impedance and infinte output impedance, whereas in the simulation a more specific and complex model is used.

To wrap it all up, the objective of this laboratory was successfully completed, obtaining a merit of 1.49519e-5.