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Circuit Theory and Electronics Fundamentals

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Contents

1 Introduction

This lab assignment has the purpose of designing and implementing a BandPass Filter (BPF) into an OpAmp, short for Operational Amplifier, with 1 kHz of central frequency and a gain on said frequency of 40dB. To calculate the quality of the designed filter, the following Merit expression is used:

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

The circuit designed is presented below followed by a table containing the value for each component in units of Volts (V), Ohms (Ω) or Farads (F).

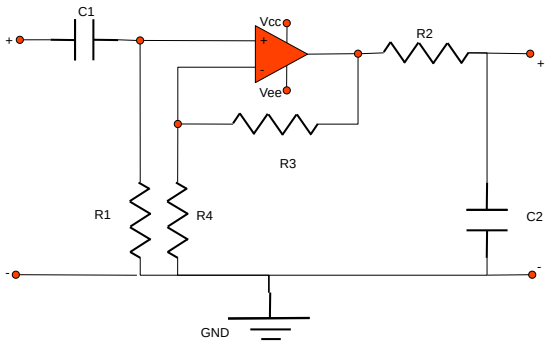


Figure 1: Studied Circuit

In the following table, the values for the components are presented, with the units being V, Ω and F.

C_1	2.200000e-07 μ F
C_2	8.270000e-08 μ F
R_1	1.000000e+03 Ohm
R_2	1.000000e+03 Ohm
R_3	1.300000e+05 Ohm
R_4	1.000000e+03 Ohm

Table 1: Initial Values

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

This section has the purpose of analyzing the designed circuit theoretically, resorting to Octave to aid in doing so. Considering the used OpAmp to be ideal, which means its input impedance is infinite and the output impedance is null.

The circuit built is composed of a high pass filter, followed by a low pass filter and finishing on a signal amplifier, all connected in series.

Using calculations learnt in lectures, the values for Gain, Z_{input} and Z_{output} at the central frequency:

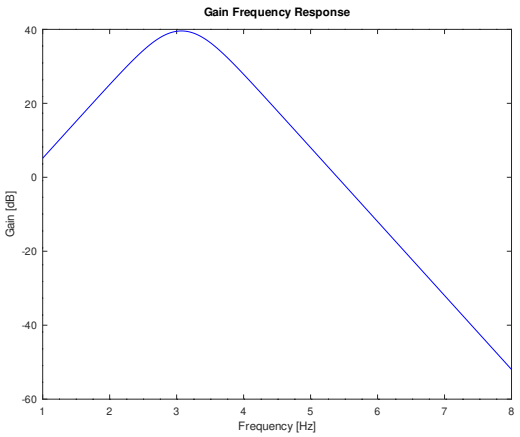
Z_{in}	1000+i-723.432 Ohm
$\|Z_{in}\|$	1234.241962 Ohm
Z_{out}	787.399+i-409.148 Ohm
$\|Z_{out}\|$	887.354991 Ohm
Gain	39.479368 dB

Table 2: Impedances and Gain obtained

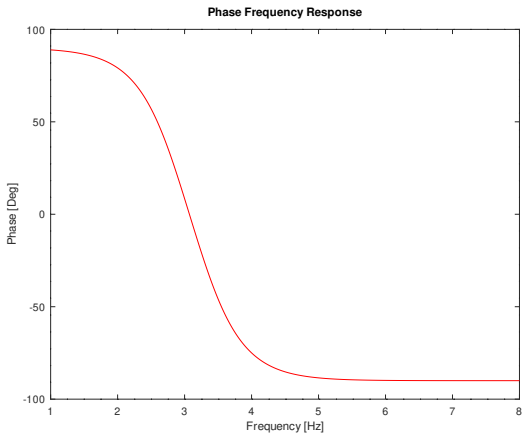
Low Frequency	443.247859 Hz
High Frequency	3122.442823 Hz
Central Frequency	1176.442135 Hz

Table 3: Frequencies obtained

With this information, it is possible to plot graphs for the frequency response $V_0(f)/V_i(f)$ in a logarithmic scale for both the phase and the gain. These are presented sequentially below:



(a) Gain Frequency Response [dB]



(b) Phase Frequency Response [°]

3 Simulation Analysis

This section consists of the analysis of the results obtained through simulation made in NGSpice.

With the provided OpAmp model, the group's circuit is inserted and analyzed while continuously altering some of the components in order to optimize the quality of the analysis and of the BPF.

After several iterations, the group came to the following values, which it considered to be the most adequate for the experience. The values obtained from that iteration are the following:

Zin	999.984 + -723.563 j Ohm
Zin (abs)	1234.31 Ohm

Table 4: Input Impedance

Zo	791.994 + -406.843 j Ohm
Zo (abs)	890.38 Ohm

Table 5: Output Impedance

Gain	39.4646 dB
Low Frequency	448.275 Hz
High Frequency	2859.53 Hz
Central Frequency	1132.19 Hz
Cost	136.66 MU
Gain deviation	0.53538 dB
Central frequency deviation	132.192 Hz
Merit	5.51315E-05

Table 6: Simulation results

With those values, the merit obtained was 5.51315E-05.

With all that information, the plots below show the frequency response for the same parameters as it did in the Theoretical Analysis section, phase and gain:

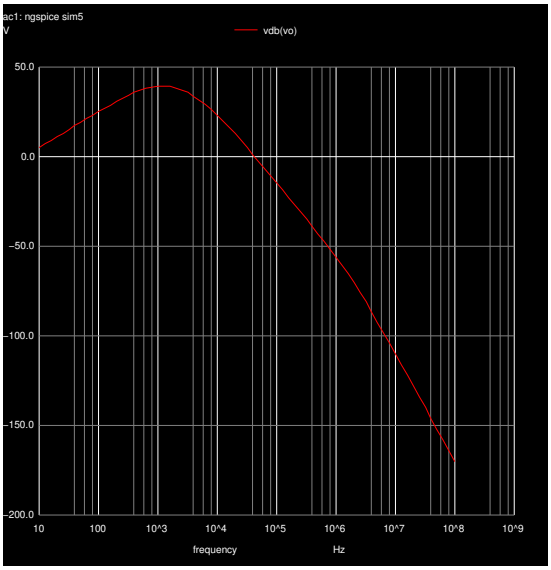


Figure 3: Gain Frequency Response [dB]

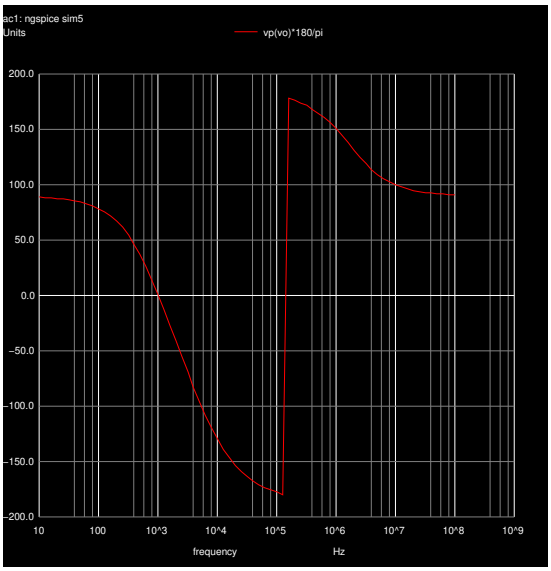


Figure 4: Phase Frequency Response [°]

4 Conclusion

The first element of this conclusion will be the comparison between theoretical results and the ones obtained using NGSpice. The first comparisson will be between the theoretical values and simulation ones:

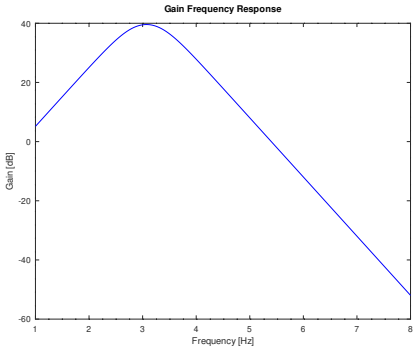
Z_{in}	1000+i-723.432 Ohm
$\|Z_{in}\|$	1234.241962 Ohm
Z_{out}	787.399+i-409.148 Ohm
$\|Z_{out}\|$	887.354991 Ohm
Gain	39.479368 dB
Low Frequency	443.247859 Hz
High Frequency	3122.442823 Hz
Central Frequency	1176.442135 Hz

Table 7: Theoretical Analysis

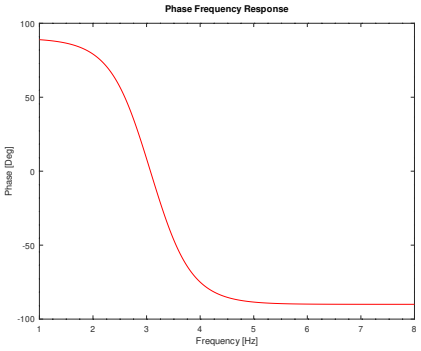
Zin	999.984 + -723.563 j Ohm
Zin (abs)	1234.31 Ohm
Zo	791.994 + -406.843 j Ohm
Zo (abs)	890.38 Ohm
Gain	39.4646 dB
Low Frequency	448.275 Hz
High Frequency	2859.53 Hz
Central Frequency	1132.19 Hz

Table 8: Simulation Analysis

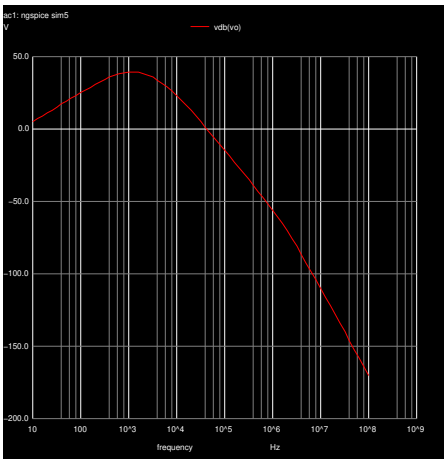
Then, the comparisson between frequency responses for gain and phase is presented:



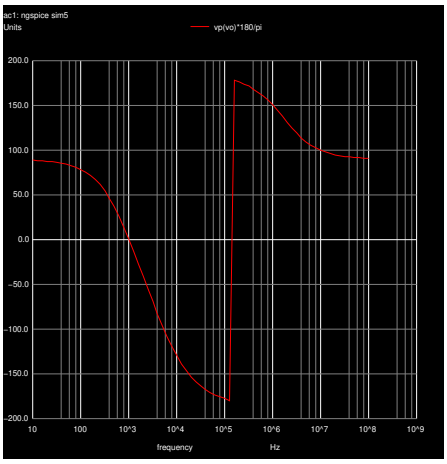
(a) Theoretical Analysis - Gain [dB]



(b) Theoretical Analysis - Phase [°]



(a) Simulation Analysis - Gain [dB]



(b) Simulation Analysis - Phase [°]

With all this information, it is clear that despite there being very small differences between the tabled results, the graphs, mainly the phase ones, have a large discrepancy. This can be due to the model used in NGSpice, which is a much more accurate and complex model than the ”ideal” one used in theory and also due to the non linearity of our components, which always brings inaccuracies in the calculations, as it was already stated in previous lab assignments. Despite all this, the model is still really satisfactory, given the accuracy of the values for frequencies and impedances and the similarity in the frequency response for the gain.

To summarize, despite all the boundaries and inaccuracies already explained, the assignment was completed as a whole and in a way the group considers satisfactory not only in theory but also in what would be the model in reality. The Merit obtained in this experience was 5.51315E-05.