Circuit Theory and Electronics Fundamentals

Department of Electrical and Computer Engineering, Técnico, University of Lisbon

Laboratory Five Report

Francisco Batista, 95792.
Miguel Jesus, 95833.
Pedro Monteiro, 96465.

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Contents

1 Introduction

The main goal of this laboratory assignment was to implement a band pass filter, that would have a gain of 40dB and a central frequency of 1khz. A band pass filter is a circuit that must be designed in a way that blocks all frequencies, except the desired ones belonging in a certain range. This task is performed with the aid of an OP-AMP. This amplifier consists of a transistor based device, which has some particular traits such as high voltage gain, high input impedance and low output impedance.

In the figure below we can see a representation of the circuit studied in this laboratory:

We then proceed to the simulation and the theoretical analysis, where we make some adjustments in an attempt to improve several parameters, that are then reflected in a merit figure.

Also, the values used for the resistors and capacitors are the following:

Component	Value
—R1—	1000.000000
—R2—	1000.000000
—R3—	400000.000000
—R4—	1000.000000
—C1—	0.000000
—C2—	0.000000

Table 1: Values of resistors and capacitors.

2 Analysis

In the theoretical section of this laboratory, we attempt to analyse the pass band filter by utilising the precets of the OP-AMP model given in the lectures. Here, we start by providing the circuit parameter values, such as the resistors, capacitors, and frequency range as the inputs, and then work our way to the desired values by establishing the governing equations of the Operational Amplifier. Based on the information provided by the professor during the lectures we decided to establish the following equations:

$$T(s) = \frac{R1 * C1 * s}{1 + R1 * C1 * s} * (1 + \frac{R3}{R4}) * \frac{1}{1 + R2 * C2 * s} \tag{1}$$

With this equation we determined the Gain in the central frequency which is maximum. This gain is presented in the table and calculated with the equation both given bellow.

$$Gain = \frac{R1 * C1 * s}{1 + R1 * C1 * s} * (1 + \frac{R3}{R4}) * \frac{1}{1 + R2 * C2 * s} \tag{2}$$

Component	Value
—Central Frequency—	1253.305091
—Gain—	100.215820

Table 2: Values of Central Frequency and Gain.

Afterwards we plotted the Gain's and Phase's Frequency response to see how the vary with the frequency. We concluded, as expected, that the Gain is maximum at the central frequency values.

According to what was taught in the theoretical lectures and using the following expressions and the Octave tool we were also able to determine the input and output impedances values.

$$\omega_L = \frac{1}{R1 + C1} \tag{3}$$

$$\omega_H = \frac{1}{R2 + C2} \tag{4}$$

$$\omega_O = sqrt\omega_L * \omega_H \tag{5}$$

$$Z_{in} = |R1 + \frac{1}{C1 * \omega_O * j}| \tag{6}$$

$$Z_{out} = |\frac{1}{j * \omega_O * C2 + \frac{1}{R2}}| \tag{7}$$

The values for the impedances are provided in this table:

Component	**Value**
—Input Impedance—	1000.000000
—Output Impedance—	249.914763

Table 3: Values of Input and Output Impedance.

Finally as requested by the professor we calculated the cost and merit of the architectured circuit. The values for both parameter are presented in the table bellow:

Component	**Value**
—Cost—	13726.880000
—Merit—	0.000000

Table 4: Cost and figure of Merit.

3 Simulation

The simulation portion of this assignment was done, as usual, with the assistance of the ngspice software, that allows one to perform detailed analysis of the circuits taught in the lectures.

Starting from the simplified ngspice file provided by the professor, we developed the circuit with the aid of not only the theory presented in the classes, but also the circuit drawn in the presential laboratory class.

After building a more complex circuit in this way, we executed time in order to obtain the required measurements such as the impedances and the voltage gain.

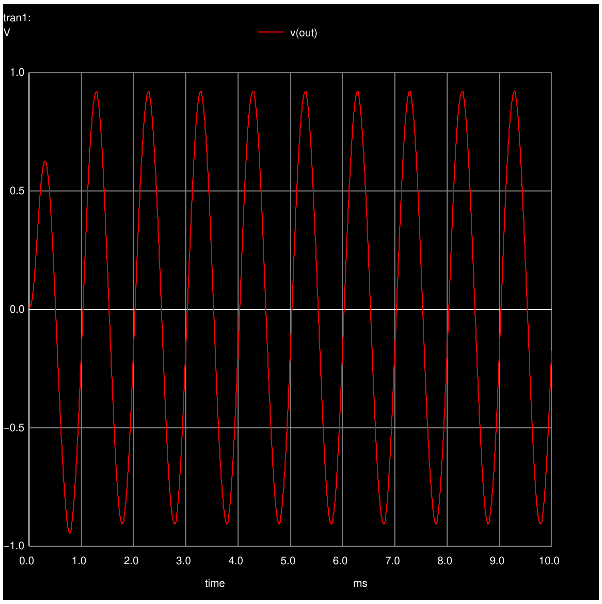

Figure 1: Voltage output

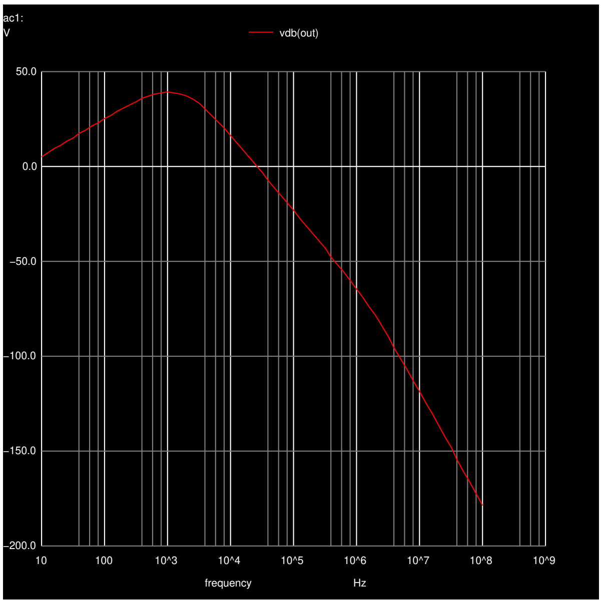

Figure 2: Voltage output, in dB

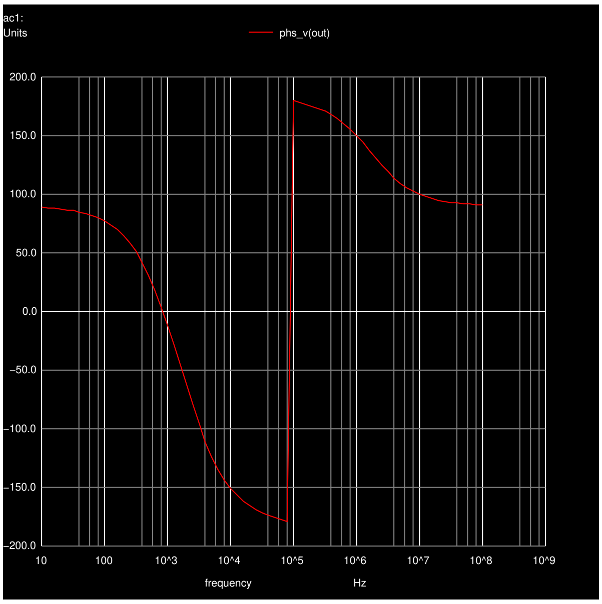

Figure 3: Output phase, in degrees

Parameter	**Value**
gain	9.135903e+01
gaindb	3.921503e+01
zin	9.989975e+02,-2.17365e+01

Table 5: Simulation Gain and Impedance

Parameter	**Value**
zout	6.454353e-01,1.387110e+01

Table 6: Output impedance

Furthermore, a frequency analysis was also carried out so as to obtain the frequency values defining the pass-band, and thus the central frequency value that was relevant to the merit calculation.

Parameter	Value
flow	4.202373e+02
fup	2.240120e+03
fvmax	1.000000e+03

Table 7: Frequency Values

Finally the parameters that defined the quality of our merit, were also calculated, and are presented in the following table.

Parameter	Value
gaindeviation	8.640966e+00
centralfreqdeviation	0.000000e+00
cost	1.372688e+04
merit	8.430743e-06

Table 8: Merit defining parameters

Furthermore, we modified the values of our circuit parameters (resistors and capacitors) in an exertion to increase our merit figure. These parameters were placed in the introduction.

4 Conclusion

The main goal of this laboratory was achieved once that we were able to architecture a band-pass filter with the provided OP-AMP. This circuit was successfully analyzed using both Ngspice and Octave.

However, there were some discrepancies between the theoretical and simulation analysis. This error was mainly caused by the presence of non-linear components in the circuit (OP-AMP). This component has an imensity of different parameters that make very hard, if not impossible, to simulate theoretically.

Despite these differences both models were correctly analysed and both result were satisfatory.