Circuit Theory and Electronics Fundamentals

Department of Physical Engineering, Técnico, University of Lisbon

Band-Pass Amplifier

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Diogo Simões, Júlia Mestre, Rafael Dias

Contents

1 Introduction

The objective of this laboratory assignment is to build an amplifying circuit based on an OP-AMP component.

In Section 3, a theoretical analysis of the circuit is presented. In Section 2, the circuit is analysed by simulation, and the results are compared to the theoretical results obtained in Section 3. The conclusions of this study are outlined in Section 5.

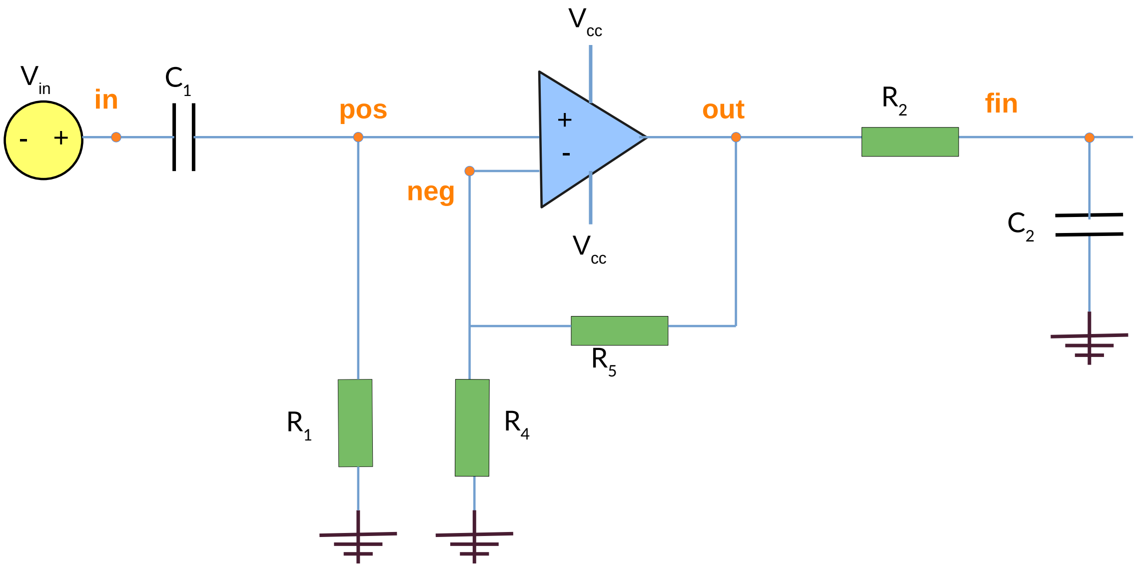


Figure 1: OP-AMP Circuit

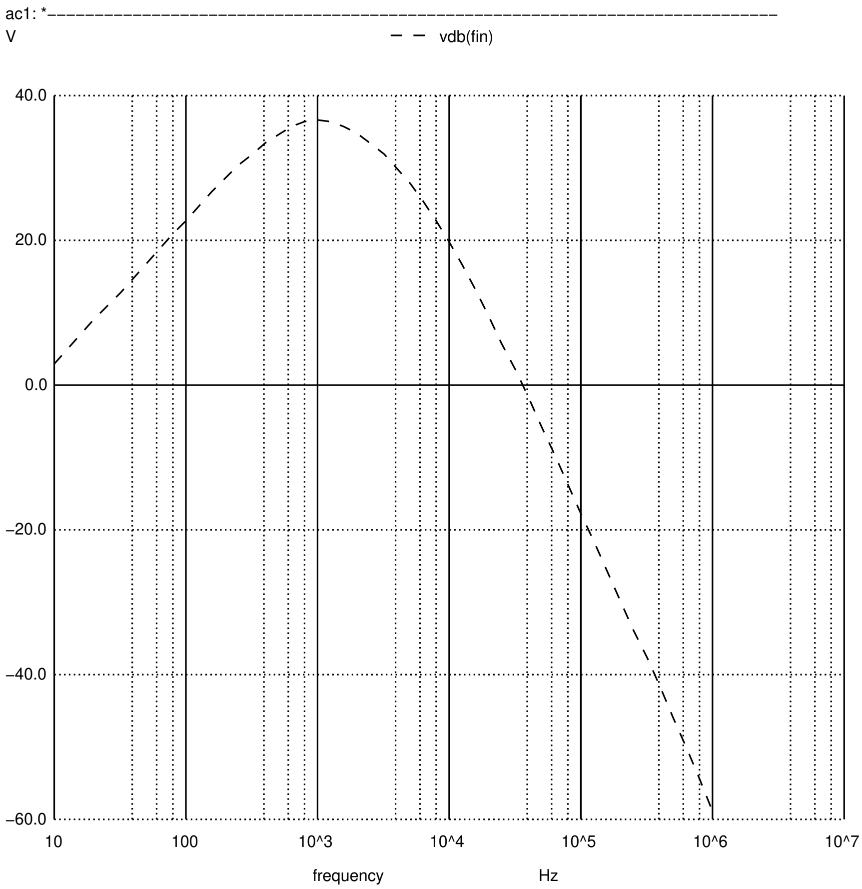
2 Simulation Analysis

We simulated the circuit using frequency analysis, using the supplied model of the OP-AMP:

Table 1: Values of capacitances and resistances for various circuit components

Vcc	$10.0V$
Vee	$10.0V$
C1	$220nF$
C2	$220nF$
R1	1000Ω
R2	500Ω
R3	$100kOhm$
R4	1000Ω

We simulate the circuit using frequency analysis and max(vin(t))=1, obtaining the following gain in v_{fin}, which is the gain at the end of the circuit:



The calculated input impedance is $(990.01 + i \cdot 7.32)\Omega$. A different setup was used to calculate the output impedance which yielded $(-0.09519 + i \cdot 7.234)\Omega$.

This circuit has a cost of 13323.3 (OP-AMP) + 113.44 (other components), a maximum gain of $36.55dB$, central frequency of $1006.5Hz$. The calculated merit is therefore $7.487043 \cdot 10^{-6}$.

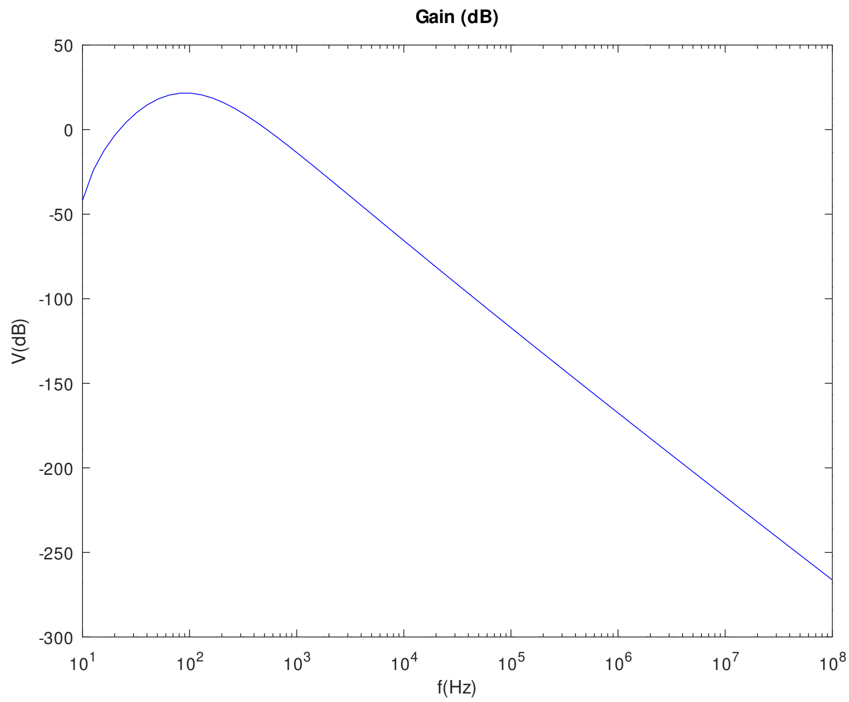
3 Theoretical Analysis

Firstly, we computed the central frequency and the gain depending on the frequency, utilizing the expressions from the laboratory class. We obtain the values of $1023.08Hz$ for the central frequency and a bandwidth of $723.4Hz$.

We then used the incremental model of the OP-AMP component, yielding the following equations for the nodal analysis of the circuit:

$$
\begin{aligned}
(C1*w*j+1/R1+1/Zi)*V_{pos}-1/Zi*V_{neg} &= V_{in}*C1*w*j \\
-Av*V_{pos}+V_A+Av*V_{neg} &= 0 \\
-1/Zo*V_A+(1/R2+1/Zo+1/R3)*V_{out}-1/R3*V_{neg}-1/R2*V_{fin} &= 0 \\
-1/Zi*V_{pos}-1/R3*V_{out}+(1/R3+1/R4+1/Zi)*V_{neg} &= 0 \\
-1/R2*V_{out}+(1/R2+C2*w*j)*V_{fin} &= 0
\end{aligned} \tag{1}
$$

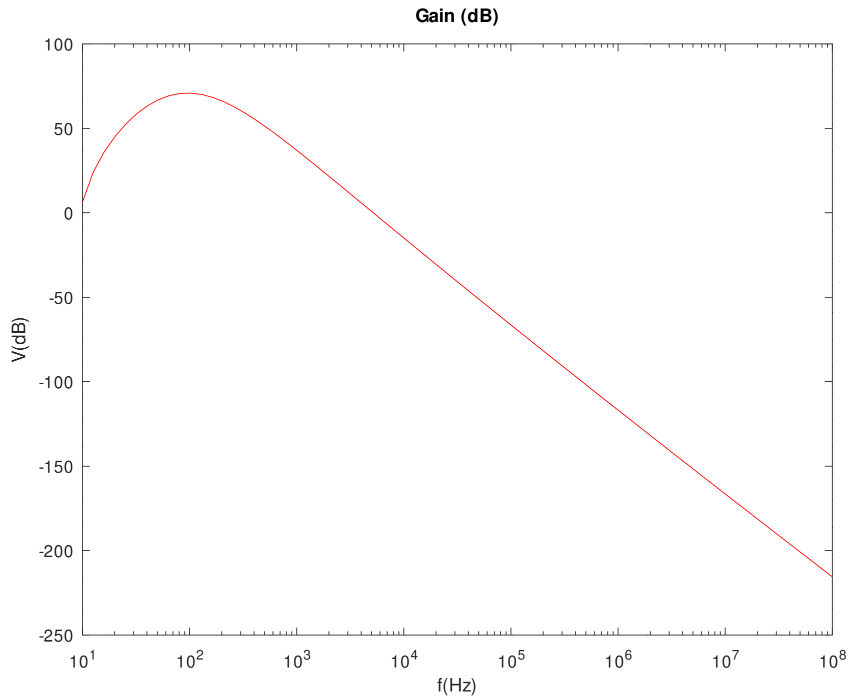
We therefore obtain the following plot for the gain as a function of frequency:



As such the central frequency is $81.855Hz$, the gain at this frequency is $21.542dB$ and the bandwidth is 143.57. These values are not consistent with the values given by simulation, however, they are consistent with the transfer function provided in the lab class:

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

As we can see in the plot below:



The input and output impedances were also calculated yielding values of 1009.6Ω and $2.24 \cdot 10^{-5}\Omega$ respectively.

4 Experimental Results

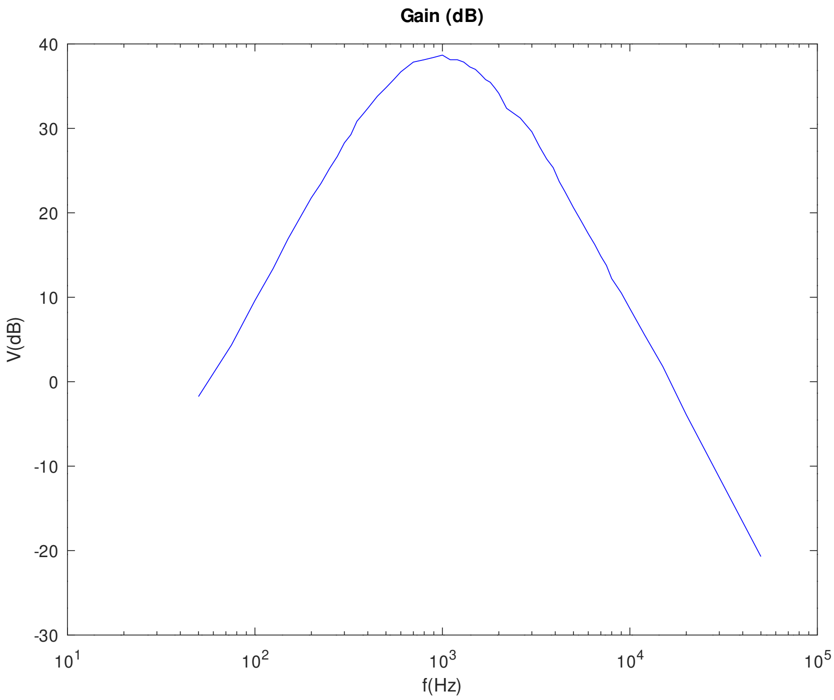
We were able to build the circuit presentially utilizing a breadboard and the various components.

Then, the frequency of the input voltage source, with an absolute value of $0.107V$, was ajusted, from $50Hz$ to $50kHz$, at various increments and, for each value, the value of the output voltage was measured. The results are in the following table:

These results were graphed below as to compare them to the theoretical analysis and simulation done above:

Table 2: Gain as a function of frequency

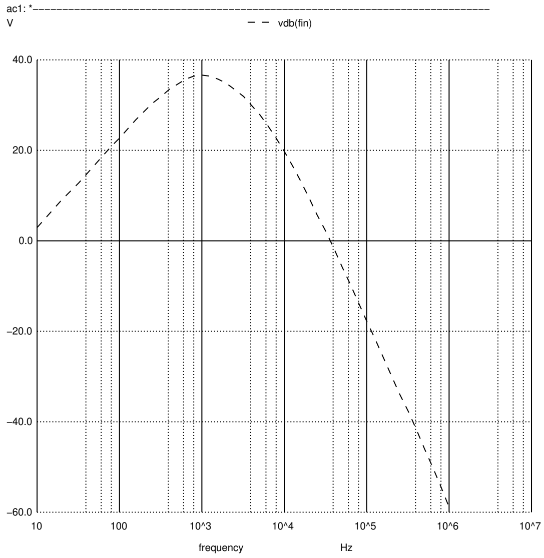
$f(Hz)$	$V_L(mV)$	$f(Hz)$	$V_L(mV)$
50.0	98	1600.0	660
75.0	133	1700.0	640
100.0	173	1800.0	630
125.0	209	1900.0	610
150.0	249	2000.0	590
200.0	318	2200.0	540
225.0	346	2600.0	510
250.0	378	3000.0	470
275.0	406	3300.0	430
300.0	440	3600.0	400
325.0	462	3900.0	380
350.0	500	4200.0	350
375.0	520	4500.0	330
400.0	540	5000.0	300
450.0	580	5500.0	277
500.0	610	6000.0	257
550.0	640	6500.0	241
600.0	670	7000.0	225
700.0	710	7500.0	213
800.0	720	8000.0	197
900.0	730	9000.0	181
1000.0	740	10000.0	165
1100.0	720	12000.0	141
1200.0	720	15000.0	117
1300.0	710	20000.0	88
1400.0	690	50000.0	38
1500.0	680		

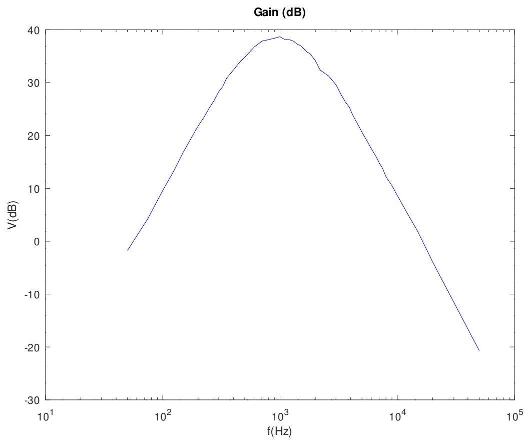


5 Conclusion

In this laboratory assignment the objective of building a bandpass filter with central frequency at aproximately 1kHz and gain at central frequency $40dB$ was achieved. The central frequency was $1006.5Hz$, so it presents a deviation of only 0.65%. The maximum obtained was $36.55dB$, which presents a deviation of 8.6%. The cost was 13436.7 MU and the merit was $7.487043 \cdot 10^{-6}$.

The results from both the physical circuit at the laboratory and the circuit simulation using ngspice appear to match, as we can see in the following figure:





We can conclude that the physical circuit and simulation analysis yield very similar results. However, the theoretical analysis yielded very lacklustre values. This is probably due to the complexity of the OP-AMP component which the simple model used failed to replicate.