



T5 - Band Pass Filter using OPAMP

Integrated Master in Physics Engineering

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Contents

1	Introduction	1
2	Presential Lab	2
3	Theoretical Analysis	2
4	Simulation Analysis	3
5	Conclusion	7

1 Introduction

In this laboratory assignment we seek to build a bandpass filter using an OP-AMP. Particularly we seek to maximize our **merit figure**, M , given by:

$$M = \frac{1}{\text{Cost}(\text{VoltageGainDeviation} + \text{CentralFreqDeviation} + 10^{-6})}$$

where the voltage gain deviation is the absolute value of the difference between the gain at 1000 Hz and 40 dB; and the central frequency deviation is the absolute value of the difference between the central frequency and 1000 Hz. The central frequency, f_c , is given by the geometric mean of the low cut-off frequency and the high cut-off frequency:

$$f_c = \sqrt{f_H f_L}$$

The circuit used was the following:

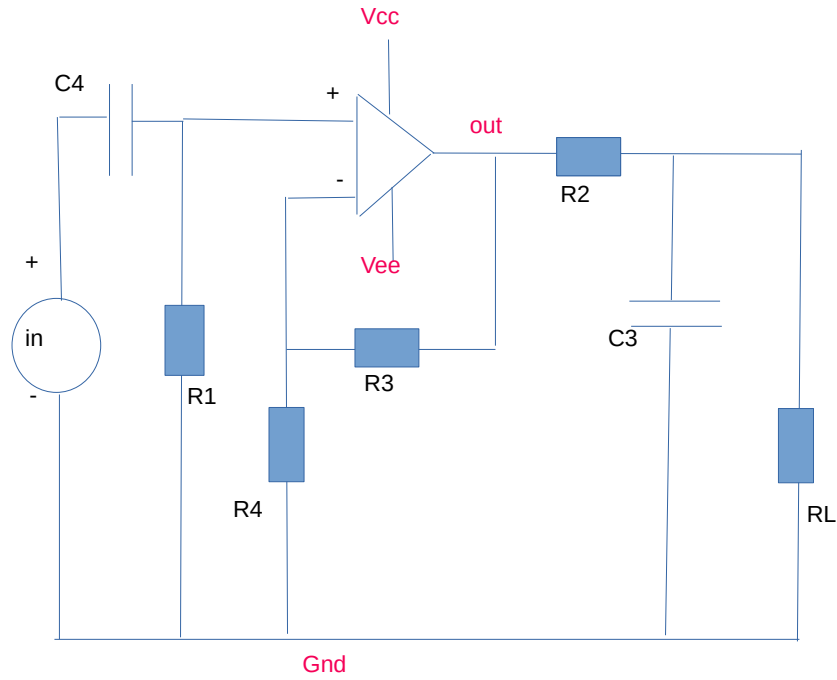


Figure 1: Circuito utilizado

2 Presential Lab

In this lab assigment we were also able to implement this circuit in real life, where we able to measured the gain and the cut-off frequencies. For the circuit configuration, we chose the following components:

R1	R2	R3	R4	C3	C4
1000K Ω	500 Ω	1000K Ω	500 Ω	220nF	220nF

With these components we were able to get a voltage gain of approximately $Gain = 40$ dbs, and cut-off frequencies of 330 Hz and 2.23 KHz , corresponding f_L and f_H , respectively. Using ngpsice, we simulated the same circuit, were we obtained the following results:

3 Theoretical Analysis

The transfer function is defined as the ration between the output and the input. In our case, the output is v_0 and the input v_s :

$$T(s) = \frac{v_0}{v_s}$$

after a little algebra, we get to the following expression:

$$T(s) = \frac{R_1 C_1 s}{1 + R_1 C_1 s} \left(1 + \frac{R_3}{R_4}\right) \left(\frac{1}{1 + R_2 C_2 s}\right) \quad (1)$$

where, as usual

$$s = j\omega$$

The theoretical cut-off frequencies, f_L and f_H , can be calculated by the Short Circuit Time Constants Method. They are given by¹:

$$f_L = \frac{1}{R_1 C_1} \quad (2)$$

$$f_H = \frac{1}{R_2 C_2} \quad (3)$$

where f_H is the high cut-off frequency and f_L is the low cut-off frequency. Experimentally, the cut off frequencies will be calculated through the following expression:

$$f = \frac{V_{max}}{\sqrt{2}}$$

where f can be either f_H or f_L .

4 Simulation Analysis

The Operating point analysis is the following:

The graphs are the following:

¹If you want to see the deduction in detail, you may visit the following link:
https://ocw.mit.edu/courses/electrical-engineering-and-computer-science/6-012-microelectronic-devices-and-circuits-fall-2009/lecture-notes/MIT6_012F09_lec23.pdf?fbclid=IwAR3ezEOiIWVJOLyNLNp49EwgcpWSC-_IQF06wASvf9cKXiGx2_OzBp1Pnb8

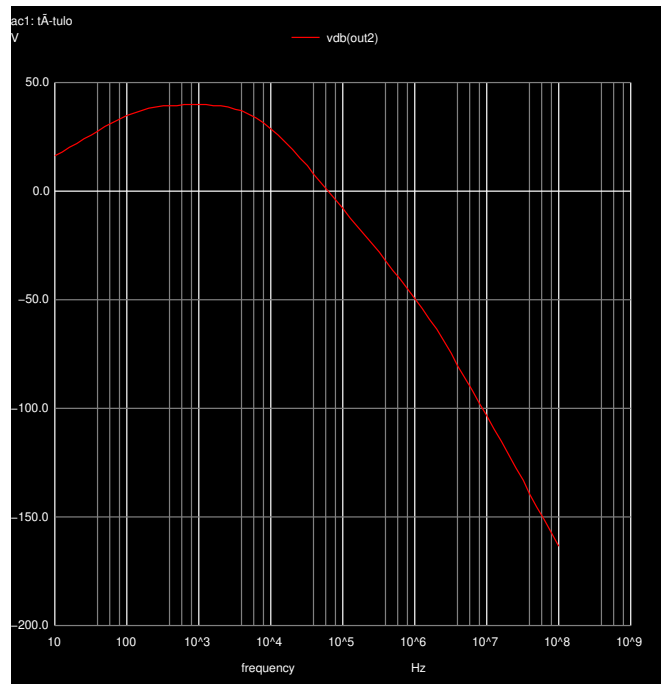


Figure 2: Time analysis

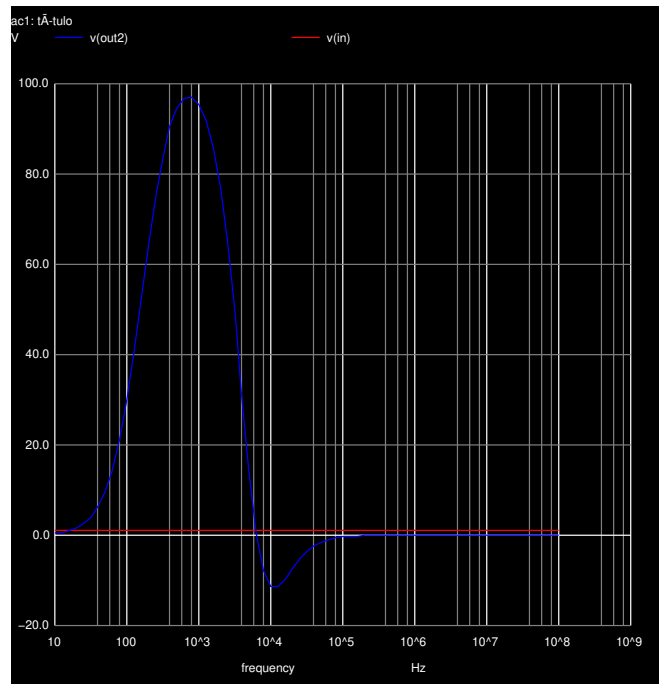


Figure 3: Frequency analysis

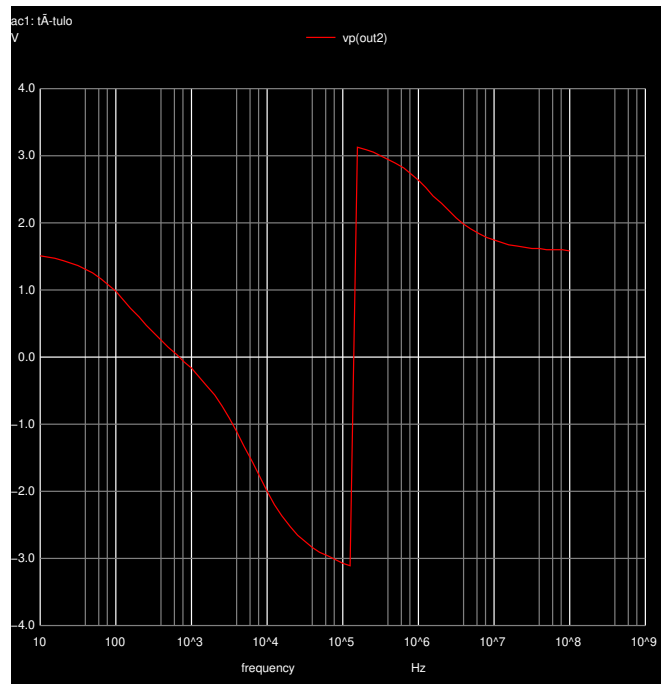


Figure 4: —

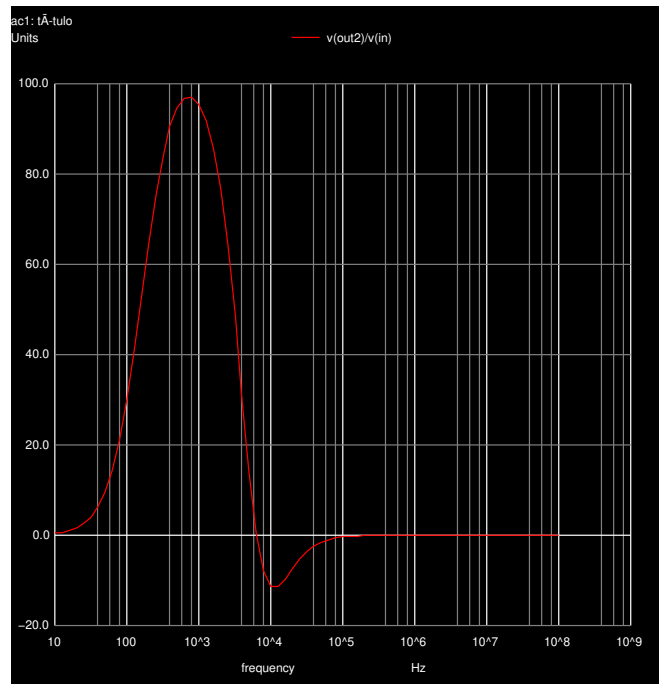


Figure 5: $v(\text{out})/v(\text{in})$

5 Conclusion