Circuit Theory and Electronics Fundamentals

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June 6th, 2021

Contents

1 Introduction

The objective of this laboratory assignment is to dimension and implement a BandPass Filter (BPF) with a central frequency of 1kHz and a gain at central frequency of 40dB.

The circuit is as shown below in Figure 1.

In Section 2, a theoretical analysis of the circuit is presented. In Section 3, the circuit is analysed by simulation, and the results are compared to the theoretical results obtained in Section 2. The conclusions of this study are outlined in Section 4.

2 Theoretical Analysis

In this section, the BandPass filter is analysed theoretically.

Since the filter is active, it's composed of a high-pass filter (R_1 and C_1), a low-pass filter (R_2 and C_eq) and a voltage amplifier.

C_eq is the approximate equivalent capacitance of C_2, C_21, C_22:

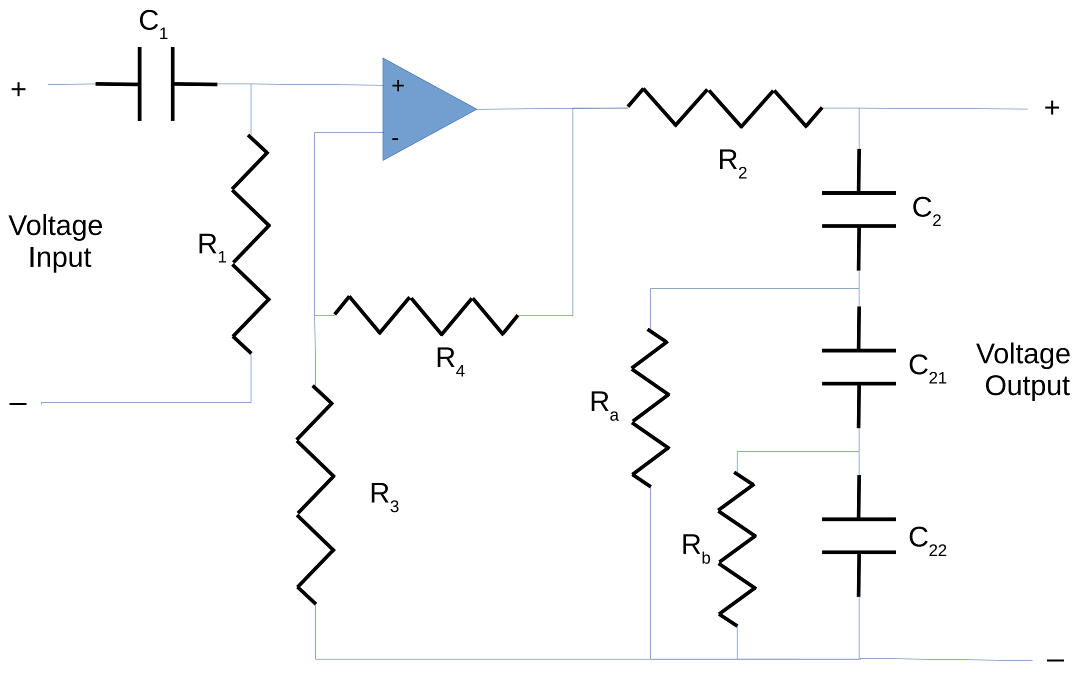

Figure 1: BandPass Filter circuit.

$$C_eq = \frac{1}{\frac{1}{C_2} + \frac{1}{C_21} + \frac{1}{C_22}}. \tag{1}$$

The voltage gain will be the product of the gain in each part of the circuit:

$$Gain = 20 * log10(abs(\frac{R_1}{\frac{1}{s*C_1} + R_1} * (1 + \frac{R_4}{R_3}) * \frac{1}{1 + R_2 * s * C_2})). \tag{2}$$

The central frequency is calculated using the lower cutt of frequency and the upper one, which are the poles of the low and high pass filters:

$$centralfrequency = \sqrt{f_h * f_L}. \tag{3}$$

Finnaly the input and output impedances are calculated considering an ideal op-amp model:

$$input_impedance = \frac{1}{s * C_1} + R_1. \tag{4}$$

$$output_impedance = \frac{1}{\frac{1}{R_2} + s * C_2}. \tag{5}$$

2.1 Central frequency analysis

First we will analyse the gain at central frequency. The results, using the equations shown above, are shown in Table 1.

Name	Value [Ohm]/[dB]/[Hz]
$@Centralfrequency$	1078.428096086632
$*Gain$	36.837882253952031
Z_{input}	(1000,-723.43155950861512)
Z_{output}	(721.01797710664209,-448.49866643691126)

Table 1: Theoretical values at central frequency. The gain is in dB. Values with @ are frequecies in Hz.

2.2 Frequency Response

The voltage gain's frequency response can be seen in figure 2 and the plot of the Phase frequency response is shown in Figure 3.

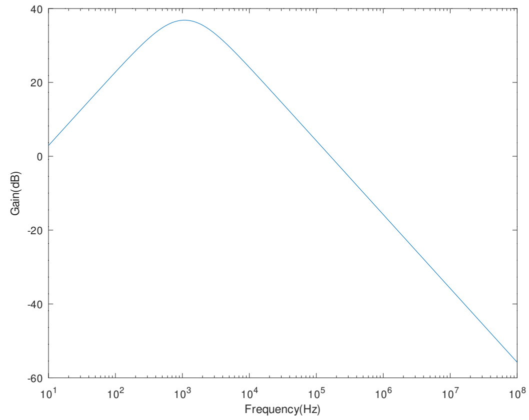

Figure 2: Gains's Frequency Response.

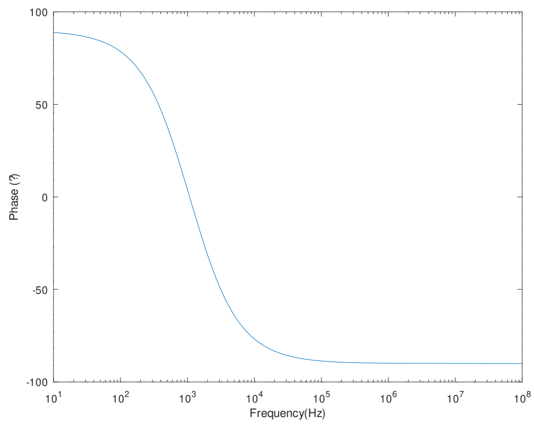

Figure 3: Phase Frequency Response.

3 Simulation Analysis

3.1 Central Frequency analysis

The simulated results for the central frequency and the merit of the circuit are shown below in Table 2 and 3.

Name	Value [V]
centralfrequency	1.063636e+03
gain	3.674084e+01
inputimpedance	9.999908e+02,-7.23534e+02
merit	8.391028e-07

Table 2: Simulated Central frequency, Gain, Input impedance and Merit.

Name	Value [Ohm]
outputimpedance	7.207384e+02,-4.40983e+02

Table 3: Simulated output impedance result.

The relative errors of each one are:
Error(Voltage Gain)=0,029%
Error(Central frequency)=1,4%
Error(abs Input Impedance)=0,005%
Error(abs Output Impedance)=0,89%
These values are within acceptable range. The error of the central frequency is slightly higher than the rest, wich is likely caused by approximations made in the calculations of the cut off frequencies (ideal op-amp and filters).

3.2 Frequency response

The plot of the Voltage Gain frequency response is shown Figure 4 and the plot of the Phase frequency response is shown in Figure 5.

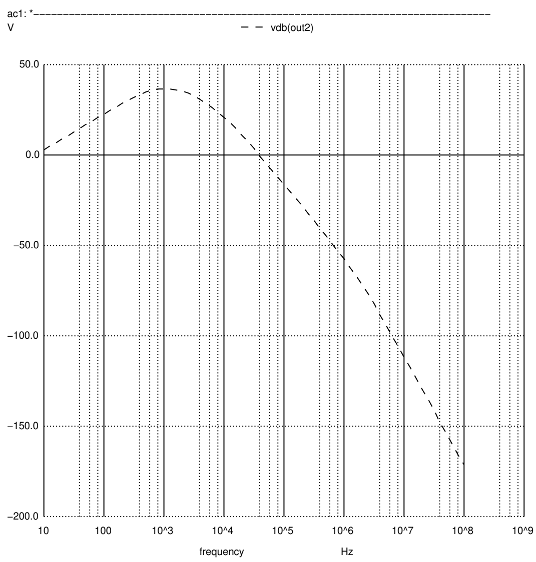

Figure 4: Voltage Gain frequency response.

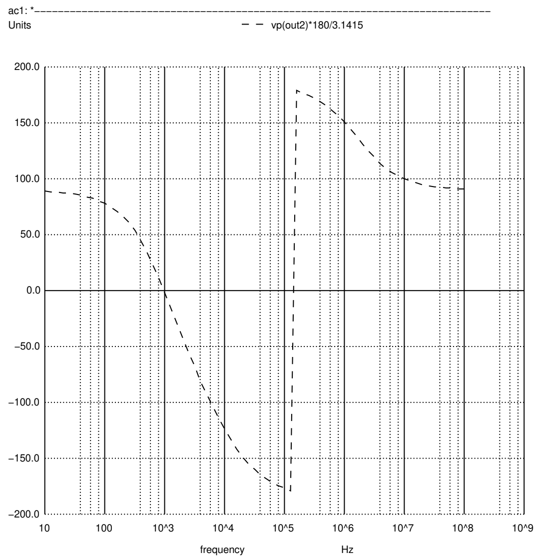

Figure 5: Phase frequency response.

We can see the simulated gain frequency response plot is similar to the theoretical one, with some discrepancies in the band pass zone caused by the reasons already described.

As for the phase frequency response plots there are significant differences due to the ideal op-amp model used for the theoretical analysis.

4 Conclusion

In this laboratory assignment the objective of creating a BandPass Filter was achieved. By comparing the theoretical and simulated results we could see that there wasn't a significant error. The total cost of the circuit is 13637.66 MU and the merit is 8.391028e-07.