Laboratory Report 5: Bandpass filter using OP-AMP

Circuit Theory and Electronics Fundamentals

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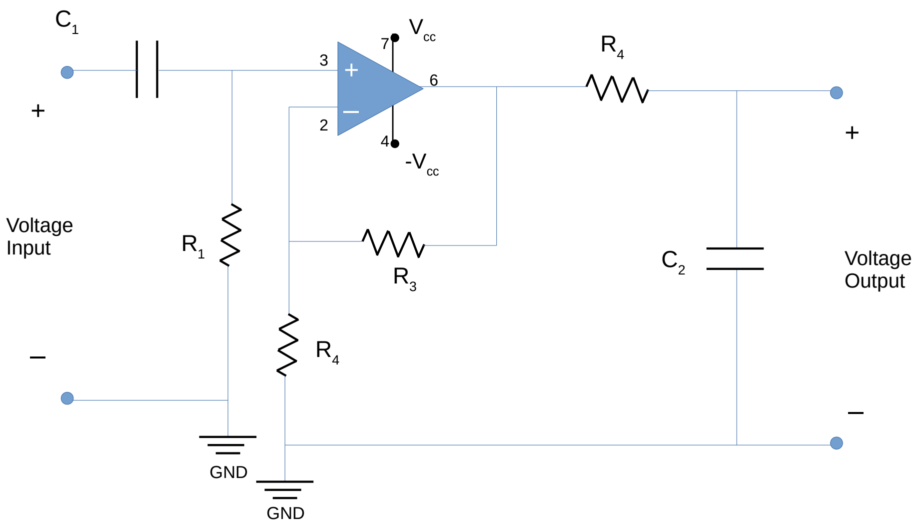
1 Introduction

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

Next, on table **??** is the list of restrictions for this design:

Name	Maximum Quantity
$741OP - AMP$	1
$1k\Omega Resistor$	3
$10k\Omega Resistor$	3
$100k\Omega Resistor$	3
$220nf capaction$	3
$1\mu f capacitor$	3

Table 1: Restrictions for this assignment



As mentioned above, it is also important to refer that we have developed an optimization algorithm (in Octave) in order to find the number of transistors, the values of the resistors and capacitor that would lead to the best value of merit, computed in Ngspice with the formula given by the Professor.

2 Simulation Analysis

In this section, we will the obtained results by simulating the referred circuit in Ngspice.

We started with the given ngspice file to simulate the audio amplifier, and further improved my doing incremental modifications, while respecting the suitable parameters.

To decide the final best values, an optimizer was used with octave, that created a new ngspice document in each iteration as to find the suitable and most optimal values.

The obtained values of interest can be found in table **??**.

Element	Value
Cost	7143.1 MU
Lower Cut Off	8.720161e+00 Hz
Upper Cut Off	3.124184e+06 Hz
Bandwidth	3.1242e+06 Hz
Voltage Gain ($\frac{V_o}{V_i}$)	4.9543e+01
Input Impedance	7.983355e+02
Output Impedance	6.567979e+00

Table 2: Obtained values from Ngspice

Using the given expression for the merit it follows that:

$$Merit = 2484.9 \tag{1}$$

It becomes clear from changing the values the different effects the resistors and capacitors have in the bandwidth and gain.

The coupling capacitors have the clear goal of behaving like a short-cirtcuit for certain frequencies, which effects the lower cutoff frequency, which directly changes the bandwidth.

The bypass capacitor on the other hand, is meant to bypass the resistor R_E as it is a short-circuit for high frequencies, as not to lower the gain, since it is stable for the passband.

The R_c resistor also affects gain, since it takes part in the stabilization process of the temperature effect as described in class number 16.

3 Theoretical Analysis

ection, the circuit is analyzed theoretically, according to the ideal op-amp model (Z i = ∞ and Z o = 0), resulting in the following equation

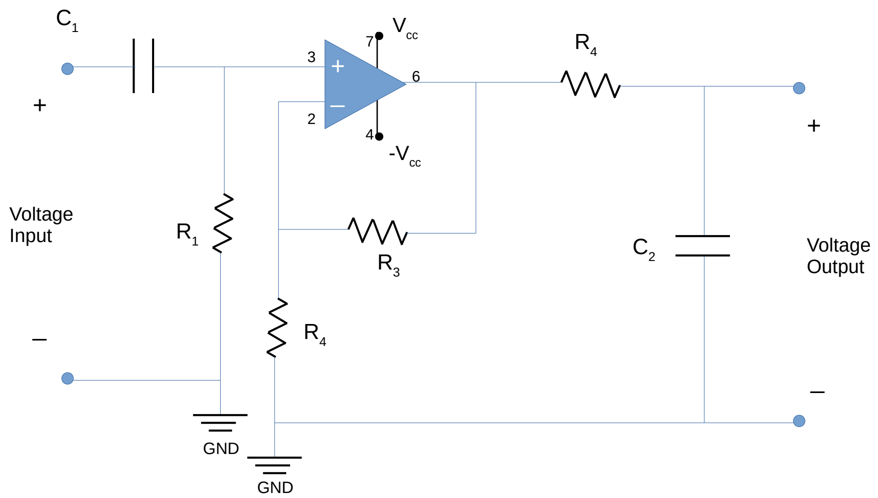


Figure 2: Representation of the BandPass Filter implemented.

In this section we will discuss the theoretical analysis of our circuit, represented in figure **??**. The value for the central frequency is 1000Hz and the gain at the central frequency is 40db throughout the calculations. The ideal op-amp model is used so that Z_input is infinite and Z_ouput is null.

The values for the resistors and capacitors used are in table **??**. The first part of the circuit composed of R_1 and C_1 form the high-pass filter. It passes all frequencies above the value from equation **??**. The signal is then amplified by the op amp by a gain proportional to resistors R3 and R4 according to the following equation. This means the gain is equal to ??.

Symbol	Value
R_1	Ω
R_2	Ω
R_3	Ω
R_4	Ω
C_1	Ω
C_2	Ω

Table 3: Values for theoretical analysis

$$Gain = 1 + \frac{R_3}{R_4}, \tag{2}$$

$$f = \frac{1}{2\pi * R_2 * C_2}, \tag{3}$$

The signal then passes through the low-pass filter, which is the second part of the circuit. The low-pass filter is composed of the resistor R_2 and capacitor C_2. It passes all frequencies below the value from the following equation. This circuit gives an amplified noinverting signal so the input signal and output signal are in phase.

$$f = \frac{1}{2\pi * R_2 * C_2}, \tag{4}$$

Here we have the table for the values of the gain, input and output impedances calculated at the central frequency and the corresponding equations.

$$|Z_i nput| = |Z_{C_1} + R_1| = |Z_{C_1} + R1||Z_o utput| = |Z_{C_2}(0R2 + R3)| = |Z_{C_2}R2| \tag{5}$$

Symbol	Value
$Gain$	??
Z_{input}	??
Z_{output}	??

Table 4: Values for the gain, input and output impedances

Finally, we can obtain the plot for the frequency response V_o(f)/V_i(f) using the incremental circuit, solving the circuit for a frequency vector in log scale with 10 points per decade, from 10Hz to 100MHz.

Figure 3: Frequency response V_o(f)/V_i(f)

4 Conclusion

In this laboratory we designed and adapted the structure of an audio amplifier circuit.
We can now compare the obtained results by theory and by simulation:

Parameter	**Value**
Total:	
Voltage Gain ($\frac{V_o}{V_i}$)	4.9543e+01
Input Impedance	7.983355e+02
Output Impedance	6.567979e+00

Table 5: Values for gain and impedances in simulation.

Element	**Value**
Total:	
Voltage Gain ($\frac{V_o}{V_i}$)	91.805
Input Impedance	843.98
Output Impedance	3.3993

Table 6: Values for gain and impedances in theoretical.

There are some clear differences between the results, which are main due to the transistor model apllied in Ngspice is much more realistic and complex than the model apllied theoretically. Considering this, the results are quite satisfactory.

Final merit obtained was 2484.9 (Ngspice).