Laboratory Report 5: Bandpass filter using OP-AMP

Circuit Theory and Electronics Fundamentals

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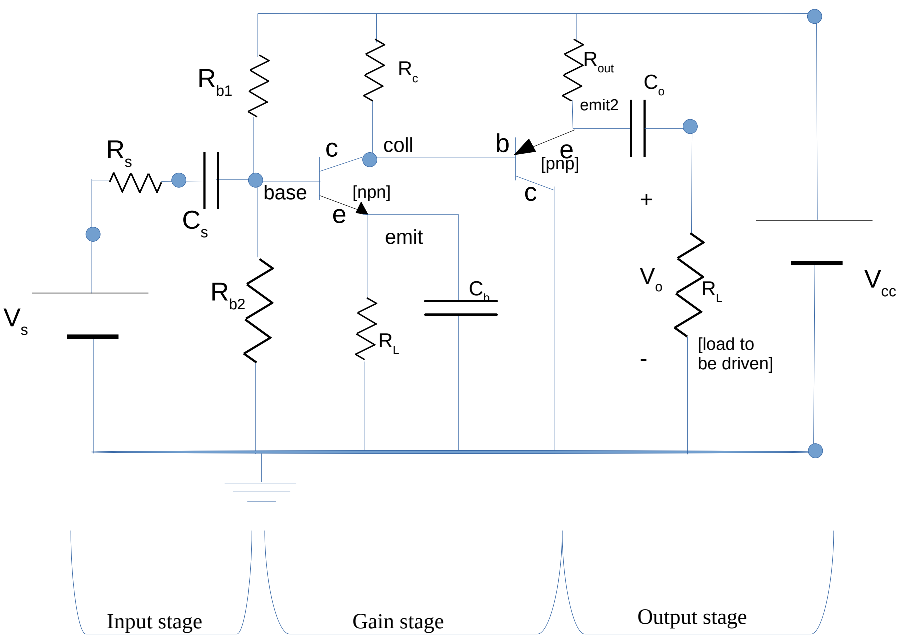
1 Introduction

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 1 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
$220nfcapactior$	3
$1\mu fcapacitor$	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 8.

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

In this section we will discuss the theoretical analysis of our circuit, represented in figure 1. For this purpose, we will first explain seperately the Gain stage and the output stage circuits on the Audio Amplifier circuit. The values used throughout this analysis are shown below.

Symbol	Value
R_S	100Ω
A_f	$12V$
$AudioINMax$	$10mV$
$Speaker$	8Ω

Table 3: Values for theoretical analysis

3.1 Gain Stage

The first stage we will discuss is the Gain Stage, which the objetive is to amplify the voltage input signal. Having a high input impedance and a high gain, this stage will have a high output impedance that makes it so there is degradation of the signal in the exit when connecting to a speaker, making it necessary an output stage, that will be explained in the next subsection. Here we used the theoretical model explained in the lectures. The explanation for both this stage and the output stage is already done in the Simulation Analysis section.

In the following table we have the values for the gain, input and output impedances in this stage.

Parameter	Value
Voltage Gain ($\frac{V_o}{V_i}$)	95.221
Input Impedance	843.98
Output Impedance	528.99

Table 4: Values for gain and impedances in Gain Stage.

3.2 Output Stage

In this output stage, we will have a low output impedance. Because of this, these two stages can now be connected without significant signal loss since the output stage input impedance is higher than the output impedance of the gain stage. The gain of this stage will also be close to one, with prevents signal amplification or attenuation.

Similar to the previous subsection, in the following table we have the values for the gain, input and output impedances in this stage.

Parameter	Value
Voltage Gain ($\frac{V_o}{V_i}$)	0.98308
Input Impedance	16308
Output Impedance	1.1935

Table 5: Values for gain and impedances in Ouput Stage.

To compute the lower cutoff frequency and the gain, we used the following incremental model.

In figure we have 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.

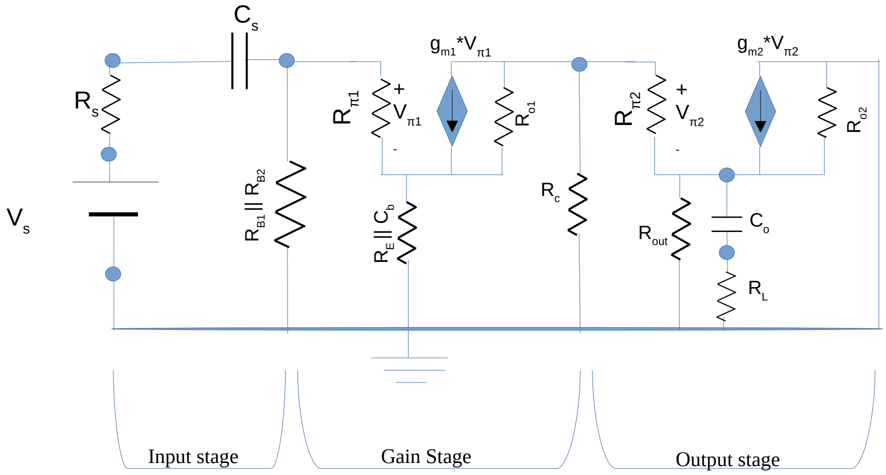


Figure 2: Diagram of the incremental model considered for the gain and frequency response computations.

Below are the total values:

Parameter	Value
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 the total circuit

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 7: 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 8: 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).