Circuit Theory and Electronics Fundamentals

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Laboratory Report

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1 Introduction

In this laboratory assignement the objective is to study an amplifier together with some of its properties, namely the input and output impedances, the voltage gain and also the influence of the frequency on this gain. The specific circuit used in the Octave and Ngspice software is the one illustrated:

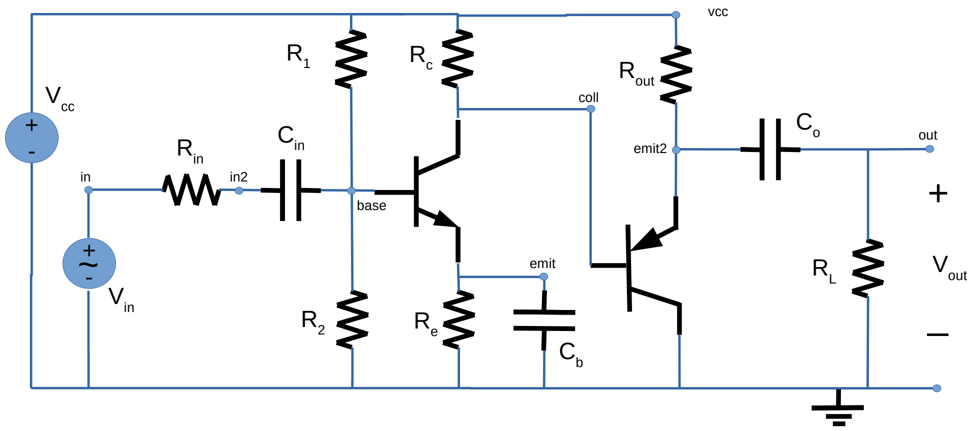

Figure 1: Amplifier circuit

The use of an amplifier generally means the ability to obtain an output signal with a greater amplitude in relation to its source signal. An example of using this type of circuit is the simplest microphones that can be found on the market.

2 Theoretical Analysis

In this section we will detail the theoretical study of the Amplifier Circuit conducted during this lab. The circuit was divided into two seperate ones: the gain stage and the outrput stage. The first one increased the gain, but it had a drop of current considered undesirable due to the output impedance. The latter one corrects this effect while having a gain near one, as to not decrease the voltage previously gained.
The entire circuit can be seen in the following image:

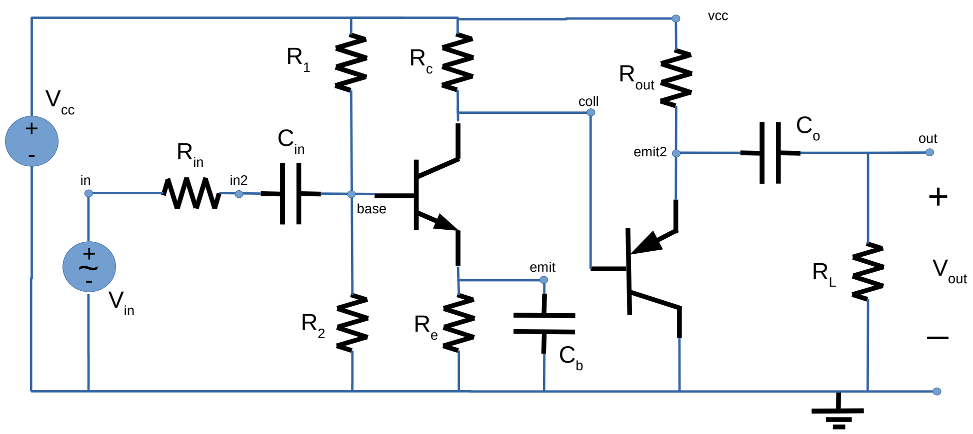

Figure 2: Amplifier circuit

One must note that Vin and Rin constitute the thevenin equivalent of the circuit to which the amplifier is connected.

The capacitator connected to Rin will enforce that only the AC part of the voltage is taken into account. The DC part is suplied by a constant 12V voltage source Vcc. With this arquitecture, we can ensure that the transistors are in foward active region (FAC), for the Vcc will force an voltage drop bigger than the one necessary for that mode of operation.
It was used an Operanting Point analysis where the DC component of the current and voltage is taken into account, but not the AC one, followed by an Incremental Analysis where the AC component of the current and voltage is taken and where a linear model of the transistor is assumed. By adding the results, we can obtain a solution for the circuit, thereby obtaining the values necessary to compute the theoretical gain of the amplifier and the various impedances, such as the input and output ones. The analysis can be divided into the following particular smaller analysis:

- Operating Point analysis for the gain stage;
- Incremental analysis for the gain stage;
- Calculation of the gain for the gain stage;
- Operanting Point analysis for the output stage;
- Incremental analysis for the output stage;
- Calculation of the gain for the output stage;
- Calculation of the input and output inpedances;

To calculate the OP of each stage, it was considered the following circuits for each stage:
[Inser images of OP analysis]

It was used the mesh method in conjuction with the Ebers-Moll bipolar npn transistor model in order to calculate the currents in each mesh and the voltage drops between nodes. With this, it was possible to calcule the DC component of the output volltage.
To calculate the incremental stage, it was considered the following incremental model of the transistor:

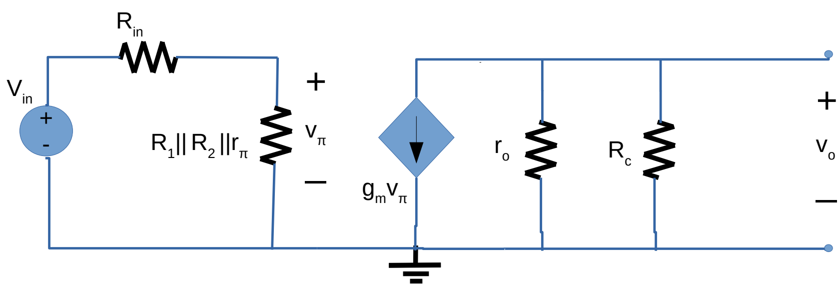

Figure 3: Amplifier circuit

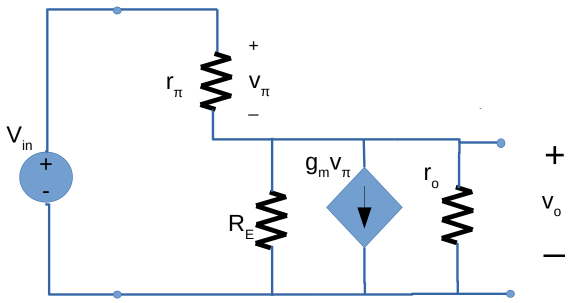

Figure 4: Amplifier circuit

Each stage was therefore modeled as follows:

$$g_m = I_C/V_T \tag{1}$$

$$r_{pi} = beta_F/g_m \tag{2}$$

$$r_o = V_A/I_C \tag{3}$$

By using the mesh method, it was possible to calculate the AC component for the output voltage.
The total voltage for each frequencie is equal to the sum of the AC with the DC component.

This analysis was repeated for various frequencies of Vin (10 equally spaced frequencies per decade), and the results were ploted on a dB scale. The calculation of the overall gain was obtained by multiplying the gain of each stage. The results can be observed in the following graphs:

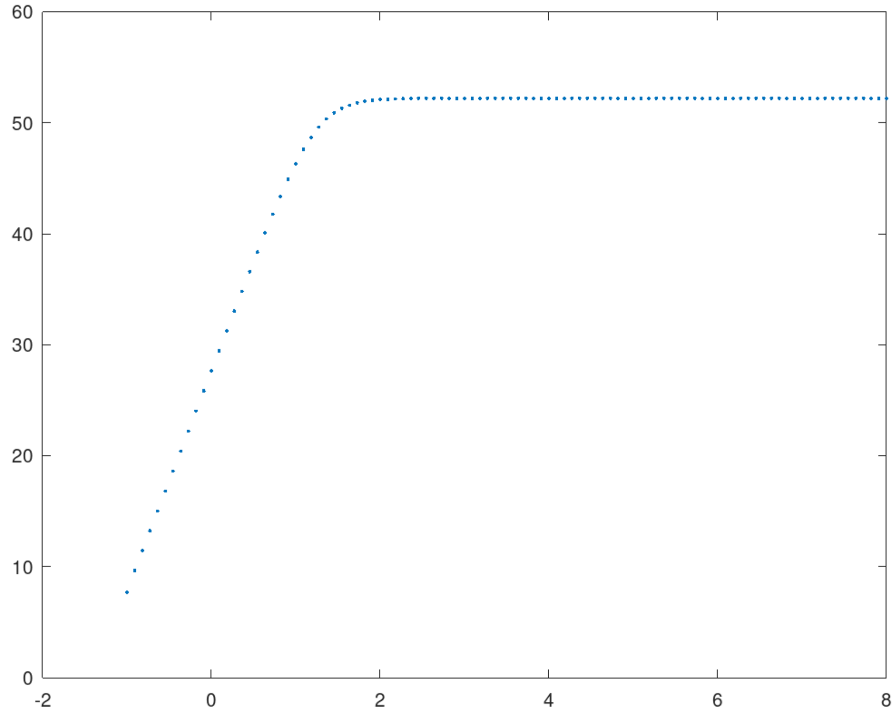

Figure 5: Amplifier circuit

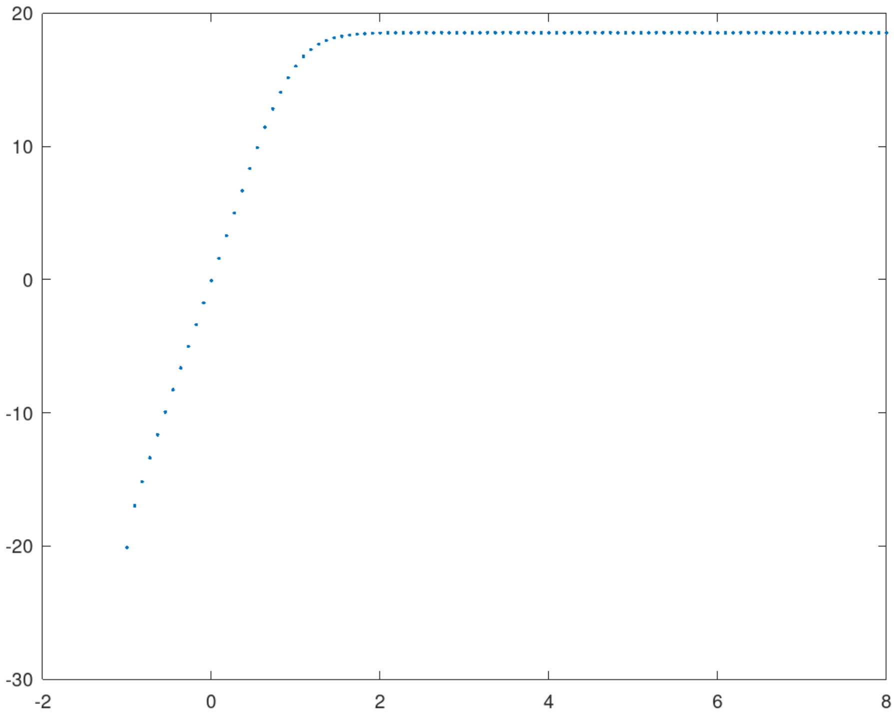

Figure 6: Amplifier circuit

3 Simulation Analysis

In the simulation study of an amplifier circuit, the Ngspice software was used, where some modifications were made to the script initially made available in order to obtain the best merit in this work. For this and also as a requirement, the NPN and PNP models were used for the transistors, referring to the Gain stage and the Output stage, respectively.

From operating point analysis we got the following results:

low	2.513670e+00
cost	7.109638e+03
gain	1.487926e+01
bandwidth	3.136186e+06
merit	2.611124e+03

Table 1: Voltages

And now for the impedances values, the input and output impedances, respectively:

zin
2.738309e+00

Table 2: Voltages

4 Comparisons

In this section, a comparision between the ngspice and octave results is made. Moreover, we delve into the reasons regarding the diffences and similarities observed

And now for the impedances values, in the tables down bellow we can compare side bye side:

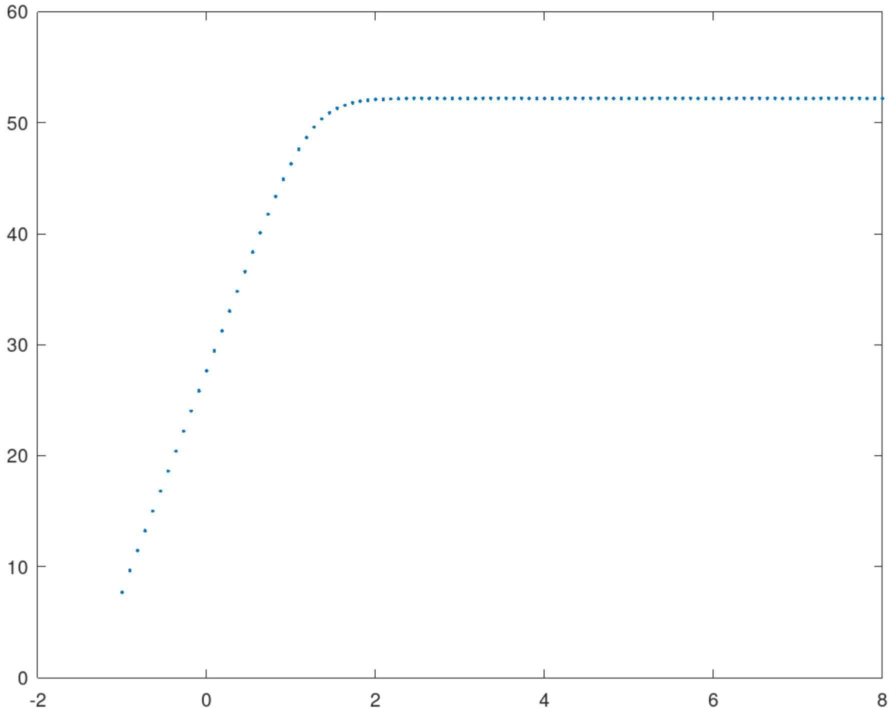

Figure 7: Amplifier circuit

zin
2.738309e+00

Table 3: Input Impedance by Ngspice

Z_{in}	Z_{out}
115705 $Omega	3.25315 $Omega

Table 4: Input and Output Impedances by Octave

Comparing both results, we can that the gain is not the same. Such a disparity is visibly noticible for high frequencies, where the gain drops in the simulation, but stabilizes in the theoretical analysis. Such a result can be explain when one notices that gain was obtained by assuming a linear incremental model. This model is based on truncating the taylor series for each component, so that the circuit components can all have a linear dependency on frequency. However, such is an aproximation and, in this case, the error grows with the frequency, for transistors are non-linear devices that depend on it. By analysing the incremental model, one notes than only the capacitators present have a dependency on frequency, the transistor does not. Since the impendance of the capacitators will decrease with the rise in frequency, it eventually becomes negligible and the gain stabilizes.
It is also possible to see that the maximum gain is not the same, growing much quicker in the ngspice model, stabilizing at a lower frequency and at a higher value.
The impedances are

5 Conclusion

We then concluded our laboratory work, corresponding to all the criteria initially proposed. It is true that there are discrpancies between the two different set of results, but these are discussed in the section of comparisons.

References

[1] K. Mayaram (1988) in 'DC and transient analyses' *CODECS: A Mixed-Level Circuit and Device Simulator, Memorandum No. UCB/ERL M88/71* Berkeley , p.23
`http://www.eecs.berkeley.edu/Pubs/TechRpts/1988/ERL-88-71.pdf`