TÉCNICO LISBOA

Circuit Theory and Electronics Fundamentals

Department of Electrical and Computer Engineering, Técnico, University of Lisbon

T4's Laboratory Report

Group 5

Carlos Ribeiro (96364), João Diniz (96416), Paulo Clemente (96462)

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1 Introduction

The objective of this laboratory assignment is to choose the architecture of the Gain and Output amplifier stages.

Firstly, we started this laboratory writing an NGspice script that simulates the the audio amplifier, based on the script given. The transistor models used were the NPN transistor for gain stage and the PNP Transistor for the output stage. We have also measured the output voltage gain in the passband, the lower and upper 3dB cut off frequencies, the bandwidth (which is the difference between the upper and lower cut off frequencies) and the input/output impedances.

Then, we have performed incremental modifications to improve the merit, which is calculated using the expression:

$$M = \frac{(VoltageGain)(bandwidth)}{Cost(lower_{Cutoff}freq)} \tag{1}$$

Where:

Cost = cost of resistors + cost of capacitors + cost of transistors

Cost of Resistors = 1 monetary unit per kOhm

Cost of capacitor = 1 monetary unit per μ F

Cost of transistors = 0.1 monetary units per transistor

After that, using octave, we have created a theoretical DC model able to compute de operating point, comparing it to Ngspice's OP. We have also computed the values of the gain, input and output impedances separately for the 2 stages, the frequency response V_i/V_o

Firstly, we have created a simple circuit and then we were updating the circuit to improve the figure of merit. The final circuit obtainned is the one shown below in figure (Fig.1):

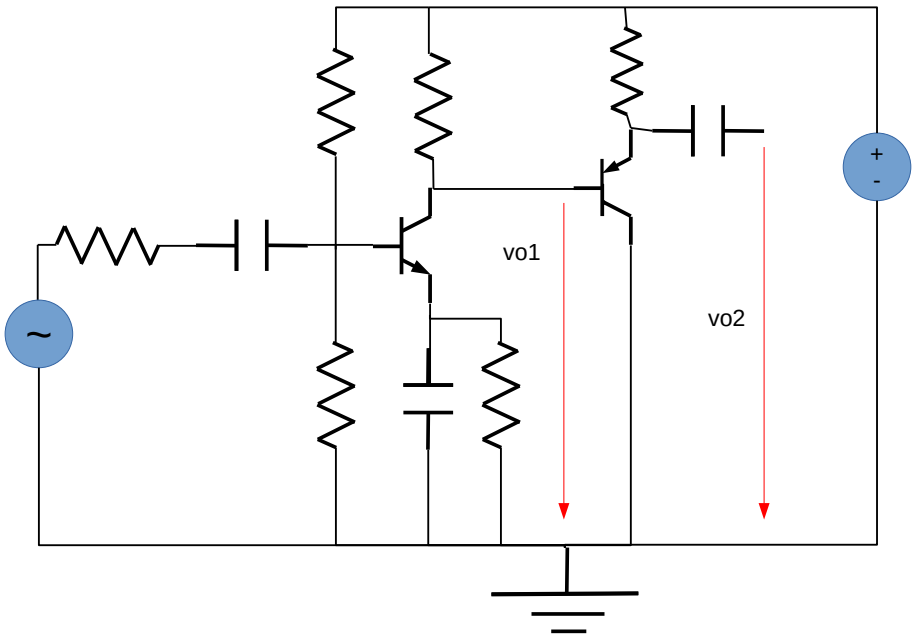

Figure 1: Final circuit

The individual costs of the components used:

Name	Value
R	27.3 kΩ
C	21 μS
Transistors	25 Units

Figure 2: Costs

2 Simulation analysis

2.1 Simulating the AC/DC converter for 10 periods

As said in the introduction, the first step to this laboratory assignment was to simulate an Audio Amplifier using the script given by the professor in NGSpice. This script included both a gain stage as well as an output stage.

After running the given script and implementing some code in order to get the figures asked by the professor, we performed incremental modifications to increase the merit figure.

2.2 Operating Point

After modifying the circuit we made NGSpice output the operating point values for every branch in the circuit in order to compare the results with the ones we got in the Theoretical Analysis in Octave.

The results we got are in the table below

Name	**Values [V or A]**
base	1.687387e+00
coll	2.600079e+00
emit	9.748156e-01
emit2	3.376090e+00
in	0.000000e+00
in2	0.000000e+00
out	0.000000e+00
out0	0.000000e+00
vcc	1.200000e+01

Figure 3: Simulation Operating Point

2.3 Output Voltage Gain in the Passband

Another value requested by the laboratory assignment was the output voltage gain in the passband. This was achieved by dividing the output voltage by the input voltage.

In the images below we can see both the input and output voltages plotted. The voltage gain value obtained is also in the table below:

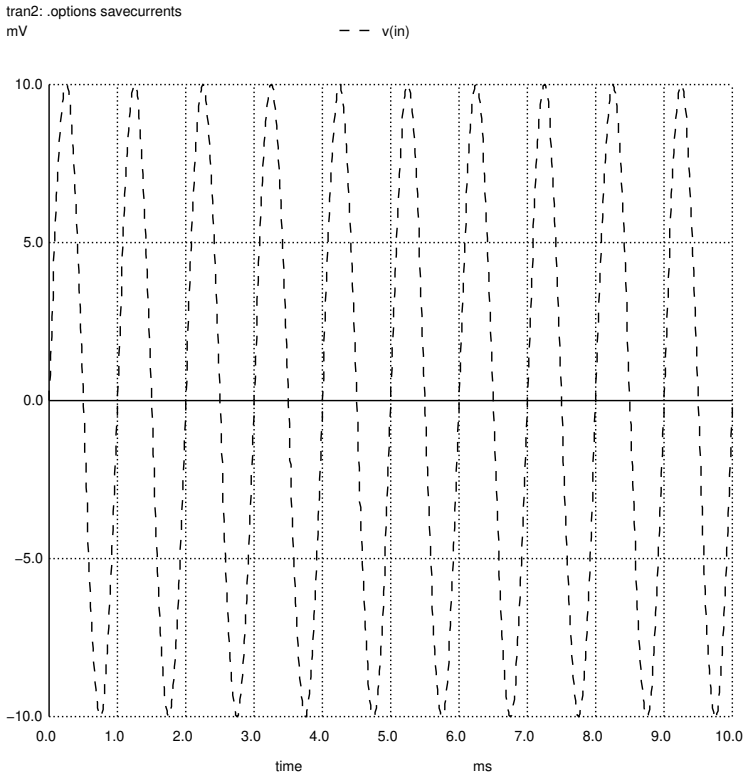

Figure 4: Input Voltage.

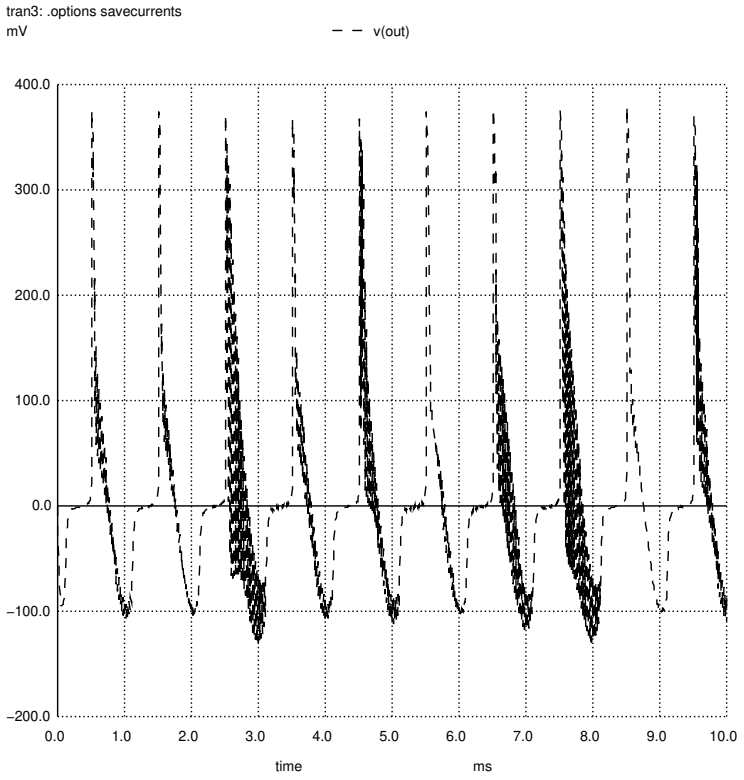

Figure 5: Output Voltage.

Name	Value [V]
voltagegain	9.471953e+01

Figure 6: Simulation Voltage Gain

2.4 Lower and Upper $3dB$ cutoff frequencies and Bandwidth

After getting the output voltage gain in the previous subsection, we plotted the voltage gain in dB in order to the frequency so that we could get the bandwidth.

In the image below we can see the plot described above and the $3dB$ line. The lower and upper cutoff frequency and the bandwidth are also in the table below with $f1$ being the lower cutoff frequency and $f2$ the upper cutoff frequency.

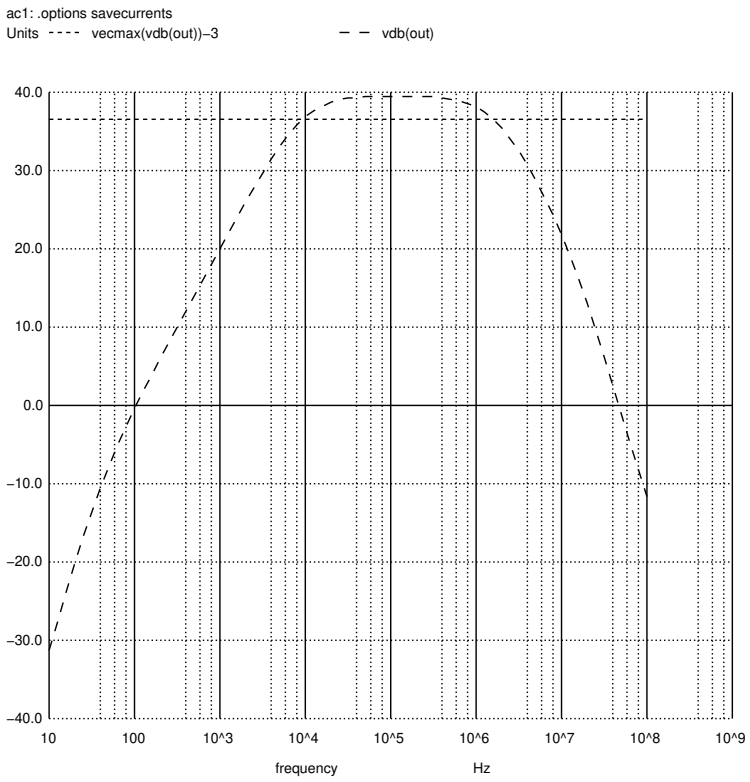

Figure 7: Frequency Analysis

Name	Value [Hz]
f1	1.051675e+02
f2	4.698041e+07
bandwidth	4.698030e+07

Figure 8: Simulation Bandwidth

2.5 Input and Output Impedances

Lastly, we made NGSpice give us the input and output impedances.

The results we got are in the table below:

Name	Value [Ω]
inputimpedance	5.931664e-01,-8.94162e-02
outputimpedance	8.000000e+00,-0.000000e+00

Figure 9: Simulation Input and Output Impedances

3 Conclusion

Summing up, this laboratory provided us the opportunity to understand how an audio amplifier circuit works with both its gain and output stages.

Similarly to the previous lab assignment, there are some differences between the theoretical and simulation values obtained. This can be explained by the non linear components used in this laboratory: the transistors. In the first 2 lab assignments only linear components were used and because of that the simple theoretical analysis made matched perfectly the simulation analysis, as it should. This was no longer the case in this assignment.

As for the merit figure calculation, we used Spice's values as they provide the most accurate results.

Finally, we are going to compare the results from simulation and theoretical analysis side by side:

Name	Value

Figure 10: Merit Figure Table

Name	Value [V or A]

Figure 11: Theoretical Operating Point

Name	Value [V or A]
base	1.687387e+00
coll	2.600079e+00
emit	9.748156e-01
emit2	3.376090e+00
in	0.000000e+00
in2	0.000000e+00
out	0.000000e+00
out0	0.000000e+00
vcc	1.200000e+01

Figure 12: Simulation Operating Point

Figure 13: Theoretical Output Voltage

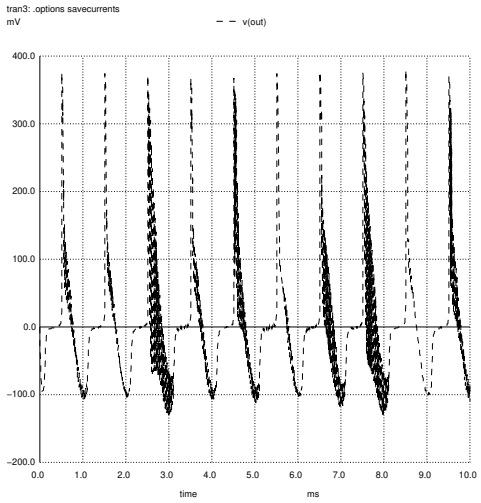

Figure 14: Simulation Output Voltage

Figure 15: Theoretical Gain Frequency Response

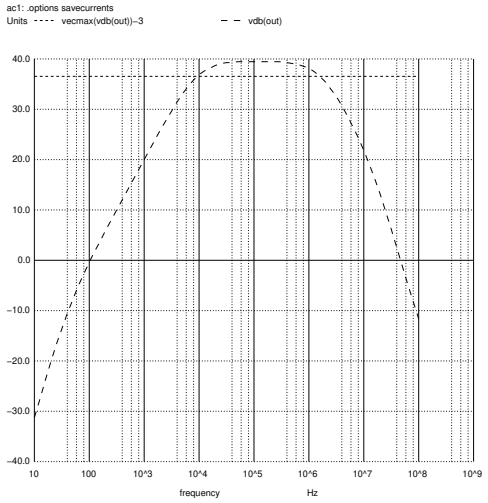

Figure 16: Simulation Gain Frequency Response

Name	**Value [Ω]**

Figure 17: Theoretical Bandwidth

Name	Value [Ω]
f1	1.051675e+02
f2	4.698041e+07
bandwidth	4.698030e+07

Figure 18: Simulation Bandwidth

Name	Value [Ω]

Figure 19: Theoretical Input and Output Impedances

Name	Value [Ω]
inputimpedance	5.931664e-01,-8.94162e-02
outputimpedance	8.000000e+00,-0.000000e+00

Figure 20: Simulation Input and Output Impedances