Circuit Theory and Electronics Fundamentals

Lab 4 - Audio Amplifier

Aerospace Engineering

Laboratory Report

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Eva Claro, 95785

Miguel Isidoro, 95834

Pedro Braz, 95837

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1 Introduction

This report is being made for the subject of Circuit Theory and Electronics Fundamentals and is related to the forth laboratory being its objective to develop an audio amplifier circuit (made of Bipolar Junction Transistors) by choosing the architecture ot the Gain and Output amplifier stages. The circuit is shown in **??**.

In Section 2 a theoretical analysis will be made and it can be decomposed in two stages: the gain stage where the objective is to have the maximum gain possible and the output stage whose objective is to lower the impedance of the amplifier. Secondly, in Section 3 it will be simulated the circuit using ngspice tools. Following with both results from Section 2 and Section 3 being compared and commented in Section **??**.

Also, it is important to notice that were used two types of BJTs transistors: BC557A (PNP type) and BC547A (NPN type).

Finally, the conclusions of this study are outlined in Section 4.

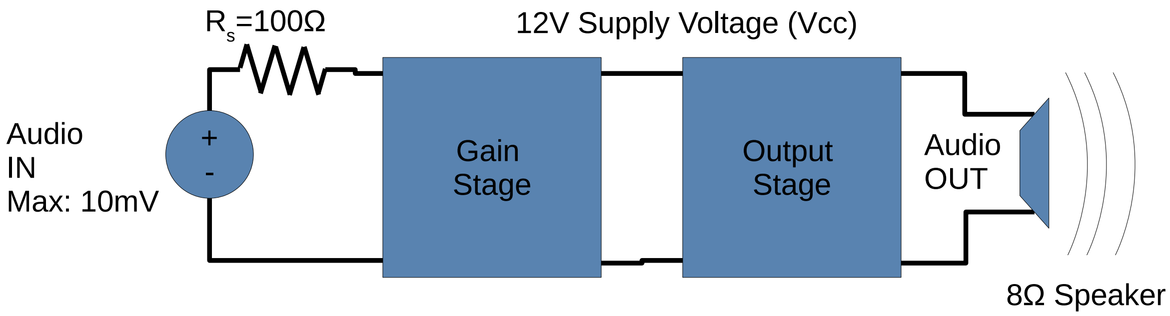

Figure 1: AC/DC converter circuit

2 Theoretical Analysis

In this section, the output voltage, voltage ripple and envelope detector output of the circuit shown in Figure 1 will be analysed theoretically.

As we were free to choose the circuit, these are the values that we decided to use for the resistors and the capacitor, as well as the given values of the voltage and frequency of the primary circuit in the transformer.

Name	Value [V/Ohm/F]
IB1	5.004416e-05
IC1	8.942891e-03
IE1	8.992935e-03
cost	1.819000e+02
VO1	3.057109e+00

Table 1: Given and choosen variables of the circuit

By using a transformer with a proportion of 1:16, we were able to change the voltage from a value as high as 230V is in the primary circuit to a value which is much closer to the aim (12V) in the secondary circuit, with the voltage being shown in Figure 2. However, we also needed two essencial components in order to change the AC source to a DC voltage.

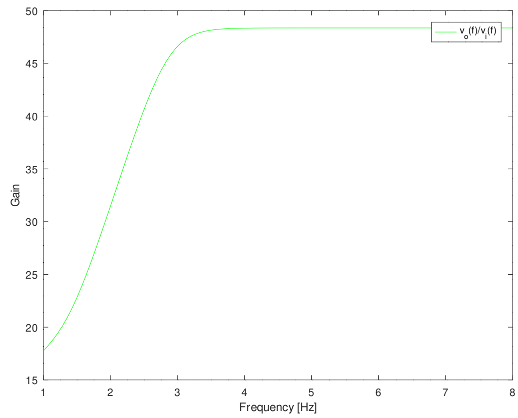

Figure 2: Output voltage of the secundary circuit

The first thing that the circuit does is transforming the voltage coming from the transformer ($vout$) to its absolute value ($vOhr$). This happens due to the 45 degree 4 diode circuit which is a full wave rectifier. (Note: the diodes are considered to be ideal for the theoretical calculations).

Then, the voltage enters in the envelope detector, where the voltage passing the capacitor starts to have behavior closer to a DC voltage. The result can be seen in the Figure 3, where we can see that the amplitude clearly decreased. We calculated the times when the diodes were ON and OFF. The equation 1 gives us the expression that we needed to compute the values of $tOFF$.

$$t_(OFF) = 1/w * atan(1/(w * R1 * C)) \tag{1}$$

While $t < tOFF$

$$vOenv(t) = vOhr(t) \tag{2}$$

And for $t > tOFF$

$$vOenv(t) = abs(vout * cos(w * tOFF) * exp(-(t - tOFF)/(R * C)) \tag{3}$$

With vOenv being the value of the voltage in the envelope detector.

The voltage ripple (the difference between the maximum and minimum value of the voltage) and the average value for the envelope detector are given in the following table.

Name	**Value [V]**
Gain stage- AV1	2.627909e+02 V
Output stage stage -AV2	9.963116e-01 V
Bandwidth	9.999045e+06 Hz
Cut Off Frequency	9.545485e+02 Hz

Table 2: Voltage Ripple and Average Voltage for the Envelope Detector

For the last segment of the circuit, the voltage regulator, we have 20 diodes in series that make a almost perfect DC, by reducing the majority of the noise produced. For the computation of the values, we decided to divide the DC component ($dcvOreg$) from the AC one ($acvOreg$). For the DC component, we analysed the voltage of the 20 diodes and, if it was superior to the average value of the vOenv, then

$$dcvOreg = VOn * ndiode \tag{4}$$

If not

$$dcvOreg = vOenvmedium \tag{5}$$

This happens in order to understand if the vOenv is a voltage with a bigger value than the maximum value the diodes can handle. For the AC component, we start by calculating the value of r_D, which is the resistance value of each diode

$$r_D = eta * v_t/(I_s * exp(VOn/(eta * v_t))) \tag{6}$$

With the value of r_D, we now are able to calculate the value of the AC component.

$$ac_vOreg = (ndiode * r_D)/((ndiode * r_D) + R2) * (vOenv - dc_vOreg) \tag{7}$$

To calculate the final value of the voltage leaving the regulator (vOreg), we simply add the AC and DC component, which gives us a value extremely close to 12V and with a small amplitude, as it can be seen in the Figure **??** (final value) and **??** (difference to 12V).

The voltage ripple (final amplitude) and the average value (DC value) for the voltage are given in the following table.

Name	**Value [V]**
Imput impedance (Gain stage)- ZI1	4.844336e+02 Ohm
Output impedance (Gain stage)-ZO1	8.862848e+02 Ohm
Imput impedance (Output stage)-ZI2	8.598855e+03 Ohm
Output impedance (Output stage)– ZO2	3.021730e-01 Ohm
Output impedance-ZO	3.981969e+00

Table 3: Voltage Ripple and Average Voltage for the Voltage Regulator

3 Simulation Analysis

This section covers the audio amplifier circuit simulation using the Ngspice tool.

As asked in the lab assignment, a NPN transistor and a PNP transistor were used in gain stage and output stage respectively. The goal was to calculate the impedances (Z_I and Z_O), the cut off frequencies (), the bandwidth (the difference between the cut off frequencies) and the total gain.

It was also confirmed if the BJTs are on the F.A.R. (forward active region) by comparing V_{CE} and V_{BE} for NPN type and V_{EC} and V_{EB} for PNP type.

Later in this report, we will compare this results with the theoretical ones but for now we will just show them.

The Table 4 and 5 shows the BJTs voltages and their F.A.R. confirmation.

Name	Value [A or V]
V(CE)	2.78156
V(BE)	0.70931
V(CE)¿V(BE)	Yes

Table 4: F.A.R. confirmation - BC547A (NPN type)

Name	Value [A or V]
V(EC)	4.49605
V(EB)	0.817257
V(EC)¿V(EB)	Yes

Table 5: F.A.R. confirmation - BC557A (PNP type)

In the next table it is presented the results asked.

Name	Value [A or V]
VGain	37.9181
Bandwidth	1.55393E+06
COFreq	8793.49

Table 6: Ngspice simulation results

The merit obtained by the groups is presentend in the following table.

Name	Value [A or V]
Cost	123.208
merit	54.3849

Table 7: Cost and merit results

Name	Value [A or V]
Zin	-548.062 + 82.7641 j

Table 8: Merit values

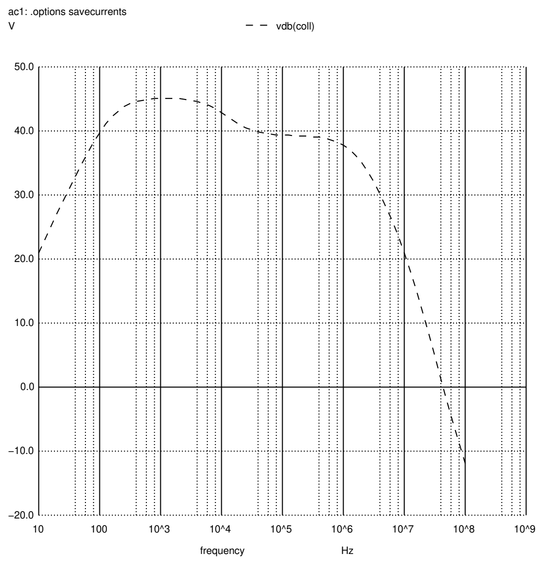

Figure 3: Output Voltage of the envelope detector v(4)

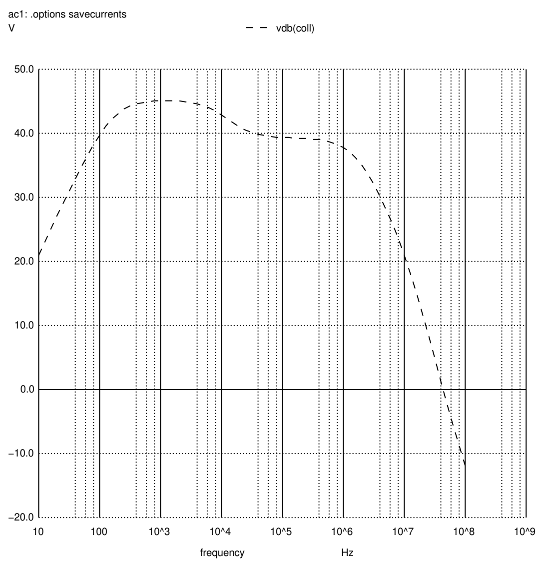

Figure 4: Input Voltage of the secondary circuit (v(2)-v(3))

4 Conclusion

The objective of this laboratory assignment was to develop an audio amplifier circuit and the main goal was achieved. However by observing analysis and simulation results it can be seen a difference between the two. This is the resukt of using a non-linear circuit whereas the model used by NGSpice is far more complex than the theoretical model used. Regarding this one and despite the differences, the theoretical model gives good results and can be used when there is no simulation tools to use or to quickly confirmed the simulation results obtained.

The objective of this laboratory assignment was to develop an audio amplifier circuit and the main goal was achieved. However it was achieved not having the best merit. The merit of the circuit was obtained by trial and error, a method that is not perfect and does not result in the best possible results. In this way, we concluded that in order to obtain good results, we were obliged to "yield" part of the merit.

We also note that this time, the results were not equal and exactly the same comparing both NGSpice and Octave.

However, we believe that the differences are not that significant and they can be explained by how NGSpice solves the circuit compared to how it was done in the theoretical analysis, processes that were also explanied on our lectures. To solve the circuit, NGSpice used far more advanced simulation methods for the diodes, with many more parameters, while we used an approximated model with V_{on} and an incremental resistor.

The error obtained between the average theoretical value and average simulated value is 4.86% which wouldn't be signficant in a real life cenario but for a online simulation is a bit significant.

This way, the objective should have never been to have equal results, but rather, have results that seemed reasonables, which we believe it was achieved. The merit obtained was 1.538149e-01.