Instituto Superior Técnico, University of Lisbon

Integrated Master in Aerospace Engineering

Circuit Theory and Electronics Fundamentals

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Fourth Laboratory Report

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1 Introduction

The objective of this laboratory assignment is to simulate a AC/DC converter circuit, which output voltage must be ideally 12 Volts. This converter must have an envelope detector and a voltage regulator. We are free to choose the architecture of both circuits, however we must consider the cost of the components in the circuit, the ripple voltage and the voltage difference between the output voltage and 12 Volts.

After multiple simulations, we have decided to simulate the following circuit. The envelope detector is composed by a full rectifier brigde and a resistor R_1 in parallel with a capacitor C, while the voltage regulator has a resistor R_2 in series with 20 diodes. The values of the components are exhibited in the table below. We have also taken advantage of the fact that, in this assignment, the number of turns n of the transformer will not influence the merit of our work. Therefore, as you can see below, we used an unusual value for n.
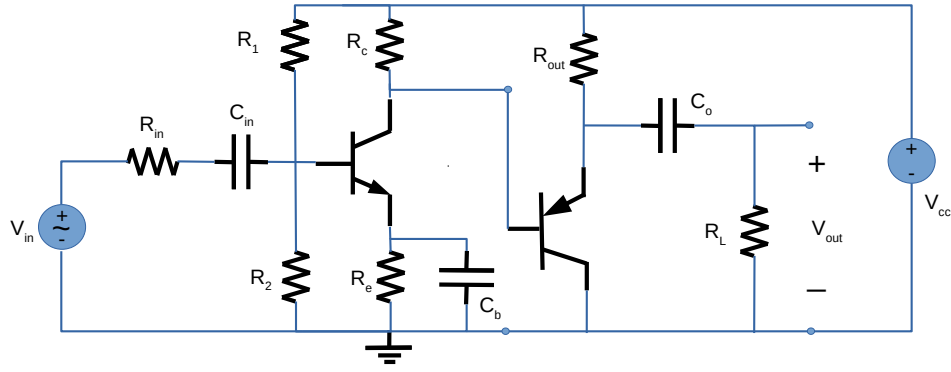
Figure 1: AC/DC converter circuit.

In Section **??**, a theoretical analysis of the circuit, performed on Octave, is presented. In Section **??**, the circuit is analysed by simulation, using NGSpice, and the results are compared to the theoretical results obtained in Section **??**. The conclusions of this study are outlined in Section **??**.

2   Theoretical Analysis

In this section, the circuit shown in Figure **??** is analysed theoretically. We will begin by analyzing the Envelope Detector circuit and, after that, the Voltage regulator circuit, in order to predict their outputs.

The theoretical values will be obtained by applying Kirchhoff laws and the diode equations. Considering the circuit of Figure **??**, it is composed by a Voltage source, a transformer, an envelope detector and a voltage regulator.

Name	Value
V_{CC}	1.200000e+01 V
R_S	1.000000e+02 Ohm
R_{B1}	8.000000e+04 Ohm
R_{B2}	2.000000e+04 Ohm
R_{C1}	1.000000e+03 Ohm
R_{E1}	1.000000e+02 Ohm
C_S	1.000000e-02 F
C_b	1.000000e-02 F

Table 1: Gain Stage Data

Name	Value
V_T	2.500000e-02 V
$beta$	1.787000e+02
V_A	6.970000e+01 V
V_{BEON}	7.000000e-01 V

Table 2: Bijector Data

2.1 Gain Stage

2.1.1 Operating Point

Name	Value
R_B	1.600000e+04 Ohm
V_{eq}	2.400000e+00 V
I_{B1}	5.004416e-05 A
I_{C1}	8.942891e-03 A
I_{E1}	8.992935e-03 A
V_{E1}	8.992935e-01 V
V_{O1}	3.057109e+00 V
V_{CE}	2.157816e+00 V

Table 3: OP - Gain Stage

3 Simulation Analysis and Comparison with Theoretical Results

3.1 Transient Analysis

Figure **??** shows the simulated transient analysis results for input voltage of the secondary circuit, the envelope detector output voltage, V_3, the voltage regulator output voltage, V_4 and the average voltage difference, V_4-12 Volts.
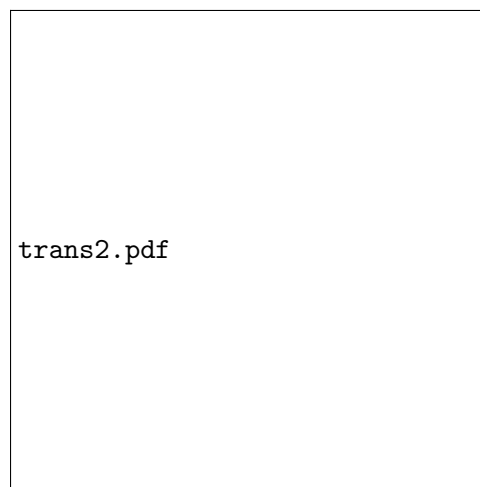

trans2.pdf

Figure 2: Transient input voltage of the secondary circuit and transient output voltage of both the envelope detector and voltage regulator and the average voltage difference.

By analysing the result of the simulation we notice that the output solution resulted in an aproximated sinusoidal fuction: in fact, because of the average voltage is not ideal, the curve has an upward sinusoidal motion and a downward motion described by a negative exponential. The input voltage is described by a sinusoidal fuction, as expected. As far as the result is concerned, the form of the theoretical solution match the one obtained by NGSpice. Note that, because of the scale, we can not see the wave form of the ripple voltage and voltage difference because they are very small, which means that we obtained a decent result for 2 of the 3 parameters that influence the merit.

Table **??** shows the measured results for the maximum, minimum and average output voltage of the circuit V_4. Notice that the values on the right were obtained by Octave, therefore

they are the theoretical values, which we already mentioned previously but, to facilitate the comparison between the simulation and theoretical values, we mentioned them again.

Name	Voltage[V]	Node	Voltage[V]

Table 4: Measured maximum, minimum and average output voltage of the circuit. The values on the right are the theoretical values for the same voltages in the circuit.

Compared to the theoretical analysis results, we noticed that the values are slightly different, this happens mainly because in order to do the theoretical analysis we assumed that the diodes were ideal, something that it is not verified in the simulation since a real diode model was used. Despite that, we realise that the error obtained is minimal making us conclude that, not only was this assignment objective achieved but we can also verify that the ideal diode model is indeed a good approximation.

Table **??** shows the ripple voltage of the circuit and the average voltage difference between the output voltage and 12 Volts. Again, we show the theoretical values obtained for this step, to make it easier to compare between simulation and theoretical values. It is also worth noticing that, for the reasons mentioned previously, the results vary slightly between the theoretical and the simulation analysis.

Name	Voltage[V]	Name	Voltage[V]

Table 5: Ripple voltage maxV_4 - minV_4 and the average voltage difference V_4 - 12. The values on the right are the theoretical values for the same voltages in the circuit.

Table **??** shows the total cost of the circuit and the figure of merit of the circuit. Note that we used the simulated voltage results to calculate the value of merit.

	Monetary Units [MU]

Table 6: Total cost

Formula	Merit

Table 7: Figure of merit with a cost of 222.4 monetary units (MU).

By analising the figure of merit, we note that its value, considering the multiple results obtained for different values of the components and layots of the circuit, is reasonable. Nevertheless, we consider the result not satisfying, since we obtained a merit of around 900 when we eliminated resistor R_1 and added 15 more diodes to the series (reducing considerably the cost, the ripple and the average voltage difference). However, the AC/DC converter obtained would not be an efficient one, since it would have an enourmous stabilization time and no resistor connected in parallel with the capacitor.

4   Conclusion

In this laboratory assignment the objective of analysing an AC/DC converter, made of an envelope detector and a voltage regulator, has been achieved. The theoretical analysis was performed with the help of the Octave math tool and the circuit simulation using the Ngspice tool.

For both analysis, we plotted the output voltages of both the envelope detector and voltage regulator and, in the case of the regulator, we also determine the maximum, minimum and average output voltage, so we could measure the voltage ripple and difference between the output and 12V, to calculate the figure of merit. As previously mentioned, the simulation results had slight differences from the theoretical ones. However, we designed an acceptable AC/DC converter - furthermore, we obtained a low stabilization time and a decent figure of merit, despite the cost being too high.