Circuit Theory and Electronics Fundamentals

Lab 3: AC/DC Converter

Technological Physics Engineering

Patrícia Lopes 96507, Catarina Cartaxo 96516, Francisco Carreira, 96527

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1 Introduction

The main objective of this laboratory assignment is to develop a circuit that convert a AC sinal (230V) to a DC sinal (with 12V), so we choose one architecture for the Envelope Detector and Voltage Regulator to be able to have that. We decided to separate this work in three different sections.

In the first one, using Ngspice tools, in the second section Simulation 2, we will present a simulation of the circuit. Then, in Theoretical Analysis 3, we present a suitable theoretical model able to predict the output of the Envelope Detector and the Voltage Regulator circuit. We also explain the reason of each component that we used in the circuit.

Finally, we put the graphs side by side and compare it and explain the differences.

Lastly, Conclusion 4, the contents of the report will be summarised and the achieved results discussed.

We decided to use the circuit below. The reason why this circuit was chosen is explained later.

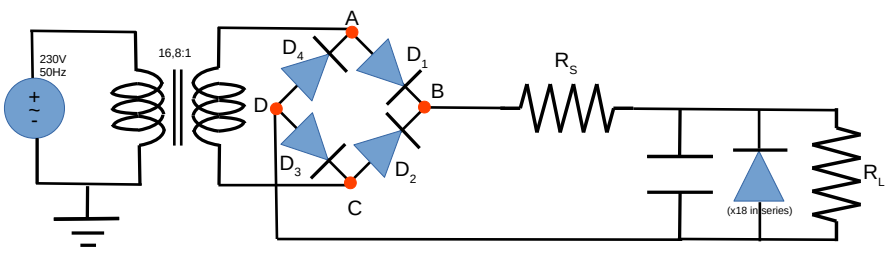

Figure 1: Circuit

2 Simulation Analysis

We obtained the plots of the output of the Envelope Detector,

the output of the Voltage Regulator

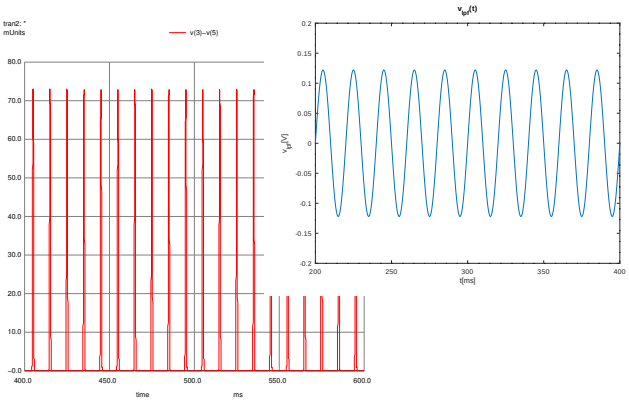

Figure 2: Graphs of the output of the envelope detector. Simulation on the left, theoretical analysis on the right.

and the plot of (V0-12) for 10 periods, respectively.

For this analysis, we substitute the transformer with a current controlled current source ($i1 = ni2$) on the left side and with a voltage controlled voltage source ($v2 = nv1$) in wich we definied $n = 16.8$ spirals. Moreover, all the diodes utilised were default.

3 Theoretical Analysis

In order to create an AC/DC converter that converts $230V$ AC to $12V$ DC current, the first component we need is a transformer. The transformer converts the $230V$ AC power source to a $12V$ AC power source. To calculate the turn ratio n of the primary and secondary coils, we apply the transformer equation

$$\frac{N_p}{N_s} = \frac{V_p}{V_s} \tag{1}$$

The next component we need is a diode. A diode is a semiconductor device that allows current to flow in one direction, but prevents it from flowing in the opposite direction.

When current is flowing in reverse biased mode, the diode is off, but when it flows in forward biased mode it turns on. Therefore, the diode allows us to convert AC into DC. In order to achieve our goal, we decided to use a full wave bridge rectifier.

We start off by labelling the diodes and the nodes between them, to better explain how the circuit transforms AC into DC. At the input, the primary side of the transformer, we have an alternating signal, which can be described by a sine wave.

Considering the positive half cycle of the sine wave, on the secondary side of the transformer, one side is positive and the other negative. Since conventional current flows from high potential

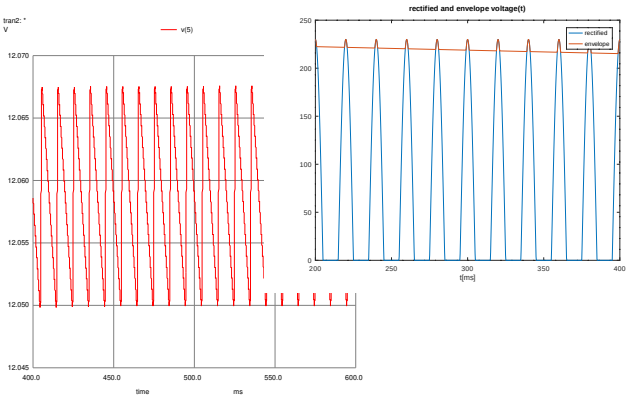

Figure 3: Graphs of the output of the voltage regulator. Simulation on the left, theoretical analysis on the right.

to low potential, the current flows from the positive terminal to the negative terminal. Consequently, current flows from the positive terminal to point A and then it flows to D_1 since it is in forward biased mode. It can't flow from point A to point D, since D_4 is in reverse biased mode and it blocks any current going in that direction, unless the voltage is extremely high.

Ignoring everything except the wave bridge rectifier and the load resistor, as current flows from A to B through D_1, it flows through the load resistor and then to point D. From D, since it makes no sense for current to go back to A and make a loop, it goes to C through D_3 and from there finally to the negative terminal. That's the flow of current during the positive half cycle of this circuit. Considering the negative half cycle of the circuit, the positive and negative terminals switch places and the analysis done is pretty similar to the one we made for the positive half cycle.

In either case, the current is flowing in one direction through the load resistor, from the top to the bottom, and that is the goal, to create a DC current. At the output we have a DC voltage that is not constant. Now our goal is to take this pulsating DC output and convert it into a steady DC output. One way to do that is to introduce a capacitive filter.

Consequently, by adding a capacitor parallel to the load resistor we can reduce the fluctuations in voltage at the output. So, instead of having a pulsating DC output, the output will more steady with less fluctuations. These fluctuations in the voltage output are known as the ripple voltage. By increasing the capacitance of the capacitor, the ripple voltage decreases. It will not be perfectly constant, but it will be fairly steady for the most part.

Another thing we have to take into account is the surge current and that is when the capacitor is charging. While it is charging, a lot of current will be flowing through the capacitor and wires for a short period of time. So to reduce the surge current and prevent the diodes from burning, we add a current limiting resistor R_s in series with the wave bridge rectifier and the capacitor. The value of R_s has to be so the output voltage is unchanged and remains at 12V

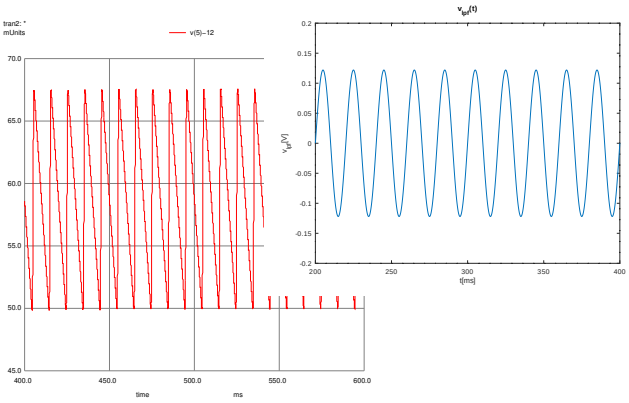

Figure 4: Graphs of v0-12. Simulation on the left, theoretical analysis on the right.

$$V_{out} = \frac{R_L}{R_L + R_s}(V_B - V_D) \tag{2}$$

4 Conclusion

In this laboratory assignment the objective of built and analyse a circuit capable of converting a AC voltage to a DC has not been quiet achieved. The time analyses has been performed both theoretically using the Octave maths tool and by circuit simulation using the Ngspice tool. The simulation results not always matched with the theoretical results perfectly. However, the final results of the output voltage was very similar between the two analyses.