Circuit Theory and Electronics Fundamentals

T3 Laboratory Report

Group 34

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Contents

1 Introduction

The objective of this laboratory assignment was to create a circuit that would transform an input AC voltage of amplitude 230V and frequency of 50 Hz to an output DC voltage of amplitude 12V and frequency 50Hz.To do this an Envelope detector, a Voltage Regulator and a Transformer were used. This last component was not actually modeled in the simulation and theorethical analysis. It was considerared that the transformer would be represented whith an alternated voltage source that would connect to the envelope detector and would reduce the amplitude of the first source in a ratio of n:1.This ratio will be decided during the simulation and theorethical analysis.

To determine whether or not the circuit was good when compared to others a merit classification sistem was created. This merit sistem took into account the cost of the components used and the ripple and average amplitude of the output voltage.The merit of the circuit will determined according to the following equation:

$$MERIT = \frac{1}{cost * (ripple_{reg} + |average_{reg} - 12| + 10^{-6})} \tag{1}$$

and the cost of the componets are the following: cost of resistors = 1 monetary unit (MU) per kOhm, cost of capacitors = 1 MU/uF and cost of diodes = 0.1 MU per diode. The voltage source that represents the transformer was not taken into account in the cost.

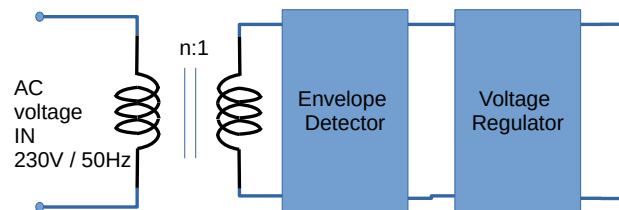The circuit that was implemented can be seen in **Figure 1**.

Figure 1: Circuit in study

In Section 2, a theoretical analysis of the circuit is presented. Here the circuit is analised using suitbale theorethicals models for the diodes in order to predict the output of the Envelope Detector and Voltage Regulator circuits. The output DC level and the voltage ripple are calculated and the plots for the voltages at the output of the Envelope Detector and Voltage Regulator circuits are presented, as well as the plot for the diference to 12 of the output of the regulator. In Section 3, the circuit is analysed by simulation using the program Ngspice.In Ngspice the default model for the diode was used. The AC/DC converter was simulated for 10 periods and the voltage average and ripple were mesured using built in functions of the program.The same plots produced in the theoretical analysis were made in this section by simultaion.The conclusions of this study are outlined in Section 4, where the theoretical results obtained in Section 2 are compared to the simulation results obtained in Section 3.

2 Theoretical Analysis

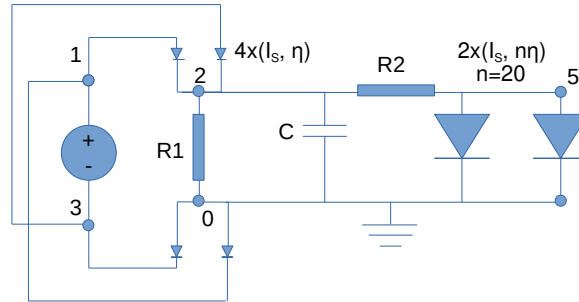In this section, the circuit shown in **Figure 2** is analysed theoretically.

Figure 2: Diagram of the circuit considered for the computations and simulations

The transformer used has an n:1 ratio. This means that the initial voltage source will have it's Amplitude (A) reduced by a factor of n. Therefore we can represent the voltage at the terminals of the transformer as a voltage source with an Amplitude of A/n and with the same frequency as the initial source.

The output of the transformer will be the input of our Envelope detector.The Envelope detector circuit is made up of a rectifier and a capacitor.The rectifier is a full-wave bridge rectifier circuit and is composed of 4 diodes and a resistor. The full-wave rectifier was used as oposed to a half-wave rectifier because the full-wave rectifier allows us to reduce the ripple without incrising the time constant which will avoid a big raise in costes. The full-wave rectifier reduces the ripple because the voltage that comes out of the transformer will leave the rectifier oscillating at twice the frequency and with less amplitude, which helps us in our ripple problem.

The output of the Envelope Detector will be the input of the Voltage Regulator. The voltage regulator is made up of 40 diodes and one resistence. The resistende is in series with a paralel of 2 rows of 20 diodes each. The diodes in each row are in series. The output of the paralel of diodes is the output of the AC/DC converter.

In the Envolope Detector the diode model used has an ideal diode and an voltage source while in the Voltage regulator de Diode model has a ideal diode, a voltage source and a resistor.

The ratio of the transformer and the values of the resistors, the capacitor nº of diodes are the following:

$n_{transformer} = 5.48 : 1$
$R_{env} = 100kohm$
$C_{env} = 100uF$
$R_{reg} = 120kohm$
$n_{diodes} = 40$

3 Simulation Analysis

In this section we will describe the steps needed to simulate this circuit using the software Ngspice. Three types of analysis will be performed: Operating Point analysis, Transient analysis ans Frequency analysis.

4 Conclusion

In this laboratory assignment the objective of creating a circuit that transforms an input AC voltage of 230V and frequency 50 Hz to an usable output DC voltage of 12V with minimun cost and ripple has been achieved .

The circuit created was analysed theoretically using the Octave maths tool, and by circuit simulation, using the Ngspice tool. The theoretical results obtained are very close to the simulation results. The slight differece obtained was mainly due to the fact that the models used for the diodes in the theorethical analysis differ from those used by Ngspice. The diode model used by Ngspice is way more complex than the one implemented theoretically. However due to the overall satisfactory match we can say that the theoretical model is acceptable due to it's low complexity and it's good results.

For more complex components and circuits, the theoretical and simulation models could differ more, given that the greater complexity of the models implemented by the simulator Ngspice, as well as the interactions between these, will be more noticeble when compared to the results obtained using the simpler models studied in the theoretical classes).

The value for the Merit was 2.7499 using the Ngsice's results and 3.6940 using Octave's theoretical results.