TÉCNICO LISBOA

Circuit Theory and Electronics Fundamentals

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T3 - AC/DC converter

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1 Introduction

The purpose of this laboratory assignment is to make an AC/DC converter, from AC(230V / 50Hz) to DC(12V), with the goal to get the highest merit, M, possible.

$$M = \frac{1}{cost * (ripple(v_O) + average(v_O - 12) + 10^{-6})}$$

After some simulations with different circuits, we found the circuit shown in Figure 1 yielded the best merit.

The circuit above is equivalent to the circuit in Figure 2.

In Section 2, it is explained the process done and the circuit is analyzed by simulation using the software Ngspice.

In Section 3, an approximated theoretical model, using the software GNU Octave, of the circuit is presented.

In Section 4, a comparison is done between the results obtained by both analyses, theoretical and simulation.

In Section 5, a circuit with a low-pass filter, as shown in Figure 3 is analyzed by simulation using the software Ngspice.

The conclusions of this study are outlined in Section 6.

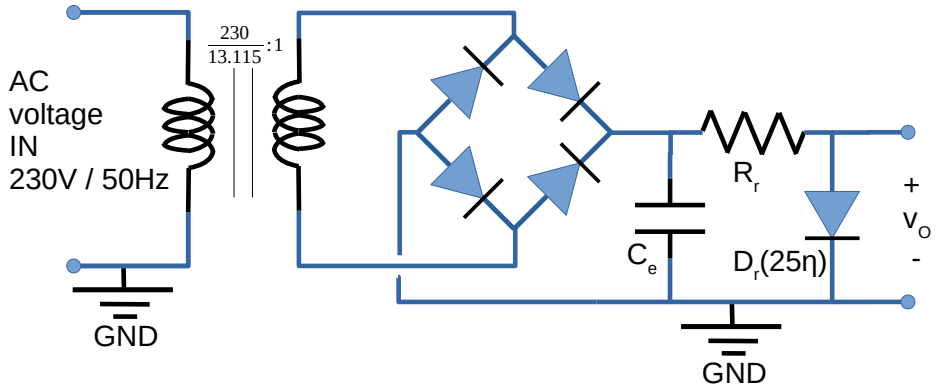

Figure 1: Circuit T3, with transformer.

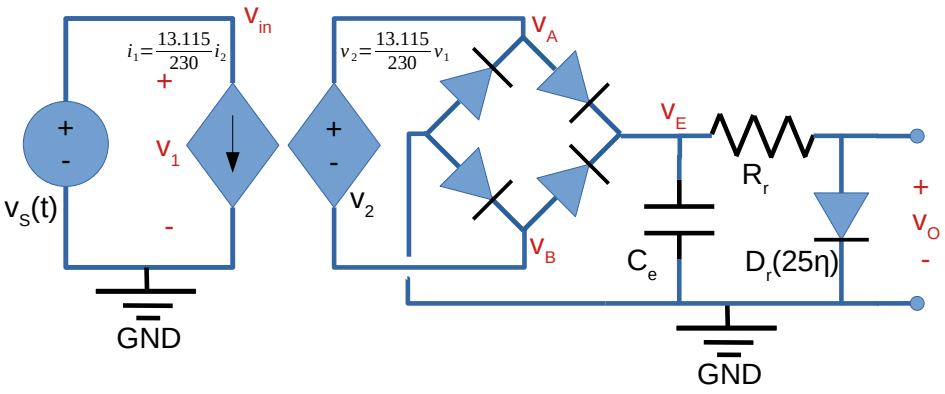

Figure 2: Circuit T3, with transformer equivalent.

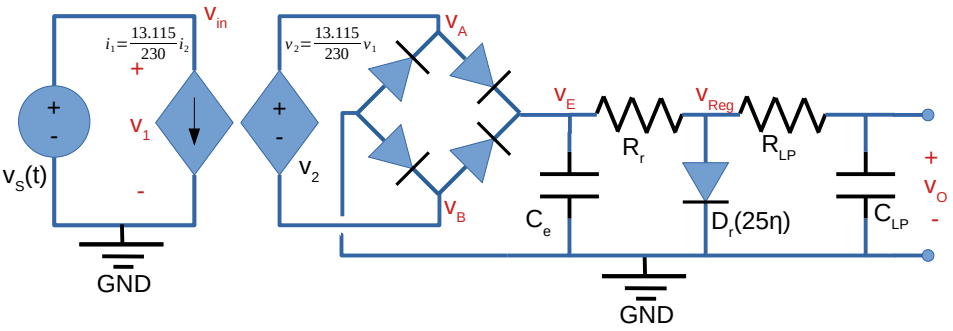

Figure 3: Circuit T3, with low-pass filter.

2 Simulation Analysis

2.1 Process

For an AC/DC converter is needed an envelope detector and a voltage regulator in parallel.

The envelope detector is usually a full-wave bridge rectifier in parallel with a capacitor and a resistor.

The voltage regulator is a resistor in series with a set of diodes.

After analyzing these two sub-circuits, we concluded that a resistor in parallel with the capacitor was not needed, since we had a resistor in the voltage regulator, and that was the only resistor necessary.

Sequentially, we tested different values in order to obtain the best merit possible.

2.2 Results

The plots obtained are shown in Figure 5. The ripple and average at the output of the envelope detector, ve, and voltage regulator, vo, and merit are presented in Table 1.

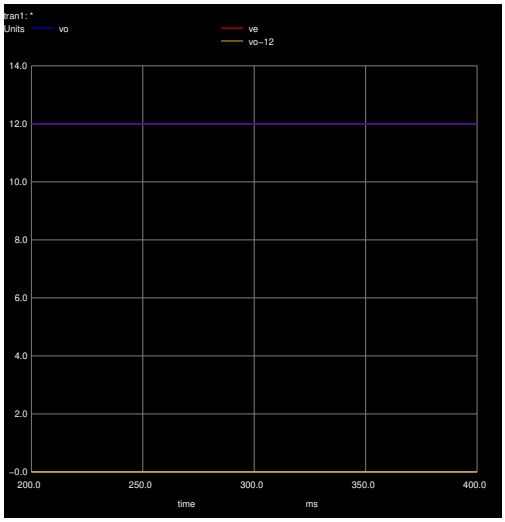

Figure 4: ve, vo, (vo-12)

Name	Value [V or %]
averageve	1.199996e+01
rippleve	1.050224e-02
averagevo	1.199984e+01
ripplevo	1.050037e-02
deviationperc	1.325901e-03
rippleperc	8.750427e-02
merit	2.345110e+01

Table 1: Results obtained.

3 Theoretical Analysis

In this section, the circuit shown in Figure 2 is analyzed theoretically, according to the following steps.

3.1 Step 1

The circuit was analyzed considering the voltage across C as constant,

$$\dot{v_C} = 0 \Rightarrow i_2 = i_D$$

, resulting in the following equations:

$$\begin{aligned} v_2 &= v_D + v_R + 25v_D + v_D \\ &= 27v_D + RI_s(e^{\frac{v_D}{V_T}} - 1) \end{aligned} \tag{1}$$

$$f(v_D) = 27v_D + RI_s(e^{\frac{v_D}{V_T}} - 1) - v_2 \tag{2}$$

$$f'(v_D) = 27 + \frac{RI_s}{V_T}e^{\frac{v_D}{V_T}} \tag{3}$$

$$v_C = RI_S(e^{\frac{v_D}{V_T}} - 1) + 25v_D \tag{4}$$

3.2 Step 2

The circuit was analyzed considering the voltage $v_2 < v_C$ and therefore the capacitor is discharging, resulting in the following equations:

$$f(v_D) = 25v_D + RI_s(e^{\frac{v_D}{V_T}} - 1) - v_C \tag{5}$$

$$f'(v_D) = 25 + \frac{RI_s}{V_T}e^{\frac{v_D}{V_T}} \tag{6}$$

$$\begin{aligned} i_C &= C\dot{v}_C \\ &= -i_D \\ &= -I_s(e^{\frac{v_D}{V_T}} - 1) \end{aligned} \tag{7}$$

$$\begin{aligned} \dot{v}_C &= -\frac{I_s}{C}(e^{\frac{v_D}{V_T}} - 1) \\ \Leftrightarrow v_{C\ next} &= -\frac{I_s}{C}(e^{\frac{v_D}{V_T}} - 1) * h + v_C \end{aligned} \tag{8}$$

3.3 Results

The results obtained are shown in Table 2, and the plots in Figure 5.

Name	Value
$Ripple\ (v_O)$	1.32645e-02 V
$Average\ (v_O)$	1.21368e+01 V
$Deviation$	1.14023e+00 %
$Ripple$	1.09291e-01 %

Table 2: Results obtained.

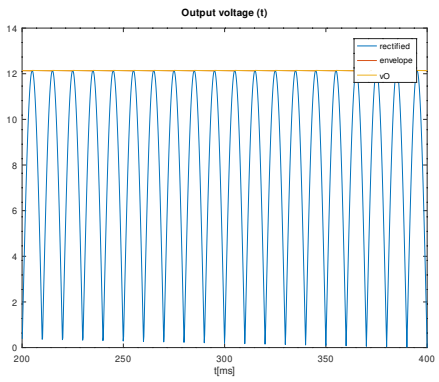

Figure 5: Plots obtained.

4 Comparison

Comparing the results achieved in the simulation, Table 1, and in the theoretical analysis, Table 2, it is possible to see a small difference.

This discrepancy may have resulted from the assumption made in Step 3.1, since $Ripple\ (\%)$ theoretical $\approx rippleperc$ simulated, and $Deviation\ (\%)$ theoretical $\not\approx rippleperc$ simulated. However this assumption is needed, since without it, the analysis would become very difficult.

Additionally, there would be always some very small differences due to the non-linearity of the equations.

5 Extra

Contrary to what was expected, the circuit with a low-pass filter, Figure 3, was found to yield a better merit, Table 3 and Figure 6.

Name	Value [V or %]
averageve	1.199979e+01
rippleve	9.391184e-03
averagevreg	1.199968e+01
ripplevreg	9.370051e-03
averagevo	1.199968e+01
ripplevo	9.368104e-03
deviationperc	2.690979e-03
rippleperc	7.806963e-02
merit	2.450776e+01

Table 3: Results obtained for a low-pass filter circuit.

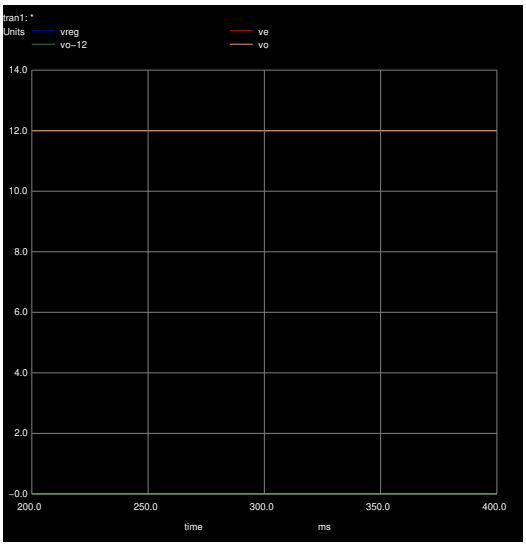

Figure 6: Plots obtained.

6 Conclusion

In this laboratory assignment, the objective of making an AC/DC converter shown in Figure 1 has been achieved. The circuit in Figure 2 has a merit of approximately 23,45 and a cost of 4 MU, with an average of 11,99984 V and a ripple of 0,0105 V (0,0875 %).