TÉCNICO LISBOA

Circuit Theory and Electronics Fundamentals

T3 Laboratory Report

Aerospace Engineering, Técnico, University of Lisbon

May 13, 2021

Group 19

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Contents

1 Introduction

The objective of this laboratory assignment is to convert an alternated current signal with 230V, 50Hz, to a 12V direct current source, using an envelope detector and a voltage regulator.

The circuit was simulated in NGSpice, with a theoretical prediction in Octave. The merit of this work is related to the ripple and cost of the components: the less ripple and the lower the cost, the higher the merit. In this assignment, the merit obtained was aproximately 0,26.

The merit is calculated using the following expression:

$$M = \frac{1}{Cost(ripple(v_0) + average(v_0 - 12) + 10^{-6})} \tag{1}$$

Where:

Cost = cost of resistors + cost of capacitors + cost of diodes

Cost of Resistors = 1 monetary unit per kOhm

Cost of capacitor = 1 monetary unit per μ F

Cost of diodes = 0.1Monetary units per diode

The final circuit obtainned is the one shown below in figure (Fig.1):

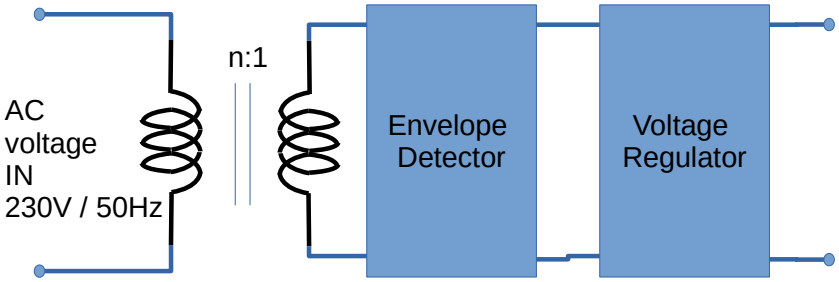

Figure 1: Final circuit

The individual costs of the components used:

- Diodes - cost: 2.3MU;
- Capacitor - 26MU;
- Resistances - 33.15MU.

The data used was the following:

Name	**Value**
R_1	26 kΩ
R_2	7.15 kΩ
C	26 μS
Diodes	19 Units

2 Simulation analysis

2.1 Simulating the AC/DC converter for 10 periods

As said in the introduction, the first step to this laboratory assignment was to simulate a simple AC/DC converter in NGSpice. The circuit features an ideal transformer, using a current controlled voltage source as well as a voltage controlled current source as explained by the professor in a previous lecture, as well as an envelope detector and a voltage regulator.

However, because it is known that the ideal transformer creates a new voltage and current with the same frequency as the original, instead of controlled sources, a simple sinusoidal voltage source would sufice. This AC/DC converter was simulated for 10 periods and all the analysis were made measuring on a $5e-5$ step in order to evaluate at least 1000 points during the 10 periods. In order to calculate this step, the frequency of the AC sourcecwas used to know the period and then multiplied by 10 in order to get the total time. We then divided the total time by 1000 points and made the step even smaller than that in order to make sure it had more than 1000 points but not too small that the program ran slowly.

2.2 Output voltage level

After describing the circuit we made NGSpice measure the average output voltage and using a transient analysis we plotted both the average and the signal of the output voltage in the same graph.

The table and the graph below show the obtained results.

Name	**Value [V]**
mean(v(n5)-v(n3))	1.200010e+01

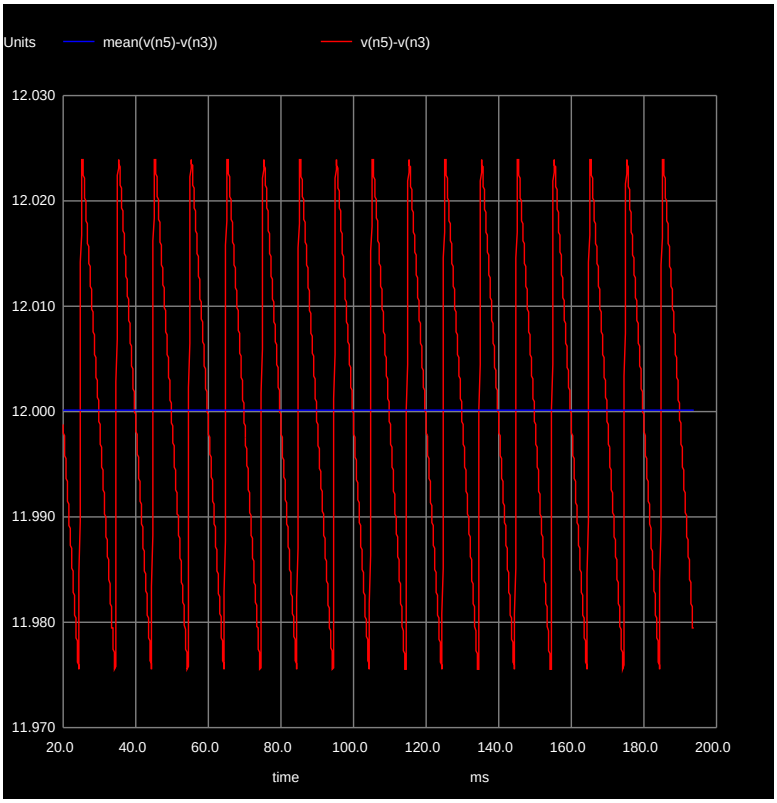

Figure 2: Plot of the average and the signal of the Output Voltage.

2.3 Output of the Envelope Detector and voltage Regulator circuits

The output voltages of both the Envelope Detector as well as the Voltage Regulator circuits were plotted and put each in a different graph as well as a graph with both voltages plotted.

The three graphs are in the images below.

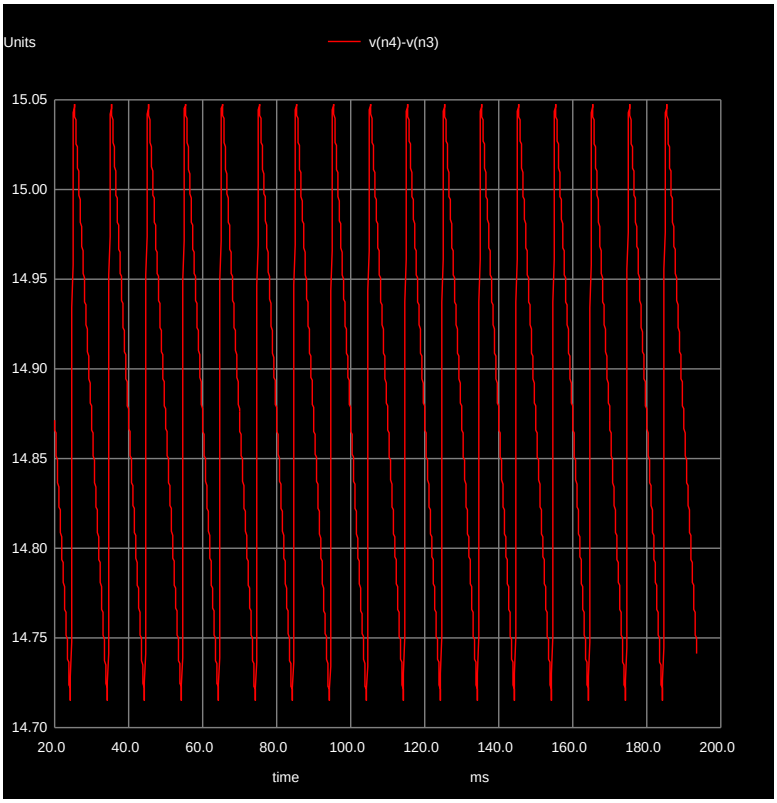

Figure 3: Envelope Detector Output Voltage.

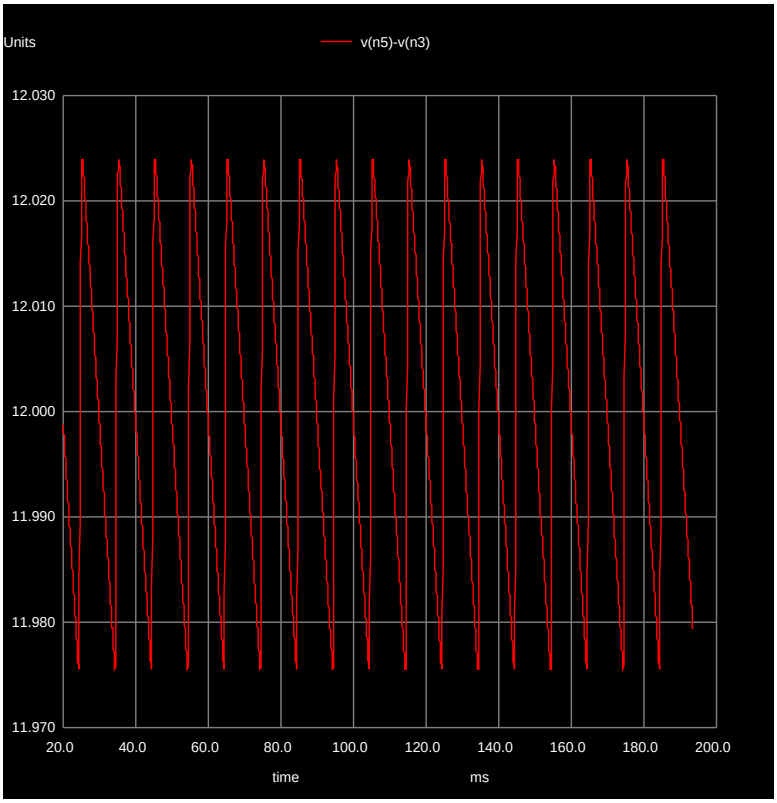

Figure 4: Voltage Regulator Output Voltage.

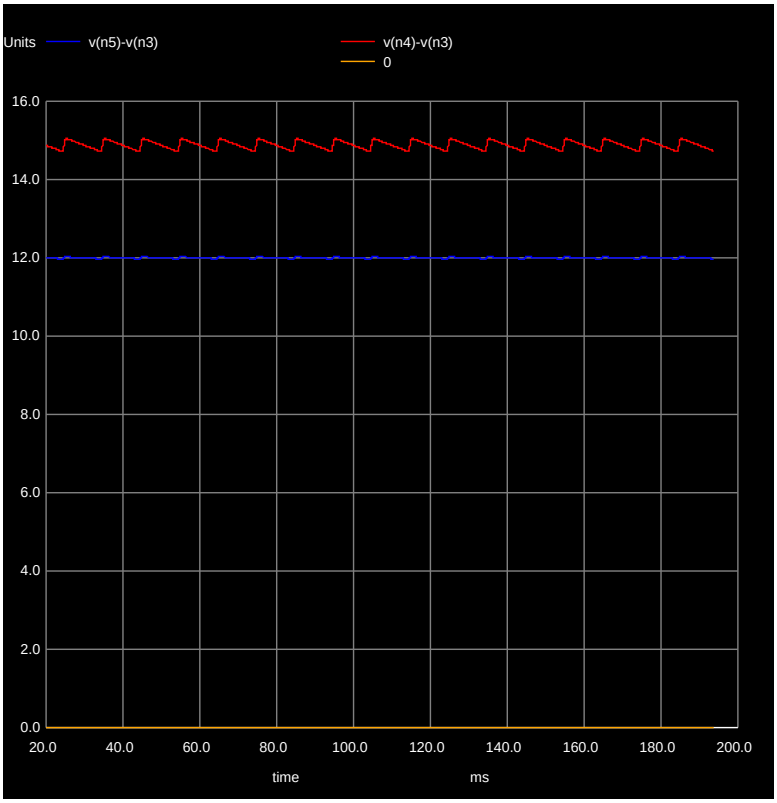

Figure 5: Envelope Detector and Voltage Regulator Output Voltages.

2.4 Output voltage ripple

We then made NGSpice measure the output voltage ripple, that is the difference between the maximum and the minimum values of the signal.

The result are the following:

Name	Value [V]
maximum(v(n5)-v(n3))-minimum(v(n5)-v(n3))	4.843233e-02

2.5 $v_0 - 12$ plot

Lastly, we plotted $v_0 - 12$, which corresponds to the output AC component plus the DC deviation, and calculated the deviation, using the mean value.

The plot can be seen in the image below, as well as the deviation in the table that follows.

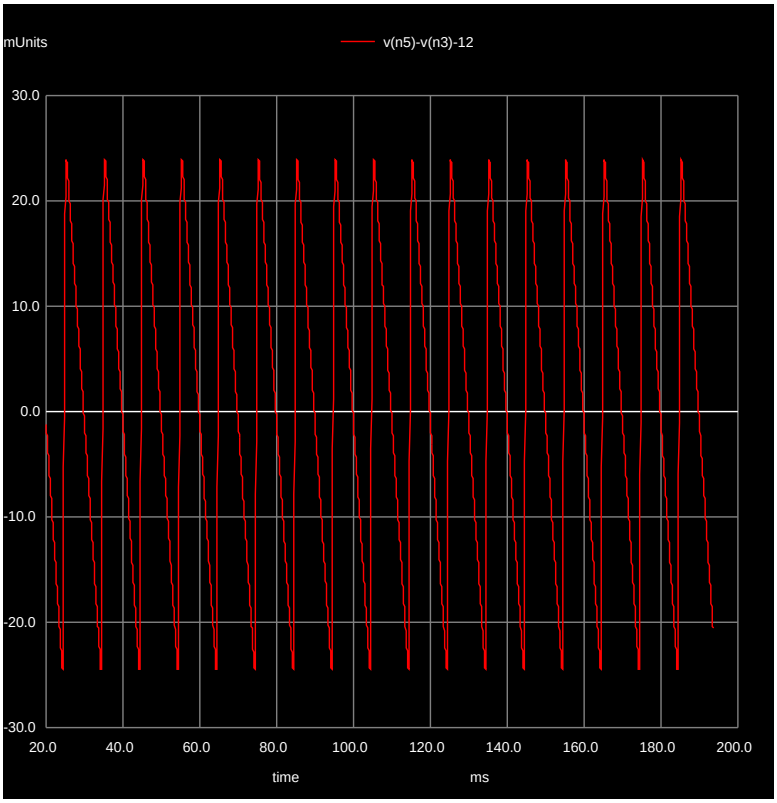

Figure 6: Output AC component + DC deviation.

Name	Value [V]
mean(v(n5)-v(n3)-12)	1.008162e-04

3 Theoretical Analysis

In this section are shown the obtained results using a suitable theoretical model able to predict the output of the Envelope Detector and voltage Regulator circuits. The theoretical output is calculated using an octave script. Within this script are used both Kirchoff's Laws and diodes equations as well as simplified models of the two.

3.1 Envelope detector

The main goal of an envelope detector is to restrict the voltage's amplitude. Different from the voltage regulator that decreases the ripple. As it was shown in the circuit's figure, the

envelope detector is, basically, the resistance and the capacitor in parallel. Its main function is to decrease the ripple using the following expression:

$$v_0(t) = Acos(\omega t_{off})^{\frac{-t+t_{off}}{RC}} \tag{2}$$

Where:

- A - Amplitude
- ω - angular frequency
- R - Resistance, constant obtained using the following expression:

$$R = R_3 + 23r_d \tag{3}$$

R_3 and r_d will be explained in the next section.

- C - Capacitance
- t_{off} - Constant obtained using the following expression:

$$t_{off} = \frac{1}{\omega} arctan(\frac{1}{\omega RC}) \tag{4}$$

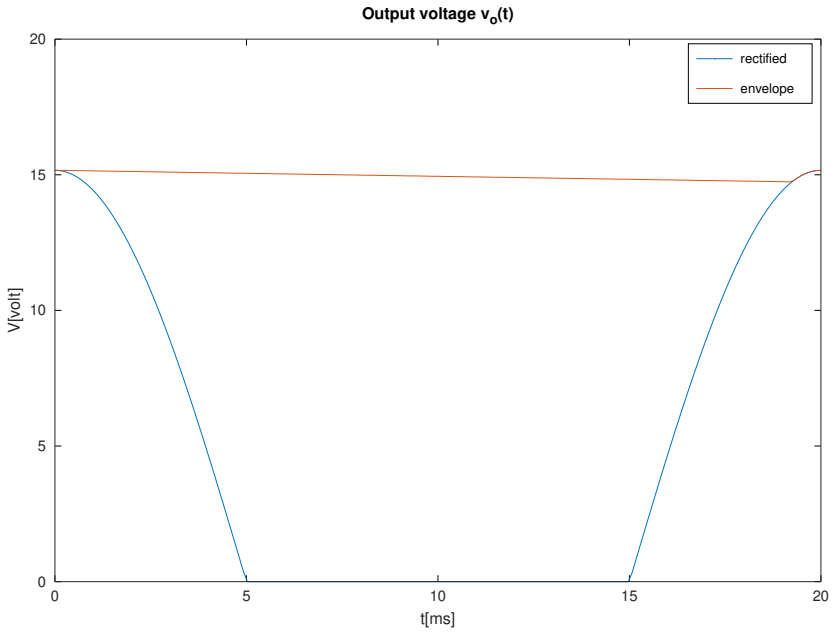

Figure 7: Rectified Signal.

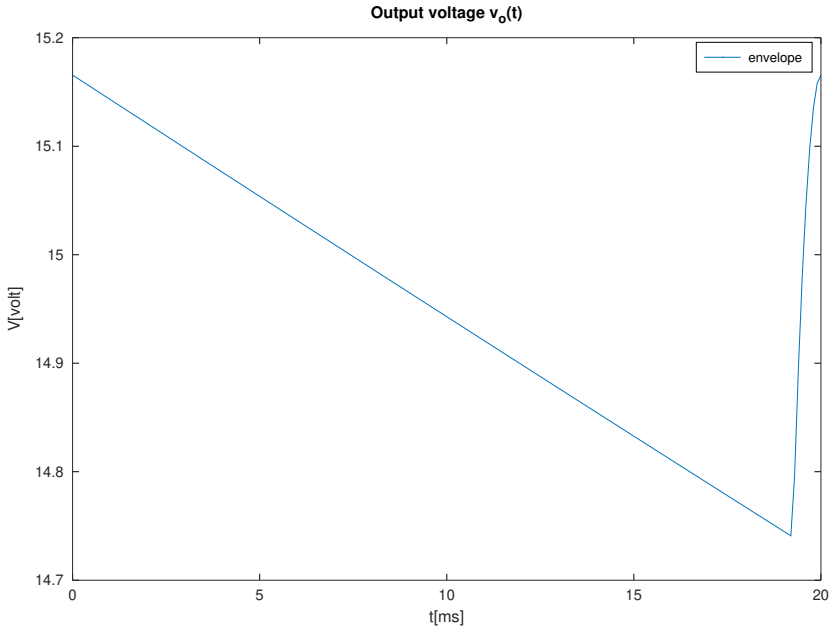

Figure 8: Envelope Detector Output Voltage.

3.2 Voltage Regulator

In our circuit, the voltage regulator consists of 19 diodes in series that will impose the 12V voltage. The resistance in series will decrease the amplitude.

The expressions used to do this were the following ones:

Sinusoidal part from envelope:

$$v_{sr} = v_O - V_s \tag{5}$$

Calculating rd_n for all the diodes, where rd is the resistance of each one:

$$rd_n = 23rd \tag{6}$$

And then, we have:

$$vO_r = (\frac{rd_n}{rd_n + R_3})v_{sr} \tag{7}$$

Where R_3 is the resistance in serie.

The expression used to obtain the vltage ripple was:

$$v_{ripple} = maximum(V_{dc}) - minimum(V_{dc}) \tag{8}$$

Where:

$$V_{dc} = 21V_{on} + vO_r \tag{9}$$

The results are shown below:

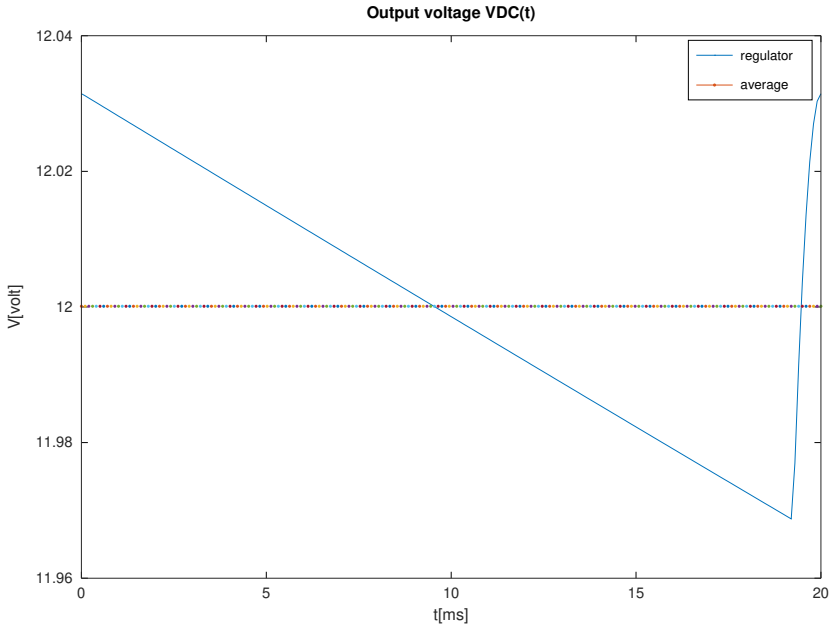

Figure 9: DC Output Signal.

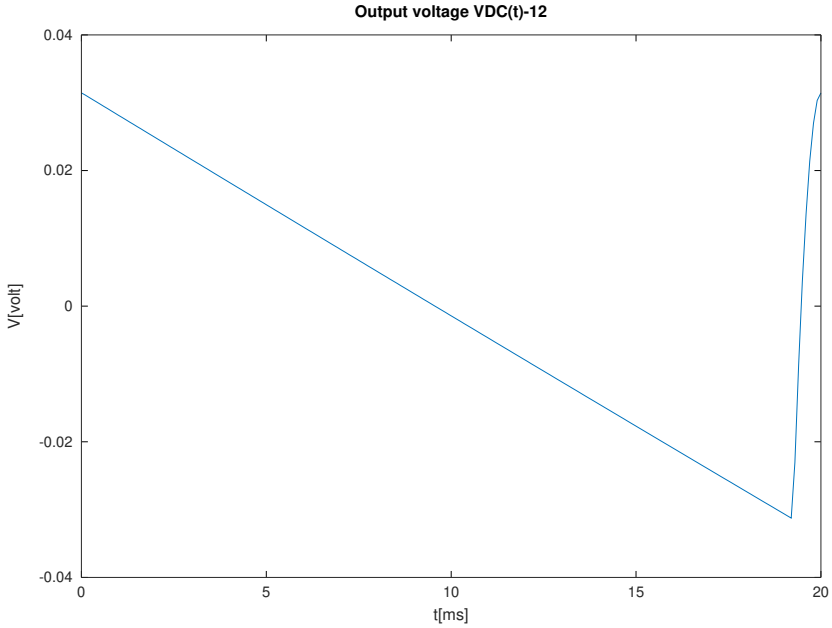

Figure 10: Output Signal - 12 (deviation).

Name	Value [V]
Ripple	6.269596e-02

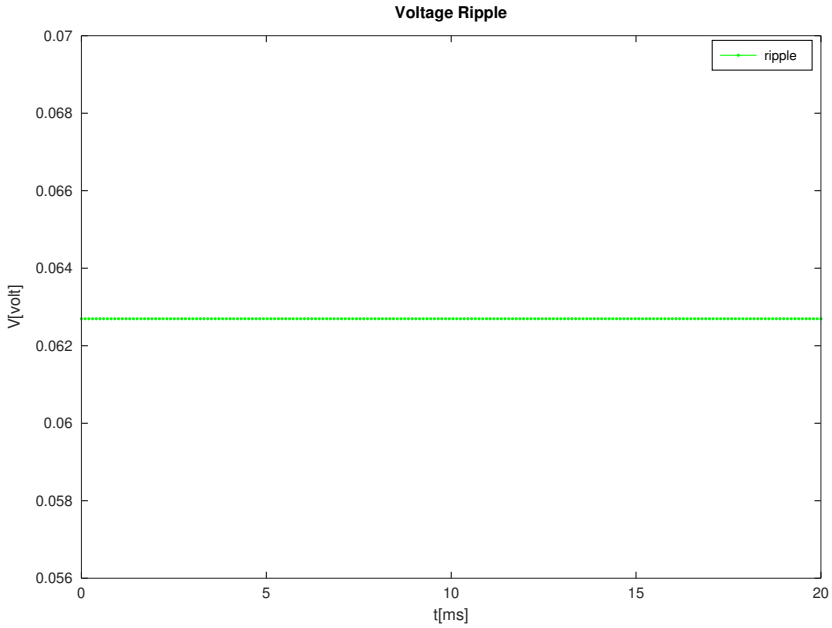

Figure 11: Ripple.

4 Conclusion

This laboratory provided us the opportunity to understand how the envelope detector and voltage regulator circuits work and also, how to improve their efficieny. We're also able to analyse carefully the working principle of an AC/DC converter.

In order to analyse the circuit theoreticaly *Ocatve* was used as well as all the Kirchoff's equations and diode models that support this analysis. The simulation was done using *Ngspice*.

Finally, we are going to compare the results from simulation and theoretical analysis side by side:

Name	Value
Resistor Cost	3.315000e+01
Capacitor Cost	2.600000e+01
Diode Cost	2.300000e+00
Total Cost	6.145000e+01
Merit	2.591430e-01

Figure 12: Merit Figure Table

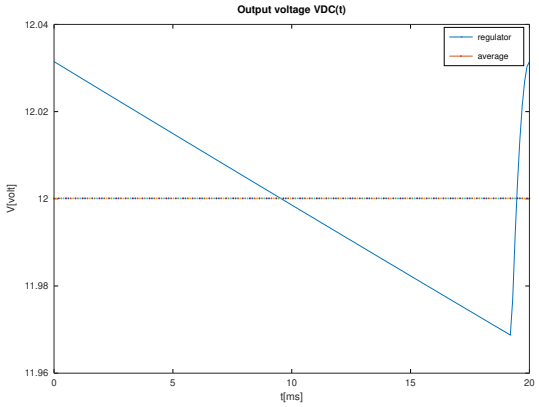

Figure 13: Theoretical Output Voltage Level

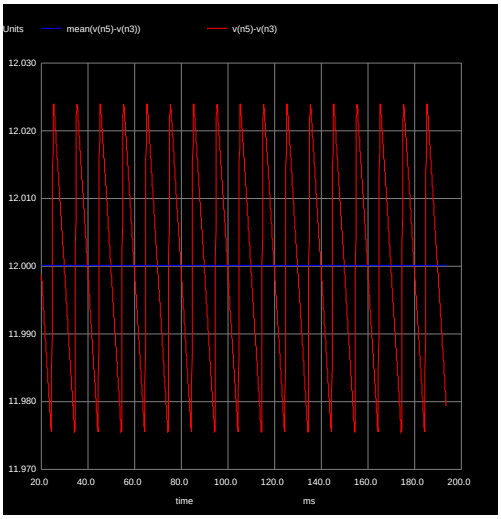

Figure 14: Simulation Output Voltage Level

Name	Value [V]
Ripple	6.269596e-02

Figure 15: Theoretical Ripple

Name	Value [V]
maximum(v(n5)-v(n3))-minimum(v(n5)-v(n3))	4.843233e-02

Figure 16: Simulation Ripple

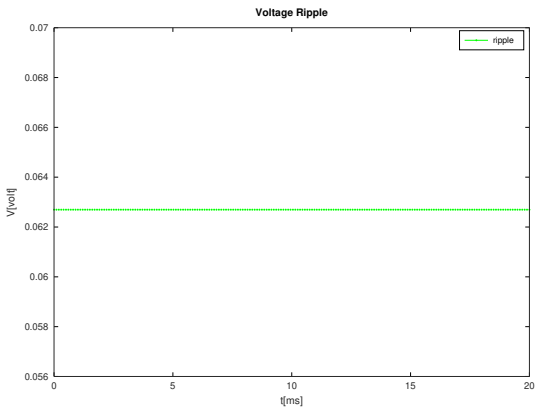

Figure 17: Theoretical Ripple

Ripple	Value [V]
maximum(v(n5)-v(n3))-minimum(v(n5)-v(n3))	4.843233e-02

Figure 18: Simulation Ripple

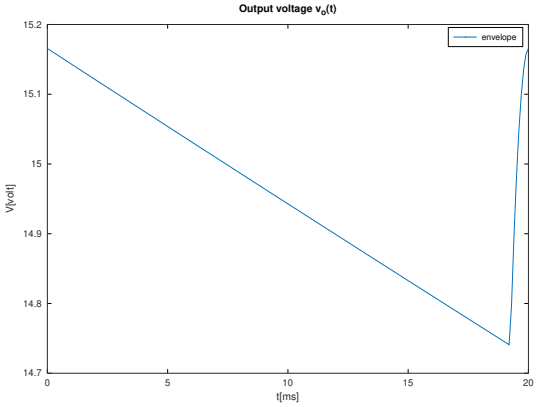

Figure 19: Theoretical Envelope Detector Voltage Level

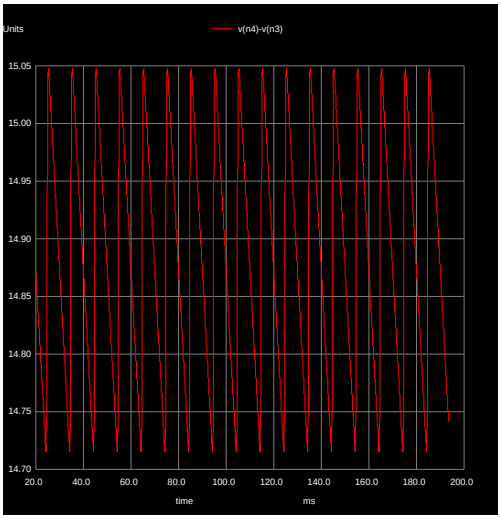

Figure 20: Simulation Envelope Detector Voltage Level

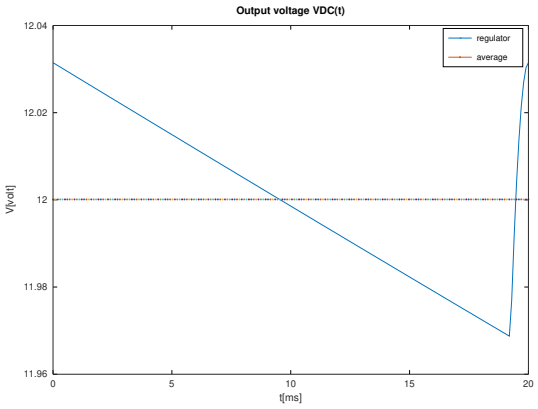

Figure 21: Theoretical Voltage Regulator Voltage Level

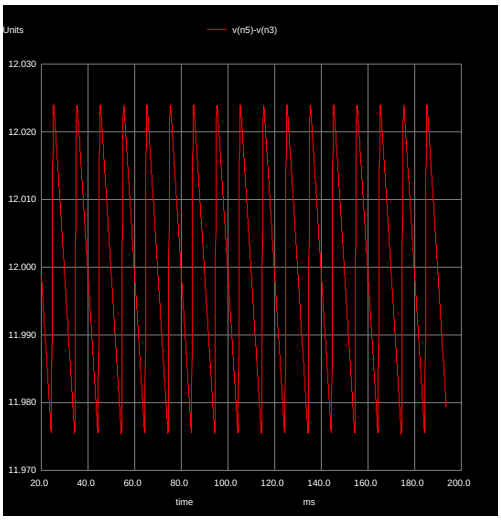

Figure 22: Simulation Voltage Regulator Voltage Level

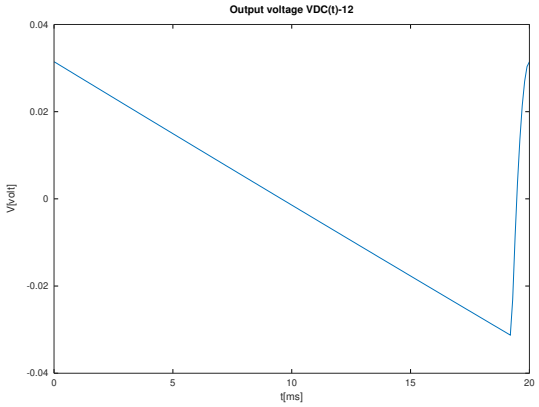

Figure 23: Theoretical $v_0 - 12$ Voltage Level

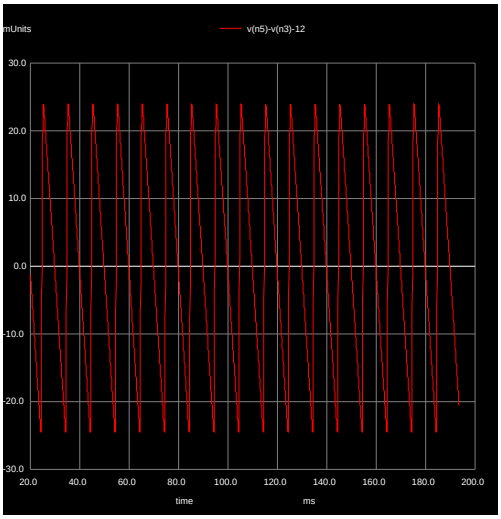

Figure 24: Simulation $v_0 - 12$ Voltage Level