Circuit Theory and Electronics Fundamentals

Integrated Masters in Aerospace Engennering, Técnico, University of Lisbon

Laboratory Report 3- Group 28

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Contents

1 Introduction

The aim of this laboratory assignment is to design and analyse an AC/DC converter circuit. To do so, the group chose the architecture of both the Envelope Detector and Voltage Regulator circuits. The final result is shown below.

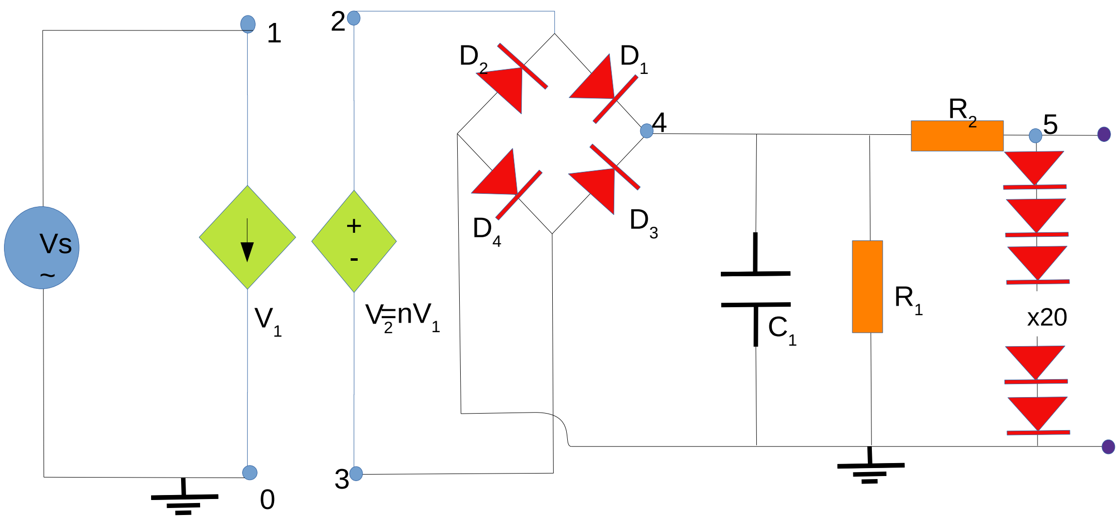

Figure 1: AC/DC converter circuit.

One method to achieve a steady DC voltage is to use every half-cycle of the input voltage instead of every other half-cycle. The circuit which allows us to do this is called a Full Wave Rectifier. As one may observe, 4 diodes are used, a pair for each half-cycle. Hence, it is completely efficient since it is produced an output for both of them.

In addition, the ripple and voltage variations were reduced by connecting smoothing capacitors. The voltage regulator circuit consists of one resistor and a series of diodes. It keeps the output voltage constant at the desired value (12V) in spite of variations in the supply voltage or in the current load.

2 Theoretical Analysis

In this section, a theoretical analysis of the circuit was conducted.

Initially, we used a transformer to transform Vs=230V in a smaller value (Vr=230/n with n=11)so that the rest of the circuit can aproximate it to 12 V. However, we want a DC voltage, not the initial AC voltage. In order to do achieve that, we use the circuit shown in Introduction.

1)The four diodes on the left are a full wave rectifier which means, they transform the AC current in an equal amplitude unidirectional current (blue plot). To compute that all we had to do was taking the the absolute value of the transformed voltage vr.

2)Then, a capacitor is used to reduce the magnitude of the voltage making it closer to a DC (yellow plot). In order to compute this, we discovered when are the diodes ON and OFF (tOFF = 1/w * atan(1/(w*R1*C))). Periodically, if t$<$tOFF we got vO = vr and if t$>$tOFF we got

vO = Vs*cos(w*tOFF)*exp(-(t-tOFF)/(R1*C)) due to the capacitor.The ripple voltage is basically max(vO)-min(vO). To make the next point clear vO will now be renamed vOenv.

Name	**Value**
RippleEnvelope	2.072966e-01
AverageEnvelope	1.427135e+01

Table 1: Ripple and average envelope values

3) Last, a series of 20 diodes reduce the noise making the current an almost perfect DC (orange plot). Calculating the vO average from 2) we are able to see if the voltage difference between v5 and v0 is limited by the maximum voltage that the diodes can handle (this happens if the average is greater than that maximum). Right now, we have the voltage due to the DC (dc_vO) so we still need the voltage due to the AC. It is possible to compute that calculating rD which is the resistance of each diode and

$ac_vO = num_diodes * rD/(num_diodes * rd + R2) * (vOenv - average_env)$.

In the end, vO= ac_vO + dc_vO. The average must be aproximadetly 12V.

Name	**Value**
RippleRegulator	5.443933e-02
AverageRegulator	1.200045e+01

Table 2: Ripple and average regulator values

The figure shows the plots mentioned above.

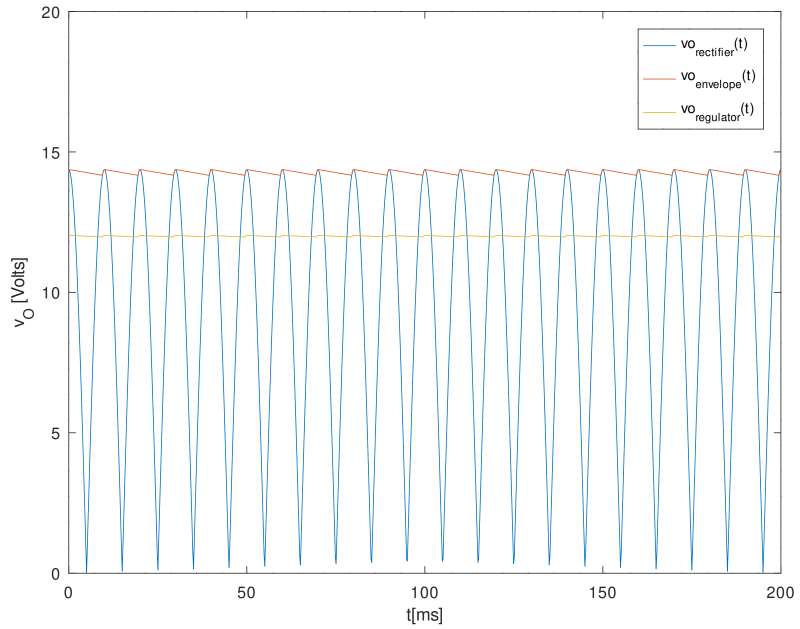

Figure 2: Input voltage of the secundary circuit (v(2)), output Voltage of the Envelope Detector (v(4)), Voltage Regulator (v(5)), and v(5)-12

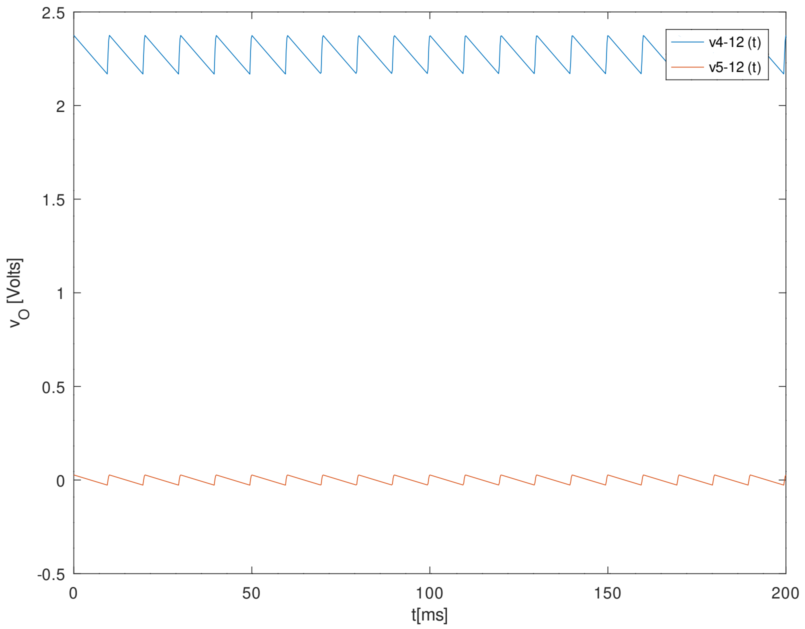

Figure 3: Output AC components + DC deviation

3 Simulation Analysis

In this section ngspice was used in order to simulate the ac/dc converter. Some modifications were made from the start in ordem to simplify the circuit.

First of all, the transformer was replaced by an ideal model, and once the Vs value was used, using a depedent current source (instead of the primary) and a dependent voltage source, (insetad of the secundary). This allowed the group to not having to model a ”real” transformer.

Then, the values of n (parameter of dependency of the dependent sources), the capacitance of the capacitor and the values of the resistance of the resistors were being adjusted through trial and error in order to achieve a maximum accurary of the output voltage, since the initial goal was to get this value close as possible to 12 V.

In the table below, the Imput voltage of the secundary circuit (v(2)), output Voltage of the Envelope Detector (v(4)), the output voltage of the Voltage Regulator (v(5)), and v(5)-12 were computed. This is a visual representation of the effect of the envelope detector, which decreases the ripple voltage and of the voltage regulator , that keeps the output voltage constant. As seen V(5)- 12 is a line (not completely straight due to the oscilations caused by the diodes, that are not linear components) close to 0, that was the main goal of the assignment.

Calculus	Value [V]
maximum(v(4))-minimum(v(4))	1.741783e-01
mean(v(4))	1.276538e+01

Table 3: Results for the voltage regulator. All variables are expressed in Volt. (Ngspice)

Name	Value [A or V]
maximum(v(5))-minimum(v(5))	7.371567e-02
mean(v(5))	1.205920e+01

Table 4: Results for the voltage regulator. All variables are expressed in Volt.(Octave)

In the figure below, as one may observe, the regulator ripple voltage has decreased in comparison with the envelope ripple voltage. Therefore, the goal was achieved.

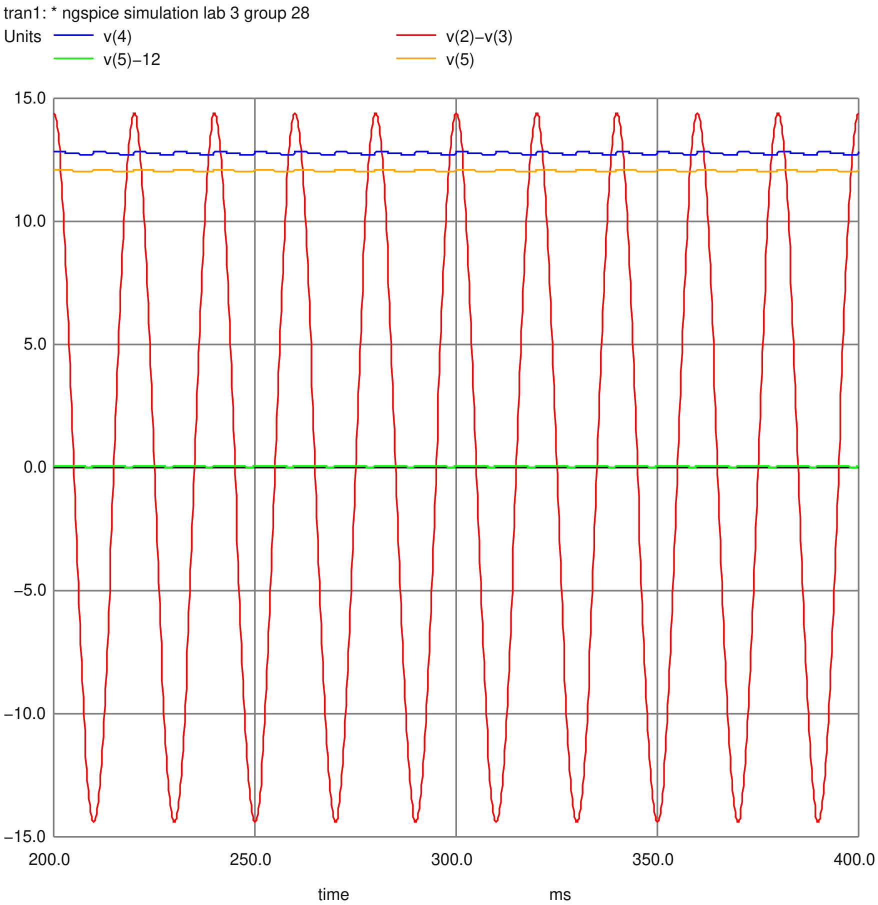

Figure 4: Input voltage of the secundary circuit (v(2)), output Voltage of the Envelope Detector (v(4)), Voltage Regulator (v(5)), and v(5)-12

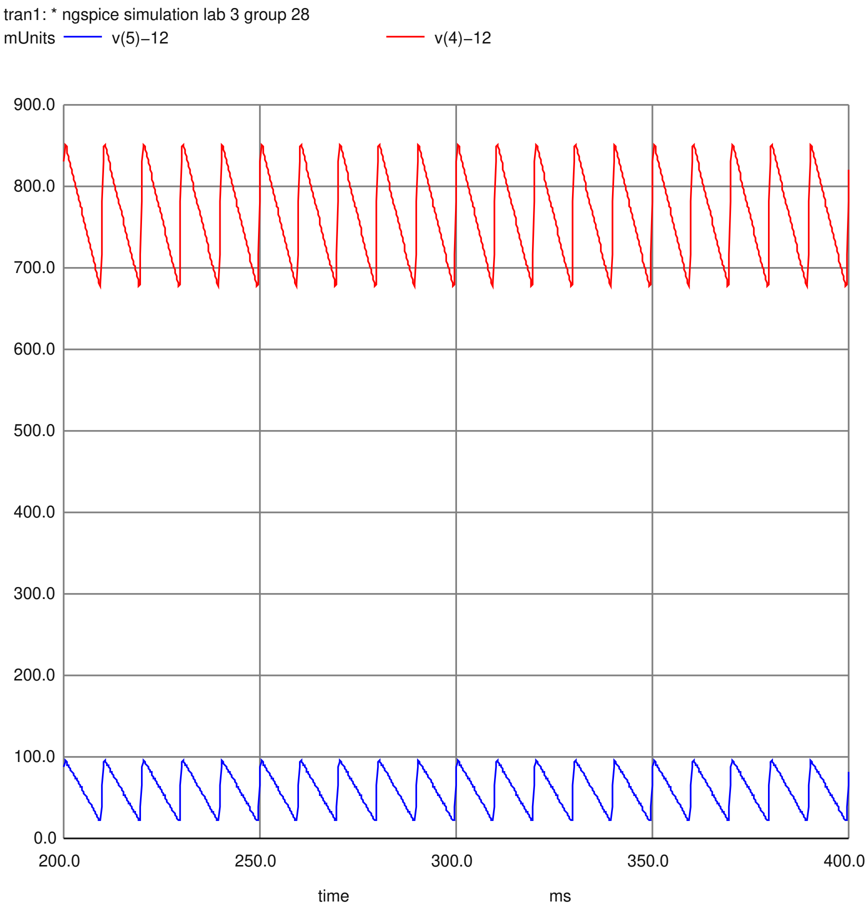

Figure 5: Output AC components + DC deviation

4 Comparison

In this section, a comparison between the ripple voltages, the average output voltages were made. In addition, the cost of the components and the figure of merit were also calculated.

First, the average and the ripple voltages of the envelope detector (v(4)) were analysed.

Calculus	**Value [V]**
maximum(v(4))-minimum(v(4))	1.741783e-01
mean(v(4))	1.276538e+01

Table 5: Results for the output of the envelope detector. All variables are expressed in Volt. (Ngspice)

Name	**Value [A or V]**
RippleEnvelope	2.072966e-01
AverageEnvelope	1.427135e+01

Table 6: Results for the output of the envelope detector. All variables are expressed in Volt.(Octave)

After analysis of the tables above, some discrepancies are observed. Nevertheless, these are due to the osilations that naturally occur in ngspice. These happen because the diodes used are non-linear components, which means that a linear relaton between the current and the voltage does not exist. The exponential function that comes into the equations leads to these type of oscilation.

However, it is felt by the group that the accuracy and precision of the results is high enough for the model of the envelope detector to be validated.

Then, the average and the ripple voltages of the voltage regulator (v(5)) were compared.

Calculus	**Value [V]**
maximum(v(5))-minimum(v(5))	7.371567e-02
mean(v(5))	1.205920e+01

Table 7: Results for the voltage regulator. All variables are expressed in Volt. (Ngspice)

Name	**Value [A or V]**
RippleRegulator	5.443933e-02
AverageRegulator	1.200045e+01

Table 8: Results for the voltage regulator. All variables are expressed in Volt.(Octave)

The oscilations between theorectial and simulation results that happened in the output voltage of the envelope detector are extended to the voltage regulator for the same reasons. Hence, a small discrepancy between the results ofboth models was expected to happen. Nevertheless and once more, we believe that once the output voltage is aproximmately 12V, as wanted, the model worked successfuly.

As for the cost and figure of merit, these are shown in table 9

1/ (509* ((maximum(v(5))-minimum(v(5))) + abs(mean(v(5)-12)) + 10e-6))	1.477965e-02

Table 9: Cost and Figure of Merit

Despite the attempts to improve the figure of merit, the group was not successfull in doing so. This was the maximum value obtained in order to match both the simulation and theorectial results. Despite the belief that in some way our results could be optimazed, we can conclude that the model used achieved the main goal of the assignment.

5 Conclusion

It was agreed by the members of the group that the main goal of the task proposed was achieved. As presented, both theoretical and simulation results(obtained using Octave tools and ngpsice simulator, including the output of the envelope detector, the output of the voltage regulator, the output voltage, the average and the ripple voltage matched, reaching total accuracy. Despite the initial belief that the considerable number of components of the circuit and the non-linearity of the diodes used to get to the final output voltage wanted, could cause some disparity in the results, such did not happened.

To conclude, the model used can then be validated.