# Circuit Theory and Electronics Fundamentals

Instituto Superior Técnico, University of Lisbon

Laboratory Report: Lab Assignment T3, Group 26

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## Contents



## 1 Introduction

The aim of this laboratory is to build an AC/DC converter circuit whose input is AC voltage source with a frequency of 50Hz and amplitude 230V.

The circuit chosen for this task is the following:

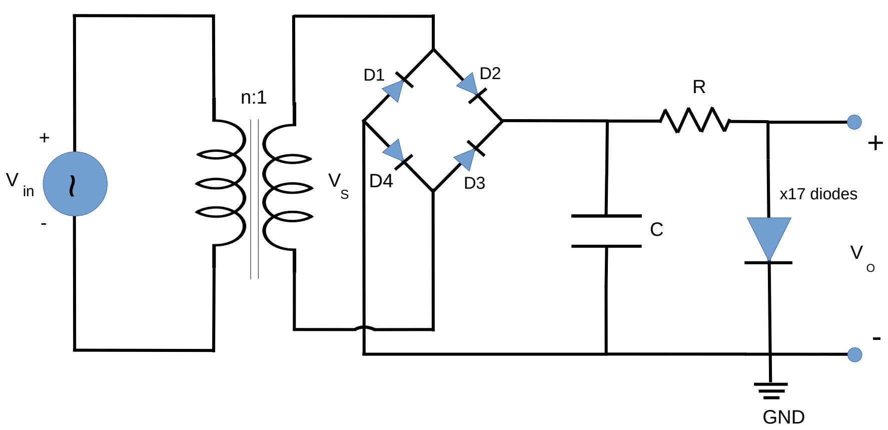


Figure 1: Circuit analysed.

The circuit is composed of several parts. The first one is a transformer with a ratio of 1:n loops with the goal of reducing the input's voltage by a factor of n. Then we can find the remaining parts of the circuit: the envelope detector and the voltage regulator. Following the transformer is a full-wave bridge rectifier composed of 4 diodes as shown. In addition to the bridge rectifier, in the envelope detector we basically decided to insert a capacitor with the objective of smoothing the ”ripple”, which is the residual periodic variation of the DC voltage which has been derived from the AC source. Lastly, in the voltage regulator we have a resistor in series with 18 diodes.

The way the full wave rectifier works is straightforward. The goal is to simply transform a sinusoidal signal that can assume positive and negative values to only positive values. We will simplify the circuit to a AC voltage source with the bridge rectifier and a load resistor as shown in figure 2 to explain.

When the input wave is positive, the route that the current takes is the following:

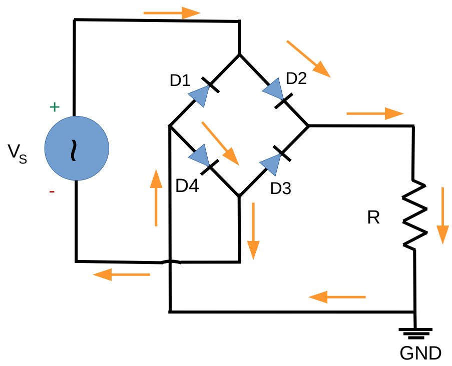


Figure 2: Positive half.

This is because the diode D1 is in reversed bias and therefore current can't pass through it. On the other hand, the diode D2 is in forward bias so the current will go that way. After it has passed the resistor, the current goes through the diode D4. The reason it won't go through D1 is because the voltage drop in this diode is negative.

When the input wave is negative, the path taken by the current is surprising, the current still flows in the same direction at the resistor!

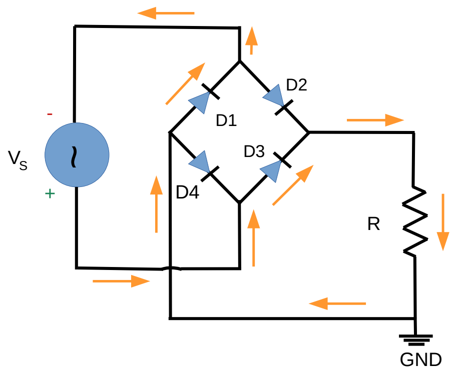


Figure 3: Negative half.

The reasoning behind why the current goes though D3 and D1 is the same as the reason why the current went through D2 and D4 in the positive half of the input wave as explained before.

In the end the objective we seeked was fullfilled as can be shown in the figure 4.

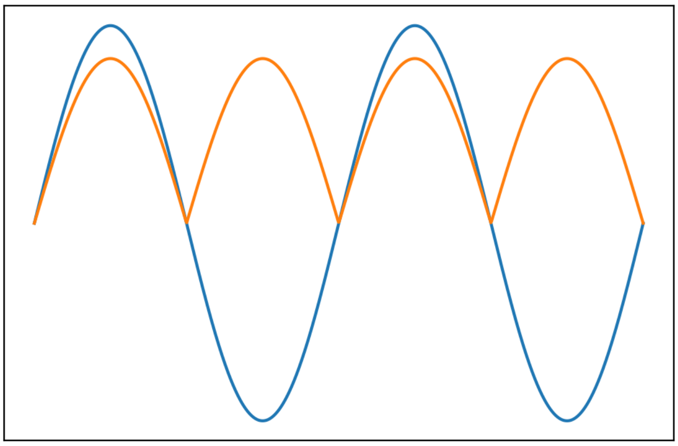

Figure 4: Wave rectified.

As we can see the voltage signal across the resistor (orange) has only positive values meanwhile the input signal (blue) has both positive and negative values.

The capacitor we've put after the bridge rectifier in the figure 1 allowed us to ”smooth” the voltage drop when the signal gets weaker. When the signal is stronger that the voltage limiter(in this case the resistor and diodes) it allows the capacitor to charge so that, when the signal is not strong enough to support the voltage limiter, the capacitor starts to discharge and in consequence the sub circuit containing the capacitor, resistor and diodes will still be active while the rest of the circuit ”stops”. When the signal gets strong again, the capacitor charges again and this whole process repeats again.

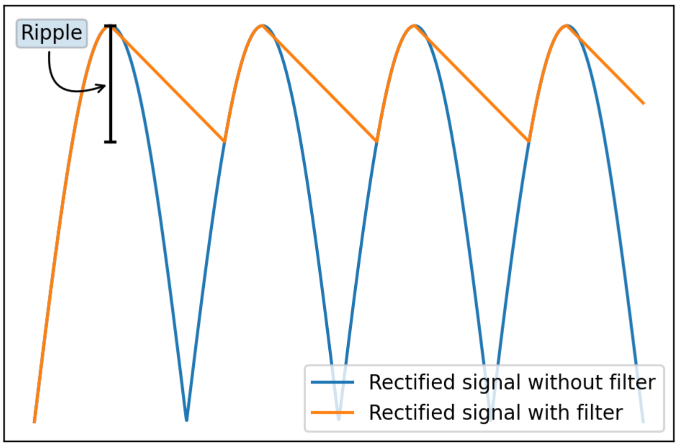


Figure 5: Wave rectified.

As we can see in figure 5 when the signal starts to drop the capacitor starts to discharge to provide sufficient voltage for the circuit resistor-diode, that is why the slope demonstrate a ”ripple” effect.

In section 3 we will give a theothericaI analysis of the circuit chosen. Hereinafter, in section 2, we will simulate the same circuit using *Ngspice*. Finally, in section 5, we will compare the theothericaI model to the simulation.

## 2 Simulation Analysis

In this section we will describe the simulation of the circuit 1. The model for diodes chosen was the default model of *Ngspice*.

Starting off, we used a smaller and simpler circuit that could achieve the goal of the laboratory just to get a grasp of the circuit's behaviour. Later we optimized the circuit with 3 objectives:

- Reduce the cost of resistors, capacitors and diodes;
- Reduce the ripple of the signal;
- Get as close as posible to an average voltage of 12V.

Keeping that in mind, we immediately knew that using a full wave rectifer opposed to a half wave was very much worth, given that the monetary cost of the diodes was low and the ripple impact using the full wave was massive. The capacitance, resistance value and number of diodes were achieved by trial and error, trying to minimize the ripple and $|V_o - 12|V$ given the total cost.

Moreover, the *Ngspice*'s functions used to calculate the average value, maximum and minimum (these last two to calculate the ripple) were respectively: AVG, MAX and MIN.

For the model of an ideal transformer, we used a current controlled current source on the side of the original input and a voltage controlled voltage source on the other side. The value of proportionality constant were the same in both and equal to n=1/15. As to fulfill *Ngspice*'s requirements for this setup to work we had to use a auxiliary voltage source with V=0 and a resistance with an absurd value (as to not pass current through it) to connect both circuits. We emphasize that these last two would not exist in a real circuit and they are just a requirement for *Ngspice* to work.

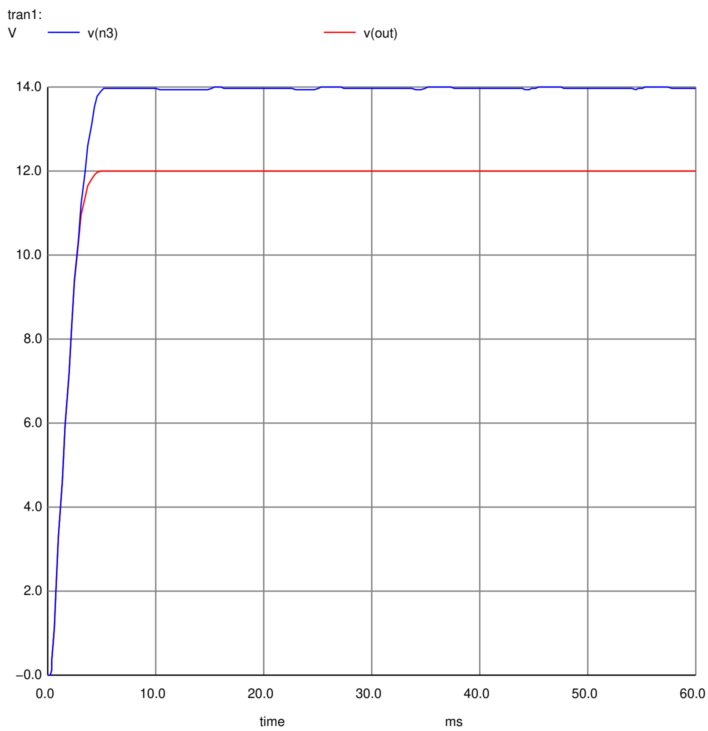


Figure 6: Voltages at the output of the envelope detetctor (blue) and voltage regulator circuits (red).

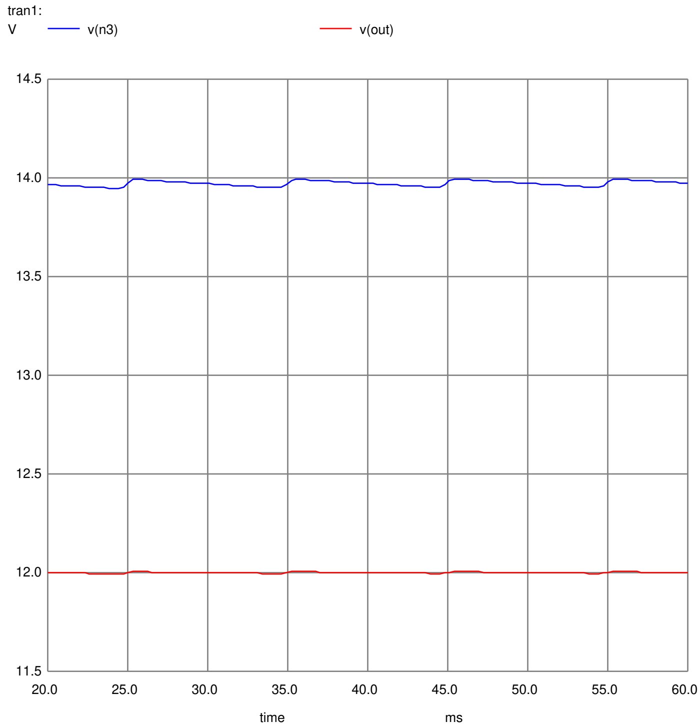


Figure 7: Voltages at the output of the envelope detetctor (blue) and voltage regulator circuits (red): detail in the interval [20, 60] ms.

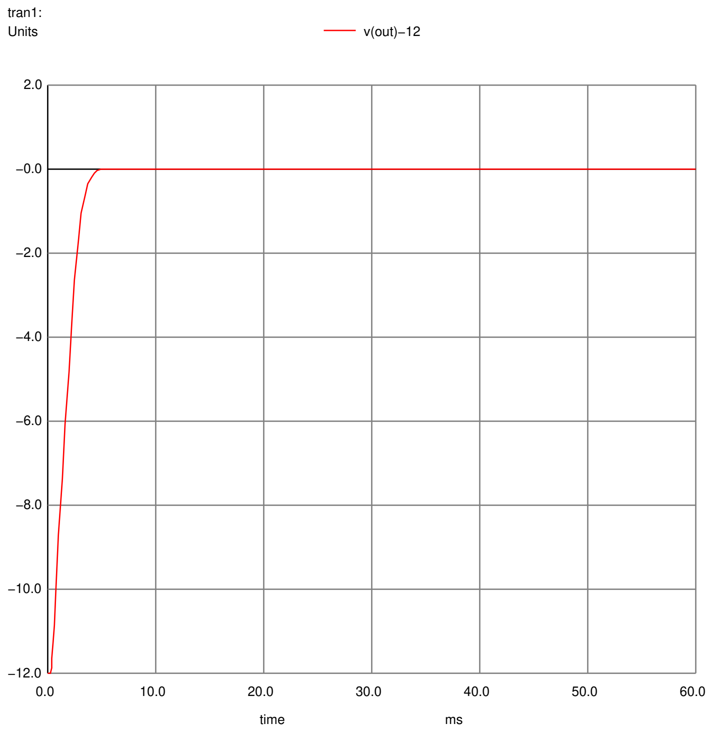


Figure 8: Circuit analysed.

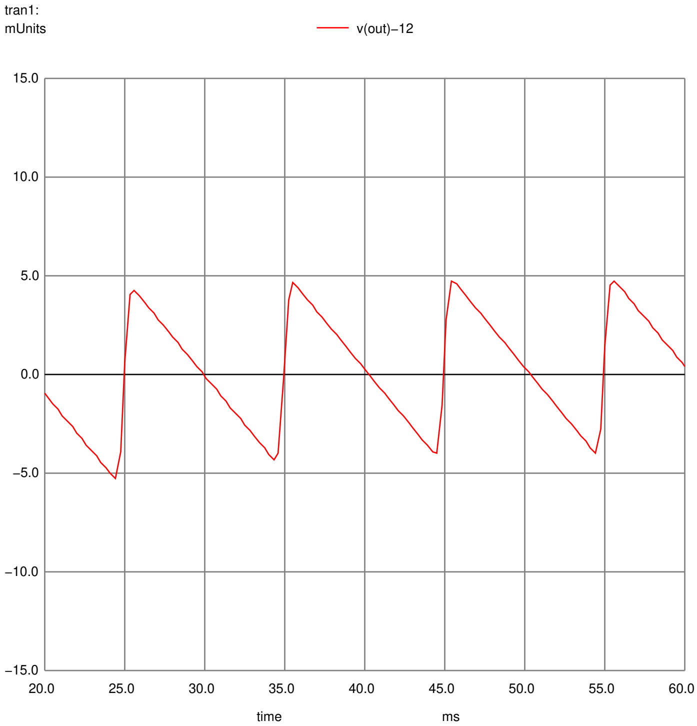


Figure 9: Circuit analysed.

Overall, the results were highly satisfactory. The average output was very close to 12V ($\overline{V_o} = ??$) and the ripple was really close to 0 ($Ripple = ??$). The total cost (in monetary units) was ??, leaving us with a merit of ??, using the formula below:

$$M = \frac{1}{cost \cdot \left( ripple\,(V_0) + \overline{(v_0 - 12)} + 10^{-6} \right)} \tag{1}$$

- Resistors $\rightarrow$ 1 MU per k$\Omega$;
- Capacitors $\rightarrow$ 1 MU per $\mu$F;
- Diodes $\rightarrow$ 0.1 MU per diode.

# 3 Theoretical Analysis

# 4 Comparing the theotherical analysis with the simulation.

In the first part of the circuit (transformer) we didn't notice any particular variation from the theoretical to the simulation as we would expect since both ideal models were equal and the calculation were straightforward.

For the rest of the circuit it is normal that both can differ since the diode's model used in *Ngspice* is very complex whereas the model we decided to use in the theoretical analysis was a simpler version. Although the difference in both models used, we achieved very similar and satisfactory results.

The following graphs summarise the small differences:

COLOCAR GRÁFICOS.

## 5 Conclusion

In this laboratory assignment, the objective of analysing the circuit presented in figure 1 has been achieved. The analysis was performed both theoretically using the Octave maths tool and by circuit simulation using the Ngspice tool. Although the theoretical results differed slightly from the simulation results we did achieve good results overall. The reason for this slight mismatch is the fact that the model for the diodes in both were different, being the theoretical a simpler of the two. In the end, we think that the goal of this laboratory was achieved. The building and optimization of the circuit allowed us to further reflect about the behaviour of diodes and their relationship with the other components already studied.

## References


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