# LAB 3: AC/DC CONVERTER

Circuit Theory and Electronics Fundamentals

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# 1 Introduction

In this laboratory assignment, an AC/DC converter was built, using a transformer and components such as diodes, resistors and capacitors. It is obvious to think that every component has its cost. Hence, the process of choosing what to use must be in line with the most accuracy possible, while keeping a reasonable price.

It was considered an input AC voltage with amplitude $230$V and frequency $50$Hz, aiming to a DC output of $12$V. The merit (M) measures the relation accuracy/cost and it is calculated with

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

with $v_O$ being the output DC voltage. The considered circuit is presented in Figure 1.

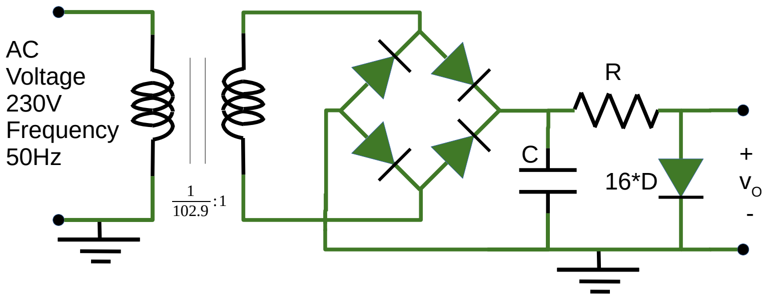



Figure 1: AC/DC Converter considered.

In Section 2, a theoretical analysis of the circuit is presented, using Circuit Theory and Electronics Fundamentals concepts. After that, in Section 3, the circuit is analysed via simulation, using the software Ngspice. The obtained results are then compared, explaining the reasons behind the differences and similarities found. Finally, one can find the conclusions of this study outlined in Section 4.

# 2 Theoretical Analysis

In this section, the previously shown circuit is theoretically analised.

First of all, it is important to refer that the transformer had to be replaced by a pair of dependent sources, so that the value of the input voltage could be modified. The following figure shows the resulting circuits.

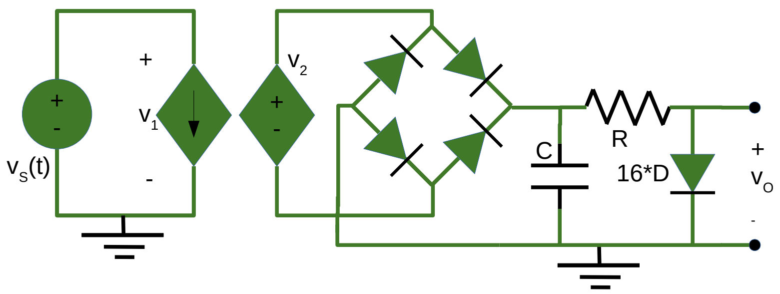



Figure 2: AC/DC Converter considered with the transformer equivalent dependent sources.

| Quantity name | Value |
|---|---|
| C | 600 $\mu$ F |
| R | 600 $k\Omega$ |
| Cost | 1201.6 MU |

Table 1: Values of circuit quantities.

After, a rectifier bridge, built with four diodes, allows our signal to be full wave rectified. Its output is nothing less than the absolute value of $v_S$, being the first step towards a more uniform signal.

An **envelop detector** containing the rectifier and a capacitor covers the signal and produces an output that oscillates between charging and discharging periods to a resistor. Note that this discharge is allowed at $t = t_{OFF}$, as the diodes go OFF.

$$t_{OFF} = \frac{1}{\omega} * arctan(\frac{1}{\omega RC}) \tag{2}$$

allowing

$$v_C(t) = Acos(\omega t_{OFF})e^{-\frac{t-t_{OFF}}{RC}} \tag{3}$$

after which, the recharge is possible due to the reactivation of the diodes.

In order to reduce the remaining ripple, a **voltage regulator** circuit built with a series of 16 diodes increases the time constant. By means of incremental analysis (application to the 16 series diodes as resistors $r_d$), the incremental output $v_O$ can be calculated with

$$v_O = \frac{16r_d}{16r_d + R}v_C \tag{4}$$

$$r_d = \frac{\eta V_T}{I_S e^{\frac{V_d}{\eta V_T}}} \tag{5}$$

with $r_d$ being the incremental resistance, $\eta = 1$ a material constant and $V_T$ the termic voltage.

To calculate the ripple, it is used

$$v_{ripple} = max(V_{DC}) - min(V_{DC}) \tag{6}$$

# 3 Simulation Analysis and result comparison

Tables 2 show the plot characteristic values for the output signal, obtained with Ngspice and Octave, respectively. Figures 3 and 4 show the plot for the voltages at the output of the Envelope Detector, obtained with Octave (wide scale) and Ngspice (short scale), respectively. Figures 5 and 6 show the plot for the voltages at the output of the Voltage Regulator minus 12, obtained with Octave and Ngspice, respectively. Figure 7 shows the plot for the voltage at the output of the Voltage Regulator and its value minus 12, obtained with Octave.

| Quantity name | Value [V or other] |
|---|---|
| ymax | 1.200000e+01 |
| ymin | 1.199999e+01 |
| yavg | 1.200000e+01 |
| ripple | 1.000000e-05 |
| merit | 7.565670e+01 |

| Quantity name | Value [V] |
|---|---|
| max | 12.00001 |
| min | 12.00000 |
| ripple | 0.00001 |
| mean | 12.00000 |

Table 2: On the left, the values obtained via simulation in Ngspice. On the right, the ones obtained from Octave.

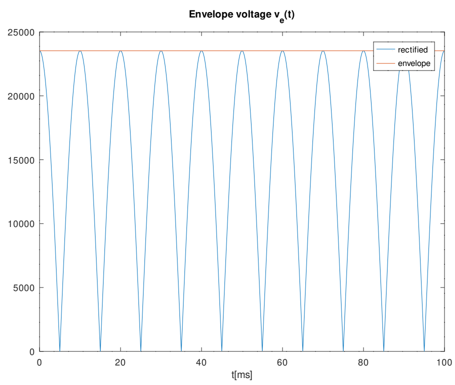



Figure 3: Plot for the voltage (V) at the output of the Envelope Detector, obtained with Octave.

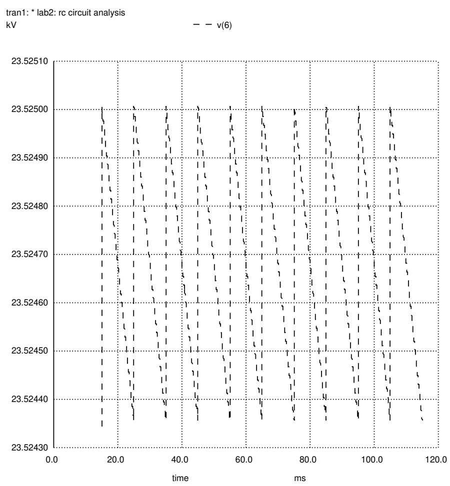
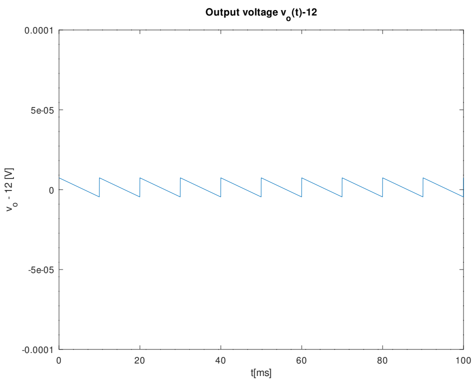



Figure 4: Plot for the voltage (V) at the output of the Envelope Detector, obtained with Ngspice.



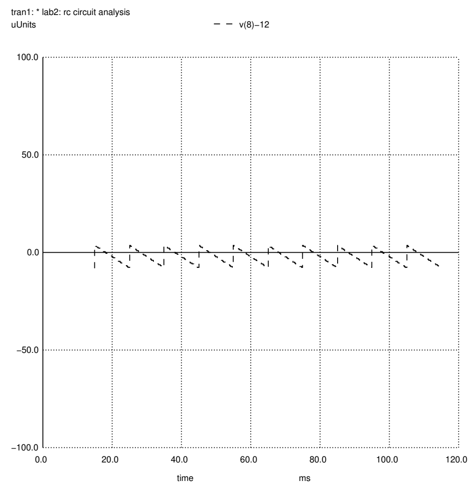




Figure 5: Plot for the voltage (V) at the output of the Voltage Regulator, obtained with Octave.

Figure 6: Plot for the voltage (V) at the output of the Voltage Regulator, obtained with Ngspice.

Comparing both the simulation and theoretical results, one notices very small differences, which indicates that the model used was quite good. However, because in Octave we had to represent a non-linear component by a simpler model, some deviations are inevitable.

The merit is very good. However, for that to happen, we had to compute the transformator in a way that its role would be to increase the amplitude of the original signal. We know that it is not the way it happens in real life converters, but we still did it for merit purposes.

# 4 Conclusion

An AC/DC Circuit allows everyone to operate with every daily basis technological material. In this work, an example was built, resulting in a merit of 75.65670 and a cost of 1201.6 MU. The obtained ripple was 0.00001.

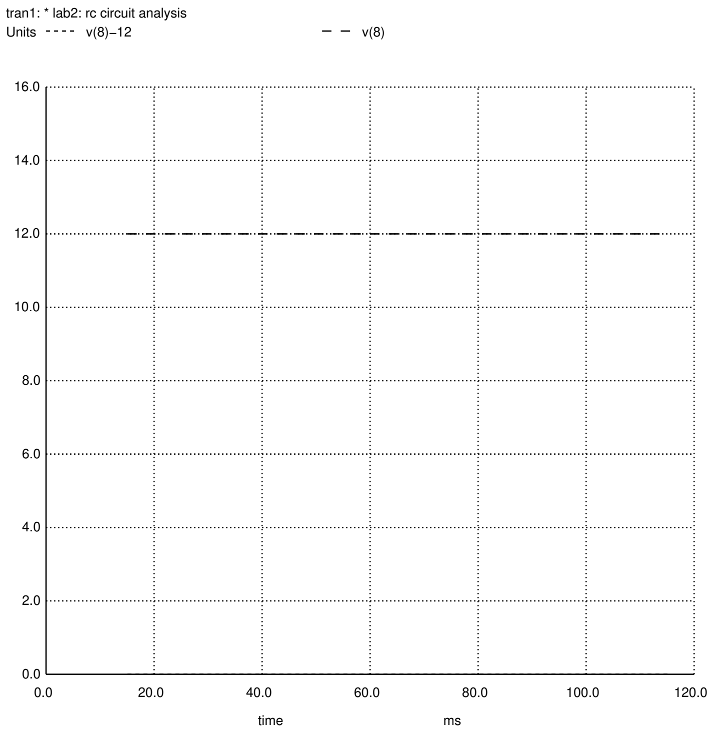



Figure 7: Plot for the voltage at the output of the Voltage Regulator and its value minus 12, obtained with Octave.