Circuits Theory and Electronic Fundamentals

Integrated Master in Engineering Physics, IST, University of Lisbon

Lab 3: AC/DC Converter

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Contents

1 Introduction

The objective of this laboratory assignment is to use an AC/DC converter to obtain an output DC signal of value 12 V from an AC signal of amplitude 230 V and frequency 50 Hz. The envelope detector and voltage regulator circuits in the converter were chosen as shown in Figure 1, in which a number has been assigned to each node.

The envelope detector is formed by a full-wave bridge rectifier circuit, with 4 diodes connected to the resistor R_1, in parallel with the capacitor. On the other hand, the voltage regulator corresponds to the resistance R_2 in series with a positive voltage limiter (18 diodes).

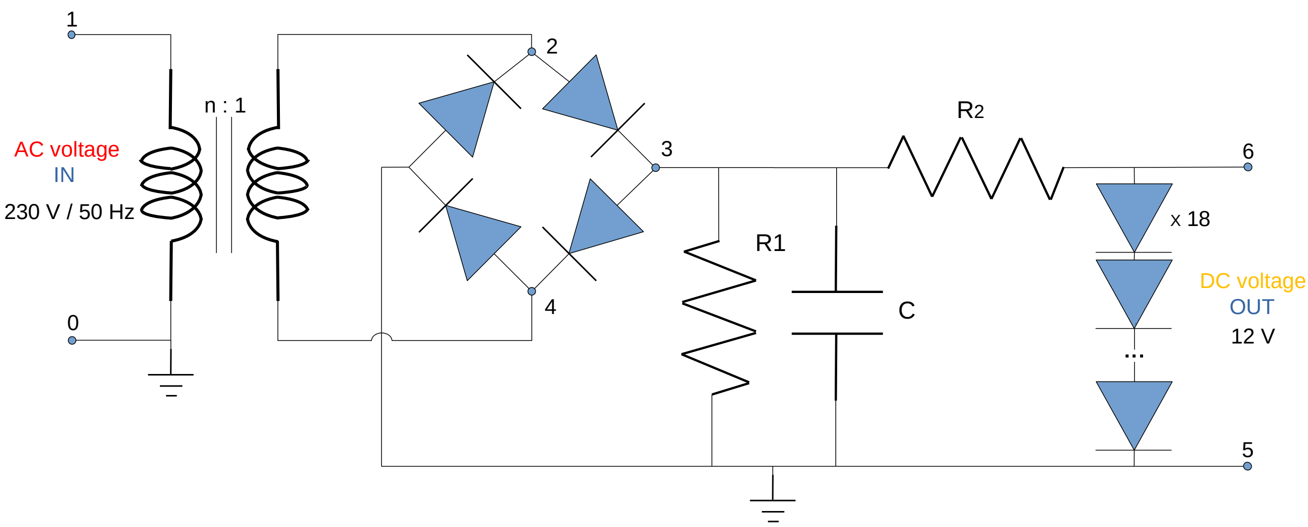

Figure 1: Circuit to be analysed in this laboratory assignment.

2 Theoretical Analysis

The values of the resistances R_1, R_2 and C have been chosen arbitrarily, in order to obtain the best results and the best merit M possible. These values are shown below.

Name	Value
R_1	1000 $[\Omega]$
R_2	5000 $[\Omega]$
C	0.0005 $[F]$

Table 1: Values used for the resistances R_1 and R_2 and for the capacitance C.

Assuming that the transformers' wires are coiled according to the conventional way, that is, in order to generate a downwards current through the left transformer (transformer 1) and an upwards current through transformer 2 (on the right), we have that v_{t1}=n v_{t2}, with n being the number of turns in transformer 1. Because the objective is to obtain a DC voltage of 12V in the ouput, a sinusoidal signal of amplitude 50V was used for transformer 2, thus the value of n was given by $n = \frac{V_{t1}}{V_{t2}} = \frac{230}{5}$, with $V_{t1} = 230$V and $V_{t2} = 50$V being the amplitudes of the sinusoidal signals in the respective transformers.

Because of the 4 diodes in the full-wave bridge rectifier circuit, the voltage through the resistance R_1 is given by

$$v_{O_{rectified}}(t) = |v_{t2}| = v_3 - v_5 \tag{1}$$

Where an ideal diode model has been considered. Now, the capacitor is used to keep the voltage approximately constant and close to 12V. As was learnt in class, the time it takes for the diode circuit to go OFF and for the capacitor to strat discharging through the resistance R_1 is given by

$$t_{OFF} = \frac{1}{\omega} atan\left(\frac{1}{\omega R_1 C}\right) \tag{2}$$

Where $\omega = 2\pi f$, with $f = 50$Hz as shown in Figure 1. After t_{OFF}, the voltage in the output of the envelope detector is not $v_{O_{rectified}}(t)$, but

$$v_{O_{envelope}}(t) = V_{t2} cos(\omega t_{OFF}) e^{-\frac{t - t_{OFF}}{R_1 C}} \tag{3}$$

When the time instant t_{ON} is reached, the voltage is again given by equation 2. To determine t_{ON}, the following non-linear equation must be solved:

$$V_{t2} cos(\omega t_{ON}) = V_{t2} cos(\omega t_{OFF}) e^{-\frac{t_{ON} - t_{OFF}}{R_1 C}} \tag{4}$$

The value of t_{ON} was obtained by Octave and by using Newton-Raphson's iterative nethod. The following values were obtained:

Name	Value
R_1	1000 $[\Omega]$
R_2	5000 $[\Omega]$
C	0.0005 $[F]$

Table 2: Values obtained for t_{ON} and t_{OFF}.

Using this information, the rectified voltages and the final voltage out of the envelope detector were plotted below.

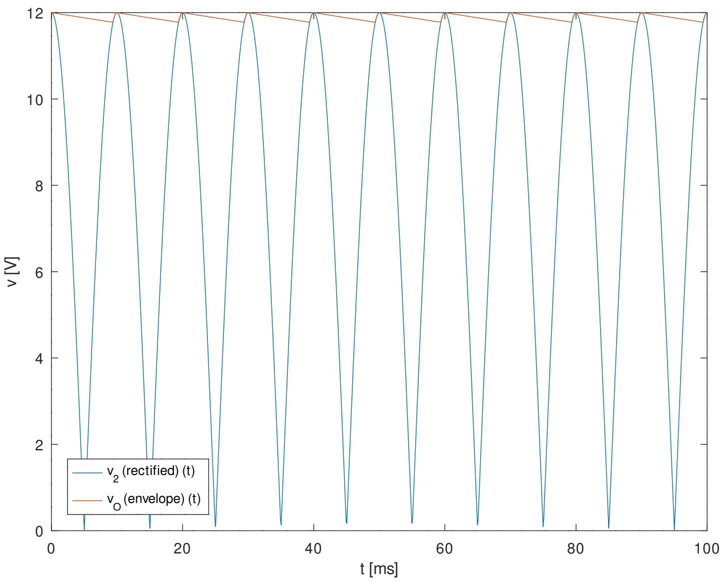

Figure 2: Voltages in the envelope detector circuit.

3 Simulation Analysis

Simulating the ciruit indicated we have obtained the following graphic that contemplates the voltage after the envelope circuit (out1) and the voltage that actually leaves the system, supposedly 12 V.

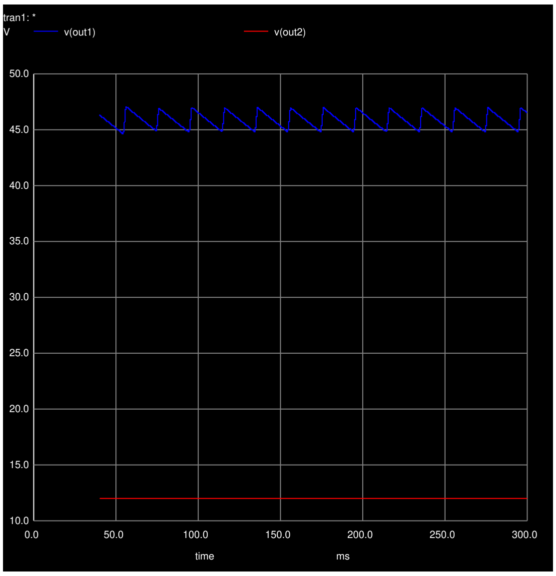

Figure 3: Voltage after envelope circuit(out1) and after voltage ripple circuit (out2)

In the next graph we tried observing the fluctuations of the output around 0 for that we plotted the output voltage obtained at any instant subtracted by the desired voltage 12 V.

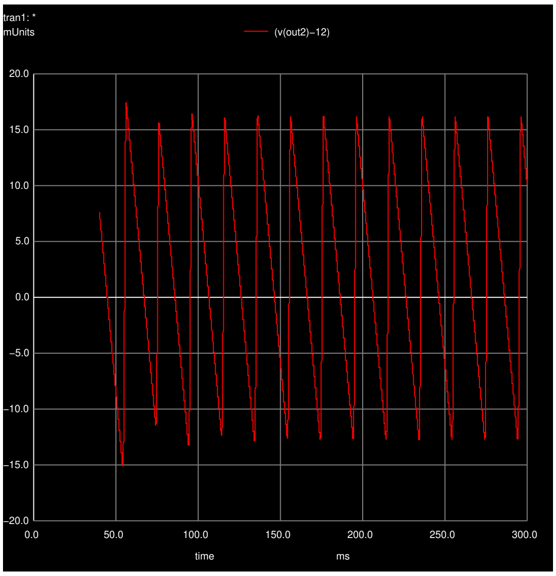

Figure 4: Deviation of output signal from the target voltage 12 V

Doing all of the analisys we where able to obtain a stable 12V DC with some fluctuation as seen in 4 the values obtained for the average of voltage and ripple are the following:

Designation	**Value [V]**
maxout	1.201743e+01
minout	1.198492e+01
ripple	3.251000e-02
avgout	1.200157e+01

Table 3: Voltage ripple and average out voltage

4 Conclusion

In this laboratory assignment, the objective of