Circuit Theory and Electronics Fundamentals

T3

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Contents

1 Introduction

The goal of this assignment is to design the group's own circuit, specifically one that converts Alternate Current into Direct Current. This circuit is composed of a full wave rectifier utilizing 4 diodes, an envelope detector and a voltage regulator designed to stabilize the voltage in 12V, which is a resistor and a series of diodes, as can be seen in the figure below.

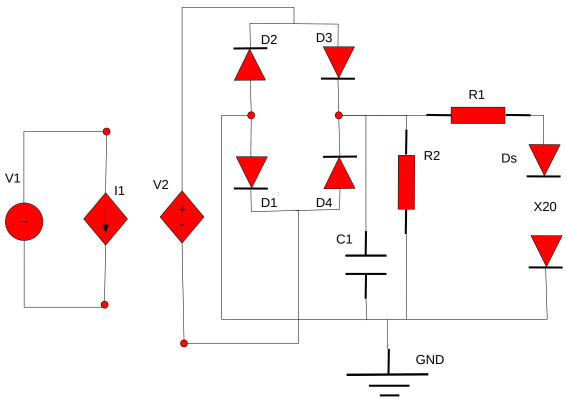


Figure 1: Studied Circuit

In Section 2, a theoretical analysis of the circuit is presented. In Section 3, the circuit is analysed by simulation using NGSpice, with its results being compared to the theoretical results obtained in Section 2 in the Section 4, while also outlining in this section the conclusions of this study.

2 Theoretical Analysis

Initially, a transformer was used to reduce the initial voltage of 230V into a smaller value, thereby enabling the rest of the circuit to approximate it to an output voltage of 12V. Another hurdle that needs to be surpassed is turning the initial AC voltage into a DC voltage and for that, the following circuit configuration, with the following components, was used:

1) Four diode full wave bridge rectifier (on the left), which transforms AC into an equal amplitude unidirectional current. Such computation was achieved by taking the absolute value of the output voltage from the transformer, V_r.

2) A capacitor, which was utilized for the purpose of reducing voltage magnitude, approximating it to a DC. To compute this, one seeks to determine whether the diodes are ON or OFF, in which

$$t_{OFF} = \frac{1}{w} arctan(\frac{1}{wR_1C}). \tag{1}$$

For $t < t_{OFF}$, $V_O = V_r$, and otherwise,

$$V_O = V_s cos(wt_{OFF}) exp(-\frac{t - t_{OFF}}{R_1C}), \tag{2}$$

due to the capacitor. Ripple voltage will be calculated by taking the difference between the max and min value of V_O. From now on, V_O will be called V_{OENV}.

3) Nineteen diodes in series for the sake of achieving an almost perfect DC. From **2)**, one is also able to calculate an average value for V_O (V_{OAVG}). This value will help to averiguate whether the potential difference between V_5 and V_0 is limited by the max voltage that could be handled by the diodes or not. Voltage values, V_O, from **2)** are relative to the DC (V_{ODC}). To compute the voltage due to AC, one must use the resistance in each diode. R_D to then achieve an expression for V_O due to AC, which is given by:

$$V_{OAC} = ndiodes \frac{R_D}{ndiodes R_D + R_2}(V_{OENV} - V_{OAVG}), \tag{3}$$

in which R_D is the resistance of each diode.

Ripple Envelope	4.315587e+00
Average Envelope	1.712652e+01
Ripple Regulator	3.029639e-01
Average Regulator	1.200000e+01

Table 1: Ripple and Average Voltages for Envelope and Regulator

The merit of the work theorized in this analysis was calculated through a simple form represented in 4

$$M = \frac{1}{cost(ripple(v_0) + average(v_0 - 12) + 10^{-6}} \tag{4}$$

where $cost$ respresents the cost of resistors, capacitors and diodes in the circuit.

The value computed was 3.44×10^{-2}, which was lower than what was expected, meaning the circuit could have been more optimized. However, it was felt that the value was satisfying for the purpose of this assignment.

Merit	8.170081e-02

Table 2: Merit calculated through Octave

The two following graphs show, first, the voltages from the transformer, the Envelope Detector, the Voltage Regulator and, second, the deviation from the desired DC.

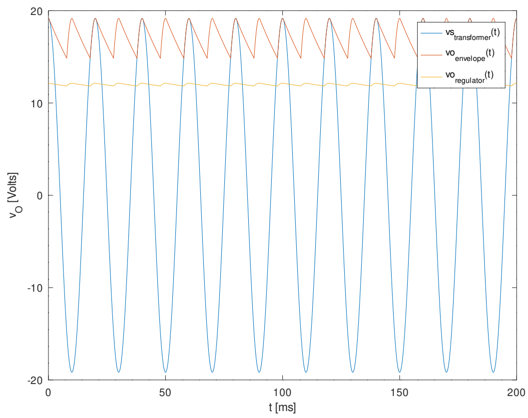


Figure 2: Voltage of the rectifier, Voltage of Envelope Detector and Voltage Regulator

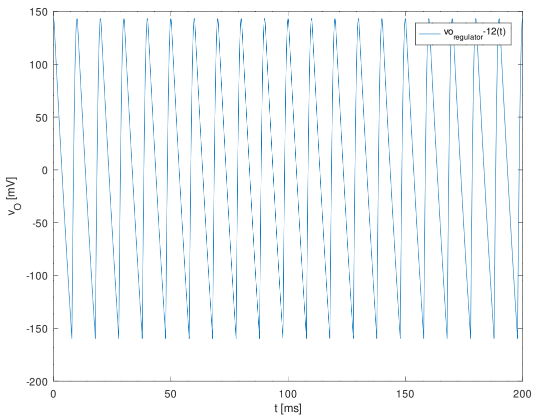


Figure 3: $v_0 - 12$ (Deviation from the desired DC voltages)

3 Simulation Analysis

A simulation through NGSpice was conducted to simulate this AC DC converter. The original circuit was slightly simplified to carry the simulation. The following table shows the results computed by the simulation: the input voltage of the secondary circuit (v(2)), the ouput voltages of the Envelope Dectector and the Voltage Regulator (v(4) and v(5), respectively).

ripenv	4.119860e+00
venvavg	1.583362e+01
ripreg	5.470200e-01
vregavg	1.209462e+01

Table 3: Ripple and Average Voltages for Envelope and Regulator

The value computed for Merit was 4.03×10^{-2}, which was lower than what was expected, meaning the circuit could have been more optimized. However, it was felt that the value was satisfying for the purpose of this assignment.

merit	4.165231e-02

Table 4: Merit calculated through NgSpice

This simulation also produced the following plot which displays how the voltage of the transformer v(2)-v(3), the voltage of Envelope Detector v(4) and Voltage Regulator v(5), varies with time.

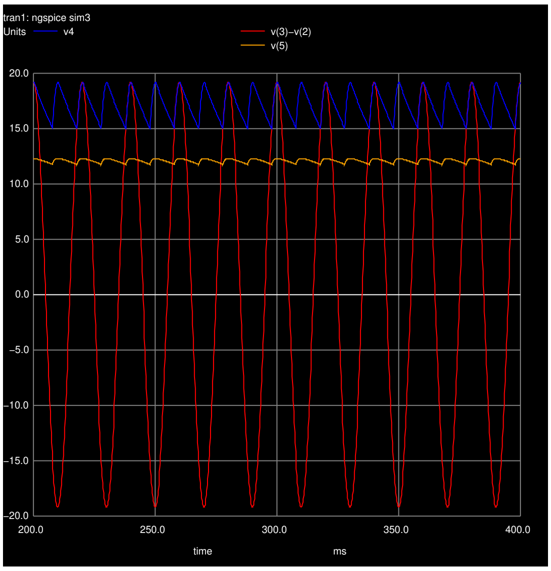


Figure 4: Voltage of the rectifier, Voltage of Envelope Detector and Voltage Regulator

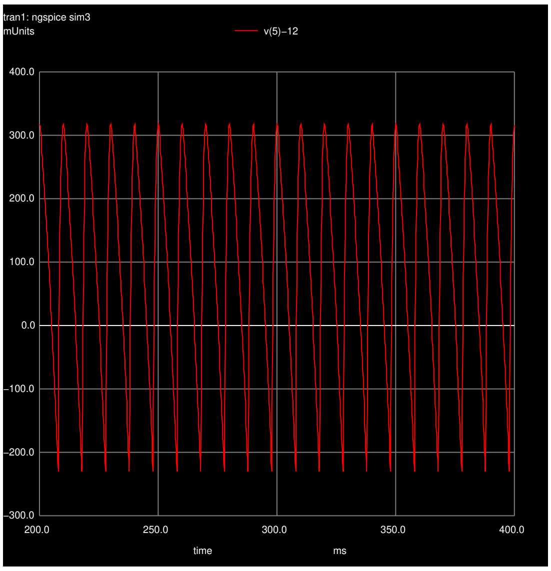


Figure 5: $v_0 - 12$ (Deviation from the desired DC voltages)

4 Conclusion

Now, the graphs and values obtained in Section 2 and Section 3 will be presented side by side and compared.

On the left there will be the graphs of the Theoretical analysis, obtained through Octave and on the right the ones achieved in Simulation with resort to NGSpice will appear.

Below will be presented the values for Ripple and Average voltages in the Envelope Detector and the Voltage Regulator.

Ripple Envelope	4.315587e+00
Average Envelope	1.712652e+01
Ripple Regulator	3.029639e-01
Average Regulator	1.200000e+01

Table 5: Ripple and Average Voltages for Envelope and Regulator in Theoretical Analysis

ripenv	4.119860e+00
venvavg	1.583362e+01
ripreg	5.470200e-01
vregavg	1.209462e+01

Table 6: Ripple and Average Voltages for Envelope and Regulator in Simulation

With the innacuracy visible between the two analysis above, the group concluded that there is a natural oscilation from NGSpice. The reason is that the diode, being a non-linear component, creates no correlation between the current and the voltage, unlike what happened in the previous lab assignments. The exponential function that is used in this situation is possibly the reason for the oscilations.

However the output voltage was still around 12V, which confirms that the discrepancy is not that impactful.

The Merit, calculated through the formula 4 was obtained by both softwares:

Merit	8.170081e-02

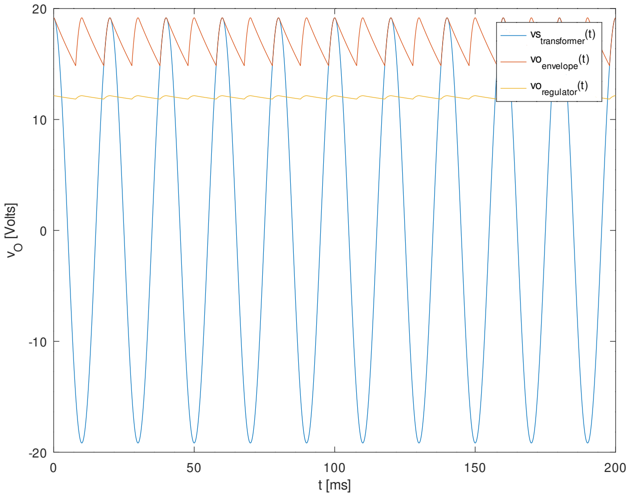
Table 7: Merit calculated in Theoretical Analysis

merit	4.165231e-02

Table 8: Merit calculated in Simulation

As for the voltage values, the Merit values also came with a slight inaccuracy. The Merit value is low, but the group couldn't make it higher, however the main objective of the assignment was achieved.

Now let's take a look at the plots done for the output of the Envelope Detector and the Voltage circuits obtained in Theorical Analysis and in Simulation. Also, the comparison between the graphs of the deviation from the desired DC voltages obtained with Octave and NgSpice.



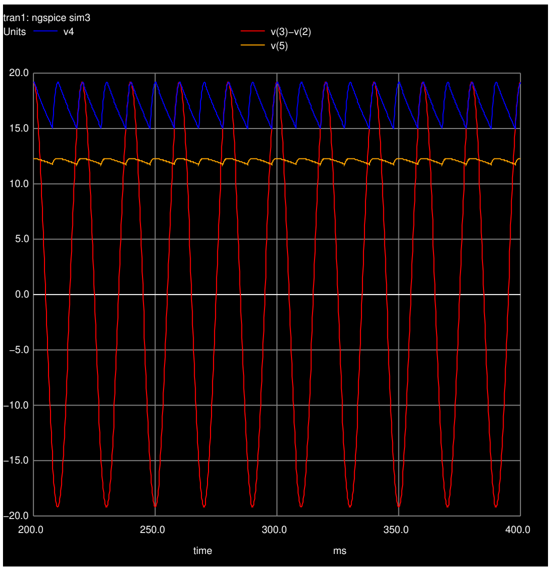
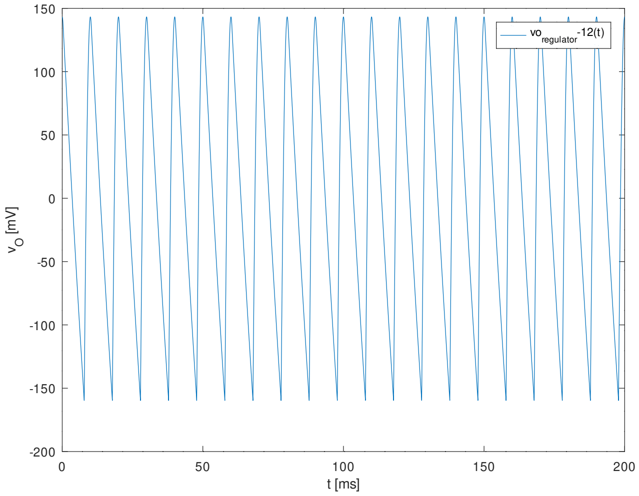


Figure 6: Voltage of the rectifier, Voltage of Envelope Detector and Voltage Regulator (Analysis top vs Simulation bottom)



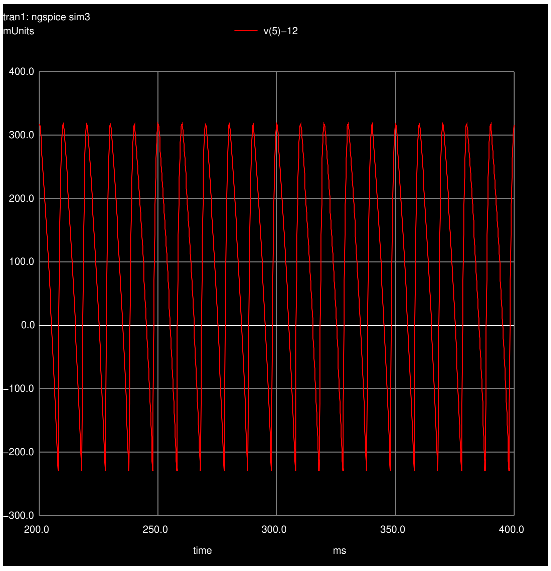


Figure 7: Deviation from the desired DC voltages (Analysis top vs Simulation bottom)

It is clear that both plots are almost identical, which proves the success of the simulation. We can also conclude that the Envelope Detector and Voltage circuits designed by the group worked as expected and theorized when simulated.