Circuit Theory and Electronics Fundamentals

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RC circuit

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Contents

1 Introduction

The objective of this laboratory assignment is to build an AC/DC converter, with a transformer, envelope detector and voltage regulator. The AC voltage of 230V and frequency 50Hz will be transformed into a DC voltage of 12V.

In Section 2, a theoretical analysis of the circuit is presented. In Section 3, the circuit is analysed by simulation, and the results are compared to the theoretical results obtained in Section 2. The conclusions of this study are outlined in Section 4.

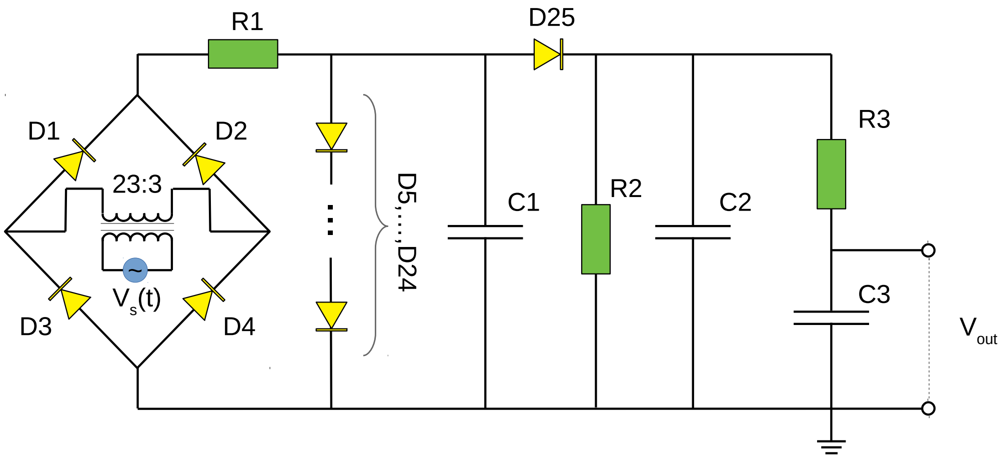

Figure 1: AC/DC Converter

2 Theoretical Analysis

In this section, the circuit shown in Figure 1 is analysed theoretically, analysing the circuit for $t < 0$, calculating the equivalent resistance, determining the natural and forced solutions and superimposing them to find the total solution.

2.1 Envelope detector

For t<0, $v_s(t) = V_s(t)$, it is a DC circuit. We can determine the voltges in all nodes and currents in all branches using the nodal method. Since this is a linear circuit, we apply Ohm's Law, $V_i = R_i * I$ and the Kirchoff Current Law (KCL), $\sum I_i = 0$.

We get the following equation, in matrix form:

$$\begin{bmatrix} -G_1 & G_1+G_2+G_3 & -G_2 & 0 & -G_3 & 0 & 0 & 0 \\ 0 & -G_2-K_b & G_2 & 0 & K_b & 0 & 0 & 0 \\ 0 & K_b & 0 & 0 & -G_5-K_b & G_5 & 0 & 0 \\ 0 & 0 & 0 & -G_6 & 0 & 0 & G_6+G_7 & -G_7 \\ 1 & 0 & 0 & -1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & -K_c*G_6 & 1 & 0 & K_c*G_6 & -1 \\ 0 & -G_3 & 0 & -G_4 & G_4+G_3+G_5 & -G_5 & -G_7 & G_7 \end{bmatrix} \cdot \begin{bmatrix} V_1 \\ V_2 \\ V_3 \\ V_4 \\ V_5 \\ V_6 \\ V_7 \\ V_8 \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \\ V_s \\ 0 \\ 0 \\ 0 \end{bmatrix} \quad (1)$$

This equation solved using octave yields the following results:

Variable	Value [A or V]

Table 1: Node Analysis Results for t<0

2.2 Voltage regulator

Now, we have to determine the equivalent resistance R_{eq} as seen from the capacitor terminals. We take out all the independent voltage sources (make $v_s = 0$) and replace the capacitor with a voltage source $Vx = V(6) - V(8)$. The values of$V(6)$ and $V(8)$ were already obtained via nodal analysis in the previous subsection. To determine the current I_x supplied by V_x we run mesh analysis. This is necessary because the resistors are arranged in such a way that they cannot be simplified into an equivalent resistor by applying the usual equations for resistors in series and in parallel. The mesh method gives us these equations in matriz form:

$$\begin{bmatrix} R_1 + R_3 + R_4 & -R_3 & -R_4 & 0 \\ -K_b R_3 & K_b R_3 - 1 & 0 & 0 \\ -R_4 & 0 & R_4 + R_6 + R_7 - K_d & 0 \\ 0 & -R_5 & K_d & R_5 \end{bmatrix} \cdot \begin{bmatrix} I_A \\ I_B \\ I_C \\ I_D \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ 0 \\ V_x \end{bmatrix} \tag{2}$$

This yields the following results:

Variable	Value [A or V]

Table 2: Equivalent resistance

For the time constant:
$\tau = R_{eq} \cdot C = 0.00313933181 s$

3 Simulation Analysis

3.1 Envelope detector

Table 4 shows the simulated operating point results for the circuit at times $t < 0$.

Name	Value [A or V]

Table 3: Operating point. A variable preceded by @ is of type *current* and expressed in Ampere; other variables are of type *voltage* and expressed in Volt.

Table 5 shows the simulated operating point results for the circuit given that $V_s = 0$ and replacing the capacitor with a voltage source imposing the voltage on the terminals of said capacitor as calculated in the earlier analysis.

Name	Value [A or V]

Table 4: Operating point. A variable preceded by @ is of type *current* and expressed in Ampere; other variables are of type *voltage* and expressed in Volt.

This is necessary so as to provide initial conditions for the analyses made below given that V_s at time $t = 0$ is equal to 0 but the voltage difference in the terminals of the capacitor stays constant for very short time intervals.

4 Conclusion

In this laboratory assignment the objective of building an AC/DC converter circuit by using a tranformer, envelope detetcor and a low-pass filter was achieved. The ripple The estabilization time The merit

The results from both the theoretical analysis using octave and the circuit simulation using ngspice appear to match.