Circuit Theory and Electronics Fundamentals

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Mestrado em Engenharia Aeroespacial

Laboratory 1 Report

Group 7

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Contents

1 Introduction **3**

2 Theoretical Analysis **4**
2.1 Mesh Analysis 4
2.2 Node Analysis 4

3 Simulation Analysis **5**
3.1 Operating Point Analysis 5

4 Conclusion **6**

1 Introduction

The objective of this laboratory assignment is to study a circuit containing both dependent (I_b, V_c) and independent (I_d, V_a) current and voltage sources, connected to resistors (R_1 to R_7). The circuit and its organization can be seen in Figure 1.

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.

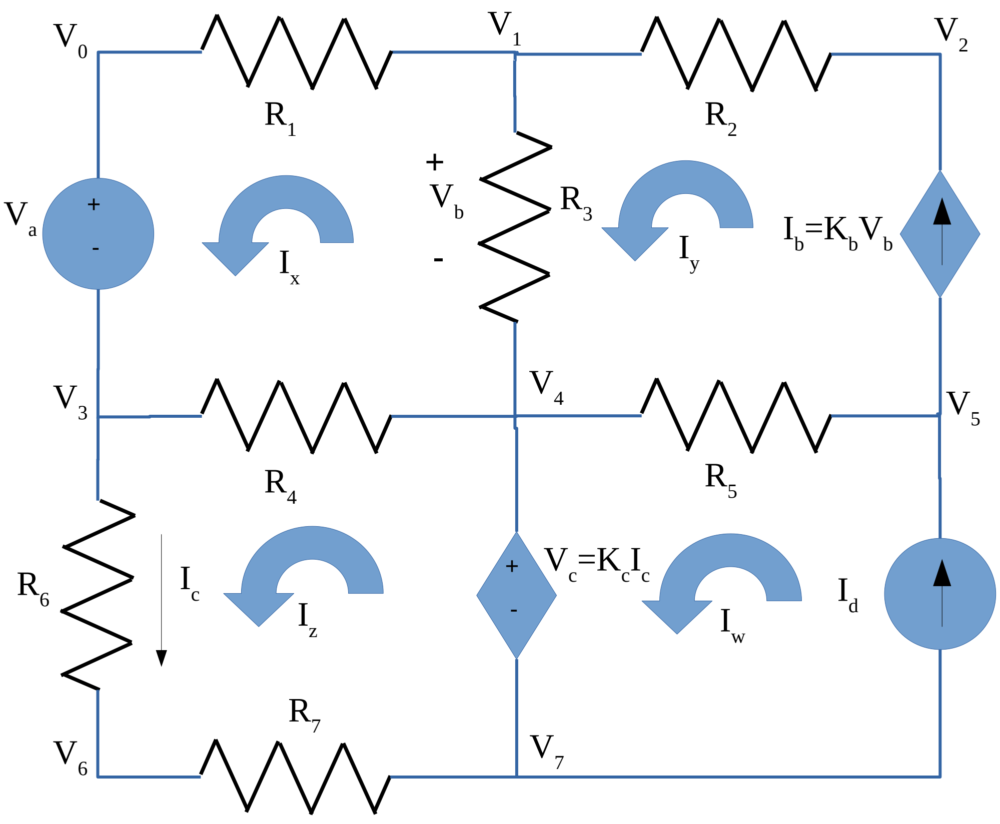

Figure 1: Circuit topography

2 Theoretical Analysis

In this section, the circuit shown in Figure 1 is analysed theoretically, through the methods of Mesh Analysis and Node Analysis.

2.1 Mesh Analysis

In this subsection of the report we are going to analyse the circuit through the Mesh method in order to obtain the four currents in the four meshes of the circuit: I_x, I_y, I_z, I_w. For that, we apply Kirchhoff's Voltage Law (KVL) in each of the meshes, obtaining the following equations:

$$V_a = I_x(R_1 + R_3 + R_4) - I_y R_3 - I_z R_4; \tag{1}$$

$$I_y = I_b; \tag{2}$$

$$V_c = I_z(R_4 + R_6 + R_7) - I_x R_4; \tag{3}$$

$$I_w = I_d. \tag{4}$$

The results obtained after implementing these equations in Octave can be seen in Table 1:

Name	Value [A]
@I_x	0.000261
@I_y	0.000273
@I_z	-0.000942
@I_w	0.001013

Table 1: Currents obtained in the theoretical analysis in Octave.

2.2 Node Analysis

Here, we made use of Node Analysis to determine the voltages in each of the nodes. For that, we assigned the nodes an identification as you see in Figure 1.

We can then solve for the nodes, by calculating the potencial diferences between each node. That leaves us with 7 equations, one for each node excluding the ground node, denoted as Node 0. Solving the equations, we obtain the following matrix:

$$\begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ G_1 & -G_1 - G_2 - G_3 & G_2 & 0 & G_3 & 0 & 0 & 0 \\ 0 & G_2 + K_b & -G_2 & 0 & -K_b & 0 & 0 & 0 \\ 1 & 0 & 0 & -1 & 0 & 0 & 0 & 0 \\ 0 & G_1 & 0 & -G_4 - G_6 & G_4 & 0 & G_6 & 0 \\ 0 & -K_b & 0 & 0 & G_5 + K_b & -G_5 & 0 & 0 \\ 0 & 0 & 0 & G_6 & 0 & 0 & -G_6 - G_7 & G_7 \\ 0 & 0 & 0 & -K_c G_6 & 1 & 0 & K_c G_6 & -1 \end{bmatrix} \begin{bmatrix} V_0 \\ V_1 \\ V_2 \\ V_3 \\ V_4 \\ V_5 \\ V_6 \\ V_7 \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ 0 \\ V_a \\ 0 \\ -I_d \\ 0 \\ 0 \end{bmatrix} \tag{5}$$

Solving the matrix in Octave, we obtain the results presented in Table 2:

Name	Value [V]
V_0	0.000000
V_1	-0.270947
V_2	-0.828812
V_3	-5.103557
V_4	-0.232967
V_5	3.777700
V_6	-7.048489
V_7	-8.000990

Table 2: Voltages obtained in the theoretical analysis in Octave.

3 Simulation Analysis

Since the voltage and current sources have constant values, we only need to use the Operating Point analysis to fully study the circuit.

3.1 Operating Point Analysis

While using Ngspice we encountered some problems with the use of current-controlled voltage sources. To overcome them, we introduced a dummy 0V voltage source between the resistors 6 and 7, originating node 8, which does not show in the Octave results since it is not needed for theoritical calculations. The voltage source V_c depends on the current I_c, which is the current on R_6. However, since Ngspice could not take the current in R_6, we introduced the null voltage source, since the current there will be I_c, which is the current that V_c depends on.

Table 3 shows the simulated operating point results for the circuit under analysis. Compared to the theoretical analysis results, one notices the following differences: describe and explain the differences.

First, we must take into consideration that the currents flowing through R1, R2, R3 and R4 are, respectively, equal to I_x, I_y, I_z and I_w. Comparing the Tables 1 and 2 with Table 3, we see that the difference between the different voltages and currents is minimal. Different digits beggin to appear only on the fourth decimal case and these disparities can be attributed to distinct methods of calculation and floating point.

On the other hand, by analysing Table 3, we note that in each resistor the current and voltage values have the same sign, as it should be since the power of a resistor must be positive.

Having verified that the theoretical results and the simulation results are very much approximate, with minor acceptable differences, we say that the methods used to study the circuit are accurate.

Name	Value [A or V]
@gib[i]	-2.60149e-04
@id[current]	1.012649e-03
@rr1[i]	2.482093e-04
@rr2[i]	-2.60149e-04
@rr3[i]	-1.19393e-05
@rr4[i]	1.192184e-03
@rr5[i]	-1.27280e-03
@rr6[i]	9.439751e-04
@rr7[i]	9.439751e-04
v(1)	-2.57730e-01
v(2)	-7.88381e-01
v(3)	-5.10356e+00
v(4)	-2.21603e-01
v(5)	3.747461e+00
v(6)	-7.05303e+00
v(7)	-8.00775e+00
v(8)	-7.05303e+00

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.

4 Conclusion

The objective of this laboratory assignment as been accomplished as can be seen by the results obtained. The Ngspice simulator is a very powerful tool, however, we encountered some problem while simulating the circuit, particularly with the current-controlled voltage source, as it was explained in subsection 3.1.

As can be seen by comparing the tables, both octave maths tool and circuit simulator Ngspice data match, although not perfectly, since both tools use different methods of calculations and the Ngspice tool is in fact simulation tool, contrary to Octave that was only used for theoretical calculations. If this was done in a laboratory with real equipment we would expect the results to be similar to the ones we obtained, having the results a slight discrepancy (which might have its source in the fact that the different programs are using a different number of decimal parcels in their calculations).