Circuit Theory and Electronics Fundamentals

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Laboratory 1

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1 Introduction

The objective of this laboratory assignment is to study a circuit containing an independent voltage source V_a, a dependent voltage source V_c, an a independent current source I_d, a dependent current source I_b and seven resistors R. The given circuit is composed by four elementary meshes. The circuit 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.

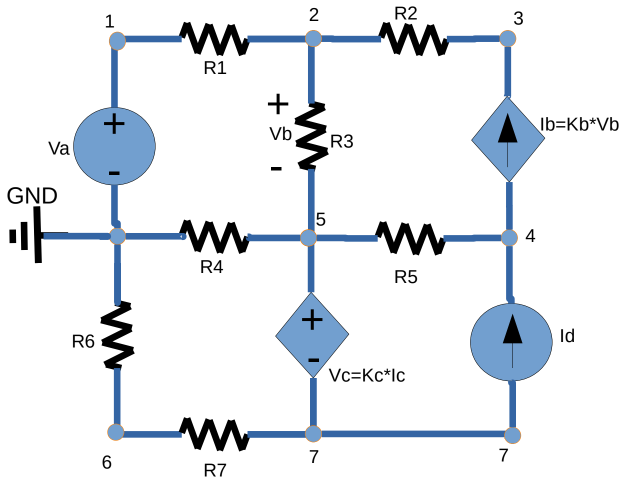

Figure 1: Circuit with independent sources, dependent sources and resistors.

2 Theoretical Analysis

In this section, the circuit shown in Figure 1 is analysed theoretically using the mesh method and the node method.

2.1 Mesh Method

To determine all the currents of a planner circuit, they can be replaced by fictitious currents and, subsequently, the Mesh Method based on Kirchhoff's Voltage Law and Ohm's Law can be applied.

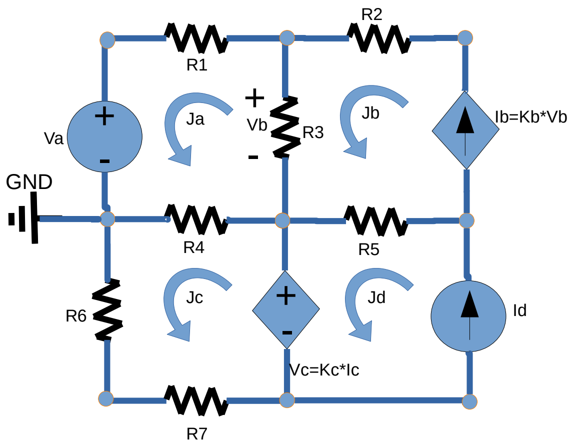

Figure 2: Circuit with mesh currents (Mesh Method).

According to this method, the algebraic sum of voltages around a loop equals zero or, in other way, the sum of voltage rises equals the sum of voltage drops around a loop. Applying this method the only unknown variables are the currents that circulate on each mesh. So, for mesh A:

$$J_a \times R_1 + V_a + R_4 \times (J_a - J_c) + R_3 \times (J_a - J_b) = 0 \tag{1}$$

Mesh B:

$$J_b = I_b = K_b \times V_b = K_b \times R_3 \times (J_b - J_a) \tag{2}$$

Mesh C:

$$J_c \times R_7 - K_c \times J_c + R_4 \times (J_c - J_a) + R_6 \times J_c = 0 \tag{3}$$

And mesh D:

$$J_d = I_d \tag{4}$$

By computing this four equations in function of the four variables: Ja, Jb, Jc e Jd. The values presented in Table 1 were obtained. For this calculations it was used the mathematical tool, Octave.

Name	Value [A]
Ja	-0.00022595
Jb	-0.00023645
Jc	0.00095088
Jd	0.0010264

Table 1: Theoretical values obtained using octave to solve equations of mesh method.

2.2 Node Method

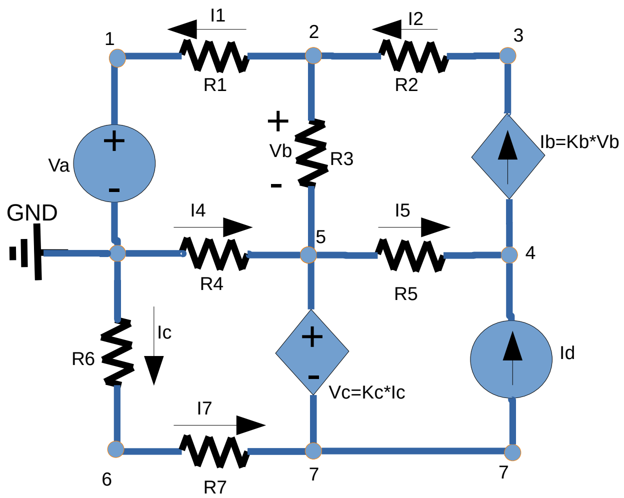

Figure 3: Circuit with currents and nodes identified (Node Method).

In the same way, we can apply the node method, this method is based in the Kirchhoff's Current Law (KCL) and in the Ohm's Law, to analyse circuits. According to this method, KCL is applied in nodes that aren't connected to voltage sources and the currents flowing into a node must add up to zero, which means that the algebraic sum of currents that enters into a node equals to the algebraic sum of currents that exits that node. In nodes related by voltage sources, additional equations are applied. So, applying KCL for node 2, we have:

$$(V_3 - V_2) \times G_2 = (V_2 - V_1) \times G_1 + (V_2 - V_5) \times G_3 \tag{5}$$

Node 3:

$$(V_3 - V_2) \times G_2 = K_b \times (V_2 - V_5) \tag{6}$$

Node 4:

$$I_d + (V_5 - V_4) \times G_5 = K_b \times (V_2 - V_5) \tag{7}$$

And node 6:

$$(-V_5) \times G_6 = (V_6 - V_7) \times G_7 \tag{8}$$

The additional equations are:

$$V_1 = V_a \tag{9}$$

$$V_5 - V_1 = K_c \times (-V_6) \times G_6 \tag{10}$$

$$(V_6 - V_7) \times G_7 + (-V_5) \times G_4 + (V_2 - V_5) \times G_3 = (V_5 - V_4) \times G_5 + I_D \tag{11}$$

The equations (9) and (10) are obtained using the voltage drop between the two voltage sources. The last equation was derived using a super-node that contains the dependent voltage source. Applying the node law, the sum of currents that enter the dependent voltage source is equal to the sum of currents that leaves it.

Name	Value [A or V]
V1	5.0102
V2	4.7774
V3	4.2972
V4	8.6049
V5	4.8099
V6	-1.9313
V7	-2.9274

Table 2: Theoretical values obtained using octave to solve equations of Node Method.

3 Simulation Analysis

3.1 Operating Point Analysis

Table 3 and Table 4 show the simulated operating point results for the circuit under analysis. Compared to the theoretical analysis results, it can be seen that the values that were obtained from the simulation are exactly the same for the voltages and currents of the circuit.

Name	Value [V]
n1	5.010158e+00
n2	4.777353e+00
n3	4.297180e+00
n4	8.604880e+00
n5	4.809850e+00
n6	-1.93130e+00
n7	-2.92744e+00

Table 3: Operating point. The variables are expressed in Volt and represent, in particular, the *voltage* at each node of the circuit.

Name	Value [A]
@r1[i]	2.259480e-04
@r2[i]	2.364497e-04
@r3[i]	-1.05017e-05
@r4[i]	-1.17683e-03
@r5[i]	1.262826e-03
@r6[i]	9.508803e-04
@r7[i]	9.508803e-04

Table 4: Operating point. The variables are expressed in Ampere and represent the *current* in each branch of the circuit.

4 Conclusion

In this laboratory assignment the objective of analysing the given circuit has been achieved.

This analyse was performed both theoretically using Octave math tool (computations using the node and mesh method), and by circuit simulation (Ngspice tool). As we can see, both the node and meshes method, gave the same results as the ones obtained with the circuit simulation using the Ngspice tool.

The simulation results matched the theoretical results precisely. The reason for this perfect match is the fact that this is a straightforward circuit containing only time independent linear components (resistors, voltage and current sources). Furthermore, Ngspice uses the same methods as the ones we used in the theoretical computations, for this reasons the theoretical and simulation models do not differ. For more complex components, the theoretical and simulation models could differ, which as we have seen is not the case, for this circuit.