Circuit Theory and Electronics Fundamentals

Integrated Masters in Aerospace Engennering, Técnico, University of Lisbon

Laboratory Report 1- Group 28

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1 Introduction

The aim of this laboratory work regarding the topics studied in the first three weeks of the course was to analyse a circuit constituted by an independent voltage source, an independent current source, a voltage controlled dependent current source, a current controlled dependent voltage source and seven resistors, as shown in the Figure 1 below. For this, a theorical analysis was made using both node and mesh methods, whose results will be discussed in Section 2. To validate these results, a simulation was conducted, as will appear in Section 3.

The results were then compared and the conclusions of the group summarized in Section 4.

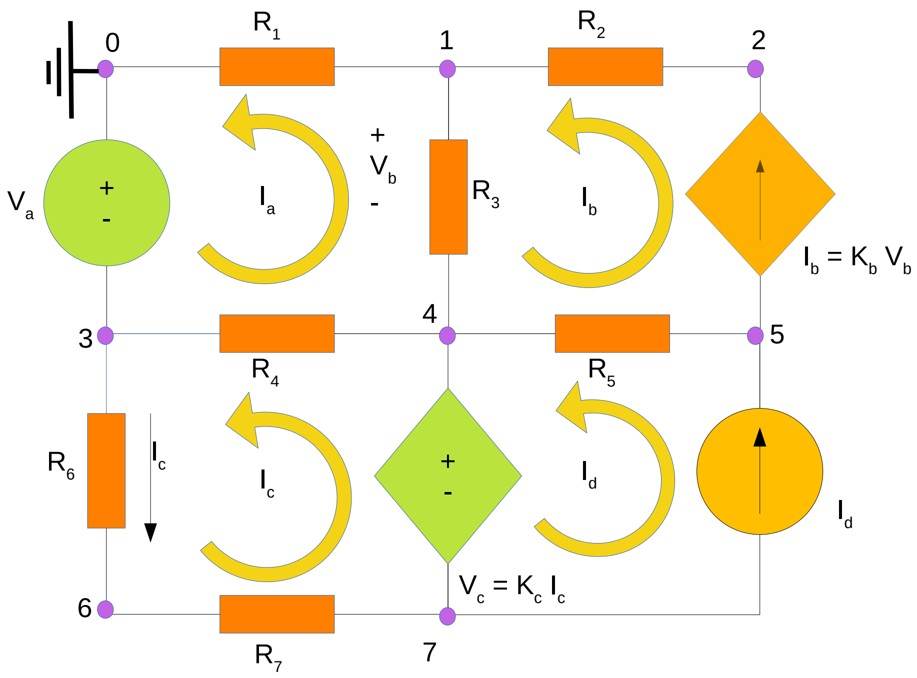

Figure 1: Circuit analysed.

The initial data was generated randomly by datagen.py as it is presented in the table below.

Generated Data										
Resistors			Voltages			Currents			Constants	
R1	1.04111259479		Va	5.06871572779		Id	1.04127523824		Kb	7.28747116393
R2	2.09945227782								Kc	8.11568444746
R3	3.13109125645									
R4	4.11947040212									
R5	3.1155879392									
R6	2.04799381798									
R7	1.02754401839									

Table 1: Units for the values: V, mA, KOhm and mS

2 Theoretical Analysis

In this section, a theoretical analysis of the circuit was conducted. Two approaches were chosen: the mesh and the node methods.

2.1 Mesh Method

The currents IA and IC were determined by examining the loop formed by R1, R3, R4 and Va and the loop formed by R4, R6, R7 and Vc, respectively. The third independent equation was obtained by matching IB to Kb*Vb (Vb=R3*(IB-IA)). These were then rearrenged in a matrix form as shown below. Octave math tools were used to solve the system.

$$\begin{bmatrix} R1+R3+R4 & -R3 & -R4 \\ -R4 & 0 & -Kc+R4+R6+R7 \\ -Kb*R3 & Kb*R3-1 & 0 \end{bmatrix} \begin{bmatrix} IA \\ IB \\ IC \end{bmatrix} = \begin{bmatrix} -Va \\ 0 \\ 0 \end{bmatrix}$$

Name	Value [A]
Ia	-2.161572e-04
Ib	-2.260646e-04
Ic	9.671728e-04

Table 2: Octave Mesh Method Results. All variables are of type *current* and expressed in Ampere.

2.2 Node Method

The aim of using this method is to determine every node voltage. To do so, a reference node(with voltage =0V) was chosen. Then, seven independent equations were written in orther to find the remaining unknown node voltage values. The equations were then put in the form of the matrix shown below. Octave math tools were used to solve the system.

$$\begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ G1 & G1-G2-G3 & G2 & 0 & G3 & 0 & 0 & 0 \\ 0 & G2+Kb & -G2 & 0 & -Kb & 0 & 0 & 0 \\ 1 & 0 & 0 & -1 & 0 & 0 & 0 & 0 \\ 0 & G1 & 0 & -G4-G6 & G4 & 0 & G6 & 0 \\ 0 & -Kb & 0 & 0 & G5+Kb & -G5 & 0 & 0 \\ 0 & 0 & 0 & G6 & 0 & 0 & -G6-G7 & G7 \\ 0 & 0 & 0 & -KcG6 & -1 & 0 & Kc*G6 & -1 \end{bmatrix} \begin{bmatrix} V0 \\ V1 \\ V2 \\ V3 \\ V4 \\ V5 \\ V6 \\ V7 \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ 0 \\ Va \\ 0 \\ -Id \\ 0 \\ 0 \end{bmatrix}$$

Name	Value [V]
V0	0.000000e+00
V1	-2.250439e-01
V2	-6.996557e-01
V3	-5.068716e+00
V4	-1.940229e-01
V5	3.754486e+00
V6	-7.049480e+00
V7	-8.043292e+00

Table 3: Octave Node Method Results. All variables are of type *voltage* and expressed in Volt.

With these results, we are able to compare both methods. Calculating $(V1 - V0)/R1$ with the voltages of the node method we get Ia. Repeating the same process for V2, V1 and R2 we obtain Ib and for V3, V6 and R6 we get Ic. The calculations lead us to the following table:

Name	**Value [A]**
Ia	-2.161572e-04
Ib	-2.260646e-04
Ic	9.671728e-04

Table 4: Current Results . All variables are of type *current* and expressed in Ampere.

As expected, the results of node method and mesh method are equal. We can infer both analysis are correct.

3 Simulation Analysis

3.1 Operating Point Analysis

Ngspice was used to simulate the circuit in question. First of all, to contextualize the values obtained using this tool, it is necessary to state that, as node 0 is connected to ground, its nodal voltage does not appear on the table of results. Furthermore, to be able to describe the voltage flowing in the dependent source, an extra voltage source (whose voltage is equal to 0 V) was created, and put after the resistor 6 and node 6. This source led to the appearence of node 8, that has the same voltage of node 6. This was necessary because ngspice does not measure the current between two nodes, only in resistors and in independent voltage sources. The circuit with these changes is shown in the drawing below.

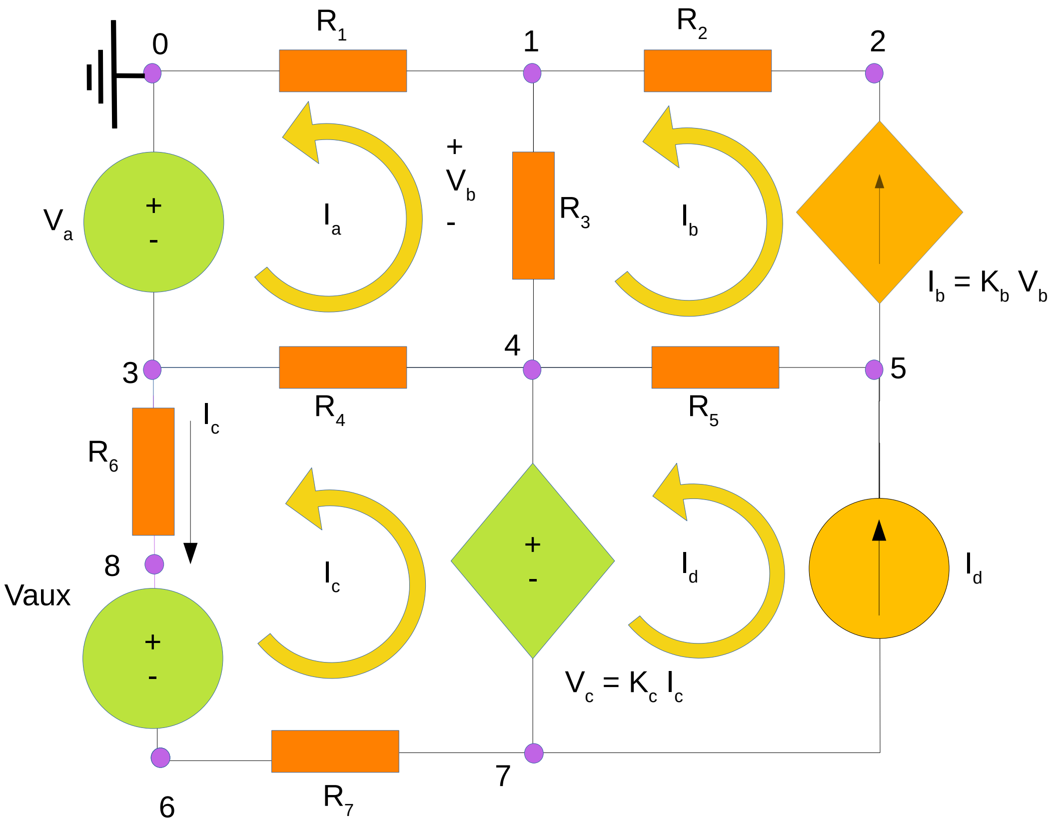

Figure 2: Circuit analysed in ngspice.

The simulated operating point results of the circuit that is being studied, allowed the group to obtain the current flowing in every resistor, the current in the dependent voltage source (IC) and even the current flowing in the dependent current source (IB). After running the simulation, the results were put in the table below.

After comparing the results obtained in ngspice with the obtained using the octave math tools, analysed in Section 2, we conclude that every result, Ia,Ib and Ic match.

Name	Value [A or V]
@gb[i]	-2.26065e-04
@id[current]	1.041275e-03
@r1[i]	-2.16157e-04
@r2[i]	-2.26065e-04
@r3[i]	9.907405e-06
@r4[i]	-1.18333e-03
@r5[i]	-1.26734e-03
@r6[i]	9.671728e-04
@r7[i]	9.671728e-04
v(1)	-2.25044e-01
v(2)	-6.99656e-01
v(3)	-5.06872e+00
v(4)	-1.94023e-01
v(5)	3.754486e+00
v(6)	-7.04948e+00
v(7)	-8.04329e+00
v(8)	-7.04948e+00

Table 5: NgSpice Results: A variable preceded by @ is of type *current* and expressed in Ampere; other variables are of type *voltage* and expressed in Volt.

4 Conclusion

It was agreed by the members of the group that the main goal of the task proposed was achieved. As presented, both theoretical and simulation results(obtained using Octave tools and ngpsice simulator, respectively) matched, reaching total accuracy. Despite the initial belief that the considerable number of components of the circuit could cause some disparity in the results, such did not happened. This proves not only the efficency of both mesh and node methods to analyse the circuit, as well as the simulator used.