Circuit Theory and Electronics Fundamentals

Lab 1 - Circuit Analysis Methods

Aerospace Engineering

Laboratory Report

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1 Introduction

This report is being made for the subject of Circuit Theory and Electronics Fundamentals and is related to the 1^{st} laboratory.

The objective of this laboratory assignment is to study a circuit containing seven resistors, one voltage source, one current source, one current controlled voltage source and one voltage controlled current source. The elementary meshes are named after the current to which they are atributed and so there are four of them.

The current controlled voltage source Vc is calculated by multiplying Kc with the current Ic, whereas the voltage controlled current source Ib can be determined by multiplying Kb with the voltage source Vb.

The display of this circuit can be seen in Figure 1.

In Section 2 we will analise theorically the circuit by both Method Analysis and present the results obtained by Octave.

Secondly, in Section 3 we will simulate the circuit using ngspice, present the results obtained and compare them with the ones gathered from Section 2.

The conclusions of this study are outlined in Section 4.

Where:

$$R_1 = 1.03431507833$$
$$R_2 = 2.02853090731$$
$$R_3 = 3.1462050633$$
$$R_4 = 4.03438547455$$
$$R_5 = 3.12170042214$$
$$R_6 = 2.07116379646$$
$$R_7 = 1.01597753093$$
$$V_a = 5.156959346$$
$$I_d = 1.01455683569$$
$$K_b = 7.1497941196$$
$$K_c = 8.12593642585$$

The units of the elements whose name starts with R (the resistors) are kOhm (kiloohm), the ones that start with I are expressed in mA (miliampere) and the ones starting with V are expressed in V (volts). While Kb is given in mS (milisiemens), Kc is also given in kOhm.

These values where obtained using the *Python* script using the lowest student number on our group - 95785.

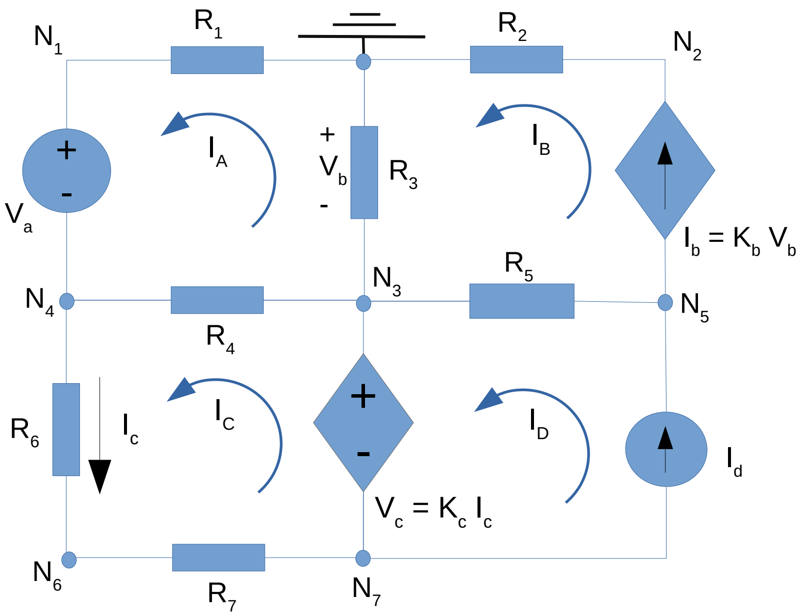

Figure 1: Circuit with the nodes

2 Theoretical Analysis

In this section, the circuit shown in Figure 1 is analysed theoretically, in terms of it's node voltages and mesh currents.

2.1 Mesh Analysis Method

For this mesh metod we defined circular currents in the counter-clockwise direction and then the circuit os evaluated considering those new currents.

Starting by number the nodes arbitrarily, assigning current names and directions to all branches also arbitrarily and defining one node as ground (GND)

Being mesh A the one with the resistors R1, R3 and R4, and the voltage source Va, the mesh B with the resistors R2, R3 and R5 and the voltage controlled current source Ib, the mesh C with the resistors R4, R6 and R7, and the current controlled voltage source Vc, and, at last, the mesh D with the resistor R5, the current source Id and the current controlled voltage source Vc.

A system of equations obtained applying the Kirchhoff Current Law (KCL)to each mesh can be written as

$$\begin{bmatrix} R_1 + R_3 + R_4 & -R_3 & -R_4 \\ -R_4 & 0 & R_4 + R_6 + R_7 - K_C \\ -K_B R_3 & K_B R_3 - 1 & 0 \end{bmatrix} \begin{bmatrix} I_A \\ I_B \\ I_C \end{bmatrix} = \begin{bmatrix} -V_A \\ 0 \\ 0 \end{bmatrix} \quad (1)$$

It was used 3 equations (4 meshes - 1 = 3 linearly independent equations) : Mesh A, Mesh C and an addicional equation which is $I_b = K_b V_b \mathit{where} V_b = (I_B - I_A)R_3$

It's important to notice that D loop is independent from the restant ones so we don't need to determine the current I_D as it is given on the inicial data.

Also we didn't use the mesh B because it had a independent current source so we couldn't aply the KVL.

After solving the system with Octave tools we get the Table 1 results.

Name	Value [A or V]
IA	-2.440917089113763e-04
IB	-2.554476012603903e-04
IC	9.804366878292505e-04
ID	1.014556835690000e-03
Ib	-2.554476012603903e-04
Ic	9.804366878292505e-04
Vb	-3.572796600675846e-02
Vc	7.966966194871432e+00

Table 1: Results obtained by mesh analysis method with octave tool

2.2 Nodal Analysis Method

The Nodal Analysis Method is another general procedure analysing circuits using node voltages as the circuit variables.

To find the nodal voltages we chose 7 equations (8 nodes - 1 = 7 linearly independent equations) that comprise:

- KCL in nodes not connected to voltage sources;

- Additional equations for nodes related by voltage sources.

It was used the equations regarding the nodes 0, 2, 5, 6 therefore it was necessary tree additional equations.

We chose to put the ground zero between tree branches ccorresponding to the ones with R_1, R_2 and R_3 because it will facilitate the system of equations .

the first equation V1-V4=Va was used for node 1 because node 1 and node 4 are connected to a independent voltage source

secondly knowing that Vc=Kc*Ic and Vc=V3-V7 it was concluded that for node 7 tha equation obtained was V3-V7=Kc(V3-V6)*G6

Finally node 3 is connected to 4 branches so applying Ohms law to the 3 resistors and knowing that the current that passes through Vc is I4=-Id+(V6-V7)G7 we get the final and thrid equation tha we need: (V4-V3)G4 + (V0-V3)G3 +(V5-V3)G5-Id+(V6-V7)G7

The system of equations that will be solved is:

$$\begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ -G_1-G_2-G_3 & G_1 & G_2 & G_3 & 0 & 0 & 0 & 0 \\ K_b+G_2 & 0 & -G_2 & -K_b & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & -1 & 0 & 0 & 0 \\ -K_b & 0 & 0 & K_b+G_5 & 0 & -G_5 & 0 & 0 \\ 0 & 0 & 0 & 0 & G_6 & 0 & -G_6-G_7 & G_7 \\ 0 & 0 & 0 & 1 & -K_cG_6 & 0 & K_cG_6 & -1 \\ G_3 & 0 & 0 & -G_4-G_3-G_5 & G_4 & G_5 & G_7 & -G_7 \end{bmatrix} \begin{bmatrix} V_0 \\ V_1 \\ V_2 \\ V_3 \\ V_4 \\ V_5 \\ V_6 \\ V_7 \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ 0 \\ V_a \\ -I_d \\ 0 \\ 0 \\ I_d \end{bmatrix} \quad (2)$$

After solving the system with Octave tools we get the Table 2 results.

Name	Value [A or V]
V0	0.000000000000000e+00
V1	2.524677350223614e-01
V2	-5.181833543549311e-01
V3	3.572796600676043e-02
V4	-4.904491610977638e+00
V5	4.000301352954461e+00
V6	-6.935136583530744e+00
V7	-7.931238228864696e+00
Vb	-3.572796600676043e-02
Ib	-2.554476012604044e-04
Vc	7.966966194871456e+00
Ic	9.804366878292535e-04

Table 2: Results obtained by nodal analysis method with octave tool

3 Simulation Analysis

3.1 Operating Point Analysis

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.

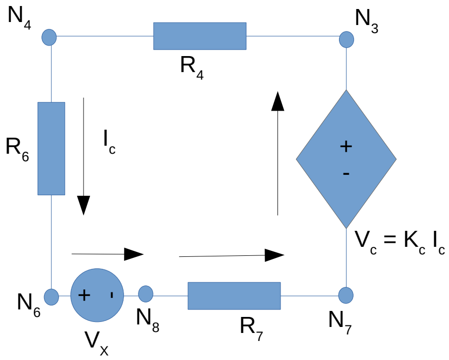

Figure 2: C Mesh with an adicional voltage source

The table below shows the simulated operating point results for the circuit described in Figure 1.

In this simulation is important to explain the creation of a auxiliary voltage Vb (with voltage equal to 0V) that was put between N6 and R7. Consequently this led to appearance of a node that we designated by N8 that has the same voltage as N6.

This was necessary because of Ngspice software requirements.

By observing the table we can conclude that the simulated results are the same of the theoretical results.

4 Conclusion

The objective of this laboratory assignment is to analise the circuit and solve it. After discussing with all members of the group we can conclude that this goal was achieved. As presented the results obtained by the Octave math toll and Ngspice simulation tool are the same. This perfect

Name	Value [A or V]
@vx[i]	9.804367e-04
@hc[i]	3.412015e-05
@va[i]	-2.44092e-04
@gb[i]	-2.55448e-04
@id[current]	1.014557e-03
@r1[i]	-2.44092e-04
@r2[i]	-2.55448e-04
@r3[i]	-1.13559e-05
@r4[i]	-1.22453e-03
@r5[i]	-1.27000e-03
@r6[i]	9.804367e-04
@r7[i]	9.804367e-04
n1	2.524677e-01
n2	-5.18183e-01
n3	3.572797e-02
n4	-4.90449e+00
n5	4.000301e+00
n6	-6.93514e+00
n7	-7.93124e+00
n8	-6.93514e+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.

match was achieved because the circuit is only composed by linear components so both models (Ngspice and Octave) used the same methos to solve the circuit and therefore the results can not differ. Also all the components used in this circuit (resistors, branches, nodes,...) are perfect this means they don't dissipate energy by heating. Finally this similaraty proves the efficency and importance of the nodes and mesh methods.