Circuit Theory and Electronics Fundamentals

Department of Electrical and Computer Engineering, Técnico, University of Lisbon

T1's Laboratory Report

Group 5

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March 21, 2021

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1 Introduction

The objective of this laboratory assignment is to study a given circuit, described in the figure 1 below, running a theoretical analysis as well as a simulation and compare both of the results.

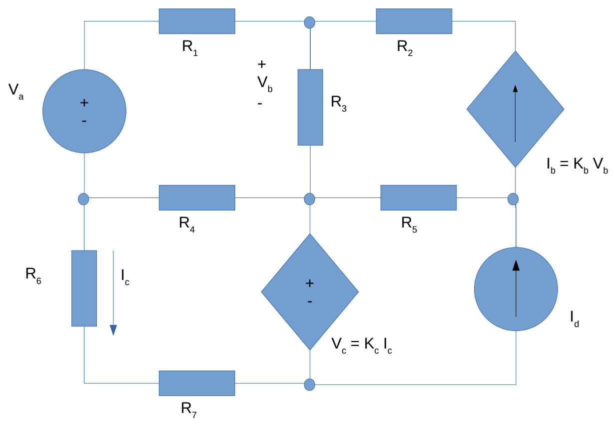

Figure 1: T1's given circuit.

The theoretical analysis will be done using both the mesh method as well as the nodal method. For the simulation, it will be done using a simple script on Ngspice.

The comparison between the three results will be made in the "Analysis" section of this report, where we will explain the small differences that we may get in our results.

The analysis will be done using values assigned to us using the professor's Python script, which was provided in his github repository.

The data used was the following.

Name	**Value [A or V or Ω or S]**
R_1	1.0331307462823254e3
R_2	2.058959312128689e3
R_3	3.0574731757898794e3
R_4	4.1598240158631485e3
R_5	3.0790247479735586e3
R_6	2.071585908343431e3
R_7	1.0200157363975357e3
V_a	5.04611069501311
I_d	1.0397027739760396e-3
K_b	7.175215229391312e-3
K_c	8.394963923537722e3

2 Theoretical Analysis

In this section, the circuit shown in Figure 1 is analysed theoretically, this is, we will be using both the mesh method and the nodal method to calculate the remaining variables (I_b, I_c, V_b and V_c).

2.1 Mesh Method

By using Mesh method or loop analysis we analyzed the given circuit splitting it in four meshes with the currents I_a I_b I_c and I_d (given). The direction of each mesh's current is shown below:

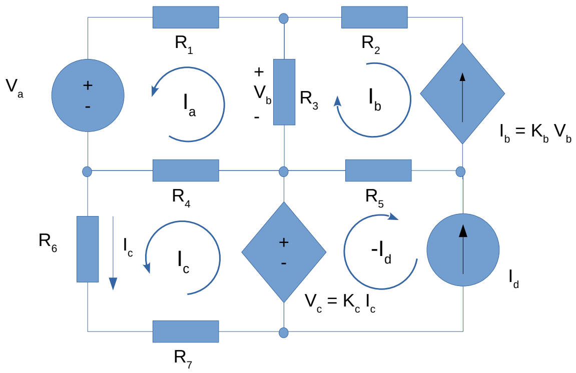

Figure 2: Mesh method circuit.

It's important to mention that in resistors R_3 and R_5 there is the current contribution from two meshes at the same time, as it is shown in the two following equations.

For mesh A, we have:

$$V_a = I_a(R_1 + R_4) - I_cR_4 + V_b \tag{1}$$

For mesh C, we have:

$$I_aR_4 - I_c(R_4 + R_6 + R_7) + V_c = 0 \tag{2}$$

And then, we´ve used additional equations, such as:

$$V_c = I_cK_c \tag{3}$$

$$I_b = V_bK_b \tag{4}$$

$$V_b = R_3(I_a + I_b) \tag{5}$$

Both the equations 3 and 4 are given in the original circuit figure.

Using these equations described above, we wrote a simple Octave script so that we could get the remaining values to fully describe the circuit.

The results we got using the mesh method were the following:

Name	Value [A or V]
V_b	-3.651601e-02
V_c	-7.636592e+00
I_b	-2.620103e-04
I_c	-9.096634e-04

All the variables preceded by I are currents and are expressed in Ampere, the other variables, preceeded by V are voltages and are expressed in Volt.

2.2 Nodal Method

This method is characterized as a powerful method to compute by using matrix analysis in octave or matlab. Nodal Voltage Analysis uses the nodal equations of Kirchhoff's first law to find the voltage potentials around the circuit. The nodes numeration is shown below:

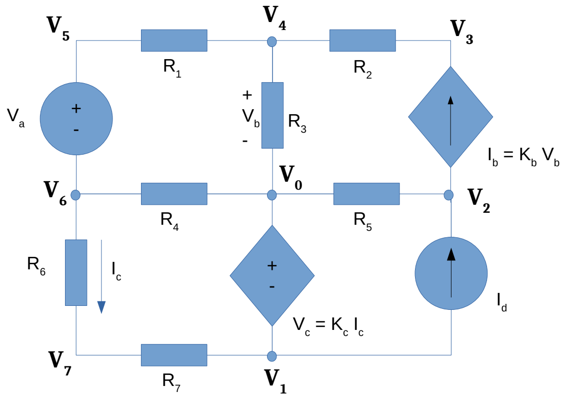

Figure 3: Nodal method circuit.

The equations used to solve the system were the following:

$$\frac{1}{R_2}(V_3 - V_4) + \frac{1}{R_1}(V_3 - V_4) - V_b\frac{1}{R_3} = 0 \tag{6}$$

$$\frac{1}{R_2}(V_4 - V_3) + I_b = 0 \tag{7}$$

$$\frac{1}{R_5}(V_0 - V_2) - I_b = -I_d \tag{8}$$

$$\frac{1}{R_6}(V_6 - V_7) - I_c = 0 \tag{9}$$

We also used the following additional equations, as the previous were not enough to solve all the variables.

$$V_0 = 0 \tag{10}$$

$$V_5 - V_6 = V_a \tag{11}$$

$$V_b - K_c I_c = 0 \tag{12}$$

$$-V_0 + V_4 - V_b = 0 \tag{13}$$

$$\frac{1}{R_7}(V_1 - V_7) + I_c = 0 \tag{14}$$

$$-V_bK_b + I_b = 0 \quad (15)$$

$$\frac{1}{R_4}(V_0 - V_6) + \frac{1}{R_1}(V_4 - V_5) - I_c = 0 \quad (16)$$

$$V_0 - V_1 - V_c = 0 \quad (17)$$

Similarly to the mesh method we used a simple Octave script to calculate the remaining variables, the results we got using the nodal method were the following:

Name	Value [A or V]
V_b	-3.651601e-02
V_c	7.636592e+00
I_b	-2.620103e-04
I_c	9.096634e-04

All the variables preceded by I are currents and are expressed in Ampere, the other variables, preceeded by V are voltages and are expressed in Volt.

3 Simulation Analysis

In this section we will be describing the simulation that we made on a software called NGSpice where we made a script describing the given circuit. After running the script, NGSpice gives us the variables that we are looking for, these variables are the same as the ones we calculated using both the mesh and nodal methods.

3.1 NGSpice Simulation

Firstly we've added the values for resistors, V_a, I_d, K_b and K_c, from the python script and then we described the circuit based on the circuit below:

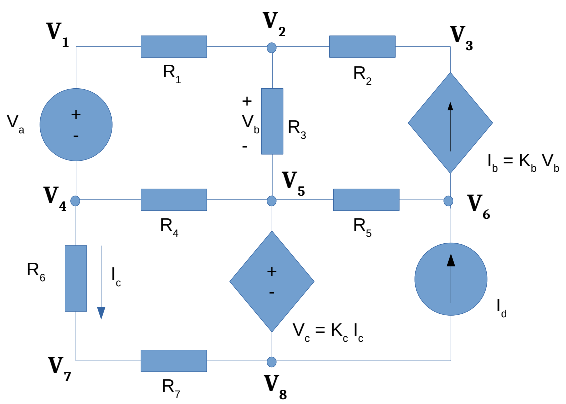

Figure 4: NGSpice simulation circuit.

After running the script, the results we get using this simulation are organized in the table below.

Name	Value [A or V]
@g0[i]	-2.62010e-04
@id[current]	1.039703e-03
@r1[i]	2.500671e-04
@r2[i]	-2.62010e-04
@r3[i]	-1.19432e-05
@r4[i]	1.159730e-03
@r5[i]	-1.30171e-03
@r6[i]	9.096634e-04
@r7[i]	9.096634e-04
n1	5.046111e+00
n2	4.787759e+00
n3	4.248290e+00
n4	-1.88445e+00
n5	4.824275e+00
n6	8.832281e+00
n8	-2.81232e+00
n9	-1.88445e+00

All the variables preceded by @ are currents and are expressed in Ampere, the other variables, preceeded by n are the voltages at each node and are expressed in Volt.

Using these voltages at the nodes, we can calculate the variables that were calculated above using both the mesh and nodal methods so we can compare them and see the what could be differences between them.

$$V_b = n2 - n5 \quad \text{which equals to } -0.036516V \tag{18}$$

$$V_c = n8 - n5 \quad \text{which equals to } -7.636595V \tag{19}$$

As for the currents I_b and I_c, we can get them in the NGSpice results by seeing in which resistor the current is that value. I_b is the current that goes through R_2 and therefore it is 0.262010mA and I_c is the current that goes through R_6 and therefore it is 0.9096634mA.

Putting these values in a table so that we can analyse them and compare them more easily we get the following table:

Name	Value [A or V]
V_b	-0.036516
V_c	-7.636595
I_b	2.62010e-04
I_c	9.096634e-04

As we can see there are little differences in the last digit of some values. These differences are very small and can be explained with approximations that may have been used in some intermediate steps along the way, either by Octave or by NGSpice, or most probably both.

4 Conclusion

Summing up, we´ve started this laboratory (T1) analyzing the circuit given using two theoretical methods: Mesh analysis and nodal analysis. As we predicted, the results are coincident in module. Then, with NGspice we were able to simulate the circuit and the obtained results were also pretty much coincident with the previous ones.

The reasoning behind these results is that we studied a very simple circuit containing only linear components. If the components used were more complex, the case would not be the same and we could detect real differences between the values calculated and simulated.