

# **Circuit Theory and Electronics Fundamentals**

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

## **T1's Laboratory Report**

### **Group 5**

**Carlos Ribeiro (96364), João Diniz (96416), Paulo Clemente (96462)**

March 21, 2021

## **Contents**

<b>1</b>	<b>Introduction</b>	<b>1</b>
<b>2</b>	<b>Theoretical Analysis</b>	<b>2</b>
2.1	Mesh Method . . . . .	2
2.2	Nodal Method . . . . .	4
<b>3</b>	<b>Simulation Analysis</b>	<b>5</b>
3.1	NGSpice Simulation . . . . .	5
<b>4</b>	<b>Conclusion</b>	<b>6</b>

## **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.

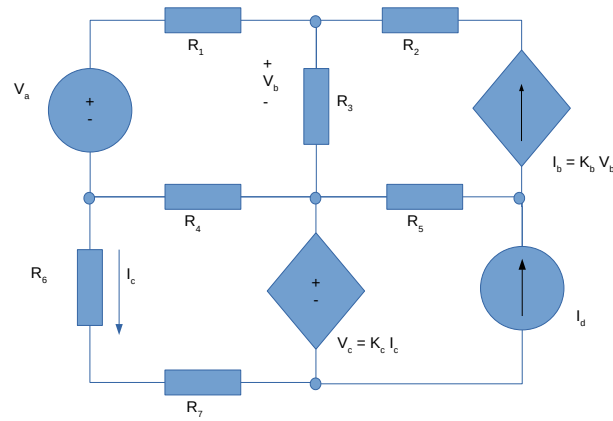


Figure 1: T1's given circuit.

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 $\Omega$ or S]
$R_1$	1.04765357286e3
$R_2$	2.06140068334e3
$R_3$	3.03459085363e3
$R_4$	4.00398818216e3
$R_5$	3.11499853456e3
$R_6$	2.04588646991e3
$R_7$	1.04390152967e3
$V_a$	5.02522591213e3
$I_d$	1.00982536324e-3
$K_b$	7.28209304852e-3
$K_c$	8.36641247715e3

## 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:

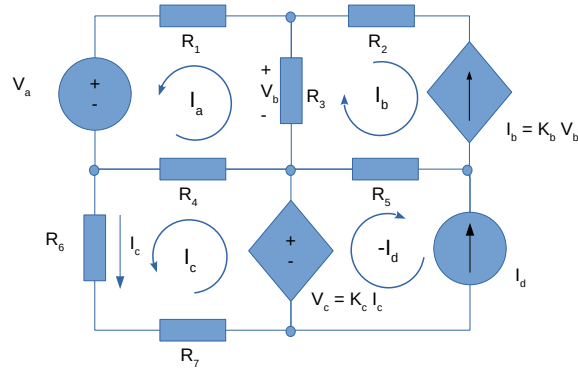


Figure 2: Mesh method circuit.

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:

$$V_a = I_a(R_1 + R_4) - I_c R_4 + V_b \quad (1)$$

For mesh C, we have:

$$I_a R_4 - I_c(R_4 + R_6 + R_7) + V_c = 0 \quad (2)$$

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

$$V_c = I_c K_c \quad (3)$$

$$I_b = V_b K_b \quad (4)$$

$$V_b = R_3(I_a + I_b) \quad (5)$$

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]
$V_b$	-4.128985e-02
$V_c$	-7.556414e+00
$I_b$	-3.006765e-04
$I_c$	-9.031846e-04

All the variables preceded by I are currents and are expressed in Ampere, the other variables, preceded 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:

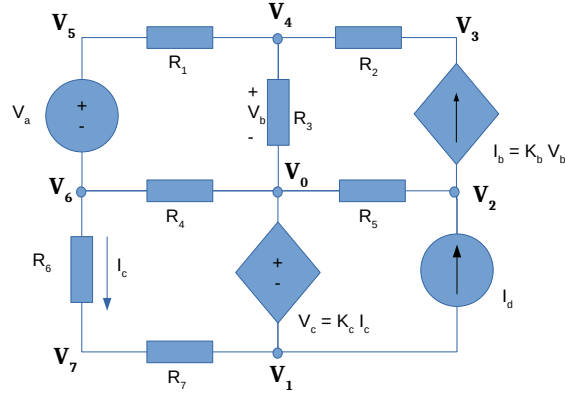


Figure 3: Nodal method circuit.

The equations used to solve the system were the following:

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

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

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

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

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

$$V_0 = 0 \quad (10)$$

$$V_5 - V_6 = V_a \quad (11)$$

$$V_b - K_c I_c = 0 \quad (12)$$

$$-V_0 + V_4 - V_b = 0 \quad (13)$$

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

$$-V_b K_b + I_b = 0 \quad (15)$$

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

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

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]
$V_b$	-4.128985e-02
$V_c$	7.556414e+00
$I_b$	-3.006765e-04
$I_c$	9.031846e-04

All the variables preceded by I are currents and are expressed in Ampere, the other variables, preceded 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:

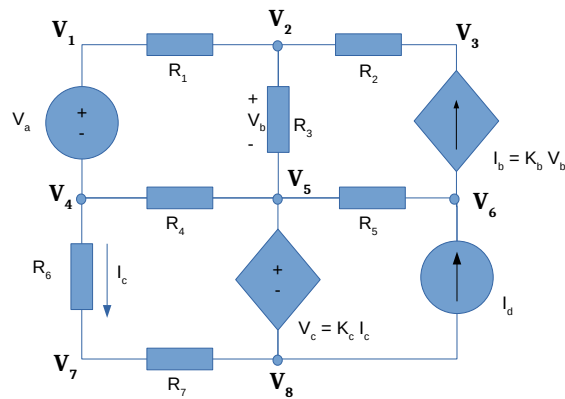


Figure 4: NGSpice simulation circuit.

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

Name	Value [A or V]
@g0[i]	-3.00677e-04
@id[current]	1.009825e-03
@r1[i]	2.870701e-04
@r2[i]	-3.00677e-04
@r3[i]	-1.36064e-05
@r4[i]	1.190255e-03
@r5[i]	-1.31050e-03
@r6[i]	9.031846e-04
@r7[i]	9.031846e-04
n1	5.025226e+00
n2	4.724476e+00
n3	4.104661e+00
n4	-1.84781e+00
n5	4.765766e+00
n6	8.847977e+00
n8	-2.79065e+00
n9	-1.84781e+00

All the variables preceded by @ are currents and are expressed in Ampere, the other variables, preceded 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.

$$V_b = n2 - n5 \quad \text{which equals to} \quad -0.041290V \quad (18)$$

$$V_c = n8 - n5 \quad \text{which equals to} \quad -7.5564V \quad (19)$$

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  $0.300677mA$  and  $I_c$  is the current that goes through  $R_6$  and therefore it is  $0.9031846mA$ .

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]
$V_b$	-0.041290
$V_c$	-7.5564
$I_b$	3.00677e-04
$I_c$	9.031846e-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.