

# **Circuit Theory and Electronics Fundamentals**

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

1º Laboratory Report

March 25, 2021

## **Contents**

<b>1</b>	<b>Introduction</b>	<b>1</b>
<b>2</b>	<b>Theoretical Analysis</b>	<b>2</b>
<b>3</b>	<b>Mesh Method</b>	<b>2</b>
<b>4</b>	<b>Nodal Method</b>	<b>3</b>
<b>5</b>	<b>Simulation Analysis</b>	<b>4</b>
5.1	Operating Point Analysis . . . . .	4
5.2	Transient Analysis . . . . .	4
5.3	Frequency Analysis . . . . .	5
5.3.1	Magnitude Response . . . . .	5
5.3.2	Phase Response . . . . .	5
5.3.3	Input Impedance . . . . .	5
<b>6</b>	<b>Conclusion</b>	<b>5</b>

## **1 Introduction**

The objective of this laboratory assignment is to compare the mesh method and nodal method to the values of current and voltage of the simulated circuit and see how accurate they are. The circuit can be seen in Figure 2.

In section 2, a theoretical analysis of the circuit is presented. In section 5, the circuit is analyzed by simulation, and the results are compared to the theoretical results obtained in section 2. Finally, in section 6, we conclude our study.

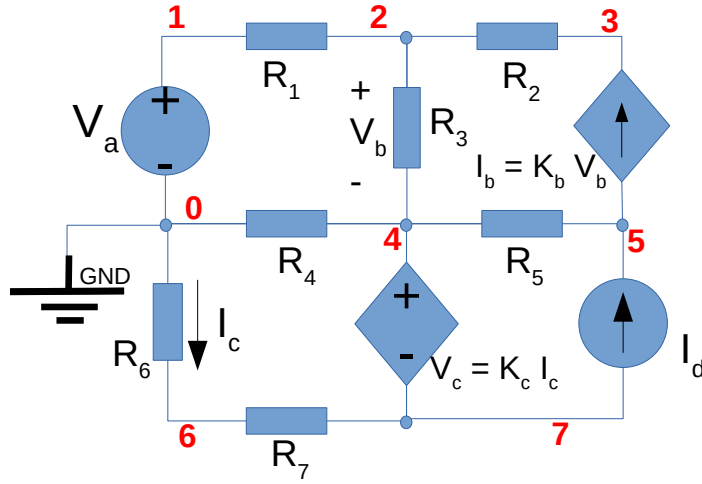


Figure 1: Nodal representation of the circuit.

## 2 Theoretical Analysis

In this section, the circuit shown in Figure 2 is analyzed theoretically, by two different methods, which use the characteristics of the components present in the circuit and one of the two Kirchhoff Laws.

For the Mesh method we used Kirchhoff's voltage law and for the nodal method we used Kirchhoff's current law. Besides the independent voltage sources and current sources, the other components of the circuit are, the resistors, which obey Ohm's law, and dependent voltage sources and current sources.

The simulator uses a dummy voltage source placed in Node 6 to measure the current that passes through  $I_c$ , thus creating the Node 8, that has the same voltage as Node 6.

## 3 Mesh Method

To determine the values of the current that goes through the branches of circuit in the Figure 2 by the Mesh method, there's only the need to use 4 equations by applying Kirchhoff's voltage law or other relations to obtain the values of 4 unknown values of the currents  $I_1$ ,  $I_2$ ,  $I_3$  and  $I_4$ , as the current of each branch can be obtained by a linear combination of these currents. The first equation can be written as:

$$I_d = I_4. \quad (1)$$

Applying Kirchhoff's Voltage Law (KVL) to the Mesh with  $I_3$  and to the Mesh with  $I_1$ , we get the following second and third equations:

$$0 = R_4 I_1 + (R_4 + R_6 + R_7 - K_c) I_3, \quad (2)$$

and

$$V_a(t) = (R_1 + R_3 + R_4) I_1 + R_4 I_3 R_3 I_2. \quad (3)$$

Knowing that:

$$I_2 = I_b, \quad (4)$$

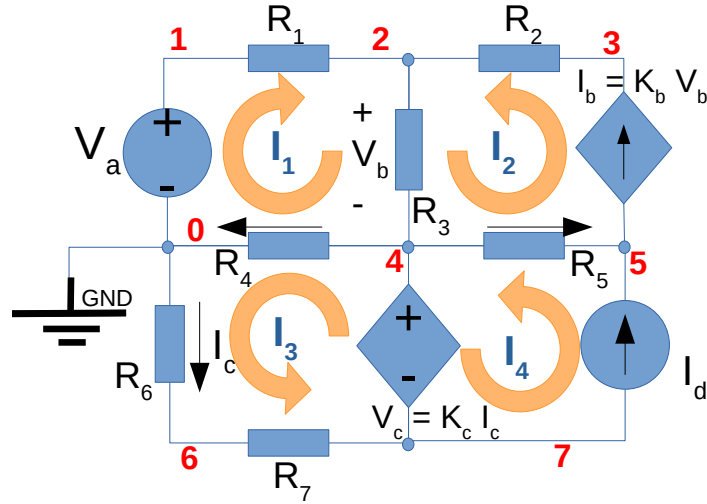


Figure 2: Circuit analyzed in the lab.

And

$$v_b = \frac{I_b}{V_b} = \frac{I_2}{V_b} \quad (5)$$

We get the fourth equation:

$$I_1(R_3 K_b) + I_2(R_3 K_b - 1) = 0 \quad (6)$$

Name	Value [A]
@I1[i]	0.240224
@I2[i]	-0.251168
@I3[i]	0.968913
@I4[i]	1.038991
@G1[i]	-0.251168
@Id[current]	1.038991
@R1[i]	0.240224
@R2[i]	-0.251168
@R3[i]	-0.010944
@R4[i]	1.209137
@R5[i]	-1.290158
@R6[i]	0.968913
@R7[i]	0.968913

Table 1: Operating point. A variable preceded by @ is of type *current* and expressed in Ampere

## 4 Nodal Method

In the nodal method, the circuit requires 6 equations to determine the values of V2, V3, V4, V5, V6, V7, which are obtained by applying Kirchhoff's current Law and a relation between the potential difference of two nodes and two other nodes, whose potential difference is imposed by a dependent voltage source.

Since we considered  $V_0$  to be the ground, which means that  $V_0 = 0$  and therefore:

$$V_1 = V_a. \quad (7)$$

We get the following equations by applying Kirchhoff's current law at different nodes:  
For node 2 we have:

$$V_a \frac{1}{R_1} = V_2 \left( \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \right) + V_3 \frac{-1}{R_2} + V_4 \frac{-1}{R_3}. \quad (8)$$

Node 3:

$$0 = V_2 \left( \frac{-1}{R_2} - K_b \right) + V_3 \frac{1}{R_2} + V_4 (K_b). \quad (9)$$

Node 5:

$$I_d = V_2 (K_b) + V_4 \left( \frac{-1}{R_5} - K_b \right) + V_5 \frac{1}{R_5}. \quad (10)$$

Node 6:

$$0 = V_6 \left( \frac{1}{R_6} + \frac{1}{R_7} \right) + V_7 \frac{-1}{R_7}. \quad (11)$$

Node 7:

$$0 = V_4 + V_6 \left( \frac{K_c}{R_6} \right) - V_7. \quad (12)$$

And finally for node 4:

$$-I_d = V_2 \frac{-1}{R_3} + V_4 \left( \frac{1}{R_3} + \frac{1}{R_4} + \frac{1}{R_5} \right) + V_5 \frac{-1}{R_5} + V_6 \frac{-1}{R_7} + V_7 \frac{1}{R_7}. \quad (13)$$

Name	Value [V]
V(1)	5.239365
V(2)	4.988788
V(3)	4.482071
V(4)	5.023118
V(5)	8.995714
V(6)	-1.962948
V(7)	-2.972813
V(8)	-1.962948

Table 2: Operating point. The variables are of type *voltage* and expressed in Volt.

## 5 Simulation Analysis

### 5.1 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.

### 5.2 Transient Analysis

Figure ?? shows the simulated transient analysis results for the circuit under analysis. Compared to the theoretical analysis results, one notices the following differences: describe and explain the differences.

Name	Value [A or V]
@g1[i]	-2.51168e-04
@id[current]	1.038991e-03
@r1[i]	2.402240e-04
@r2[i]	-2.51168e-04
@r3[i]	-1.09438e-05
@r4[i]	1.209137e-03
@r5[i]	-1.29016e-03
@r6[i]	9.689131e-04
@r7[i]	9.689131e-04
v(1)	5.239365e+00
v(2)	4.988788e+00
v(3)	4.482071e+00
v(4)	5.023118e+00
v(5)	8.995714e+00
v(6)	-1.96295e+00
v(7)	-2.97281e+00
v(8)	-1.96295e+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.

## 5.3 Frequency Analysis

### 5.3.1 Magnitude Response

Figure ?? shows the magnitude of the frequency response for the circuit under analysis. Compared to the theoretical analysis results, one notices the following differences: describe and explain the differences.

### 5.3.2 Phase Response

Figure ?? shows the magnitude of the frequency response for the circuit under analysis. Compared to the theoretical analysis results, one notices the following differences: describe and explain the differences.

### 5.3.3 Input Impedance

Figure ?? shows the magnitude of the frequency response for the circuit under analysis. Compared to the theoretical analysis results, one notices the following differences: describe and explain the differences.

## 6 Conclusion

In conclusion, the values we obtained in the simulation agree with the theoretical values obtained by the mesh and nodal methods, showing negligible errors. These are excellent results which show that the methods we used are legitimate, as expected, and can be used by the simulation program to simulate the circuit.

Nevertheless, the simulator and methods used might produce solutions, which may not occur in a real circuit due to various factors including the Joule effect in the cables that connect the components in the circuit, and other random and systematic errors, which compromise the

precision and accuracy of the results. However, the results might still be a good approximation of the real values, which can be verified by analyzing a real representation of the circuit.