# Circuit Theory and Electronics Fundamentals

Integrated Master's in Aerospace Engineering, Técnico, University of Lisbon

Laboratory 1 Report

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## Contents



## 1 Introduction

The objective of this laboratory assignment is to study a circuit containing an independent voltage source $V_a$, an independent current source $I_d$, seven resistors $R_1$ to $R_7$, a linearly dependent current source $I_b$ and a linearly dependent voltage source $V_c$. The circuit can be seen in Figure 1. The study of the circuit is done using both mesh and nodal analysis methods.

In Section 2, a theoretical analysis of the circuit using Octave is presented. In Section 3, the circuit is analysed by simulation with Ngspice software and the results are compared to the theoretical results obtained in Section 2. Conclusions of this study can be found in Section 4.

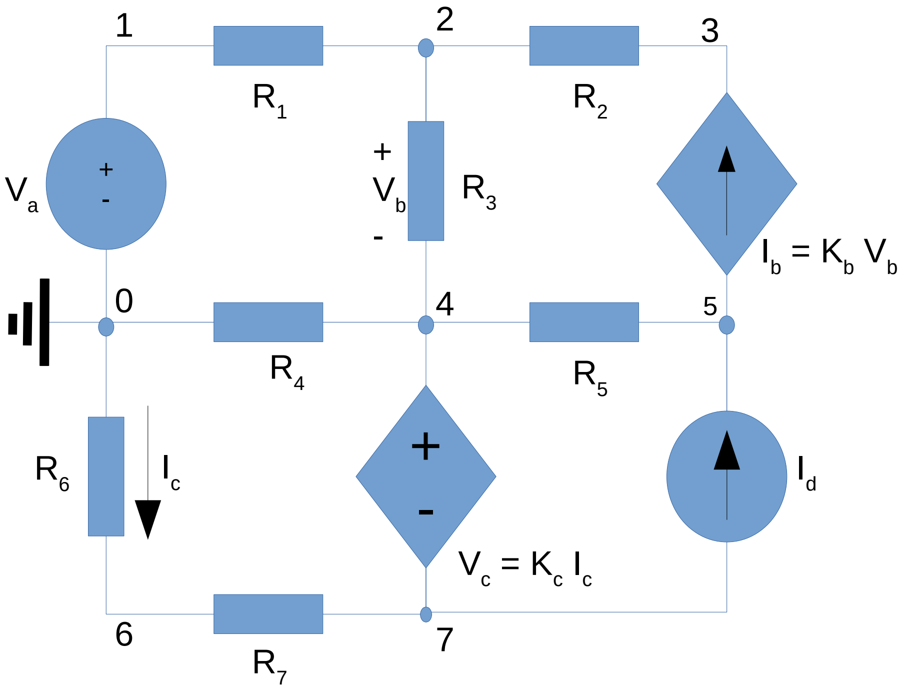


Figure 1: Circuit in study.

## 2 Theoretical Analysis

In this section, the circuit shown in Figure 1 is analysed theoretically, in terms of each branch's current and voltage. The current flows considered in the analysis are the following: $R_1$ from node 1 to 2; $R_2$ from node 2 to 3; $R_3$ from node 2 to 4; $R_4$ from node 4 to 0; $R_5$ from node 4 to 5; $R_6$ from node 0 to 6; $R_7$ from node 6 to 7. Also, the potencial in Node 0 was considered to be 0V (ground).

### 2.1 Nodal Analysis

This method is based on Kirchhoff's Current Law (KCL), and firstly consists in deriving equations for the current flow in nodes not connected to voltage sources, followed by writing aditional equations in nodes related to voltage sources. The node identification can be seen on Figure 1. Moreover, the equations relative to nodes 0, 2, 5 and 0, respectively, are

$$(V_0 - V_4)G_4 + (V_0 - V_6)G_6 + (V_1 - V_2)G_1 = 0 \quad (1)$$

$$(V_2 - V_1)G_1 + (V_2 - V_4)G_3 + (V_2 - V_3)G_2 = 0 \quad (2)$$

$$(V_5 - V_4)G_5 + I_b - I_d = 0, I_b = K_b(V_2 - V_4) \quad (3)$$

$$(V_6 - V_7)G_7 + (V_0 - V_4)G_4 + (V_1 - V_2)G_1 = 0 \quad (4)$$

The aditional equations for the method are

$$V_0 = 0 \quad (5)$$

$$V_1 = V_a \tag{6}$$

$$V_4 - V_7 = K_c(V_0 - V_6)G_6 \tag{7}$$

$$I_b = (V_3 - V_2)G_2, I_b = K_b(V_2 - V_4) \tag{8}$$

| Name | Value [mA or V] |
|---|---:|
| $I_b$ | -0.265898 |
| $I_d$ | 1.028722 |
| $I_{R1}$ | 0.253649 |
| $I_{R2}$ | 0.265898 |
| $I_{R3}$ | -0.012249 |
| $I_{R4}$ | 1.205310 |
| $I_{R5}$ | -1.294619 |
| $I_{R6}$ | 0.951662 |
| $I_{R7}$ | 0.951662 |
| $V_1$ | 5.054819 |
| $V_2$ | 4.793705 |
| $V_3$ | 4.258198 |
| $V_4$ | 4.831047 |
| $V_5$ | 8.907510 |
| $V_6$ | -1.934226 |
| $V_7$ | -2.905231 |
| $V_8$ | -1.934226 |

Table 1: Nodal Analysis' variable values, where $I_j$ is expressed in milliampere and $V_j$ is expressed in Volt.

### 2.2 Mesh Analysis

This method is based on Kirchoff's Voltage Law (KVL), and consists on analysing the circuit's meshes after creating arbitrary currents with arbitrary flows for each mesh in the circuit. The top left mesh was named mesh A with clockwhise current flow $I_A$; the top right mesh was named mesh B with counterclockwhise current flow $I_B$; the bottom left mesh was named mesh C with counterclockwhise current flow $I_C$; the bottom right mesh was named mesh D with counterclockwhise current flow $I_D$. Furthermore, the equations associated with these meshes and currents are

$$R_1 I_A + R_3(I_A + I_B) + R_4(I_A + I_C) - V_a = 0 \tag{9}$$

$$R_6 I_C + R_7 I_C - K_c I_C + R_4(I_A + I_C) = 0 \tag{10}$$

$$I_D = I_d \tag{11}$$

$$I_B = K_b R_3(I_A + I_B) \tag{12}$$

| Name | Value [mA or V] |
|---|---|
| $I_b$ | -0.265898 |
| $I_d$ | 1.028722 |
| $I_{R1}$ | 0.253649 |
| $I_{R2}$ | 0.265898 |
| $I_{R3}$ | -0.012249 |
| $I_{R4}$ | 1.205310 |
| $I_{R5}$ | -1.294619 |
| $I_{R6}$ | 0.951662 |
| $I_{R7}$ | 0.951662 |
| $V_1$ | 5.054819 |
| $V_2$ | 4.793705 |
| $V_3$ | 4.258198 |
| $V_4$ | 4.831047 |
| $V_5$ | 8.907510 |
| $V_6$ | -1.934226 |
| $V_7$ | -2.905231 |
| $V_8$ | -1.934226 |

Table 2: Mesh Analysis' variable values, where $I_j$ is expressed in milliampere and $V_j$ is expressed in Volt.

# 3 Simulation Analysis

## 3.1 Ngspice Analysis

Table 3 shows the simulated operating point results for the circuit under analysis. Once again, current flows are the ones referred in 2 and node 0 is considered to have 0V potential.

A new voltage source $V_{aux}$ with voltage 0V (so it doesn't affect the circuit) was added to the circuit between components $R_6$ and $R_7$ so that Ngspice could simulate and calculate the current value in that branch. This current is needed since the voltage source $V_c$ depends on its value and as expected, this current's value is the same as the one that flows through $R_6$ and $R_7$. Adding a new voltage source led to the creation of node 8 between $R_6$ and $V_{aux}$. Also, has predicted, voltage $V_8$ is the same as voltage $V_6$ since the voltage in $V_{aux}$ is 0V.

| Name | Value [A or V] |
|---|---|
| gb[i] | -2.65898e-04 |
| id[current] | 1.028722e-03 |
| r1[i] | 2.536488e-04 |
| r2[i] | 2.658976e-04 |
| r3[i] | -1.22488e-05 |
| r4[i] | 1.205310e-03 |
| r5[i] | -1.29462e-03 |
| r6[i] | 9.516615e-04 |
| r7[i] | 9.516615e-04 |
| v(1) | 5.054819e+00 |
| v(2) | 4.793705e+00 |
| v(3) | 4.258198e+00 |
| v(4) | 4.831047e+00 |
| v(5) | 8.907510e+00 |
| v(6) | -1.93423e+00 |
| v(7) | -2.90523e+00 |
| v(8) | -1.93423e+00 |

Table 3: Operating point. A variable proceeded by [i] is of type *current* and expressed in Ampere; other variables are of type *voltage* and expressed in Volt.

# 4 Conclusion

Comparing the results given by Nodal and Mesh analysis, it can be observed that both methods achieved the same values. Also, the results given by the Ngspice simulation are the same as those of the methods stated above. All in all, the analysis of the given circuit using the stated methods was achieved successfully. Nodal and mesh methods were performed both theoretically using the Octave maths tool and by circuit simulation using the Ngspice software. Given the fact that the circuit only has linear components, it makes sense that no discrepancies were detected. However, if we had been given a circuit with more complex components, the theoretical and simulation models could not match as precisely as they did in this laboratory assignment.