

# **Circuit Theory and Electronics Fundamentals**

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# 1 Introduction

The objective of this laboratory assignment is to study a circuit containing one independent and one dependent voltage sources,  $V_a$  and  $V_c$  respectively, as well as one independent and one dependent current sources,  $I_d$  and  $I_b$ , connected to 7 resistors. The circuit can be seen in Figure 1.

In Section 2, a theoretical analysis of the circuit is presented. In Section 3, the circuit is analysed by simulation, and the results are compared to the theoretical results obtained in Section 2. The conclusions of this study are outlined in Section 4.

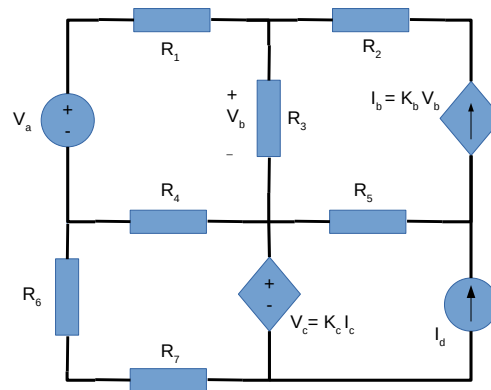


Figure 1: Circuit for Lab T1.

# 2 Theoretical Analysis

In this section, the circuit shown in Figure 1 is analysed theoretically, using the mesh and nodal methods.

## 2.1 Mesh Method

The circuit consists of 4 meshes, with 7 resistors, 2 independent sources ( $V_a$  for voltage source and  $I_d$  for current source) and 2 dependent sources ( $V_c$  for current controlled voltage source and  $I_b$  for voltage controlled current source).

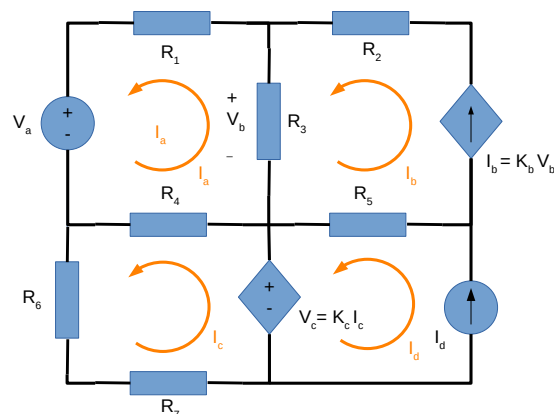


Figure 2: Mesh method analysis.

Applying Kirchoff's Voltage Law (KVL) to the two meshes on the left ( $I_a$  is the current for the top one,  $I_c$  for the bottom one,  $I_b$  for the top right one,  $I_d$  for the bottom right, as illustrated in Figure 2, we get two equations:

$$(R_4 + R_3 + R_1)I_a - R_3I_b - R_4I_c = 0. \quad (1)$$

$$-R_4I_a + (R_6 + R_7 - K_c + R_4)I_c = 0. \quad (2)$$

The other two meshes have current sources, so we cannot apply KVL to them. Instead, we recognize the relation between the sources and the meshes' currents:  $I_d$  is equal to the current coming from the  $I_d$  source and the following equation:

$$I_b = K_b V_b. \quad (3)$$

Now, because

$$V_b = R_3(I_b - I_a). \quad (4)$$

we get:

$$I_b = K_b R_3(I_b - I_a). \quad (5)$$

The solution is obtained by solving Equations (1), (2) and (5) and is illustrated in Table 1.

Name	Value[A or V]
@ $I_a$	-0.00023372996529640106
@ $I_b$	-0.00024517951245893801
@ $I_c$	0.00098327653344681271
$I_d$	0.00102526488404
$V_b$	-0.03496414637530082
$V_c$	7.931247031167528

Table 1: Mesh Method. A variable preceded by @ is of type *current* and expressed in Ampere; other variables are of type *voltage* and expressed in Volt.

## 2.2 Nodal Method

The circuit consists of 8 nodes. These were numbered from 0 to 7 as illustrated in the image below. The node 0 was chosen as the reference node.

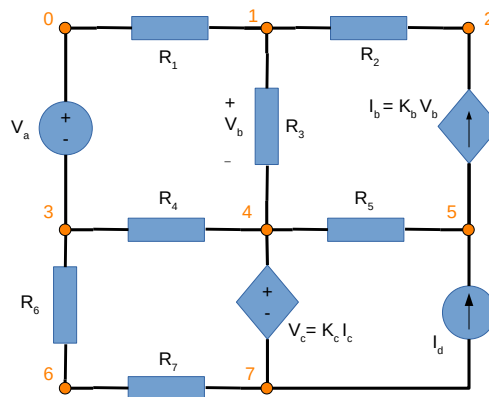


Figure 3: Node method analysis.

Appling Kirchoff's Current Law (KCL) to nodes 1, 2, 5 and 6 we get four equations:

$$-V_1G_1 - (V_2 - V_1)G_2 + (V_4 - V_1)G_3 = 0. \quad (6)$$

$$K_b(V_1 - V_4) + (V_1 - V_2)G_2 = 0. \quad (7)$$

$$I_d + (V_4 - V_5)G_5 - K_b(V_1 - V_4) = 0. \quad (8)$$

$$(V_3 - V_6)G_6 + (V_7 - V_6)G_7 = 0. \quad (9)$$

In addition, because voltage source  $V_a$  is connected between the reference node and a non reference node, we simply set the voltage at the non-reference node equal to the voltage of the voltage source.

$$V_3 = -V_a. \quad (10)$$

As the voltage source  $V_c$  is between two non reference nodes then it forms a supernode whose analysis is done as following:

$$(V_3 - V_4)G_4 + (V_1 - V_4)G_3 + (V_5 - V_4)G_5 - I_d + (V_6 - V_7)G_7 = 0. \quad (11)$$

$$(V_4 - V_7) = K_c(V_3 - V_6)G_6. \quad (12)$$

The solution is obtained by solving Equations (6), (7), (8), (9), (10), (11) and (12) and is illustrated in Table 2.

Name	Value[A or V]
$V_0$	0
$V_1$	-0.23790844246659815
$V_2$	-0.73947695823628645
$V_3$	-5.1277592116299999
$V_4$	-0.20294429609129594
$V_5$	3.6935601924823294
$V_6$	-7.1316871834296993
$V_7$	-8.1341913272588204
$V_b$	-0.034964146375302207
$V_c$	7.9312470311675245
@ $I_b$	-0.00024517951245894094

Table 2: Nodal Method. A variable preceded by @ is of type *current* and expressed in Ampere; other variables are of type *voltage* and expressed in Volt.

### 3 Simulation Analysis

#### 3.1 Operating Point Analysis

Table 3 shows the simulated operating point results for the circuit under analysis. The results are identical to the theoretical values for the node voltages and mesh currents (excluding approximation differences).

Name	Value [V]
@gib[i]	-2.45180e-04
@id[current]	1.025265e-03
@r1[i]	2.337300e-04
@r2[i]	2.451795e-04
@r3[i]	-1.14495e-05
@r4[i]	-1.21701e-03
@r5[i]	-1.27044e-03
@r6[i]	9.832765e-04
@r7[i]	9.832765e-04
v(1)	-2.37908e-01
v(2)	-7.39477e-01
v(3)	-5.12776e+00
v(4)	-2.02944e-01
v(5)	3.693560e+00
v(6)	-7.13169e+00
v(7)	-8.13419e+00
v(8)	-5.12776e+00
v(1,4)	-3.49641e-02
v(4,7)	7.931247e+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.

### 4 Conclusion

We have successfully analysed theoretically the given circuit, through the nodal method and the mesh method, using the Octave maths tool. By comparing with the results obtained with the simulation done with the Ngspice tool, we could see they were identical, which allowed us to confirm the validity of the methods and their perfect precision in simple circuits like the one given.