Circuit Theory and Electronics Fundamentals

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Laboratory number 1-Report

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Contents

1 Introduction

The objective of this laboratory assignment is to study a circuit with 4 meshes, containing a total of 7 resistors (from R_1 to R_7), 2 current sources (I_d and I_b), one of them, I_b, linearly voltage-controlled (VCCS), and 2 voltage sources (V_a and V_c), one of them, V_c, linearly current-controlled (CCVS). 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.

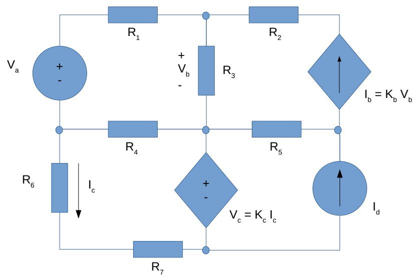

Figure 1: Circuit of Laboratory no 1.

2 Theoretical Analysis

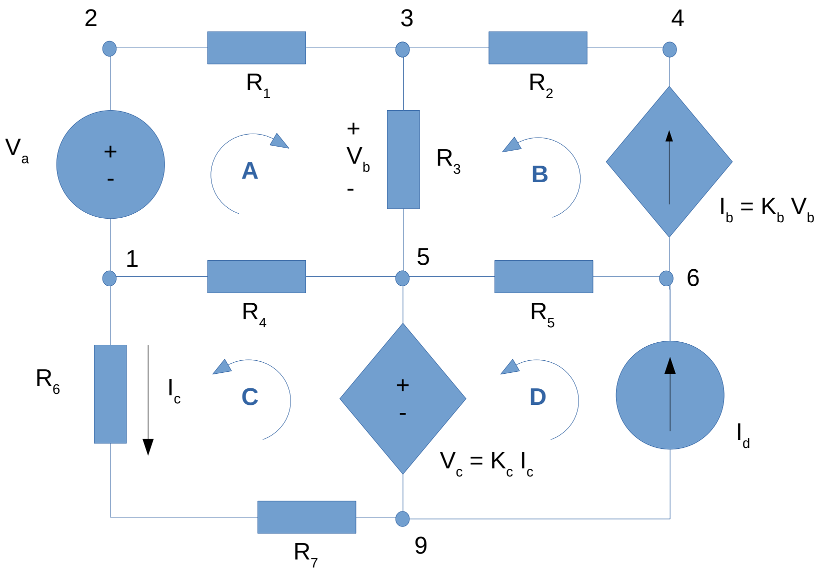

Figure 2: Circuit Nodes and Meshes Identification; nodes are identified by numbers and meshes are identified by capital letters; the circular arrows indicate de flow of the current that was arbitrarily chosen for each of the mesh's calculations.

In this section, the circuit shown in Figure 2 is analysed theoretically, in terms of the voltages and current intensities of the various branches and components of the circuit.

For convenience and coherence purposes, we chose to number the nodes of this circuit in the same manner that they will be numbered in the modified circuit used in the simulation. This means that nodes with the same number are in equivalent positions in the two circuits and explains why some numbers are skipped in this original circuit (the modified circuit has more nodes). In Section 3 these modifications will be properly explained. The nodes and meshes used in the following calculations are identified in Figure 2.

The values of the circuit Resistors, independent voltage and current sources, transconductance and transresistance were obtained by running the t1-datagen.py file and are shown in Table 1.

Name	Value
R1	1.00196314014
R2	2.082319235
R3	3.05798143645
R4	4.10496355098
R5	3.03658050119
R6	2.00356698935
R7	1.0495200477
Va	5.06400320393
Id	1.01960705059
Kb	7.0260450587
Kc	8.35916956066

Table 1: Table with the values of the circuit Resistors (R), independent voltage (V) and current (I) sources, transconductance (Kb) and transresistance(Kc); currents are expressed in milliAmpere, voltages are expressed in Volts, resistances and transresistance are expressed in kiloOhm and transconductance is expressed in milliSiemens.

2.1 Mesh Method

The circuit consists of multiple loops with various values of current, i, circulating in each of its branches. There are two voltage sources, v_a and v_c, driving their inputs. Applying the Mesh Method, which in this case consists of identifying the KVL equations for meshes A and C, as well as any other necessary additional equations, we reached a system of 5 equations and 5 unknowns, that was solved using the Octave math tools. Those equations are:

$$MeshA : v_a - R_1 \times i_a - R_3 \times (i_a + i_b) - R_4 \times (i_a + i_c) = 0. \tag{1}$$

$$MeshC : v_c - R_4 \times (i_a + i_c) - (R_6 + R_7) \times i_c = 0. \tag{2}$$

Additional equations:

$$v_c = K_c \times i_c. \tag{3}$$

$$i_b = K_b \times v_b. \tag{4}$$

$$v_b = R_3 \times (i_a + i_b). \tag{5}$$

The solution to this system of equations is presented in Table 2.

Name	Value [A or V]
Ia	2.667112036144088e-01
Ib	-2.797307053897956e-01
Ic	9.115165062107574e-01
Vb	-3.981339474096013e-02
Vc	7.619521032756115

Table 2: Table with the values of the unknowns from the system of equations obtained with the Mesh Method, solved using Octave; currents are expressed in Ampere and voltages are expressed in Volts.

2.2 Nodal Method

Another way of analysing the circuit is by applying the Nodal Method, which consists of identifying the FCL equations for the nodes not connected to a voltage source, as well as any other necessary additional equations. In this particular case, this means analysing nodes 3, 4 and 6, which led us to a system of 11 equations and 11 unknowns. After obtaining these equations, we repeated the previous procedure and solved the system with the Octave software. The equations obtained by applying this method are:

$$Node3 : (v_3 - v_5) \times G_3 + (v_3 - v_2) \times G_1 + (v_3 - v_4) \times G_2 = 0. \tag{6}$$

$$Node4 : (v_4 - v_3) \times G_2 - i_b = 0. \tag{7}$$

$$Node6 : i_b - i_d + (v_6 - v_5) \times G_5 = 0. \tag{8}$$

Additional equations:

$$v_1 = 0. \tag{9}$$

$$v_2 - v_1 = v_a. \tag{10}$$

$$v_3 - v_5 = v_b. \tag{11}$$

$$v_5 - v_9 = v_c. \tag{12}$$

$$i_b = K_b \times v_b. \tag{13}$$

$$v_c = K_c \times I_c. \tag{14}$$

$$v_9 - v_1 = -i_c \times (r_6 + r_7). \tag{15}$$

$$(v_2 - v_3) \times G_1 + i_c + (v_1 - v_5) \times G_4 = 0. \tag{16}$$

The solution to this system of equations is presented in Table 3.

Name	Value [A or V]
V0	0
V2	5.064003203930000
V3	4.796768408845987
V4	4.214279780392698
V5	4.836581803586947
V6	8.782125497855164
V9	-2.782939229169170
Ib	-2.797307053897955e-01
Ic	9.115165062107577e-01
Vb	-3.981339474096013e-02
Vc	7.619521032756118

Table 3: Table with the values of the unknowns from the system of equations obtained with the Nodal Method, solved using Octave; currents are expressed in Ampere and voltages are expressed in Volts.

3 Simulation Analysis

3.1 Operating Point Analysis

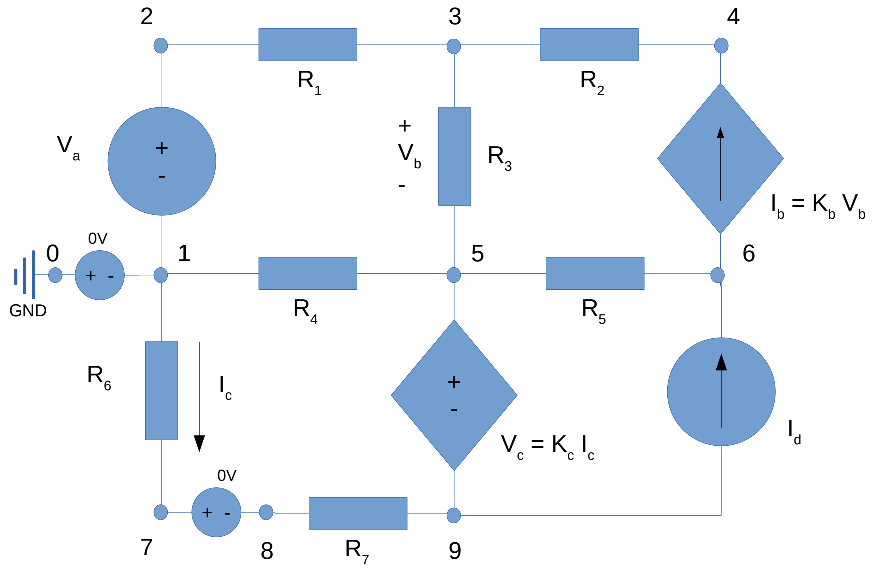

Figure 3: Modified circuit for Ngspice simulation; numbers represent nodes.

To properly analyse this circuit using Ngspice, it was convenient to slightly modify it. By defining the Ground voltage reference, we added a 0V voltage source between nodes 0 and 1, as shown in 3. To correctly define Vc, which is a CCVS that therefore requires a voltage source through which the controlling current flows, we had to add to the circuit another 0V voltage source. Because we knew that current Ic (which controlled Vc) flew through R6, we decided to add the aforementioned voltage source between resistors R6 and R7. Despite being necessary to the sucess of the simulation, these modifications create an equivalent circuit. This means that these additions do not compromise the analysis of the original circuit in any way.

Table 4 shows the simulated operating point results for the circuit under analysis. Compared to the theoretical analysis results, one notices that: the values obtained by simulating the circuit are identical in absolute value when compared to the theoretical predictions; the only notable difference is that while some theoretical values of current are negative, the ones obtained by the simulation are positive. This is a result of the arbitrary decision of the direction of the currents in each mesh. A negative value means that the actual direction of the current is the opposite of the one chosen.

Name	**Value [A or V]**
@gib[i]	-2.79731e-01
@id[current]	1.019607e+00
@r1[i]	2.667112e-01
@r2[i]	2.797307e-01
@r3[i]	-1.30195e-02
@r4[i]	-1.17823e+00
@r5[i]	-1.29934e+00
@r6[i]	9.115165e-01
@r7[i]	9.115165e-01
v(1)	0.000000e+00
v(2)	5.064003e+00
v(3)	4.796768e+00
v(4)	4.214280e+00
v(5)	4.836582e+00
v(6)	8.782125e+00
v(7)	-1.82628e+00
v(8)	-1.82628e+00
v(9)	-2.78294e+00

Table 4: 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 achieved the goal of analysing the given circuit for this laboratory assignment. We've performed both a theoretical analysis using Octave and a circuit simulation using Ngspice. The values given by the simulation were coincident with the ones that we got from the theoretical results. As this is a fairly simple circuit without any non-linear components, this result was expected.