Circuit Theory and Electronics Fundamentals

T1 Laboratory Report

Group 34

José Bento, Nº95815
Thomas Childs, Nº 95847
Luís Pacheco, Nº 96425

Aerospace Engineering (MEAer), Técnico, University of Lisbon

March 22, 2021

Contents

1 Introduction

The objective of this laboratory assignment is to study a circuit containing independent and linearly dependent voltage and current sources. The circuit also contains 7 resistors, totaling 11 components that are conected both in series and in paralel.

The circuit has 7 nodes and 4 meshes. The nodes of the circuit were numbered arbitrarily (from V_0 to V_7), and it was considered that *node 0* was the ground node. The voltage-controlled current source I_b has a linear dependence on Voltage V_b of constant K_b. The voltage V_b is the voltage drop at the ends of resistor R_3. The current-controlled voltage source V_c has a linear dependece on current I_c of constant K_c. The control current I_c is the current that passes through the resistor R_6. The circuit can be seen in Figure 1.

The values for the resistors, the independent sources and the constants for the dependent sources are presented in Table 1. These values were obtained using the Python script provided by the professor responsable for the laboratory assigment and using the number 95815 as the seed.

In Section 2, a theoretical analysis of the circuit is presented using two methodes: the mesh analisys and the nodal analysis. In Section 3, the circuit is analysed by simulation using the program Ngspice, and the results are compared to the theoretical results obtained in Section 2. The conclusions of this study are outlined in Section 4.

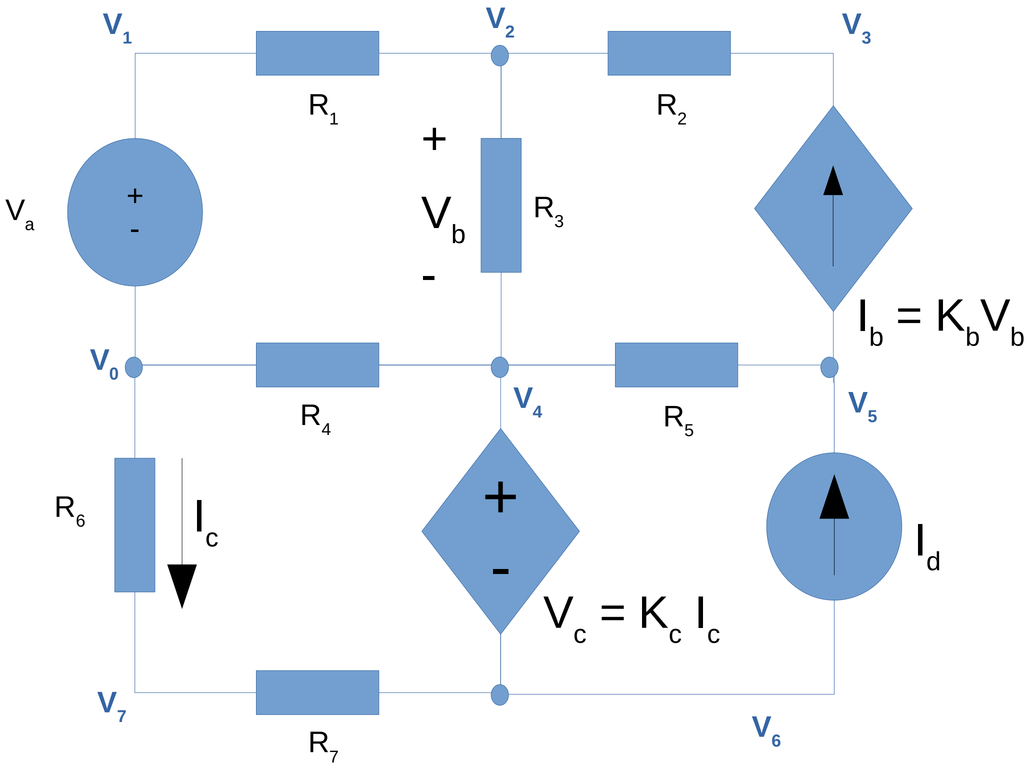

Figure 1: Circuit in study

Name	Python-generated values
R1	1.04606282456
R2	2.00732621328
R3	3.06060705885
R4	4.07055531265
R5	3.1225213804
R6	2.06927045958
R7	1.01531018068
Va	5.24359648479
Id	1.01891541651
Kb	7.0473187437
Kc	8.3479788681

Table 1: The variables that starts with an *R* are the values of the resistors and are expressed in kiloohm (kOhm).The variable *Va* is a *voltage* and expressed in Volt (V) and the variable *Id* is a *current* and expressed in milliampere (mA).The constants *Kc* and *Kb* are expressed in kiloohm (kOhm) and millisiemens (mS) respectively.

2 Theoretical Analysis

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

For the mesh analysis 4 variables were created - the 4 mesh currents.I_{SE} is the mesh current of the mesh on the top left corner of our circuit (clockwise). $I_{SD}$is the mesh current of the mesh on the top right corner of our circuit (counter clockwise).I_{IE} is the mesh current of the mesh on the lower left corner of our circuit(counter clockwise). I_{ID} is the mesh current of the mesh on the lower right corner of our circuit(counter clockwise).Knowing the mesh currents, and using Ohm's law we can determine any node voltage or branch current. To determine the 4 unknown mesh currents we used the following 4 equations.

$$R_1 I_{SE} + R_3(I_{SE} + I_{SD}) + R_4(I_{SE} + I_{IE}) = Va \tag{1}$$

$$R_6 I_{IE} + R_7 I_{IE} + R_4(I_{IE} + I_{SE}) = K_c I_{IE} \tag{2}$$

$$I_{SD} = K_b R_3(I_{SE} + I_{SD}) \tag{3}$$

$$I_{ID} = Id \tag{4}$$

With the help of Octave, the equations yielded the following values for the mesh currents.

Name	Current (mA)
I_{SE}	0.27805
I_{SD}	-0.29157
I_{IE}	0.94884
I_{ID}	1.0189

For the nodal analysis we apply the Kirchhoff Current Law (KCL) to the nodes that are not conected to voltage sources (equations 7 to 11). We obtain 2 more equations from the potencial difference at the terminals of the voltage sources (equations 12 and 13).As it was stated before, node 0 is the ground node and therefore the voltage at this node is 0V (equation 1). For the simulation analysis it was necessesary to add an other "fictional" voltage source that provides 0 volts to the circuit, between node 7 and resistor 6. This "fictional" voltage source was also considered in the Theoretical Analysis, as it has no real effect on the circuit. This yiels equation number 6. Now we have 9 equations for 9 unkown variables- voltage (V_0 to V_8.Using Octave we determine the values of every node voltage of the circuit.

$$V_0 = 0 \tag{5}$$

$$V_8 = V_7 \tag{6}$$

$$(V_1 - V_2)/R_1 + (V_0 - V_8)/R_6 + (V_0 - V_4)/R_4 = 0 \tag{7}$$

$$(V_2 - V_4)/R_3 + (V_2 - V_3)/R_2 + (V_2 - V_1)/R_1 = 0 \tag{8}$$

$$-K_b(V_2 - V_4) + (V_3 - V_2)/R_2 = 0 \tag{9}$$

$$(V_5 - V_4)/R_5 + K_b(V_2 - V_4) - Id = 0 \tag{10}$$

$$(V_7 - V_6)/R_7 + (V_7 - V_0)/R_6 = 0 \tag{11}$$

$$V_1 - V_0 = V_a \tag{12}$$

$$V_4 - V_6 = K_c(V_0 - V_7)/R_6 \tag{13}$$

In Table 2 the values for the branch currents and the node voltages obtained from the ocatve script for both methods are presented.

Name	Mesh method	Node method
@Gb	-0.291567	-0.291567
@id	1.018915	1.018915
@r1	-0.278049	-0.278049
@r2	-0.291567	-0.291567
@r3	-0.013518	-0.013518
@r4	1.226887	1.226887
@r5	1.310482	1.310482
@r6	-0.948838	-0.948838
@r7	-0.948838	-0.948838
V1	5.243596	5.243596
V2	4.952740	4.952740
V3	4.367469	4.367469
V4	4.994112	4.994112
V5	9.086122	9.086122
V6	-2.926767	-2.926767
V7	-1.963402	-1.963402
V8	-1.963402	-1.963402

Table 2: A variable preceded by @ is of type *current* and expressed in milliampere (mA); other variables are of type *voltage* and expressed in Volt (V).

As it can be seen this values are the same, which suggests that for this simple circuit, the methods are equally precise.

3 Simulation Analysis

3.1 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.

Name	**Value [mA or V]**
@gb[i]	-2.91567e-01
@id[current]	1.018915e+00
@r1[i]	-2.78049e-01
@r2[i]	-2.91567e-01
@r3[i]	-1.35178e-02
@r4[i]	1.226887e+00
@r5[i]	1.310482e+00
@r6[i]	-9.48838e-01
@r7[i]	-9.48838e-01
v(1)	5.243596e+00
v(2)	4.952740e+00
v(3)	4.367469e+00
v(4)	4.994112e+00
v(5)	9.086122e+00
v(6)	-2.92677e+00
v(7)	-1.96340e+00
v(8)	-1.96340e+00

Table 3: Operating point. A variable preceded by @ is of type *current* and expressed in miliAmpere; other variables are of type *voltage* and expressed in Volt.

4 Conclusion

In this laboratory assignment the objective of analysing an RC circuit has been achieved. Static, time and frequency analyses have been performed both theoretically using the Octave maths tool and by circuit simulation using the Ngspice tool. The simulation results matched the theoretical results precisely. The reason for this perfect match is the fact that this is a straightforward circuit containing only linear components, so the theoretical and simulation models cannot differ. For more complex components, the theoretical and simulation models could differ but this is not the case in this work.