Circuit Theory and Electronics Fundamentals

Mestrado em Engenharia Física Tecnológica, Técnico, University of Lisbon

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March 22, 2021

Contents

1 Introduction

The objective of this laboratory assignment is to study a circuit containing 2 independent sources, V_a and I_d, 1 voltage controlled source, I_b, 1 current controlled source, V_c, all of which are connected to 7 resistors. The circuit can be seen in Figure 1.

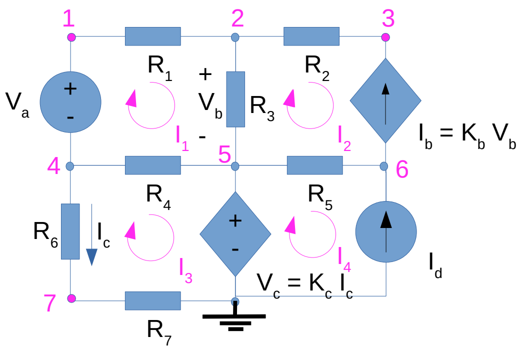

Figure 1: A circuit containing many sources and resistors

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.

2 Theoretical Analysis

In this section, the circuit shown in Figure 1 is analysed via node analysis and mesh analysis.

2.1 Node analysis

We have decided to numerate every node from 1 to 7 (the 8th of which being the ground). This is helpful because we can, therefore, derive direct equations in terms of the voltage at these nodes. The voltage V_i refers to the node i. Since we can only apply KCL (Kirchoff's Current Law), which states that the sum of currents leaving a node must be the same as the sum of currents entering a node, to nodes not connected to voltage sources, we can only derive 4 of these equations. The others are obtained from simple analysis of nodes connected to sources. The equations are as follows

$$\begin{cases} Node\,2: \frac{V_1-V_2}{R_1}+\frac{V_3-V_2}{R_2}+\frac{V_5-V_2}{R_3}=0 \\ Node\,3: \frac{V_2-V_3}{R_2}+K_bV_b=0 \\ Node\,6: \frac{V_5-V_6}{R_5}-K_bV_b=\,-I_d \\ Node\,7: \frac{V_4-V_7}{R_6}-\frac{V_7}{R_7}=0 \\ Caused\,by\,V_a: V_1-V_4\,=V_a \\ Caused\,by\,V_b: \frac{V_3-V_2}{R_2}-K_bV_b=0 \\ Caused\,by\,V_b: V_2-V_5-V_b=0 \\ Caused\,by\,V_c: V_5-V_c=0 \\ Caused\,by\,I_c: -\frac{V_4-V_7}{R_6}+\frac{V_c}{K_c}=0 \end{cases} \tag{1}$$

We then use $GNUOctave$, a $software$ that can solve them, to obtain the values of all the unknowns. Knowing all the voltages allows us to know every current aswell, which means the circuit is solved. The results of these computations are compiled in this table.

Name	Value [A and V]
V1	5.1850419e+00
V2	-8.8372594e-01
V3	-1.3737754e+01
V4	0.0000000e+00
V5	0.0000000e+00
V6	2.1867128e+01
V7	0.0000000e+00
Vb	-8.8372594e-01
Vc	0.0000000e+00
Ib	-6.1882804e-03
Ic	0.0000000e+00

Table 1: Node analysis computation results. A variable starting with I is of type *current* and expressed in Ampere; a variable starting with V is of type *voltage* and expressed in Volt.

2.2 Mesh analysis

We have decided to numerate every mesh from 1 to 4. This is helpful because we can, therefore, derive direct equations in terms of the current passing through these meshes. The current I_i refers to the mesh i. For this method, we apply KVL (Kirchoff's Voltage Law), which states that the sum of all the voltages around any closed loop in a circuit is equal to zero, and relate the fictional currents we created to currents given in the circuit (for example, I_d). The equations are as follows

$$
\begin{cases}
Mesh\,1: R_1\,I_1 + V_b + R_4(I_1 - I_3) = V_a \\
Mesh\,2: I_2 = -I_b = -K_b\,V_b \\
Mesh\,3: R_4(I_3 - I_1) + K_c\,I_c + R_7\,I_3 + R_6\,I_3 = 0 \\
Mesh\,4: I_4 = -I_d \\
I_3 = -I_c \\
V_b = R_3(I_1 - I_2)
\end{cases}
\tag{2}
$$

We use the same procedure to compute these equations. The results of these computations are compiled in this table.

Name	Value [A or V]
I1	2.3690260e-04
I2	2.4828279e-04
I3	-9.7373690e-04
I4	-1.0314759e-03
Ib	-2.4828279e-04
Ic	9.7373690e-04
Vb	-3.5456366e-02
Vc	7.9316995e+00

Table 2: Mesh analysis computation results. A variable starting with I is of type *current* and expressed in Ampere; a variable starting with V is 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.

Name	Value [A or V]
@gb[i]	1.188883e-03
@id[current]	1.031476e-03
@r1[i]	1.243376e-03
@r2[i]	-1.18888e-03
@r3[i]	5.449316e-05
@r4[i]	9.090902e-04
@r5[i]	1.574073e-04
@r6[i]	-3.34286e-04
@r7[i]	-3.34286e-04
v(1)	4.170690e+00
v(2)	2.892752e+00
v(3)	4.232549e-01
v(4)	-1.01435e+00
v(5)	2.722972e+00
v(6)	3.199725e+00
v(7)	-3.35807e-01
v(8)	-1.01435e+00

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

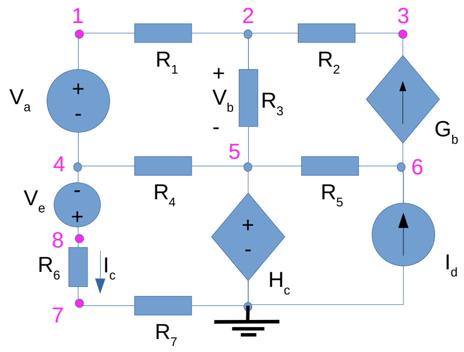

Figure 2: A circuit containing many sources and resistors

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.