# Circuit Theory and Electronics Fundamentals 2020/2021

Integrated Masters in Aerospace Engineering, Técnico, University of Lisbon

First Laboratory Report

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## Contents



# 1 Introduction

The objective of this laboratory assignment is to study a circuit containing a voltage source $V_A$, a current-controlled voltage source $V_C$, a current source $I_D$ and a voltage-controlled current source $I_B$ connected to different fixed value resistors $R_1$, $R_2$, $R_3$, $R_4$, $R_5$, $R_6$, $R_7$. The circuit can be seen in Figure 1.

************************** In Section 3, a theoretical analysis of the circuit is presented. In Section 4, the circuit is analysed by simulation, and the results are compared to the theoretical results obtained in Section 3. The conclusions of this study are outlined in Section 5.

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# 2 Theoretical Introduction

The Mesh Current Method is another well-organized method for solving a circuit and is based on Kirchhoff's Voltage Law (KVL). To apply this method, we need to define what mesh current is. When we use the term mesh current, we are referring to an imagined current flowing around a loop. To aplly this first step of this method, we first need to identify and distinguish a loop from a mesh. A loop correspond to any closed path around the circuit and, to trace it, we start

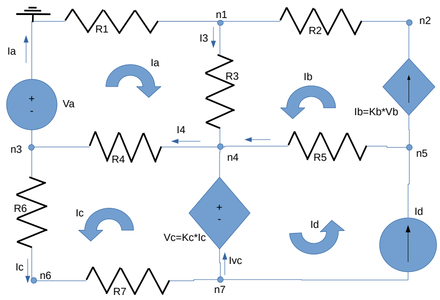


Figure 1: Voltage driven serial RC circuit.

at any component terminal and trace a path through connected elements until we get back to the starting point. A loop is allowed to go through an element just one time. That leads us to the definition of a restricted kind of loop, a mesh, which contains no other loops.

The implementation of the Mesh Current Method to analyse the circuit was done following the common sequence of steps, summarized below. Identify the meshes. Assign a current variable to each mesh, using a consistent direction (clockwise or counterclockwise). Write Kirchhoff's Voltage Law equations around each mesh . Solve the resulting system of equations for all mesh currents. Solve for any element currents and voltages you want using Ohm's Law.

The Node Voltage Method is another way to analyze a circuit. This method is based on Kirchhoff's Current Law (KCL). To apply this method, we need to define what node voltage is. When we use the term node voltage, we are referring to the potential difference between two nodes of a circuit. We select one of the nodes in our circuit to be the reference node and, therefore, all the other node voltages are measured with respect to the referenced one. This reference node is called the ground node and, as it gets the ground symbol in Figure 1, corresponds to the node between resistor $R_1$ and voltage source $V_A$. The potential of the ground node is defined to be null and the potentials of all the other nodes are measured relative to ground.

The implementation of the Node Voltage Method to analyse the circuit was done following the common sequence of steps, summarized below. Assign a reference node (ground). Assign node voltage names to the remaining nodes. Solve the easy nodes first, the ones with a voltage source connected to the reference node. Write Kirchhoff's Current Law for each node. Do Ohm's Law in your head. Solve the resulting system of equations for all node voltages. Solve for any currents you want to know using Ohm's Law.

# 3 Theoretical Analysis

******************************************************************** In this section, the circuit shown in Figure 1 is analysed theoretically, in terms of its time and frequency responses.

## 3.1 Mesh Current Method Analysis

TOMAS

| Nodal Analysis Voltages | |
|---|---|
| Node Voltage 1 | -2.45701846174e-01 |
| Node Voltage 2 | -7.41098638311e-01 |
| Node Voltage 3 | -5.02924600001e+00 |
| Node Voltage 4 | -2.11713274972e-01 |
| Node Voltage 5 | 3.74034647031e+00 |
| Node Voltage 6 | -6.88395862436e+00 |
| Node Voltage 7 | -7.80086877032e+00 |

NODE VOLTAGE METHOD

We start to apply the Node Voltage Method by starting to identify the nodes of the circuit. In this case, our circuit has 7 nodes and each one has a node voltage designated $V_1$, $V_2$, $V_3$, $V_4$, $V_5$, $V_6$ and $V_7$, according to the related node. Then, we apply the KCL to each one of the nodes.

$$\begin{cases} Node1: I_1 + I_2 = I - 3 \\ Node2: I_B = \frac{V_2 - V_1}{R_2} \\ Node3: V_3 = -V_A \\ Node4: V_4 - V_7 = V_C \\ Node5: I_B + I_5 = I_D \\ Node6: I_6 = I_7 \\ Node7: V_4 - V_7 = V_C \end{cases}$$

### 3.2 Node Voltage Method Analysis

| Nodal Analysis Currents | |
|---|---|
| Mesh Current Ia | 2.35432076795e-04 |
| Mesh Current Ib | -2.46391641626e-04 |
| Mesh Current Ic | 9.14823521600e-04 |
| Mesh Current Id | 1.03087754949e-03 |
| Branch Current Ia | 2.35432076795e-04 |
| Branch Current Ib | -2.46391641626e-04 |
| Branch Current I3 | -1.09595648304e-05 |
| Branch Current I4 | 1.15025559840e-03 |
| Branch Current I5 | 1.27726919112e-03 |
| Branch Current Ic | 9.14823521600e-04 |
| Branch Current Ivc | -1.16054027890e-04 |
| Branch Current Id | 1.03087754949e-03 |

## 4 Simulation Analysis

### 4.1 Operating Point Analysis

Ngspice is a circuit-simulation program that makes it possible to have an accurate representation of how the circuit would behave if it was actually mounted. Table 1 shows the simulated operating point results for the circuit under analysis.

As it can be seen, the table shows the values of the voltage in all nodes, the currents in all of the branches and also the currents in independent voltage sources. When looking at the simulation results there is one very interesting detail which is very important: Ngspice operates with the idea that the positive current flows from the positive pole to the negative in

| Node/Component | Value [A or V] |
|---|---|
| @gb[i] | -2.46392e-04 |
| @idd[current] | 1.030878e-03 |
| @r1[i] | 2.354321e-04 |
| @r2[i] | -2.46392e-04 |
| @r3[i] | -1.09596e-05 |
| @r4[i] | 1.150256e-03 |
| @r5[i] | 1.277269e-03 |
| @r6[i] | 9.148235e-04 |
| @r7[i] | 9.148235e-04 |
| n1 | -2.45702e-01 |
| n2 | -7.41099e-01 |
| n3 | -5.02925e+00 |
| n4 | -2.11713e-01 |
| n5 | 3.740346e+00 |
| n6 | -6.88396e+00 |
| n7 | -7.80087e+00 |
| na | -5.02925e+00 |

Table 1: Operating point. A variable preceded by @ is of type *current* and expressed in Ampere; other variables are of type *voltage* and expressed in Volts.

all components, sources included. This explains why, for example, in the the very same branch where resistor $R1$ and branch $Va$ are, the current given by ngspice in the whole branch is the symetric of the one given specifically in the voltage source $Va$.

Another important detail about this table is the node $na$ and a voltage source of 0V $Vab$, which are absent from the circuit's picture. This is because the Current-Controlled Voltage Source is dependent on current Ic, but Ngspice requires a voltage source where this current flows through, which made it necessary the usage of an auxiliary voltage source in series with $R6$ and thus, an auxiliary node.

When the simulation results given by NGspice are compared to the theoretical ones obtained in the previous section, it is possible to highlight the fact that these are, in reality, extremely close to each other. Such observation can be explained by the fact that this is a very simple circuit with very simple components, thus not having a lot of chances to differ greatly.

# 5 Conclusion