Circuit Theory and Electronics Fundamentals

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RC circuit

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Contents

1 Introduction

The objective of this laboratory assignment is to study a RC circuit containing a AC voltage source V_s, a capacitor C, a voltage controlled current source I_b, a current controlled voltage source V_d and resistors, R_1, R_2, R_3, R_4, R_5, R_6 and R_7. The circuit can be seen in Figure 5.

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.

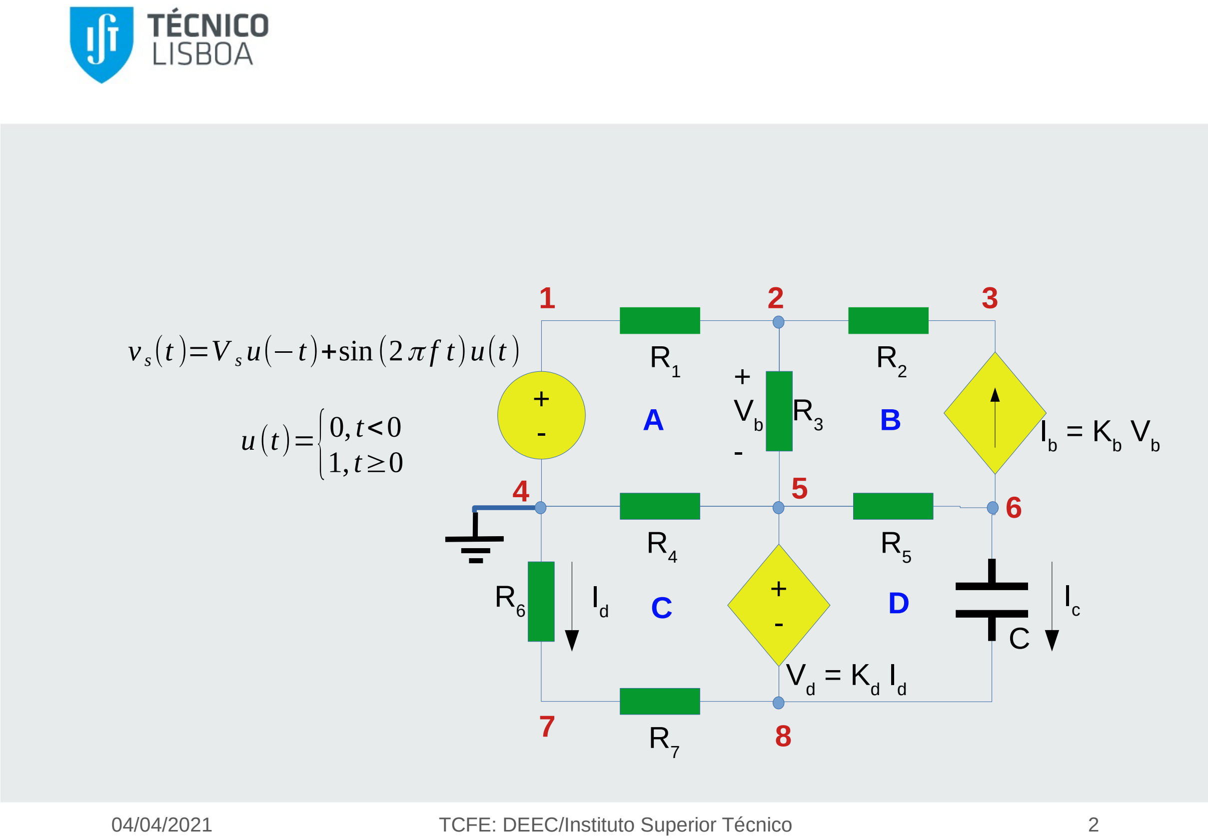

Figure 1: RC circuit to be analysed

2 Theoretical Analysis

In this section, the circuit shown in Figure 5 is analysed theoretically, using both the mesh and node methods.

2.1 t¡0

For t¡0, vs(t)= Vs(t), it is a DC circuit. We can determine the voltges in all nodes and currents in all branches using the nodal method. Since this is a linear circuit, we apply Ohm's Law, $V_i = R_i * I$ and the Kirchoff Current Law (KCL), $\sum I_i = 0$.

We get the following equation, in matrix form:

$$\begin{bmatrix} -G_1 & G_1+G_2+G_3 & -G_2 & 0 & -G_3 & 0 & 0 & 0 \\ 0 & -G_2-K_b & G_2 & 0 & K_b & 0 & 0 & 0 \\ 0 & K_b & 0 & 0 & -G_5-K_b & G_5 & 0 & 0 \\ 0 & 0 & 0 & -G_6 & 0 & 0 & G_6+G_7 & -G_7 \\ 1 & 0 & 0 & -1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & -K_c*G_6 & 1 & 0 & K_c*G_6 & -1 \\ 0 & -G_3 & 0 & -G_4 & G_4+G_3+G_5 & -G_5 & -G_7 & G_7 \end{bmatrix} \cdot \begin{bmatrix} V_1 \\ V_2 \\ V_3 \\ V_4 \\ V_5 \\ V_6 \\ V_7 \\ V_8 \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \\ V_s \\ 0 \\ 0 \\ 0 \end{bmatrix} \quad (1)$$

This equation solved using octave yields the following results:

Variable	Value [A or V]

Table 1: Node Analysis Results for t¡0

3 Simulation Analysis

3.1 Operating Point Analysis

Table 2 shows the simulated operating point results for the circuit under analysis. When compared to the theoretical analysis results, we see the same values up to the 5 decimal places provided by ngspice.

Name	Value [A or V]
@ca[i]	0.000000e+00
@gb[i]	-2.53212e-04
@r1[i]	2.414774e-04
@r2[i]	2.532123e-04
@r3[i]	-1.17349e-05
@r4[i]	-1.20106e-03
@r5[i]	-2.53212e-04
@r6[i]	9.595831e-04
@r7[i]	9.595831e-04
v(1)	5.136122e+00
v(2)	4.884647e+00
v(3)	4.361951e+00
v(5)	4.920010e+00
v(6)	5.690271e+00
v(8)	-2.94454e+00
v(71)	-1.96654e+00
v(72)	-1.96654e+00

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

Name	Value [A or V]
@gb[i]	-6.24390e-18
@r1[i]	5.954528e-18
@r2[i]	6.243896e-18
@r3[i]	-2.89368e-19
@r4[i]	1.300919e-18
@r5[i]	-2.83857e-03
@r6[i]	-8.67362e-19
@r7[i]	1.165891e-21
v(1)	0.000000e+00
v(2)	-6.20107e-15
v(3)	-1.90901e-14
v(5)	-5.32907e-15
v(6)	8.634810e+00
v(8)	1.776357e-15
v(71)	1.777545e-15
v(72)	1.777545e-15

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.

3.2 Natural response

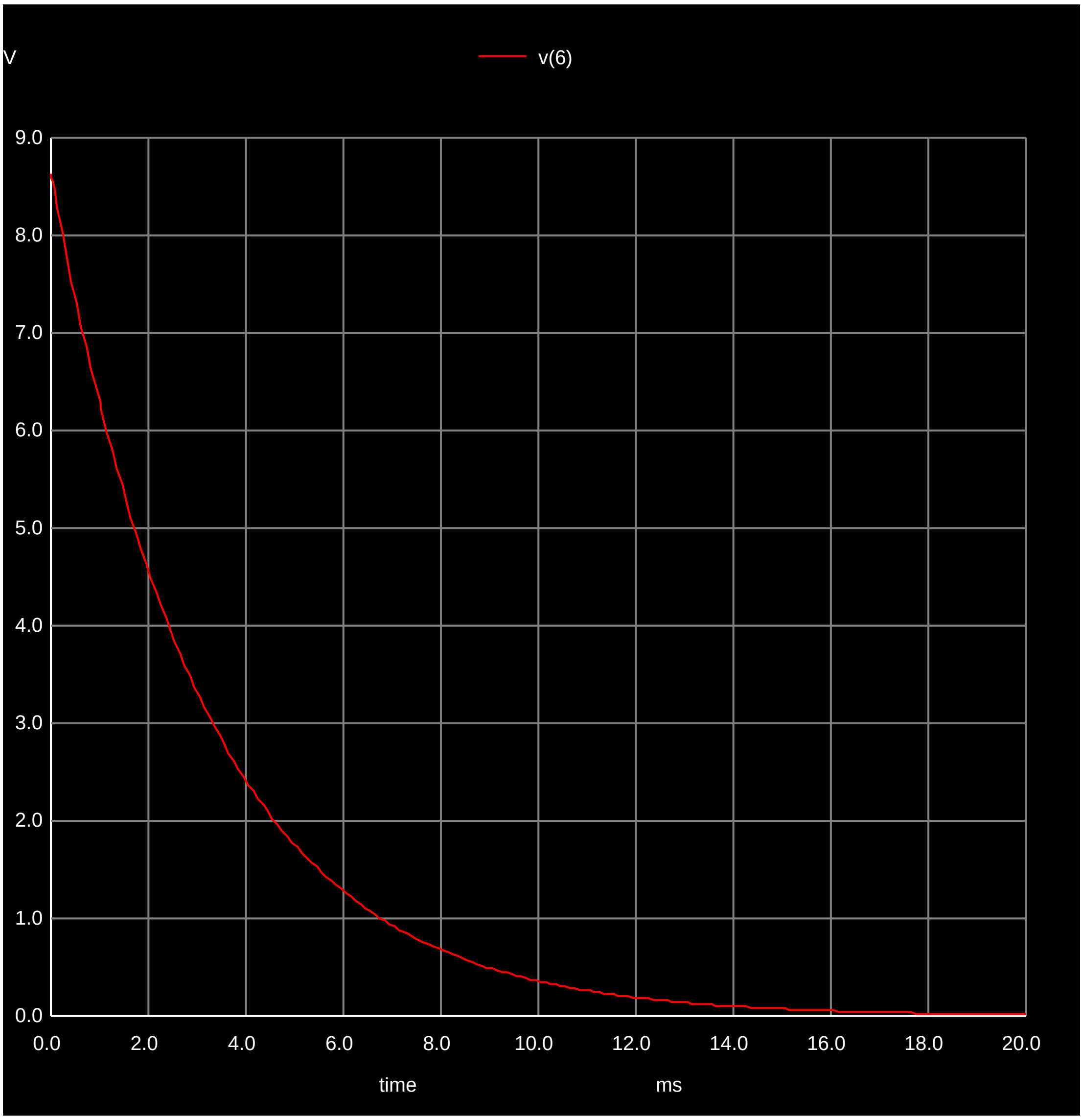

Figure 2: RC circuit to be analysed

3.3 Forced response

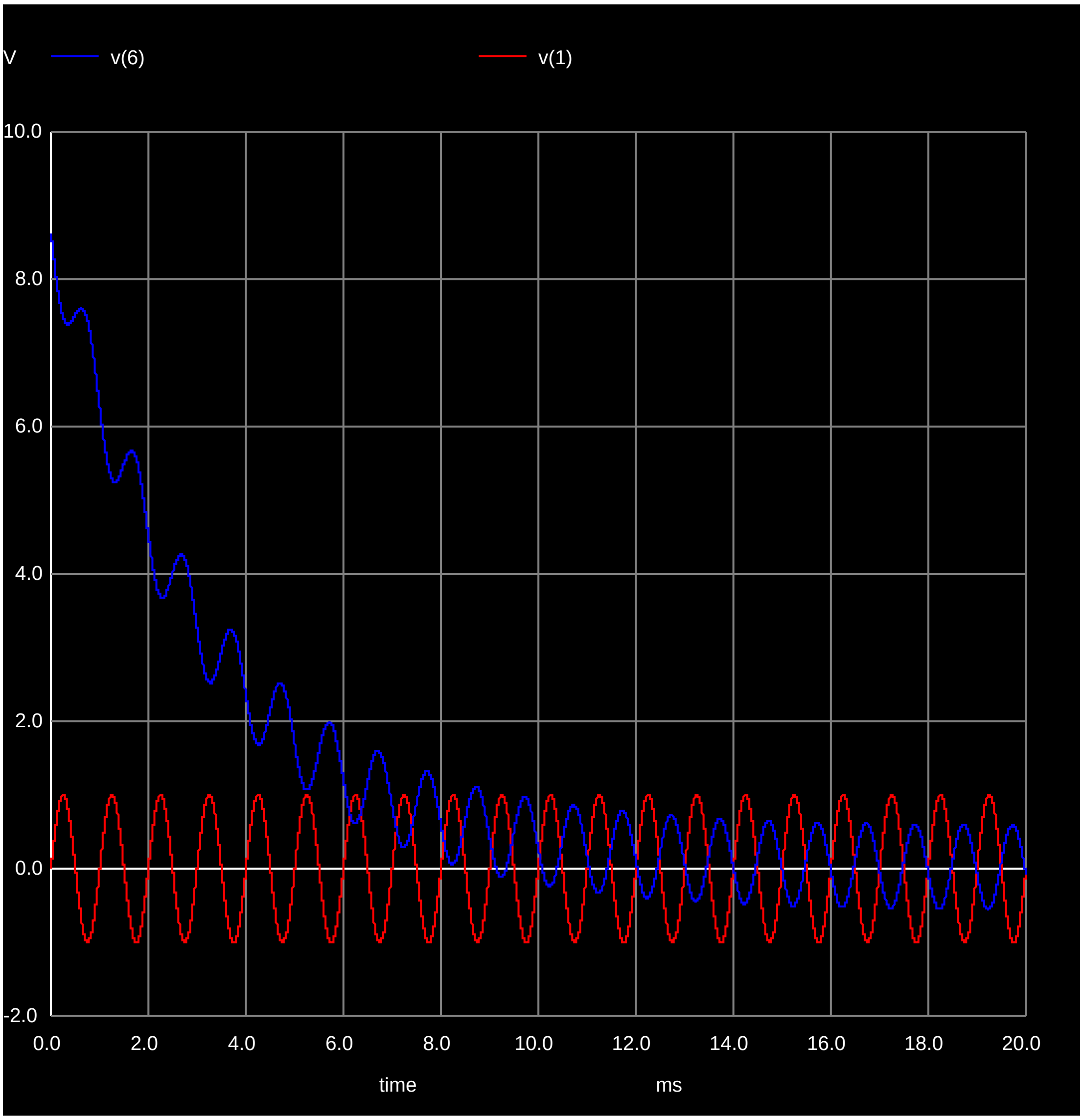

Figure 3: RC circuit to be analysed

3.4 Frequency analysis

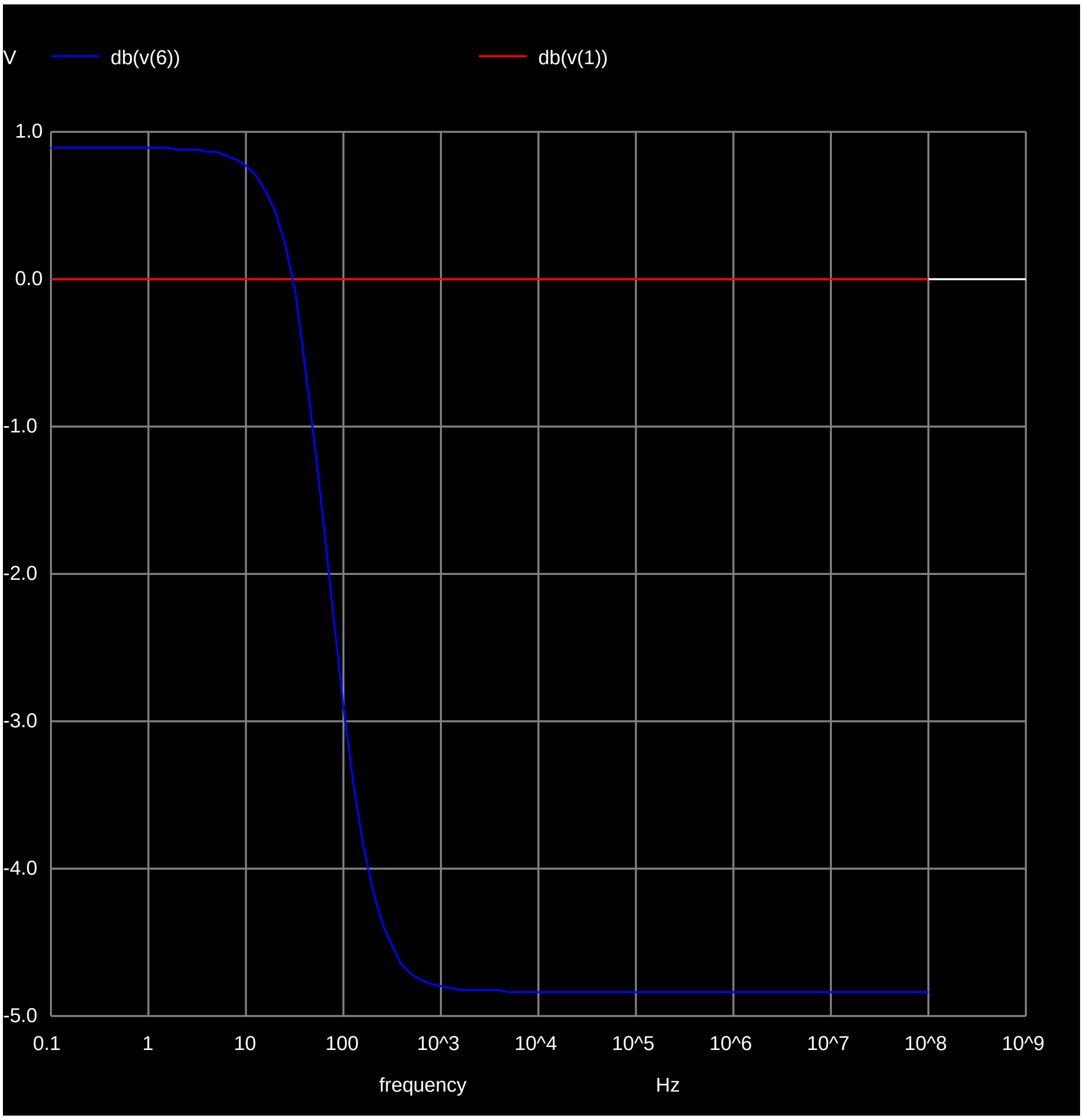

Figure 4: RC circuit to be analysed

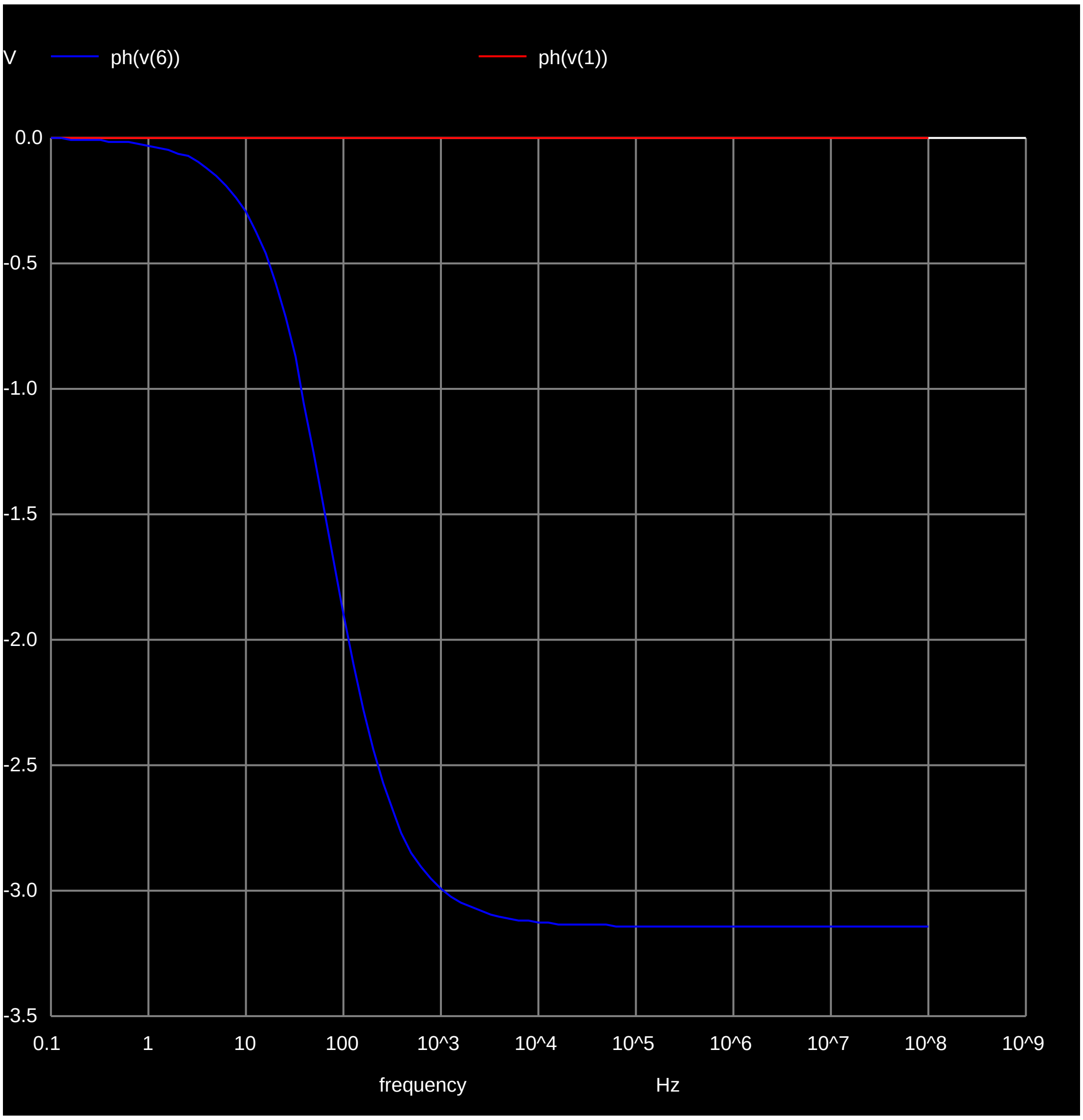

Figure 5: RC circuit to be analysed

It should be noted that nodes G1 and G2 represent the same node G, and exist seperatly so as to allow the measuring of current I_c in ngspice, for the purpose of defining the dependent voltage source V_c.

4 Conclusion

In this laboratory assignment the objective of analysing a static DC circuit has been achieved. A static analysis has been performed on the circuit, through both the node analysis and mesh analysis methods, using the Octave software, and a simulation was run using ngspice. The three sets of results all match with all available decimal places of precision. The reason for this perfect match is the fact that although this circuit has multiple components and nodes, all of the components are linear, and no time dependence exists. The matching of results for the various methods also helps to confirm the accuracy of the equations used for the theoretical analysis.