Circuit Theory and Electronics Fundamentals

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Example 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 2, a theoretical analysis of the circuit is presented. In Section 5, 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 6.

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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

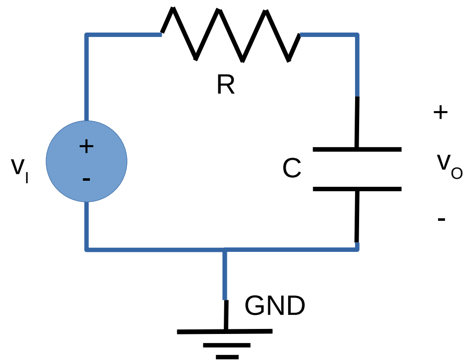

Figure 1: Voltage driven serial RC circuit.

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 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.

2 Theoretical Analysis

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

3 Time response

The circuit consists of a single V-R-C loop where a current $i(t)$ circulates. The voltage source $v_I(t)$ drives its input, and the output voltage $v_O(t)$ is taken from the capacitor terminals. Applying the Kirchhoff Voltage Law (KVL), a single equation for the single loop in the circuit can be written as

$$Ri(t) + v_O(t) = v_I(t). \tag{1}$$

Because v_O is the voltage between capacitor C's plates, it is related to the current i by

$$i(t) = C\frac{dv_O}{dt}. \tag{2}$$

Hence, Equation (1) can be rewritten as

$$RC\frac{dv_O}{dt} + v_O(t) = v_I. \tag{3}$$

Equation (3) is a linear differencial equation whose solution is a superposition of a natural solution v_{On} and a forced solution v_{Of}:

$$v_O(t) = v_{On}(t) + v_{Of}(t). \tag{4}$$

As learned in the theory classes the natural solution is of the form

$$v_{On}(t) = Ae^{-\frac{t}{RC}}, \tag{5}$$

where A is an integration constant.

The forced solution is of the form given in Equation (6) and is illustrated in Figure 2.

$$V_{Of}(t) = |\bar{V}_{Of}|cos(\omega t + \angle\bar{V}_{Of}), \tag{6}$$

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4 Frequency response

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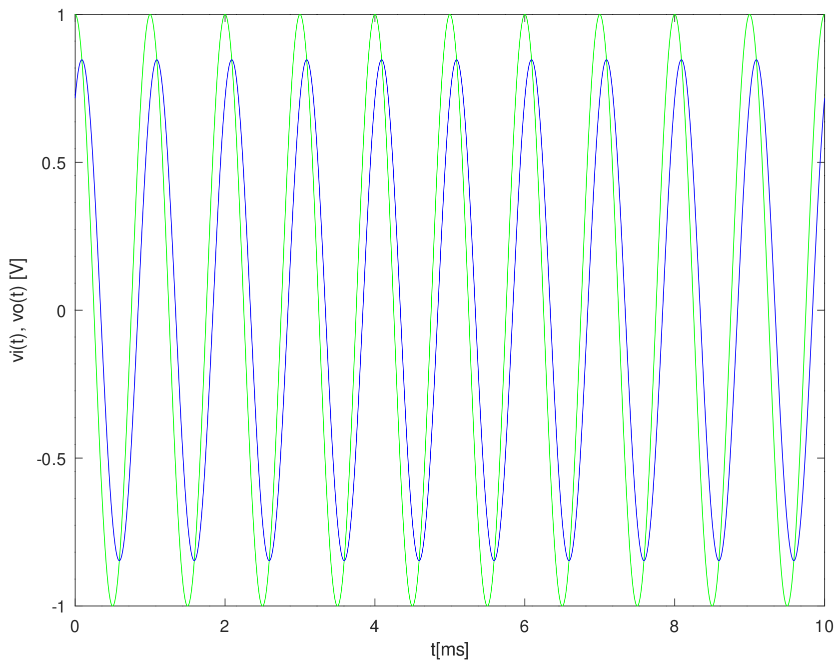

Figure 2: Forced sinusoidal response.

5 Simulation Analysis

5.1 Operating Point Analysis

Table 1 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.

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5.2 Transient Analysis

Figure 3 shows the simulated transient analysis results for the circuit under analysis. Compared to the theoretical analysis results, one notices the following differences: describe and explain the differences.

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Name	Value [A or V]
@cb[i]	0.000000e+00
@ce[i]	0.000000e+00
@q1[ib]	7.022567e-05
@q1[ic]	1.404513e-02
@q1[ie]	-1.41154e-02
@q1[is]	5.765392e-12
@rc[i]	1.411536e-02
@re[i]	1.411536e-02
@rf[i]	7.022567e-05
@rs[i]	0.000000e+00
v(1)	0.000000e+00
v(2)	0.000000e+00
base	2.254108e+00
coll	5.765392e+00
emit	1.411536e+00
vcc	1.000000e+01

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 Volt.

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5.3 Frequency Analysis

5.3.1 Magnitude Response

Figure 4 shows the magnitude of the frequency response for the circuit under analysis. Compared to the theoretical analysis results, one notices the following differences: describe and explain the differences.

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5.3.2 Phase Response

Figure 5 shows the magnitude of the frequency response for the circuit under analysis. Compared to the theoretical analysis results, one notices the following differences: describe and explain the differences.

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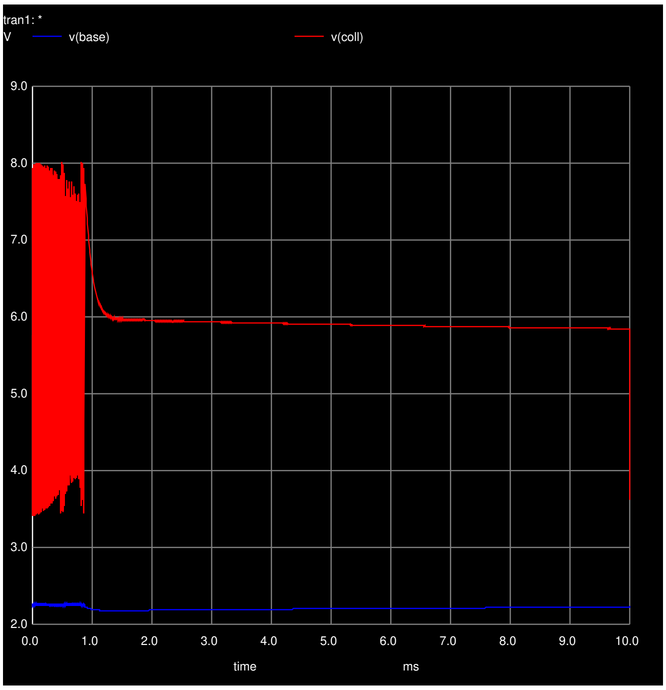

Figure 3: Transient output voltage

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5.3.3 Input Impedance

Figure 6 shows the magnitude of the frequency response for the circuit under analysis. Compared to the theoretical analysis results, one notices the following differences: describe and explain the differences.

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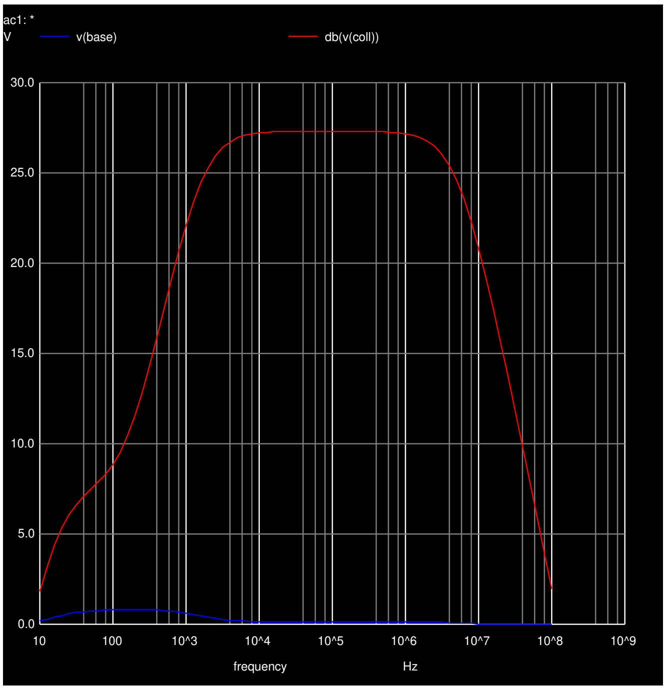

Figure 4: Magnitude response

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6 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.

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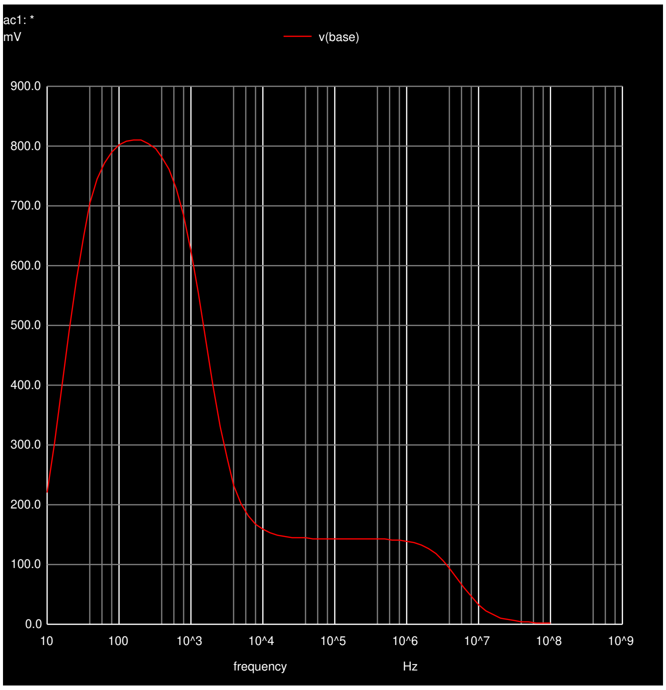

Figure 5: Phase response

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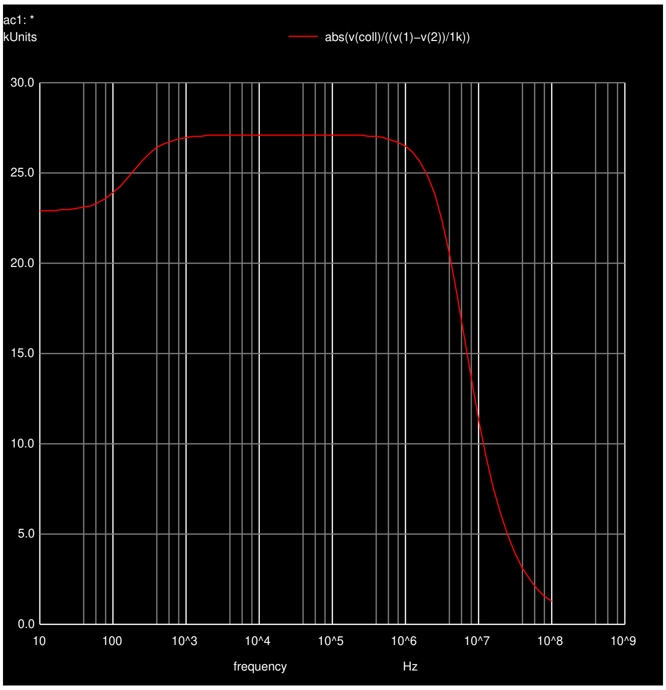

Figure 6: Input impedance