T1 - Circuit Analysis Methods

Mestrado Integrado em Engenharia Física Tecnológica

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Contents

1 Introduction

The objective of this laboratory assignment is to study a circuit containing a two voltage sources, two current sources and seven resistors. The circuit will be analysed using first the mesh method and later the nodal method. The circuit can be seen if Figure 1.

In Section 2, a theoretical analysis of the circuit is presented. First a mesh method aproach is used in subsection 2.1, then we use the nodal method aproach in subsection 2.2. 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, where we compare theoretical and simulation results.

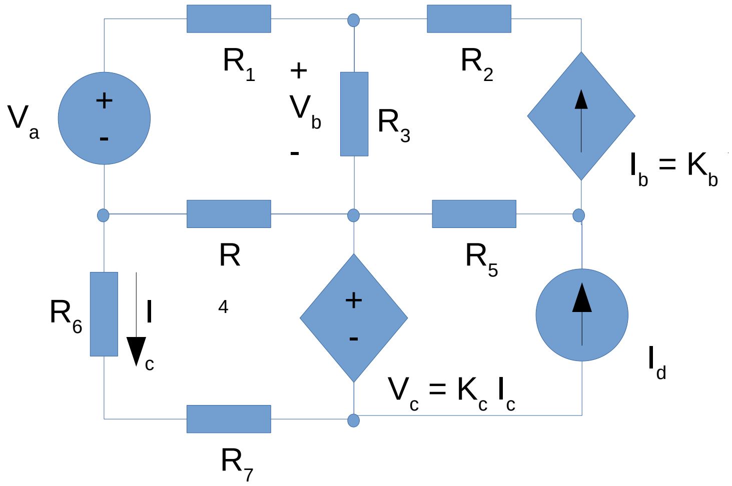

Figure 1: Voltage driven serial RC circuit.

2 Theoretical Analysis

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

2.1 Mesh Method Analysis

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.

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

2.2 Nodal Method Analysis

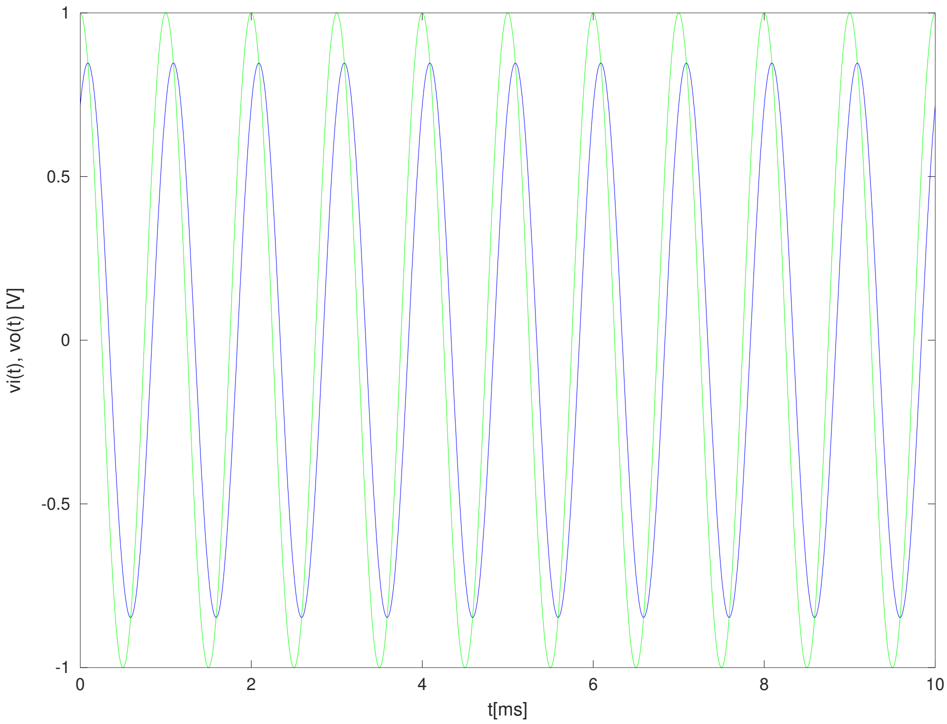

Figure 2: Forced sinusoidal response.

3 Simulation 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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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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3.1 Frequency Analysis

3.1.1 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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3.1.2 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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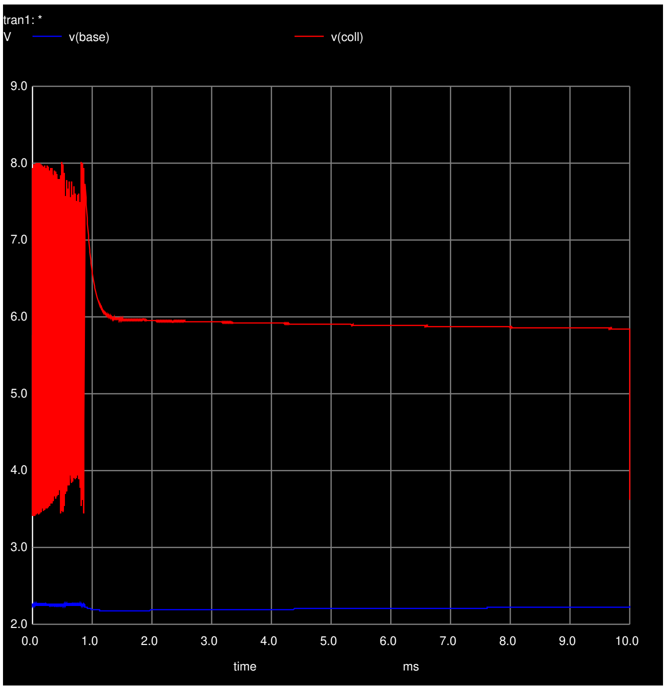

Figure 3: Transient output voltage

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3.1.3 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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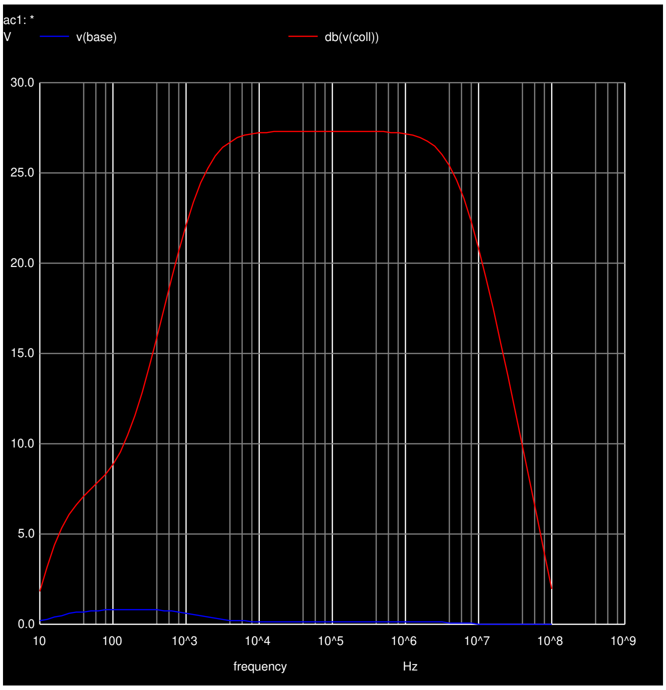

Figure 4: Magnitude response

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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.

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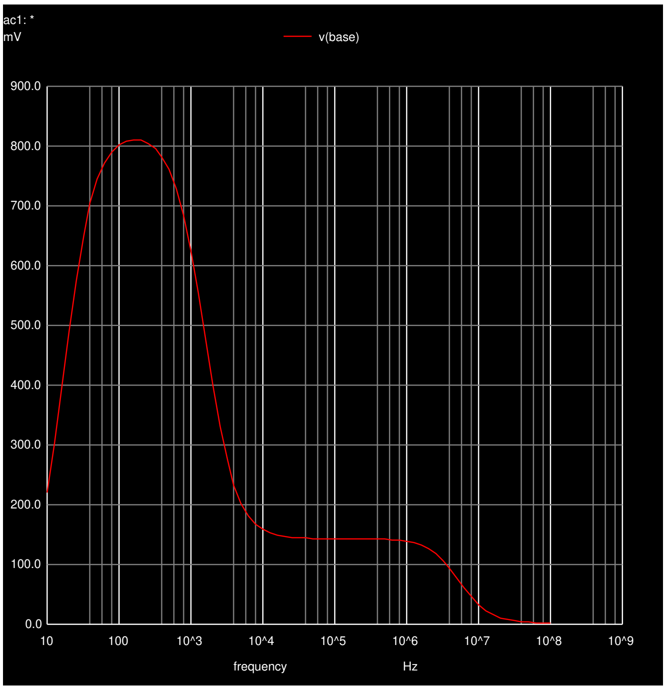

Figure 5: Phase response

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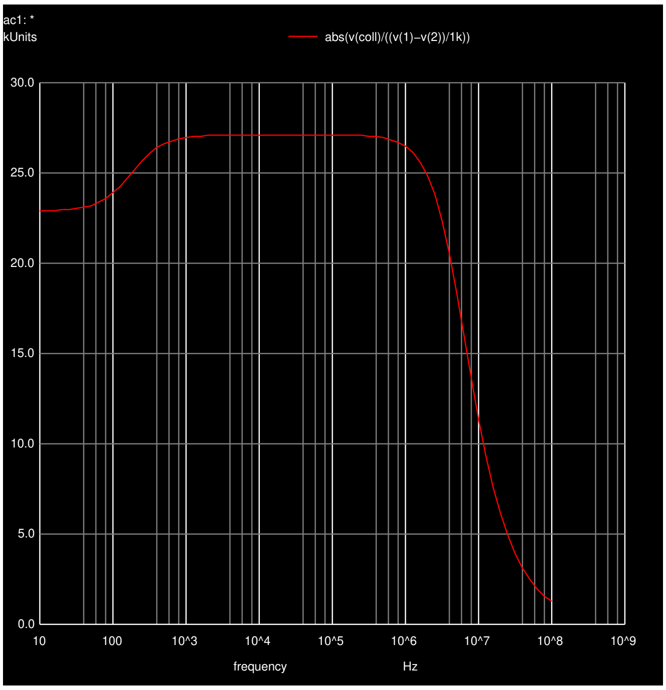

Figure 6: Input impedance