

**[DEEC]**

DEPARTMENT OF ELECTRICAL AND COMPUTING ENGINEERING

# LABORATORY 1

## LINEAR CIRCUIT ANALYSIS

March 24, 2021

**Group 1:**

António Nunes, 95770  
Francisco Branco, 95788  
Pedro Alves, 95836

**Professor:** José Teixeira de Sousa

# Contents

<b>List of Tables</b>	<b>2</b>
<b>List of Figures</b>	<b>2</b>
<b>1 Introduction</b>	<b>1</b>
<b>2 Theoretical Analysis</b>	<b>1</b>
2.1 Node Analysis . . . . .	1
2.2 Mesh Analysis . . . . .	1
<b>3 Time response</b>	<b>1</b>
<b>4 Frequency response</b>	<b>2</b>
<b>5 Simulation Analysis</b>	<b>2</b>
5.1 Operating Point Analysis . . . . .	2
5.2 Transient Analysis . . . . .	3
5.3 Frequency Analysis . . . . .	4
5.3.1 Magnitude Response . . . . .	4
5.3.2 Phase Response . . . . .	4
5.3.3 Input Impedance . . . . .	4
<b>6 Conclusion</b>	<b>5</b>

## List of Tables

1	Operating point. A variable preceded by @ is of type <i>current</i> and expressed in Ampere; other variables are of type <i>voltage</i> and expressed in Volt. . . . .	3
---	--	---

## List of Figures

1	Linear Circuit with Resistors, Dependent and Independent Sources. . . . .	1
---	---	---

# 1 Introduction

The aim of this laboratory assignment is to study the behaviour of a circuit containing linear components, in this case, resistors. Moreover, it also presents Voltage and Current Sources, either Independent or Dependent. In Figure 1 the stated circuit is presented. Despite being a simple circuit, it is perfect to experiment some important Circuit Theory's analysing tools, presented in Section 2, so that software simulation and theoretical analysis can be stacked up against each other more easily.

In Section 2, a theoretical analysis of the circuit is presented, either by the Node Analysis and Mesh Analysis methods, giving us some insights on different, although equivalent forms of exploring a linear circuit. In Section 5, the circuit is analysed by computational simulation tools, via *ngspice*, and the results are compared to the theoretical results obtained in Section 2. The conclusions of this study are outlined in Section 6.

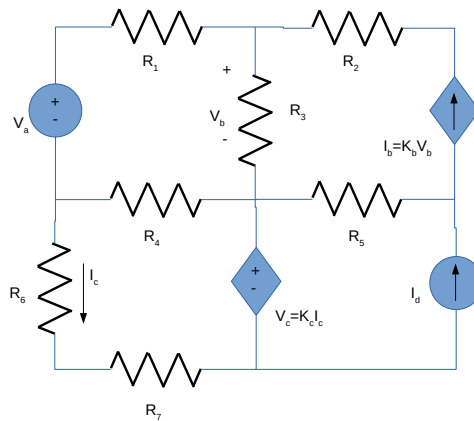


Figure 1: Linear Circuit with Resistors, Dependent and Independent Sources.

## 2 Theoretical Analysis

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

### 2.1 Node Analysis

### 2.2 Mesh Analysis

## 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

$$Ri(t) + v_O(t) = v_I(t). \quad (1)$$

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

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

Hence, Equation (1) can be rewritten as

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

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

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

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

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

where  $A$  is an integration constant.

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

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

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Ut purus elit, vestibulum ut, placerat ac, adipiscing vitae, felis. Curabitur dictum gravida mauris. Nam arcu libero, nonummy eget, consectetur id, vulputate a, magna. Donec vehicula augue eu neque. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Mauris ut leo. Cras viverra metus rhoncus sem. Nulla et lectus vestibulum urna fringilla ultrices. Phasellus eu tellus sit amet tortor gravida placerat. Integer sapien est, iaculis in, pretium quis, viverra ac, nunc. Praesent eget sem vel leo ultrices bibendum. Aenean faucibus. Morbi dolor nulla, malesuada eu, pulvinar at, mollis ac, nulla. Curabitur auctor semper nulla. Donec varius orci eget risus. Duis nibh mi, congue eu, accumsan eleifend, sagittis quis, diam. Duis eget orci sit amet orci dignissim rutrum.

## 4 Frequency response

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Ut purus elit, vestibulum ut, placerat ac, adipiscing vitae, felis. Curabitur dictum gravida mauris. Nam arcu libero, nonummy eget, consectetur id, vulputate a, magna. Donec vehicula augue eu neque. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Mauris ut leo. Cras viverra metus rhoncus sem. Nulla et lectus vestibulum urna fringilla ultrices. Phasellus eu tellus sit amet tortor gravida placerat. Integer sapien est, iaculis in, pretium quis, viverra ac, nunc. Praesent eget sem vel leo ultrices bibendum. Aenean faucibus. Morbi dolor nulla, malesuada eu, pulvinar at, mollis ac, nulla. Curabitur auctor semper nulla. Donec varius orci eget risus. Duis nibh mi, congue eu, accumsan eleifend, sagittis quis, diam. Duis eget orci sit amet orci dignissim rutrum.

## 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.

Name	Value [A or V]
@gb[i]	-2.38996e-04
@id[current]	1.047911e-03
@r1[i]	2.282360e-04
@r2[i]	-2.38996e-04
@r3[i]	-1.07597e-05
@r4[i]	1.224163e-03
@r5[i]	-1.28691e-03
@r6[i]	9.959274e-04
@r7[i]	9.959274e-04
v(1)	5.225520e+00
v(2)	4.989286e+00
v(3)	4.508524e+00
v(4)	5.021948e+00
v(5)	9.009942e+00
v(6)	-2.00134e+00
v(7)	-2.00134e+00
v(8)	-3.03868e+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 Volt.

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Ut purus elit, vestibulum ut, placerat ac, adipiscing vitae, felis. Curabitur dictum gravida mauris. Nam arcu libero, nonummy eget, consectetur id, vulputate a, magna. Donec vehicula augue eu neque. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Mauris ut leo. Cras viverra metus rhoncus sem. Nulla et lectus vestibulum urna fringilla ultrices. Phasellus eu tellus sit amet tortor gravida placerat. Integer sapien est, iaculis in, pretium quis, viverra ac, nunc. Praesent eget sem vel leo ultrices bibendum. Aenean faucibus. Morbi dolor nulla, malesuada eu, pulvinar at, mollis ac, nulla. Curabitur auctor semper nulla. Donec varius orci eget risus. Duis nibh mi, congue eu, accumsan eleifend, sagittis quis, diam. Duis eget orci sit amet orci dignissim rutrum.

## 5.2 Transient Analysis

Figure ?? 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.

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Ut purus elit, vestibulum ut, placerat ac, adipiscing vitae, felis. Curabitur dictum gravida mauris. Nam arcu libero, nonummy eget, consectetur id, vulputate a, magna. Donec vehicula augue eu neque. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Mauris ut leo. Cras viverra metus rhoncus sem. Nulla et lectus vestibulum urna fringilla ultrices. Phasellus eu tellus sit amet tortor gravida placerat. Integer sapien est, iaculis in, pretium quis, viverra ac, nunc. Praesent eget sem vel leo ultrices bibendum. Aenean faucibus. Morbi dolor nulla, malesuada eu, pulvinar at, mollis ac, nulla. Curabitur auctor semper nulla. Donec varius orci eget risus. Duis nibh mi, congue eu, accumsan eleifend, sagittis quis, diam. Duis eget orci sit amet orci dignissim rutrum.

## 5.3 Frequency Analysis

### 5.3.1 Magnitude Response

Figure ?? 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.

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Ut purus elit, vestibulum ut, placerat ac, adipiscing vitae, felis. Curabitur dictum gravida mauris. Nam arcu libero, nonummy eget, consectetur id, vulputate a, magna. Donec vehicula augue eu neque. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Mauris ut leo. Cras viverra metus rhoncus sem. Nulla et lectus vestibulum urna fringilla ultrices. Phasellus eu tellus sit amet tortor gravida placerat. Integer sapien est, iaculis in, pretium quis, viverra ac, nunc. Praesent eget sem vel leo ultrices bibendum. Aenean faucibus. Morbi dolor nulla, malesuada eu, pulvinar at, mollis ac, nulla. Curabitur auctor semper nulla. Donec varius orci eget risus. Duis nibh mi, congue eu, accumsan eleifend, sagittis quis, diam. Duis eget orci sit amet orci dignissim rutrum.

### 5.3.2 Phase Response

Figure ?? 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.

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Ut purus elit, vestibulum ut, placerat ac, adipiscing vitae, felis. Curabitur dictum gravida mauris. Nam arcu libero, nonummy eget, consectetur id, vulputate a, magna. Donec vehicula augue eu neque. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Mauris ut leo. Cras viverra metus rhoncus sem. Nulla et lectus vestibulum urna fringilla ultrices. Phasellus eu tellus sit amet tortor gravida placerat. Integer sapien est, iaculis in, pretium quis, viverra ac, nunc. Praesent eget sem vel leo ultrices bibendum. Aenean faucibus. Morbi dolor nulla, malesuada eu, pulvinar at, mollis ac, nulla. Curabitur auctor semper nulla. Donec varius orci eget risus. Duis nibh mi, congue eu, accumsan eleifend, sagittis quis, diam. Duis eget orci sit amet orci dignissim rutrum.

### 5.3.3 Input Impedance

Figure ?? 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.

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Ut purus elit, vestibulum ut, placerat ac, adipiscing vitae, felis. Curabitur dictum gravida mauris. Nam arcu libero, nonummy eget, consectetur id, vulputate a, magna. Donec vehicula augue eu neque. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Mauris ut leo. Cras viverra metus rhoncus sem. Nulla et lectus vestibulum urna fringilla ultrices. Phasellus eu tellus sit amet tortor gravida placerat. Integer sapien est, iaculis in, pretium quis, viverra ac, nunc. Praesent eget sem vel leo ultrices bibendum. Aenean faucibus. Morbi dolor nulla, malesuada eu, pulvinar at, mollis ac, nulla. Curabitur auctor semper nulla. Donec varius orci eget risus. Duis nibh mi, congue eu, accumsan eleifend, sagittis quis, diam. Duis eget orci sit amet orci dignissim rutrum.

## 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.

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Ut purus elit, vestibulum ut, placerat ac, adipiscing vitae, felis. Curabitur dictum gravida mauris. Nam arcu libero, nonummy eget, consectetur id, vulputate a, magna. Donec vehicula augue eu neque. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Mauris ut leo. Cras viverra metus rhoncus sem. Nulla et lectus vestibulum urna fringilla ultrices. Phasellus eu tellus sit amet tortor gravida placerat. Integer sapien est, iaculis in, pretium quis, viverra ac, nunc. Praesent eget sem vel leo ultrices bibendum. Aenean faucibus. Morbi dolor nulla, malesuada eu, pulvinar at, mollis ac, nulla. Curabitur auctor semper nulla. Donec varius orci eget risus. Duis nibh mi, congue eu, accumsan eleifend, sagittis quis, diam. Duis eget orci sit amet orci dignissim rutrum.