

# Circuit Theory and Electronics Fundamentals

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## T2's Laboratory Report

### Group 5

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## 1 Introduction

The objective of this laboratory assignment is to study a circuit with resistances, sinusoidal voltage source and a capacitor (Fig.1). The main objective is to simulate the circuit using NGspice and compare results with the theoretical analysis.



Figure 1: T2's given circuit.

Firstly, in the theoretical analysis we will determine the voltages in all nodes and the currents in all branches using the nodal method, like in the previous laboratory assignment. Then, we calculate the equivalent resistance ( $R_{eq}$ ) as seen from the capacitor terminals and determined the natural solution for  $V_{6n}(t)$  and plot the result from 0ms to 20ms. The forced solution was also obtained in the same interval (for  $f=1\text{KHz}$ ) and the total solution was plotted for -5ms to 20ms. At last, the frequency response was calculated and the results were analysed.

At the same time, the circuit was simulated using NGSpice in order to obtain the same results and, considering that some of them could be lightly different, they were compared and analysed.

The data used was the following:

Name	Value [F, V, $\Omega$ or S]
$R_1$	1.04765357286e3
$R_2$	2.06140068334e3
$R_3$	3.03459085363e3
$R_4$	4.00398818216e3
$R_5$	3.11499853456e3
$R_6$	2.04588646991e3
$R_7$	1.04390152967e3
$V_s$	5.02522591213
$C$	1.00982536324e-3
$K_b$	7.28209304852e-3
$K_c$	8.36641247715e3

## 2 Theoretical Analysis

### 2.1 Question 1: Node Analysis

This preliminary analysis of the circuit is the basis of the rest of the work and to do this we used the nodal method in the same way as used in T1. We have the equations: (the nomenclature for all nodes and branches is present in figure 1).

Node 0 (ground):

$$\frac{1}{R_1}(V_2 - V_1) + \frac{1}{R_4}(V_5 - 0) - I_d = 0 \quad (1)$$

Node 2:

$$\frac{1}{R_1}(V_1 - V_2) + \frac{1}{R_2}(V_3 - V_2) + \frac{1}{R_3}(V_5 - V_2) = 0 \quad (2)$$

Node 3:

$$\frac{1}{R_2}(V_2 - V_3) + I_b = 0 \quad (3)$$

Node 5:

$$\frac{1}{R_3}(V_2 - V_5) + \frac{1}{R_5}(V_6 - V_5) + \frac{1}{R_4}(0 - V_5) - I_d = 0 \quad (4)$$

Node 6:

$$\frac{1}{R_5}(V_5 - V_6) - I_b - I_c = 0 \quad (5)$$

Node 7:

$$\frac{1}{R_6}(V_7 - 0) + I_d = 0 \quad (6)$$

Node 8:

$$\frac{1}{R_7}(V_7 - V_8) - I_d + I_c = 0 \quad (7)$$

Additional equation:

$$V_5 - V_8 - K_d I_d = 0 \quad (8)$$

Additional equation:

$$V_2 - V_5 - \frac{I_b}{K_b} = 0 \quad (9)$$

And the results are shown in the following table:

Name	Value [A or V]
$V_1$	5.025226e+00
$V_2$	4.724476e+00
$V_3$	4.104661e+00
$V_5$	4.765766e+00
$V_6$	5.702373e+00
$V_7$	-1.847813e+00
$V_8$	-2.790649e+00
$I_1$	-2.870701e-04
$I_2$	-3.006765e-04
$I_3$	1.360640e-05
$I_4$	1.190255e-03
$I_5$	3.006765e-04
$I_6$	9.031846e-04
$I_7$	9.031846e-04
$I_s$	-2.870701e-04
$I_d$	9.031846e-04
$I_b$	-3.006765e-04
$I_c$	-2.168404e-19

All the variables preceded by I are currents and are expressed in Ampere, the other variables, preceded by V are voltages and are expressed in Volt.

## 2.2 Question 2: Equivalent Resistance ( $R_{eq}$ )

The resolution of this question was based on the suggestion presented. Firstly, we set  $V_s = 0$  and replaced the capacitor by a voltage source  $V_x = V_6 - V_8$  and ran the nodal analysis in order to obtain the current  $I_x$  which is the current supplied by  $V_x$ .

Then, with the equation:

$$R_{eq} = \frac{V_x}{I_x} \quad (10)$$

We obtain the Equivalent resistance.

The time constant  $\tau$  is calculated by doing  $\tau = R_{eq}C$

Basically, the procedure was based on *Thévenin* theorem. Since, the capacitor was replaced by a Voltage source with terminals have the same difference of potential as  $V_6 - V_8$  in Question 1, this is a known variable and  $I_x$  can also be obtained by running the nodal method with  $V_s = 0$ . We needed to do this because there is no easiest way to calculate the Equivalent Resistance in a circuit where there are resistances in parallel, series and a capacitor.

The results:

Name	Value [A or V]
$V_x$	8.493021e+00
$V_1$	0.000000e+00
$V_2$	0.000000e+00
$V_3$	-0.000000e+00
$V_5$	0.000000e+00
$V_6$	8.493021e+00
$V_7$	0.000000e+00
$V_8$	0.000000e+00
$I_1$	0.000000e+00
$I_2$	0.000000e+00
$I_3$	0.000000e+00
$I_4$	0.000000e+00
$I_5$	2.726493e-03
$I_6$	-0.000000e+00
$I_7$	-0.000000e+00
$I_s$	0.000000e+00
$I_d$	-0.000000e+00
$I_b$	0.000000e+00
$I_x$	2.726493e-03
$Req(kOhm)$	3.114999e+00
$tau(ms)$	3.145605e+00

### 2.3 Question 3: Natural solution $v_{6_t}(t)$

The natural solution  $v_{6_t}(t)$  in the interval  $[0,20]$ ms calculating:

$$v_{6_n} = V_x - V_8 e^{\frac{-t}{\tau}} \quad (11)$$

Where  $V_x$  is the same as in question 1 ( $t < 0$ ). By doing this, the plot obtained is the one shown below:

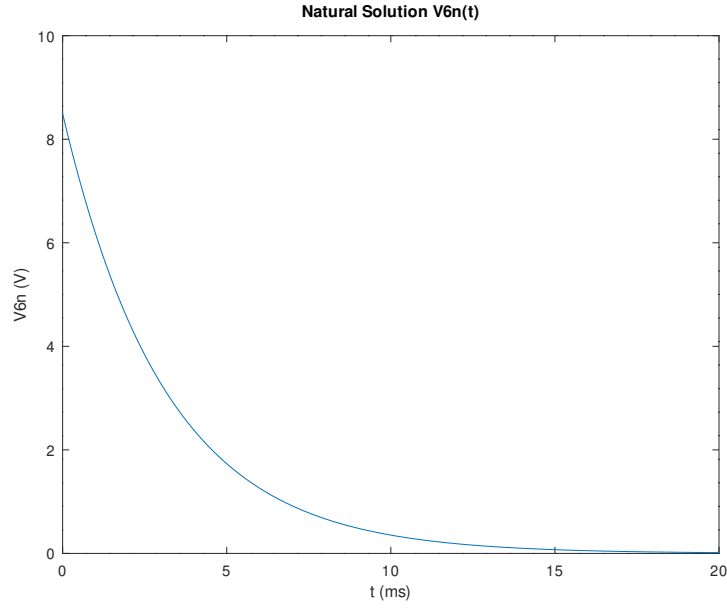


Figure 2: Plot alinea 3.

#### 2.4 Question 4: Forced solution $v_{6_t}(t)$ (f=1Khz)

In this question, we have used a phasor voltage source  $V_s = 1$ , so:

$$v_s = V_s e^{-i\frac{\pi}{2}} \quad (12)$$

Then, replacing C with impedance  $Z_c$  and running the nodal analysis to determine the phasor voltages in all nodes we have the following results:

Name	Value [A or V]
$V_1$	6.123234e-17
$V_2$	5.756770e-17
$V_3$	5.001526e-17
$V_5$	5.807082e-17
$V_6$	8.493021e+00
$V_7$	-2.251559e-17
$V_8$	-3.400403e-17

We have calculated the module of  $V_6$  with "abs" Octave's function. Then, the phase is calculated in the expression:

$$phase = 0 + \arctan(2\pi R_{eq}C) \quad (13)$$

Where  $R_{eq}$  and  $C$  are the equivalent resistance and the Capacitor's capacitance, respectively.

And, finally, the forced solution is given by the expression:

$$V_{6_f} = V_6 \cos(t2\pi - phase) \quad (14)$$

where  $V_6$  is the module value, calculated in the previous expression.

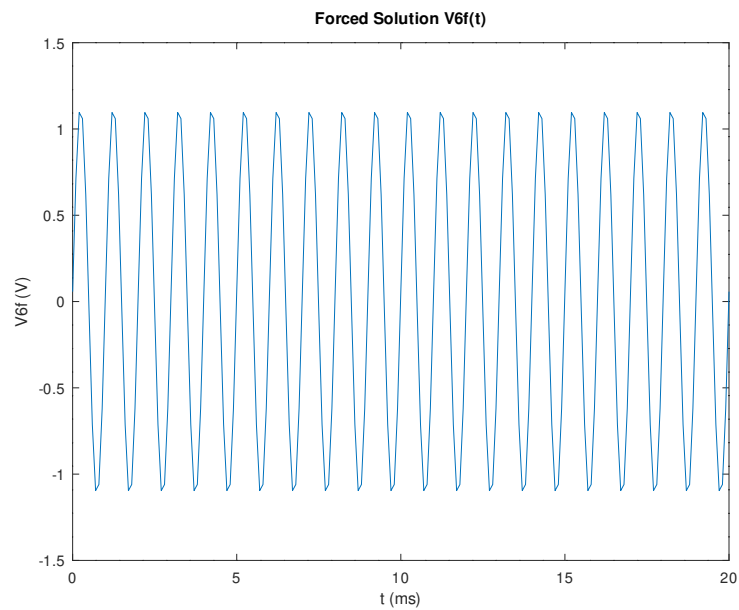


Figure 3: Plot alinea 4.

## 2.5 Question 5: Final solution $v_{6t}(t)$

## 3 Simulation analysis

### 3.1 Question 1:

### 3.2 Question 2:

### 3.3 Question 3:

### 3.4 Question 4:

### 3.5 Question 5:

## 4 Conclusion

In this lab...