Circuit Theory and Electronics Fundamentals

Department of Electrical and Computer Engineering, Técnico, University of Lisbon

T2's Laboratory Report

Group 5

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Contents

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.

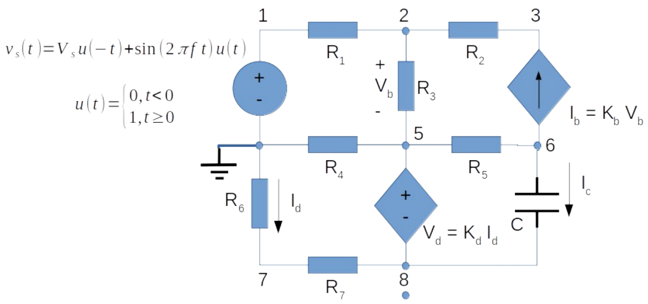

Figure 1: T2's given circuit.

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_{e_q}) as seen from the capacitor terminals and determined the natural solution for $V_{6_n}(t)$ and plot the result from 0ms to 20ms. The forced solution was also obtainned in the same interval (for f=1KHz) and the total solution was plotted for -5ms to 20ms. At last, the frequency response was calculated and the results were analised.

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 analised.

The data used was the following:

Name	Value [F, V, Ω 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):

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

Node 2:

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

Node 3:

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

Node 5:

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

Node 6:

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

Node 7:

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

Node 8:

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

Additional equation:

$$V_5 - V_8 - K_d I_d = 0 \tag{8}$$

Additional equation:

$$V_2 - V_5 - \frac{I_b}{K_b} = 0 \tag{9}$$

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, preceeded by V are voltages and are expressed in Volt.

2.2 Question 2: Equivalent Resistance (R_{e_q})

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 witch is the current supplied by V_x.

Then, with the equation:

$$R_{e_q} = \frac{V_x}{I_x} \tag{10}$$

We obtain the Equivalent resistance.

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

Basically, the procedure was based on *Thévenin* theorem. Since, the capacitor was replaced by a Voltage source witch 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 obtainned 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 paralell, 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:

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

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

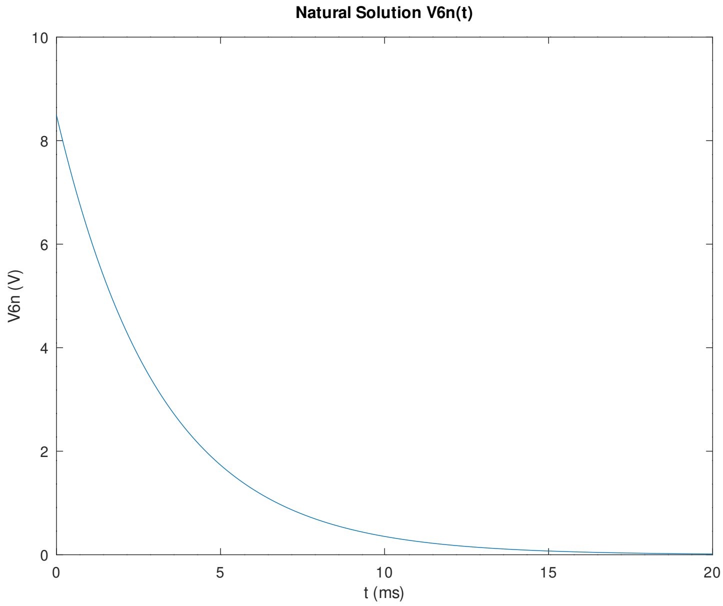

Figure 2: Plot alinea 3.

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:

$$v_s = V_s e^{-i\frac{\pi}{2}} \tag{12}$$

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:

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

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

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

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

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

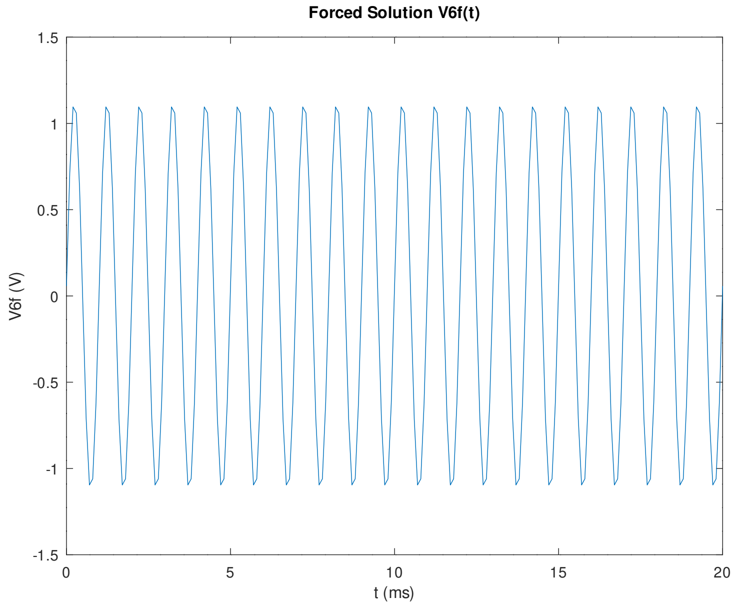

Figure 3: Plot alinea 4.

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

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...