University of California Merced
School of Engineering
Department of Electrical Engineering

ENGR 065 Circuit Theory

Lab 10: Transient Response of RLC Circuits

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Section

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Objectives

- Observe the transient responses of RLC circuits with SPICE simulator.
- Apply Laplace transform to predict behavior of RLC circuits.
- Learn how R, L, and C affect the behavior of RLC circuits.

1. Introduction

The point for this lab is to set up our circuit in the PSPICE environment. My partner and I constructed many circuits using PSPICE and saw the different responses of the RL and RC circuits. With this information we learned how to measure the time constant of the first order circuits. Finally, we then learned how R, L, and C affect the circuit behaviors.

2. Methods & Procedures

The circuit that we focused on in the lab has many applications as the oscillator circuits are described as a second-order circuit (voltage and/or current in the circuit can be described by a second-order differential equation). The lab was required the use of the equation $\alpha = R/2L$, and $\omega_0 = 1/(LC)$ to calculate the damping ratio (α/ω_0) of a circuit in series. In addition to using $\alpha = 1/2RC$ along with $\omega_0 = 1/\sqrt{(LC)}$ for parallel circuits.

My partner and I were then assigned the circuits that are presented to us in the lab and with the configurations that are shown. Furthermore, we looked at the graphs that they create when looking at the pulse. Once this is all done we can start calculating things like the neper frequency (α), resonant frequency (ω) and damping ratio (α/ω) for each circuit.

3. Results & Discussion

	Variable	Case I: R=4Ω $C = 0.1F$
1	maximum value of inductor current $i(t)$	294 mA
2	maximum energy that the inductor stores	0.0173 J
3	maximum value of the capacitor voltage $v_c(t)$	1.6 V
4	maximum energy that the capacitor stores	0.128 J

Once we get the circuit into the SPICE simulator we then mark down the inductors and capacitors values within the circuit. As for I(t) and Vc(t) approaches infinity the amount of storage increases in the capacitor and inductor.

Part B:

	Case II	Case III	Case IV
Resistance R	**2Ω**	**0 Ω**	**0 Ω**
Capacitance C	$\mathbf{0.1}F$	$\mathbf{0.1}F$	$\mathbf{0.01}F$
Laplace transform of the inductor current: $I(s) = \mathcal{L}\{i(t)\}$	$\frac{4}{s^2+5s+25}$	$\frac{4}{s^2+25}$	$\frac{4}{s^2+250}$
Inductor current, time domain: $i(t)$	(*) $\frac{8}{5\sqrt{3}} e^{-\frac{5t}{2}} \cdot \sin\left(\frac{5\sqrt{3}\,t}{2}\right)$	$4\sin 5t$	$4\sin(5\sqrt{10}\,t)$
Neper Frequency (α)	2.5	0	0
Resonant Frequency (ω_0)	5	5	15.8114
Poles of $I(s)$		$j5, -j5$	$j\sqrt{250}, -j\sqrt{250}$
Type of Poles (Real, Complex or Purely Imaginary?)	complex	imaginary	imaginary

	Case II	Case III	Case IV
Resistance R	**2Ω**	**0 Ω**	**0 Ω**
Capacitance C	$\mathbf{0.1}F$	$\mathbf{0.1}F$	$\mathbf{0.01}F$
maximum value of inductor current $i(t)$	437 mA	800 mA	252 mA
maximum energy that the inductor stores	0.038 J	0.128 J	0.127 J
maximum value of the capacitor voltage $v_c(t)$	1.86 V	3.2 V	3.2 V
maximum energy that the capacitor stores	0.692 J	2.048 J	2.048 J

$\omega_L = \frac{1}{2} L(i^2)$ $\quad L = 0.4$

$\omega_c = \frac{1}{2} C(V^2)$

We then get the validity of the time-domain current formula i(t) by comparing the theoretical values (obtained through inverse Laplace transform) and the simulated values (obtained from the SPICE simulator) when t = 0.5s.

	Case I	Case II	Case III	Case IV
Resistance R	4Ω	2Ω	0 Ω	0 Ω
Capacitance C	$0.1F$	$0.1F$	$0.1F$	$0.01F$
Theoretical value for $i(t = 0.5s)$	0.164	0.219	2.394	3.995 A
Simulated value for $i(t = 0.5s)$	164 mA	220mA	481mA	252 mA

Cases 1, 2, 3, & 4:

For I(t) and Vc(t) approaches infinity the theoretical value of Amps are increasing. Systems with complex poles can have oscillations in their impulse and step responses.

Cases 3 & 4:

When C went to 0.1 to 0.01F the simulated value went down but the theoretical value continued to go up. By bringing the capacitor down the amount of voltage that can be transferred through it has to be lowered if not, the capacitor will explode in a sense.

Since there is no resistance we would have similar answers depending on the capacitance value and the frequency. The higher the capacitance the more storage of value of energy it can hold and the lower the capacitance is the less energy it can hold thus releasing it earlier than a greater one.

4. Conclusion and Recommendations

During this lab we explored a circuit that showed us how the values alter depending on the resistor, capacitance, inductor, and frequency. We can find the critical values for both series and parallel circuits by using characteristic equations. As we know that these equations are different that is the reason why we were expected a different response each time.