University of California Merced
School of Engineering
Department of Electrical Engineering

ENGR 065 Circuit Theory

Lab 9: RL and RC Circuits

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Section

Friday 9:00 am - 11:50 am

Date

11/25/2022

Fall 2022

Objective

The objective of Lab 9 demands the ability to stimulate the RC and RL circuit through SPICE software, and observe and record their transient and steady-state via the time constraint values and circuit behavior within an operational domain.

Introduction

RC circuits are circuits equipped with capacitors and resistors connected to each other in parallel or series, while RL circuit models contain varied connections between resistor and inductor. By applying circuit analysis first order differential computation, we may fully understand these circuit behavior under electrical influence. Consider that for this lab, the foci is first order operation; thus, the circuit model will only contain one resistor and one capacitor or inductor. Additionally, this lab focuses on the transient and steady-state of the RL and RC model, an analysis of the circuit within a time interval where there is an initial attenuation in either the voltage of current which eventually reaches a plateau becoming less volatile and constant in electrical behavior, the steady state. The principle lies in the idea that when power is introduced to a circuit modeled with inductor and,or capacitors - while the voltage will maximize at resistor nodes(Vr), the voltage of the capacitor(Vc) will remain zero, this operation will then repeat in reverse order as the capacitor begins to build up voltage and capacitance values decrease to zero. Such oscillation behavior will be stimulated via SPICE and exploited for further understanding.

Procedure

Utilize the spice stimulation and employ the create new circuit operation to begin construction of the first model. This model will require 1 kOhm resistor, 1 uF capacitor, a clock voltage with consideration for wiring for interconnection. The clock voltage will be located on the left side which is 5V leading up and flooding running through the first 1 kOhm resistor, out and again folding 90 degrees, also the node in which the voltage indicator will be placed, leading in and out of the 1 uF capacitor and folding 90 degrees once more leading into the ground. Now, set the clock voltage setting to VP as 5 V and frequency domain as 100 HZ - this completes our first order RC circuit model construction. Consider setting the time domain stimulation to initial time as 0s, finished time at 10e^-3s and step size as 1e^-6s.

With reference to the previous step, the second model is the RL circuit model containing the resistor and inductor component. Employ new file and create new circuit as previous step - first introduced the capacitor on the left hand side, leading up to a point will be the first voltage indicator (blue), then folding 90 degrees and running through and out both the first 1 kOhms resistor and the first probe represented by A then meeting at the second voltage indicator (green), folding 90 degrees again through and out of the 10 uF inductor, which again folds and leads to the group. Once more, another RL circuit will be constructed using the same procedure, but this time, the capacitance will have 10 uF, there will be a pile in the middle of the first and second voltage indicator while leaving the voltage source the same.

The final model consists of building an RC circuit with an LED light with a switch. From the stimulation program, we will need 10 V DC voltage supply, 100 Ohms resistor, and 1 mF capacitor with consideration for running a ground line for the circuit. Beginning by mapping out the circuit - create the 10V DC vs on the left hand side, then run connection wire up which folds 90 degrees and run through and out the 100 Ohms resistor, which will be left open. Now, from the bottom side of the 1 mF capacitor, run wire down and fold 90 degrees which will run though the ground and up, running through the capacitor and up. Now between the open points after the resistor and capacitors, there will be a single pole which will act as a switch for the circuit. Now, from the folding angle before the capacitor, branch out and make another region of the circuit. The wire should branch leftward then fold up and fold right, again, branching out meeting up at the point in which we have just created a switch for. This, between this point, and the opening after the first resistor are points which the switch will oscillate to during the stimulation.

Data presentation

- RC circuit model data

Capacitance	Resistance	Calculated Time Constant*	Measured Time Constant
$1\mu F$	1 kΩ	1 ms	0.998 ms

3. Place two 1 μF capacitors in series. Repeat 1 and 2.

Capacitance	Resistance	Calculated Time Constant*	Measured Time Constant
0.5 uF	1 kΩ	0.5 ms	0.501 ms

4. Place two 1 μF capacitors in parallel. Repeat 1 and 2. Note: to facilitate the measurement of the time constant you may decrease the function generator frequency to 50Hz.

Capacitance	Resistance	Calculated Time Constant*	Measured Time Constant
2 uF	1 kΩ	2 ms	1.997 ms

Does the time constant change with different capacitor combinations? Why?

Yes indeed, as seen within the simulation since the capacitance and time constraint has a direct correlation, additional capacitors series are introduced to the model, the equivalent capacitance decreases and in turn, the time constraints also decrease.

- RL circuit model data 1 kOhms and 10 uH

	Calculated Value*	Measured Value
Current	0.01 A	0.01 A
Voltage across the inductor	0 V	0 V
Voltage across the resistor	10 V	10 V

- RC circuit with 2.2 kOhms, 10 uF and pole

	Calculated Value*	Measured Value
Current	0 A	9.98 pA
Voltage across the capacitor	10 V	10 V
Voltage across the resistor	0 V	0 V

- RLC circuit with LED and switch application

8. At the beginning, the switch is placed in the position **"a"**. What happens to the capacitor voltage?

   The capacitor charges up to the voltage of the source, 10V in this case

9. Then move the switcher to the position "**b**" (you can click on the switch during simulation mode to change its position). What happens to the capacitor voltage? Check also the color of the LED. Does the LED become red? Explain why.

   The capacitor slowly discharges. This causes the LED to glow, but as the capacitor loses voltage, the LED loses brightness.

Data discussion

Within the first model of the RC circuit model, in order to compute time, consider the formula T= RC in which T denoted as Tuo recognized as time is equal to resistor times the capacitance. In the case that the capacitance is 1 uF and resistor is 1 kOhms, by applying the equation, 1*10^-6 * 1*10^3 = 1*10-3 = 1ms. The same may apply for the time computation for the rest of the data. On the other hand, while making the stimulation base off the model, it appears that the time contraction mirrors that of the computed values indicating validity. The error margin between the stimulated and computed values are within 1 - 1.5 percent errors.

In order to compute for the current within the RL circuit given the resistor and inductor value, given that it is a first order RL circuit, to find the maximum current, apply the formula, If = E/f in which E is the 10V voltage source and R is 1 kOhms resistor, when imputed into the equation, the computed current value becomes 10/100 = 0.1 A which aligns with our stimulated value. Now since, it is know that current value is 0.01, in order to find voltage across the resistor, consider R = IR which is 10*0.01 which is 0 and likewise to our stimulation. The last computation for this model is the voltage across the induction, note that it is simply taking the difference of the voltage across resistor and inductor which is 10 - 0 = 10 V. Similarly, the same procedure will be applied for the RC circuit with a pole; however, the application of KCL may be required with order of substitution to allow for a more thorough mathematical summary of the circuit analysis. As for the RLC circuit model with LED light the same mathematical approach can be applied to find the current, and current and voltage across the inductor, but KCL should be applied to partition of the circuit based on the pole's switch indicator in order to obtain the desired values.

Conclusion

Substantially, the objective of the lab was sufficed through the demonstration of the circuit construction for the three models: the first order RC, RC circuit with pole RL and RC circuit with an LED. The idea is to first construct, then mathematically analyze the circuit model which will ultimately allow us to compare our computation through actual stimulation from SPICE. We come to understand that for the analysis of the RL and Rc circuit, the main concern is the time construction which acts upon the operation interval of a circuit as it exhibits stimulation from a power source. By the employment of precise stimulation tools, we are able to understand that within RC and RL circuits there is a direct correlation between the time constraint and the equivalent inductance or capacitance value. While RL stores energy in terms of electric field, RC stores energy in terms of magnetic field which first obstructs current flow known as the transient state and gradually subsides into the steady state. By careful construction and mathematical formula application, the data shows to align that to the stimulation with less than 1.5 percent error in each recorded data indicating that in theory and practice, the values for RL and RC values should be closely aligned ensuring our objective and method of approach.