RC & RL TRANSIENT RESPONSE

INTRODUCTION

The student will analyze series RC and RL circuits. A step input will excite these respective circuits, producing a transient voltage response across various circuit elements. These responses will be analyzed by theory, simulation and experimental results. The primary response properties of concern are time constant, initial value and final value.

The equations that govern RC and RL circuit transient responses will be calculated by the student, both forward using theory and backwards after having observed experimental results. Methods to measure the time constant of an experimental system and produce a step input using a function generator will be shown.

BACKGROUND

Equations for RC Circuits

Time constant = T_C = RC

Capacitor voltage transient equation = $V_C(t) = V(\infty) + [V(0) - V(\infty)]e^{-t/T_C}$

Equations for RL Circuits

Time constant = T_C = L/R

Theoretical inductor instantaneous voltage = $V_L = L\frac{di_L}{dt}$

Inductor current transient equation = $I_L(t) = I(\infty) + [I(0) - I(\infty)]e^{-t/T_C}$

Inductor voltage transient equation = $V_L(t) = V(\infty) + [V(0) - V(\infty)]e^{-t/T_C}$

Hints

- Remember that the order of components is arbitrary in a series circuit
- Capacitor voltage cannot change instantaneously
- Inductor current cannot change instantaneously
- An ideal unit step is zero volts until time zero whereas it instantaneously jumps to one volt
- To find the voltage transient equation for a resistor in a RC or RL circuit one must only subtract the capacitor or inductor voltage transient equation from that of the unit step [Don't forget to take into account the function generator's output impedance]

- A real inductor has both resistive and inductive components. Writing a voltage transient equation for a real inductor requires adding these two components together. [Equations for V_L assume ideal inductor, thus the value of the inductor's resistance must be multiplied by the inductors current and must be added to V_L to find the real inductor's voltage transient equation]
- The ideal inductor's voltage at t=0+ will not be 0

<u>PRELAB</u>

Voltage transient response in RC components due to a unit step

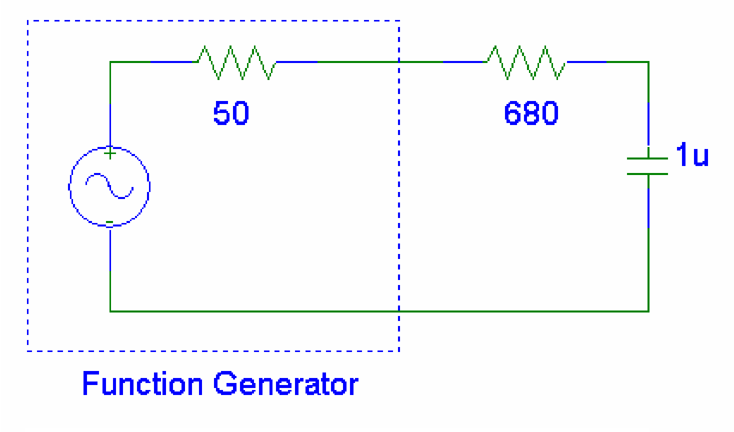

Figure 1: RC Circuit

Suppose a unit step occurs at time t=0 in the RC circuit displayed as Figure 1. Calculate the initial voltage across the capacitor V_C (t=0+), final voltage across the capacitor (V_C (t=∞)), initial voltage across the 680Ω resistor (V_R (t=0+)), final voltage across the 680 Ω resistor (V_R (t=∞)), and the time constant (T_C) of the circuit. Using nominal component values, calculate the voltage transient time response equation for the capacitor (V_C (t)) and voltage transient time response equation for the resistor (V_R (t)).

Voltage transient response in RL elements due to a unit step

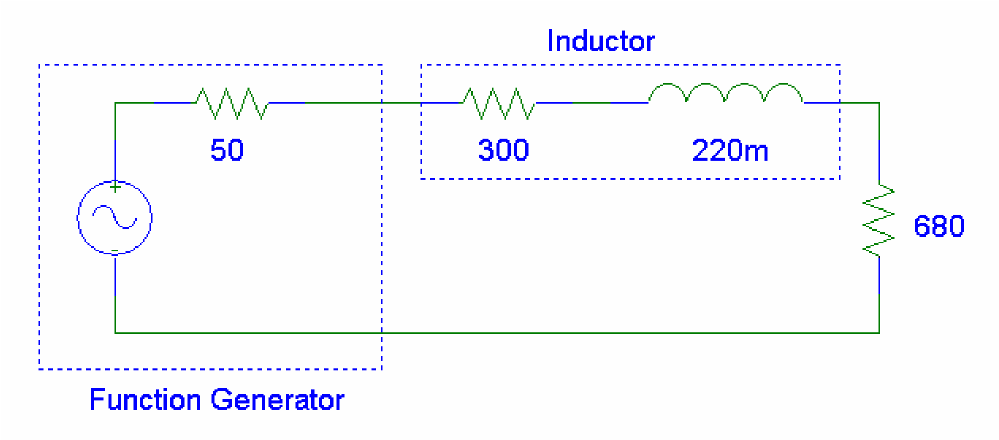

Figure 2: RL Circuit

Suppose a unit step occurs at time t=0 in the RL circuit displayed as Figure 2. Calculate the initial voltage across the inductor (V_L (t=0+)), final voltage across the inductor (V_L (t=∞)), initial voltage across the 680Ω resistor (V_R (t=0+)), final voltage across the 680 Ω resistor (V_R (t=∞)), and the time constant (T_C) of the circuit: Using nominal component values, calculate the voltage transient time response equation for the inductor (VL (t)) and voltage transient time response equation for the resistor (V_R (t)).

EXPERIMENTAL PREPARATION

Imitating a unit step

We do not provide the equipment to produce and analyze the response of a single unit step. We model a unit step by generating a square wave with a period much greater than the time constant (T_C) of the circuit. This provides enough time for the circuit to settle before another imitated unit step is initiated.

The square wave generated should be 0 volts for 10 T_C and 1 volt for another 10 T_C. Thus, the square wave period will be 20 T_C with a corresponding frequency of 1 / (20 T_C). An amplitude of 1 volts along with an offset of 0.5 volts must be set to ensure proper effect.

Measuring the Time Constant

The time constant is defined as the ratio $1-e^{-1}$ of the rise or fall to the final value. This corresponds to approximately 63% of the rise or fall to the final value. The voltage corresponding to one time constant is $V_{T_C} = [V(\infty) - V(0)] * [1 - e^{-1}] + V(0)$. The time constant can be computed by finding the time it takes to reach V_{T_C} .

With one of the oscilloscope's vertical bars at the beginning of the unit step and one at V_{T_C} the time difference will be displayed as ΔT. A similar method can be used with the PSPICE curosor.

EXPERIMENTAL PROCEDURE

Voltage transient response in RC components due to a unit step

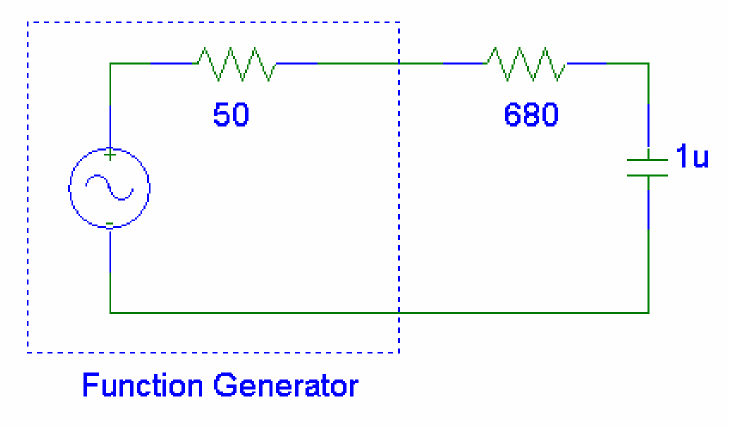

Figure 3: RC Circuit

Construct the circuit in Figure 3. The function generator should model a unit step as described in the experimental preparation. Measure the voltage across the capacitor with one channel's probe and the voltage across the function generator with the other channel's probe. Enable the MATH function to display the voltage across the 680Ω resistor.

Using the oscilloscope horizontal bars, measure the initial capacitor voltage, final capacitor voltage, initial 680Ω resistor voltage, final 680Ω resistor voltage and determine the time constant.

V_C (t=0+) = __________ V_C (t=∞) = __________

V_R (t=0+) = __________ V_R (t=∞) = __________

T_C = __________

Include Oscilloscope Screenshot of displaying both capacitor and resistor voltage transient responses to a unit step in report.

Voltage transient response in RL elements due to a unit step

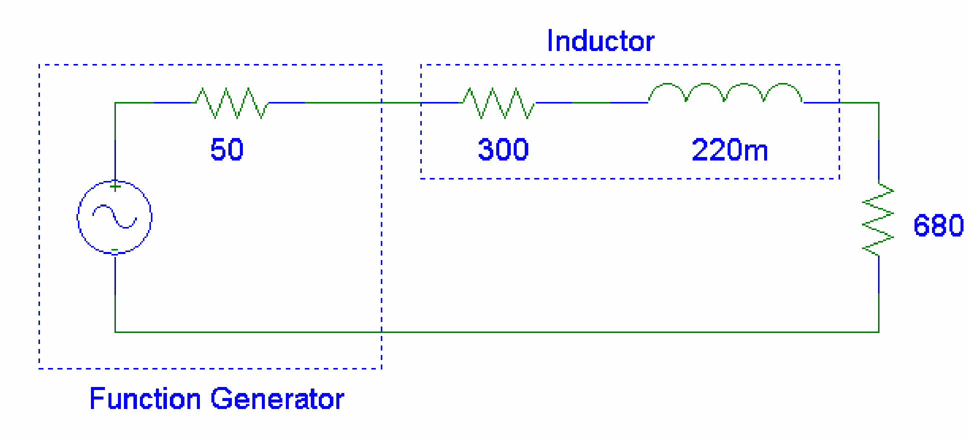

Figure 4: RL Circuit

Construct the circuit in Figure 3. The function generator should model a unit step as described in the experimental preparation. As with the RC circuit, place one channel's probe across the unit step and the other across either the inductor or the 680Ω resistor utilizing the MATH function in a similar manner. The circuit components may be arranged in a different manner than that shown in Figure 4 for convenience.

Measure the initial capacitor voltage, final capacitor voltage, initial 680Ω resistor voltage, final 680Ω resistor voltage and determine the time constant.

V_L (t=0+) = __________ V_L (t=∞) = __________

V_R (t=0+) = __________ V_R (t=∞) = __________

T_C = __________

Include <u>Oscilloscope Screenshot</u> of displaying both inductor and resistor voltage transient responses to a unit step in report.

SIMULATED PROCEDURE

Voltage transient response in RC components due to a unit step

Generate a schematic modeling the RC circuit's voltage transient response to a unit step. Using the PSPICE cursor, measure the initial capacitor voltage, final capacitor voltage, initial 680Ω resistor voltage, final 680Ω resistor voltage and determine the time constant.

V_C (t=0+) = __________ V_C (t=∞) = __________

V_R (t=0+) = __________ V_R (t=∞) = __________

T_C = __________

Include a schematic screenshot and a screenshot of the transient analysis of the voltage across the function generator, the capacitor and the resistor. These three traces should be displayed on the same graph.

Voltage transient response in RL elements due to a unit step

Generate a computer simulation modeling the RL circuit's voltage transient response to a unit step. Measure the initial capacitor voltage, final capacitor voltage, initial 680Ω resistor voltage, final 680Ω resistor voltage and determine the time constant.

V_L (t=0+) = __________ V_L (t=∞) = __________

V_R (t=0+) = __________ V_R (t=∞) = __________

T_C = __________

Include a schematic screenshot and a screenshot of the transient analysis of the voltage across the function generator, the capacitor and the resistor. These three traces should be displayed on the same graph.

QUESTIONS

Note and explain reasons for discrepancies between the theoretical, simulated and experimental values for V_C (t=0+), V_C (t=∞),V_L V(t=0+), V_L V(t=∞), V_R (t=0+) , V_R (t=∞) and T_C.

RC & RL TRANSIENT RESPONSE

Attendance	___ / **5**
Prelab	___ / **5**
Presentation	___ / **5**
Content	___ / **5**
SPICE	___ / **5**
TOTAL SCORE	___ / **25**

Turn these sheets in at beginning of lab session. Remember to show all work:

RC Circuit

V_C (t=0+) = __________ V_C (t=∞) = __________

V_R (t=0+) = __________ V_R (t=∞) = __________

T_C = __________

V_C (t) = ______________________________________

V_R (t) = ______________________________________

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RL Circuit

V_L (t=0+) = __________ V_L (t=∞) = __________

V_R (t=0+) = __________ V_R (t=∞) = __________

T_C = __________

V_L (t) = ____

V_R (t) = ____