DEPT. OF ELECTRICAL & ELECTRONICS ENGINEERING

SRM INSTITUTE OF SCIENCE AND TECHNOLOGY, Kattankulathur – 603 203

Title of Experiment	: **3.Transient analysis of Series RL, RC circuits**
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Register Number	: RA2011004010051
Date of Experiment	: 25th May 2021

Sl. No.	Marks Split up	Maximum marks (50)	Marks obtained
1	Pre Lab questions	5	
2	Preparation of observation	15	
3	Execution of experiment	15	
4	Calculation / Evaluation of Result	10	
5	Post Lab questions	5	
Total		**50**	

Staff Signature

PRE-LAB QUESTIONS

1) Define Transient.

Electrical transients are momentary bursts of energy induced upon power, data, or communication lines. They are characterized by extremely high voltages that drive tremendous amounts of current into an electrical circuit for a few millionths, up to a few thousandths, of a second.

2) Time constant for RL Circuit.

The time constant for an RL circuit is defined by $\tau = L/R$.

3) Time constant for RC Circuit.

The time constant for an RC circuit is defined by $\tau = R \times C$.

4) How will you design the values of L & C in a transient circuit?

The current is sinusoidal and the voltages over the L and C are both sinusoidal, too. The voltage over the C swings between 0 and 2E. In circuit theory we have 2 state variable differential equations, one for the inductor current and one for the capacitor voltage. They can be used "as is" for numerical simulation.

Experiment No. 3 Date : 25th May 2021	Transient analysis of series RL, RC circuits

Aim:

To obtain the transient response and measure the time constant of a series RL and RC circuit for a pulse waveform.

Apparatus Required:

Sl. No.	Apparatus	Range	Quantity
1	Function Generator	800 Hz	1
2	Inductor	1 mH	1
3	Resistor	4 KΩ	1
4	Capacitor	1 nF	1
5	Bread Board & Wires	--	Required
6	CRO		1
7	CRO Probes		2

Theory

In this experiment, we apply a pulse waveform to the RL or RC circuit to analyze the transient response of the circuit. The pulse-width relative to a circuit's time constant determines how it is affected by an RC or RL circuit.

Time Constant (τ): A measure of time required for certain changes in voltages and currents in RC and RL circuits. Generally, when the elapsed time exceeds five time constants (5τ) after switching has occurred, the currents and voltages have reached their final value, which is also called steady-state response.

The time constant of an RC circuit is the product of equivalent capacitance and the Thevenin's resistance as viewed from the terminals of the equivalent capacitor.

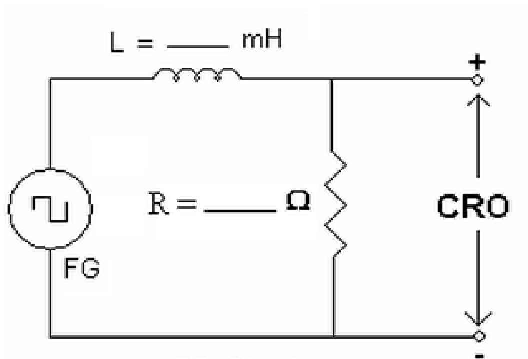
$$\tau = RC$$

A Pulse is a voltage or current that changes from one level to the other and back again. If a waveform's high time equals its low time, as in figure, it is called a square wave. The length of each cycle of a pulse train is termed its period (T). The pulse width (tp) of an ideal square wave is equal to half the time period.

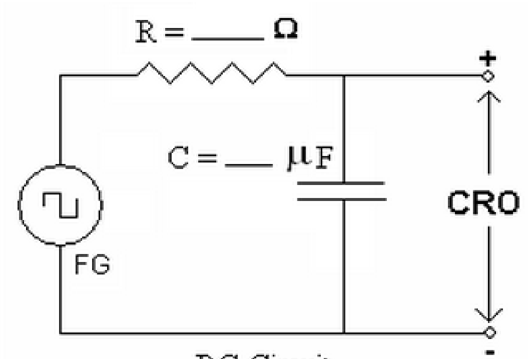
Procedure for RL:

1. Make the connections as per the circuit diagram.
2. Choose square wave mode in signal generator
3. Using CRO, adjust the amplitude to be 2 volts peak to peak.
4. Take care of the precaution and set the input frequency.
5. Observe and plot the output waveform.
6. Calculate the time required by the output to reach 0.632 times the final value (peak).
7. This value gives the practical time constant. Tabulate the theoretical and practical values.

Circuit Diagram:



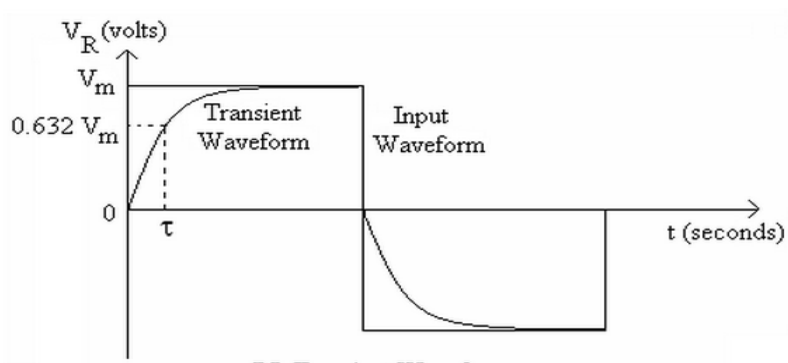
RL Circuit



RC Circuit

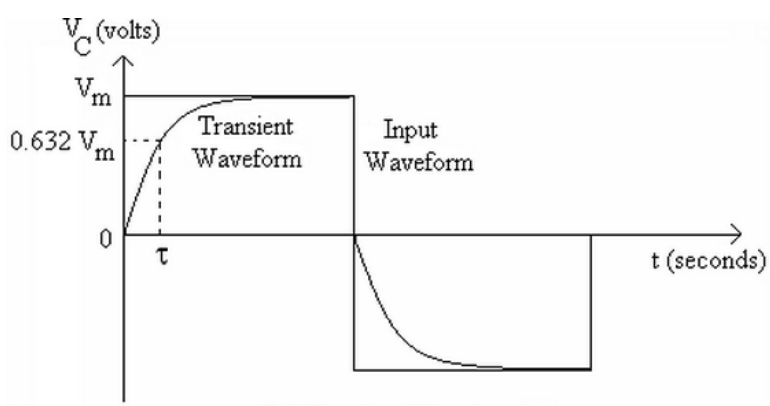
Model Graph:

a) RL Transient :Output voltage across Resistor:



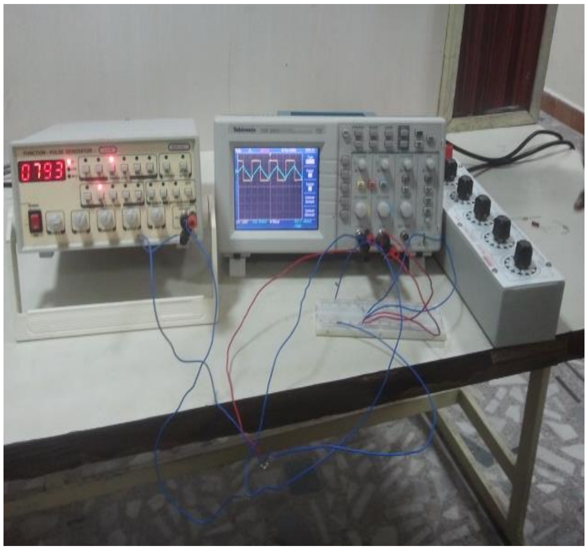
RL Transient Waveform

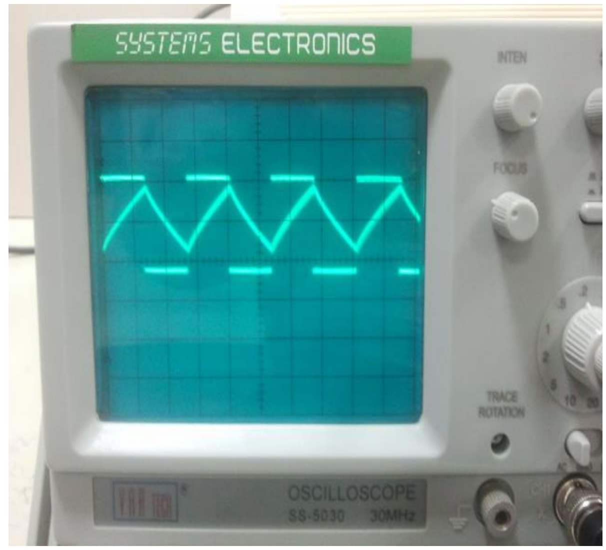
b) RC Transient :Output voltage across Capacitor:



RC Transient Waveform

<u>Hardware setup:</u>

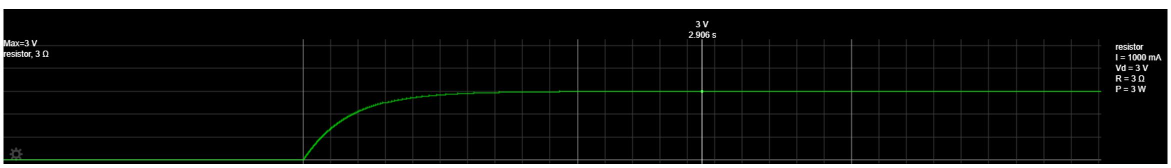




RL Transient Analysis:

R(ohms)	L(henry)	Experiment	
		t(s)	V_R
3	1	2.9	3
3	2	5.8	3

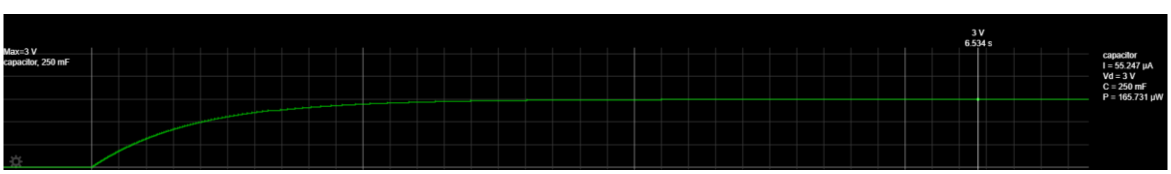
Graph:



RC Transient Analysis:

R(ohms)	C(farads)	Experiment	
		t(s)	V_C
3	0.5	13	3
3	0.25	6.5	3

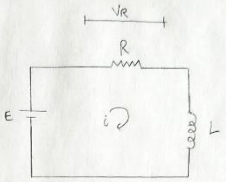
Graph:



Model Calculations:

RL Transient Analysis: (1)

The transient current at time t is given by



$i(t) = I(1 - e^{-t/\tau})$ — (1)

where,

I - total current

τ - time constant. τ for RL circuit = $\tau = \frac{L}{R}$

In eqn (1)

$V_R = i(t) R = IR(1 - e^{-t/\tau}) = E(1 - e^{-t/\tau})$ — (2)

(voltage across resistor)

Using eqn (2)

t	0	∞	τ
V_R	0	E	0.632 E

It is seen that τ = 0.632 E.

To find the time taken to reach E and at what t is $V_R = 0.632E$.

(Note that the same applies for RC circuit as well).

CASE - I: (2)

$R = 3\Omega$; $E = 3V$; $L = 1H$.

The time constant is given by

$\tau = \frac{L}{R} = \frac{1}{3} = 0.333 s$.

At 0.333 s the V_R = 63.2 % of E

$= \frac{63.2}{100} \times 3$

$= 1.896$ V.

$\therefore$ when $\boxed{\tau = 0.333 \quad V_R = 1.896}$

Time taken to reach 3v from $V_R \to E$, through circuit simulation is

$t = 2.9 s$

$\therefore \boxed{\text{At } t = 2.9s \ ; \ V_R = E}$

CASE - II:

$R = 3\Omega$; $E = 3V$; $L = 2H$.

Time constant is given by,

$\tau = \frac{L}{R} = \frac{2}{3} = 0.666 s$.

At 0.666 s the V_R = 63.2 % of E = 1.896 V

$\therefore$ when $\boxed{\tau = 0.666 s \quad V_R = 1.896 V}$

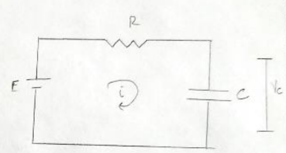
Time taken to reach 3V from $V_R \to E$ through circuit simulation is (3)

$t = 5.8 s$

$\boxed{\therefore \text{ at } t = 5.8s, \ V_R = E}$

RC - Transient Analysis:

Voltage rise across capacitor C is given by



$V_c = E(1 - e^{-t/\tau})$ — (1)

where τ is the time constant and the τ for RC circuit is given by

$\tau = R \times C$.

Also in equation (1), when $t = \tau$

$V_c = 0.632$ E.

CASE - I:

$R = 3\Omega$; $E = 3V$; $C = 0.5F$

The time constant is given by

$\tau = R \times C = 3 \times 0.5 = 1.5 s$.

when τ = 1.5 s $V_c = 0.632 \times E = 1.896$ V.

(4)

$\therefore$ when $\boxed{\tau = 1.5 s \quad V_c = 1.896 V}$

Time taken to reach 3V from $V_c \to E$ is given by circuit simulation.

$t = 13 s$

$\boxed{\therefore \text{ at } t = 13s \ ; \ V_c = E}$

CASE - II:

$R = 3\Omega$; $E = 3V$; $C = 0.25 F$

The time constant is given by

$\tau = R \times C = 0.75 s$.

at 0.75 s $V_c = 1.896$ V.

$\therefore$ when $\boxed{\tau = 0.75 s \quad V_c = 1.896V}$

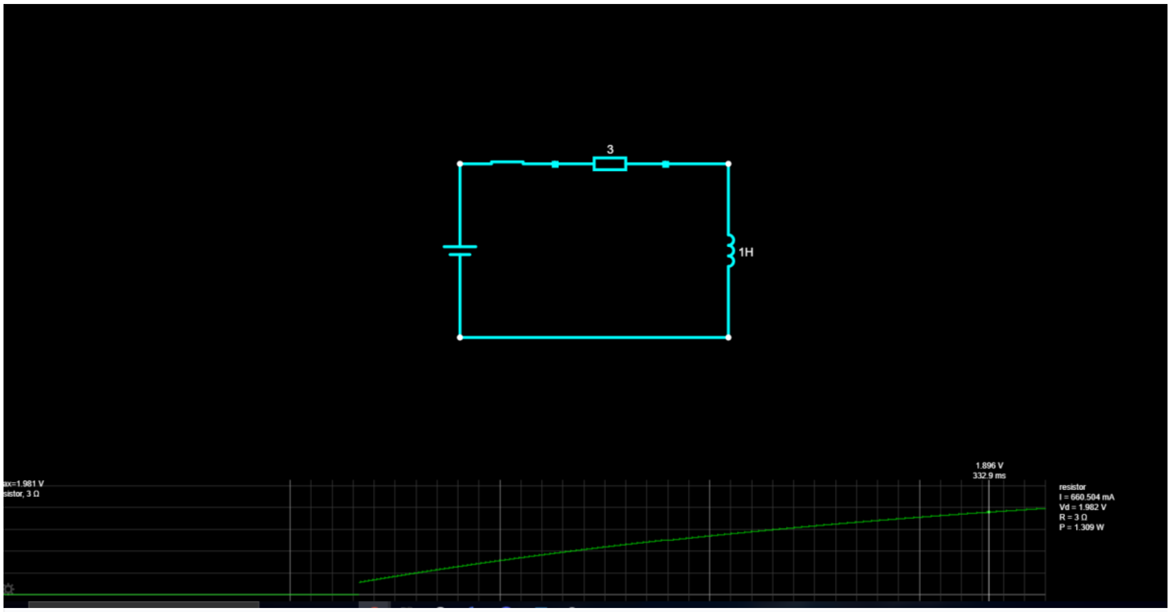
Time taken to reach 3V from $V_c \to E$ is given by circuit simulation.

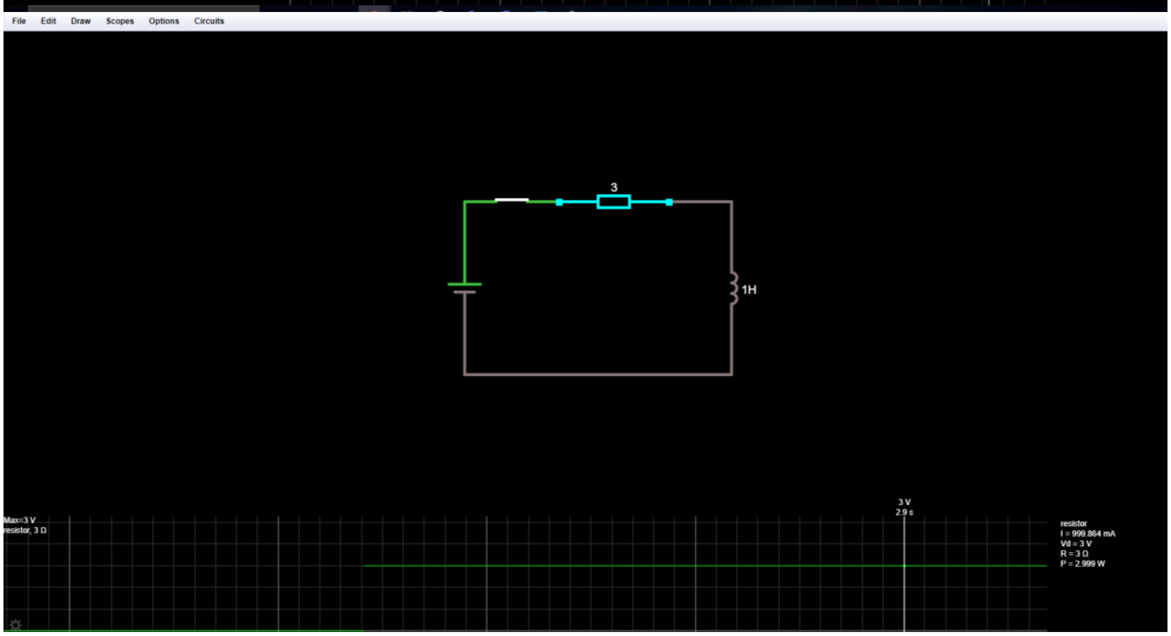
$t = 6.5 s$

$\boxed{\therefore \text{ at } t = 6.5s \ ; \ V_c = E}$

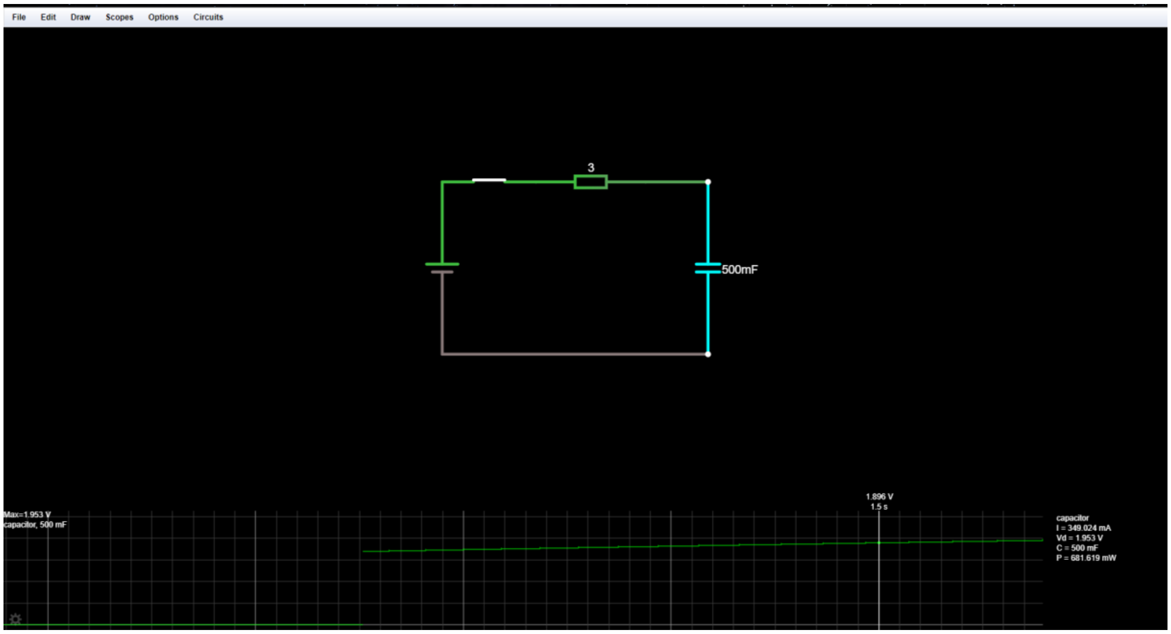
Result:

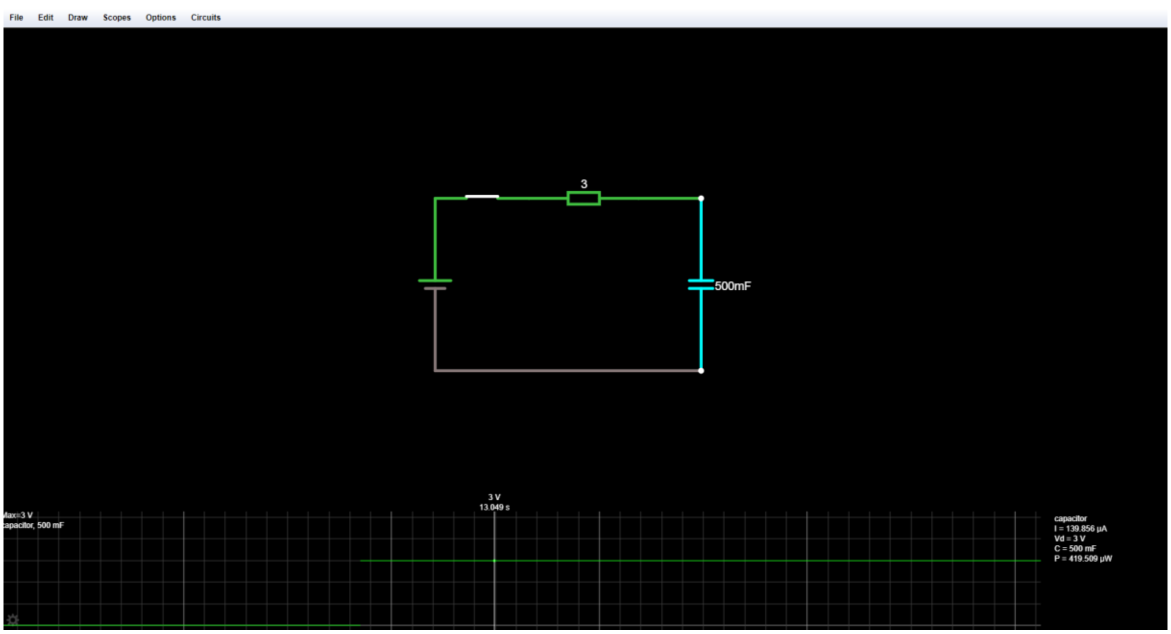
RL Transient:





RC Transient:





POST LAB QUESTIONS

1) Why is it necessary to discharge the capacitor every time you want to record another transient voltage across the capacitor?

A charged capacitor left by itself will retain the charge for even months or years. So, when it is disconnected from supply, the instant voltage it carries across terminals is maintained, which could often be dangerous.

So before handling a disconnected capacitor, it is very essential to discharge it to remove all charge and corresponding voltage. It is usual to discharge it through a resistor first, and then short the terminals directly to bring the voltage to zero.

2) If the capacitor remains charged, what would you expect to see across the capacitor when you re-close the switch to try to record another transient?

Because capacitors store energy in the form of an electric field, they tend to act like small secondary-cell batteries, being able to store and release electrical energy. A fully discharged capacitor maintains zero volts across its terminals, and a charged capacitor maintains a steady quantity of voltage across its terminals, just like a battery.
If the battery was replaced by a short circuit, when the switch is closed the capacitor would discharge itself back through the resistor, R as we now have a RC discharging circuit.

3) What does the derivative of a step function look like?
The unit step function is level in all places except for a discontinuity at t = 0. For this reason, the derivative of the unit step function is 0 at all points t, except where t = 0. Where t = 0, the derivative of the unit step function is infinite.

The derivative of a unit step function is called an impulse function.

4) What does the integral of a step function look like?
The integral of a unit step function is computed as such:

$$\int_{-\infty}^{t} u(s)ds = \left\{ \begin{array}{cc} 0, & \text{if } t < 0 \\ \int_0^t ds = t, & \text{if } t \geq 0 \end{array} \right\} = tu(t)$$

In other words, the integral of a unit step is a "ramp" function. This function is 0 for all values that are less than zero, and becomes a straight line at zero with a slope of +1.