BIRZEIT UNIVERSITY

**Faculty of Engineering and Technology**

**Electrical and Computer Engineering Department**

**ENEE2103 - Circuits and Electronics Laboratory**

# Exp3: First and Second Order Circuit

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# 1. Abstract

In this experiment we want to test and analyze the time responses of RL and RC circuits, test and analyze the time response of the second order RLC circuit, test the effect of the initial state of the dynamic elements on the time response and to determine the first and second order circuits parameters from the circuit response.

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## 2. Theory

### • RC Circuit

**Definition:** The combination of a pure resistance R in ohms and pure capacitance C in Farads is called **RC circuit**. The capacitor stores energy and the resistor connected in series with the capacitor controls the charging and discharging of the capacitor. The RC circuit is used in camera flashes, pacemaker, timing circuit etc.

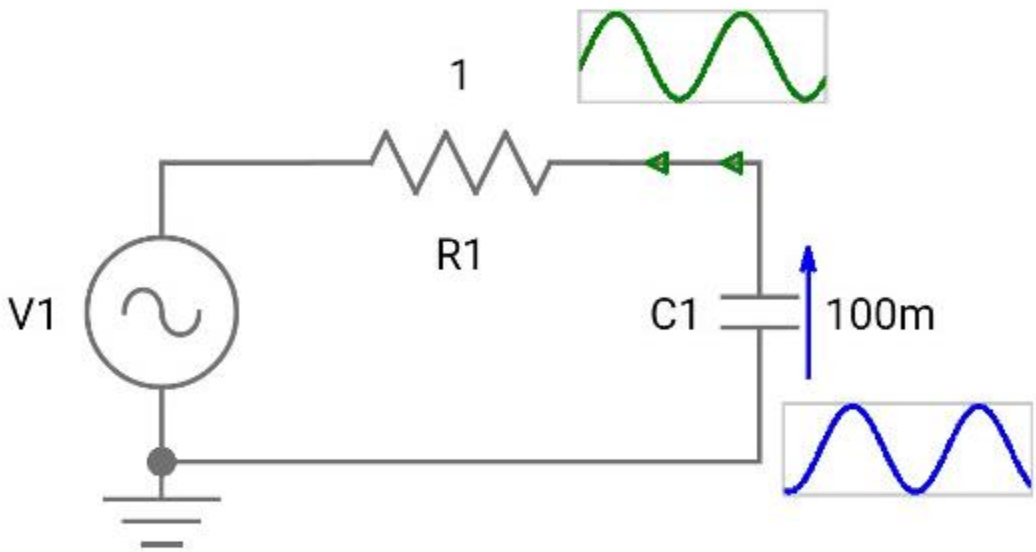


*Figure 1: Simple RC Circuit*

When a voltage source is applied to an RC circuit, the capacitor, C charges up through the resistance, R.

Figure 1 shows a capacitor, ( C ) in series with a resistor, ( R ) forming a **RC Charging Circuit** connected across a DC battery supply ( Vs ). at time zero, the capacitor gradually charges up through the resistor until the voltage across it reaches the supply voltage of the battery.

Since the initial voltage across the capacitor is zero, ( Vc = 0 ) at t = 0 the capacitor appears to be a short circuit to the external circuit and the maximum current flows through the circuit restricted only by the resistor R. Then by using Kirchhoff's voltage law (KVL), the voltage drops around the circuit are given as:

$$V_S - R \times i(t) - V_C(t) = 0$$

The current now flowing around the circuit is called the Charging Current and is found by using Ohms law as: i = Vs/R.

- **RC Charging Circuit Curves:**

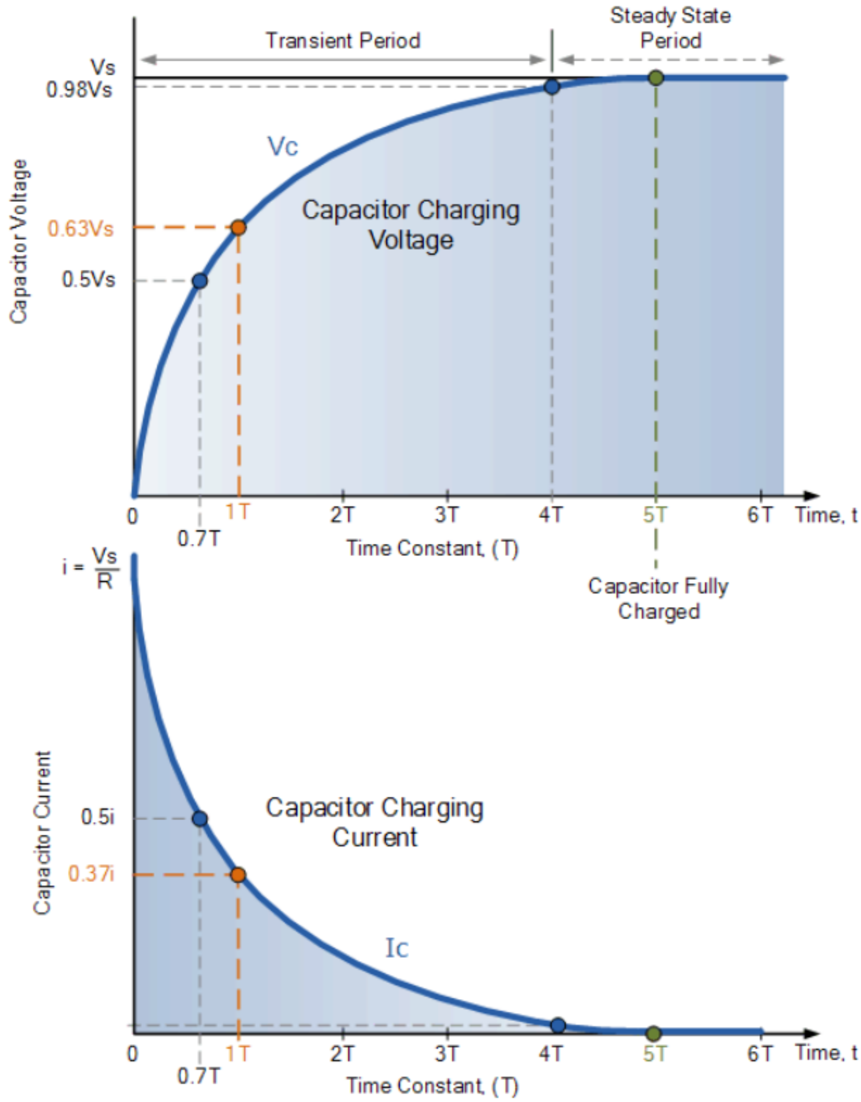


*Figure 2: Capacitors charging voltage and current*

➢ **RC Time Constant, Tau**

$$\tau \equiv R \times C$$

This RC time constant only specifies a rate of charge where, R is in Ω and C in Farads.

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- ## RL Circuit

A circuit that contains a pure resistance R ohms connected in series with a coil having a pure inductance of L (Henry) is known as **RL Series Circuit**. When an AC supply voltage V is applied, the current, I flows in the circuit.

So, $I_R$ and $I_L$ will be the current flowing in the resistor and inductor respectively, but the amount of current flowing through both the elements will be same as they are connected in series with each other. The circuit diagram of RL Series Circuit is shown below:

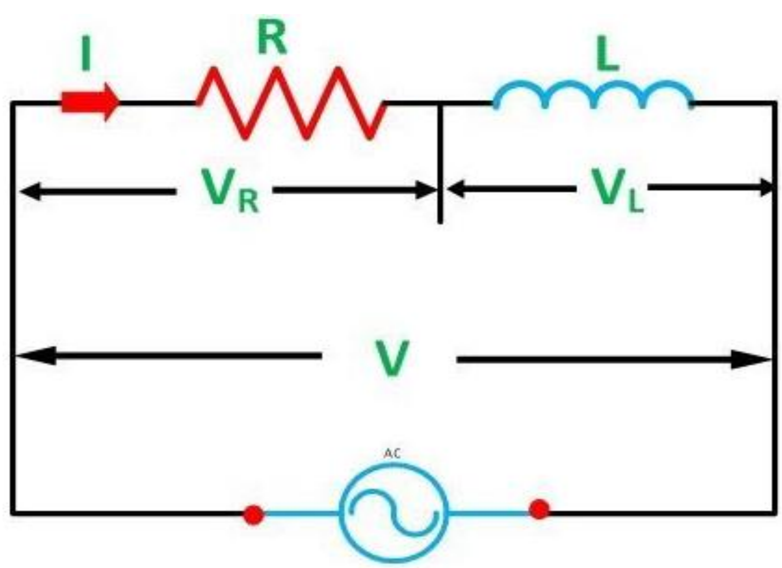


***Figure 3: RL Circuit***

The RL circuits are more complex and heavy than RC circuit . This is because inductors are heavy and are not found abundantly but they are created by wounding metallic wire in the iron core.

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## • RLC Circuit

A **series** *RLC* circuit contains elements of resistance, inductance, and capacitance connected in series with an AC source, as shown in figure below :

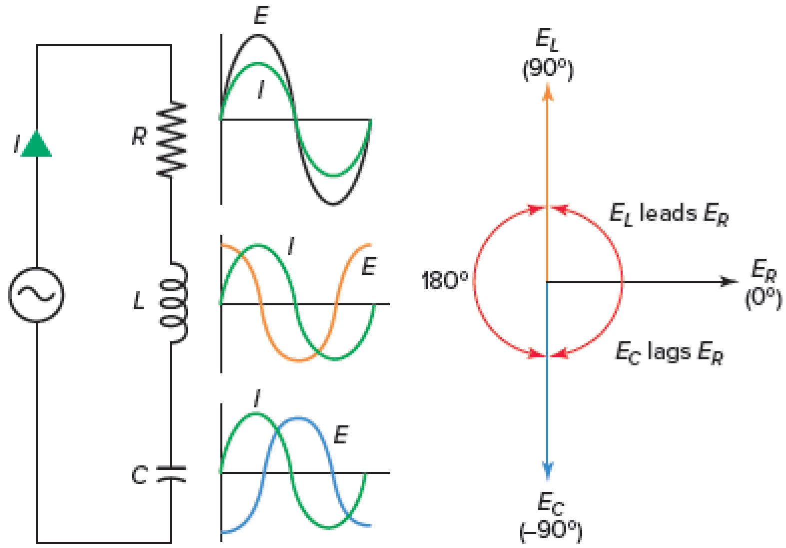


*Figure 4: Series RLC circuit diagram*

The characteristics of the RLC series circuit can be summarized as follows:

- The current is the same through all components, but the voltage drops across the elements are out of phase with each other.
- The voltage dropped across the resistance is in phase with the current.
- The voltage dropped across the inductor leads the current by 90 degrees.
- The voltage dropped across the capacitor lags the current by 90 degrees.
- The voltages dropped across the resistor, inductor, and capacitor depends on the circuit current and the values of R, XL, and XC

# 3. Procedure and Discussion

## 3.1 RC Circuit:

Firstly we draw the circuit shown in figure 5 on Pspice as shown in figure 6, note that we set the content values as the following:

- R = 22kΩ
- C = 100nF
- square wave 5Vp-p and 50Hz as shown in Fig.7

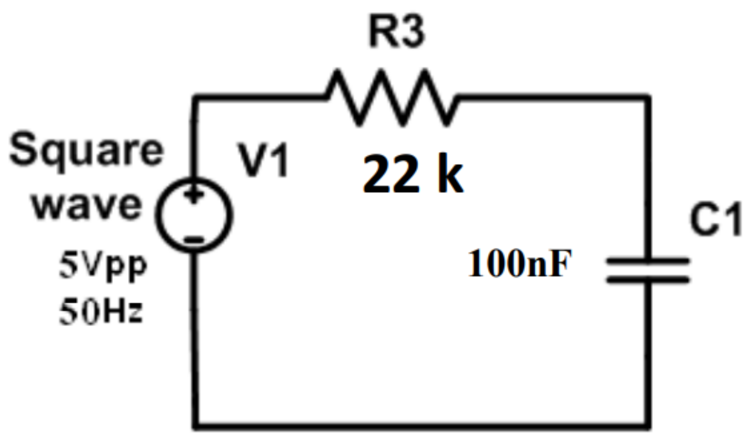


*Figure 5: RC Circuit*

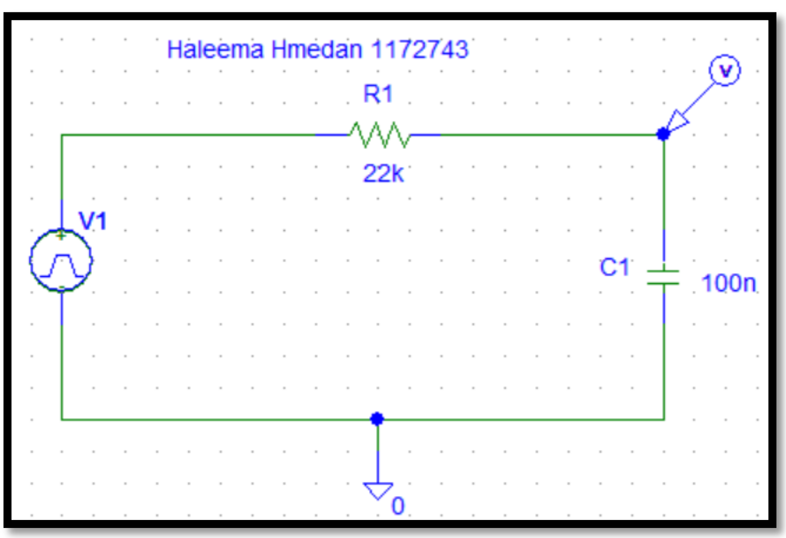


*Figure 6: RC Circuit connection*

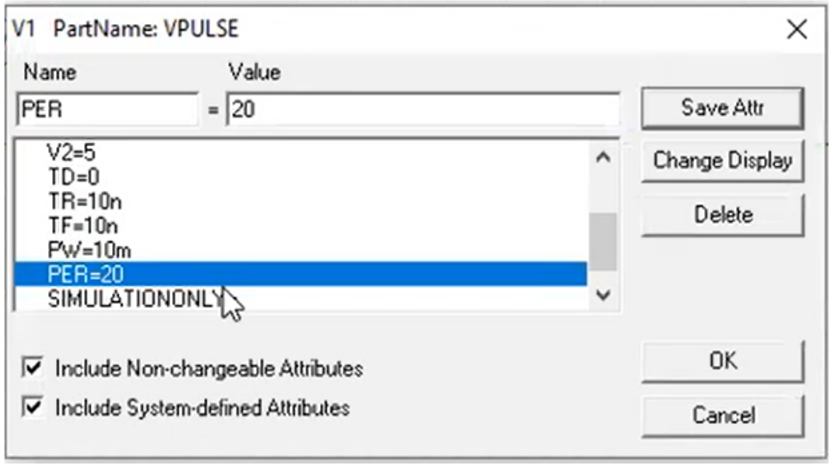


*Figure 7: Values inside square wave*

Then we simulated this circuit by using Bias point detail ->Transient as shown in the figure below, the output curve of RC circuit was shown on Fig.9

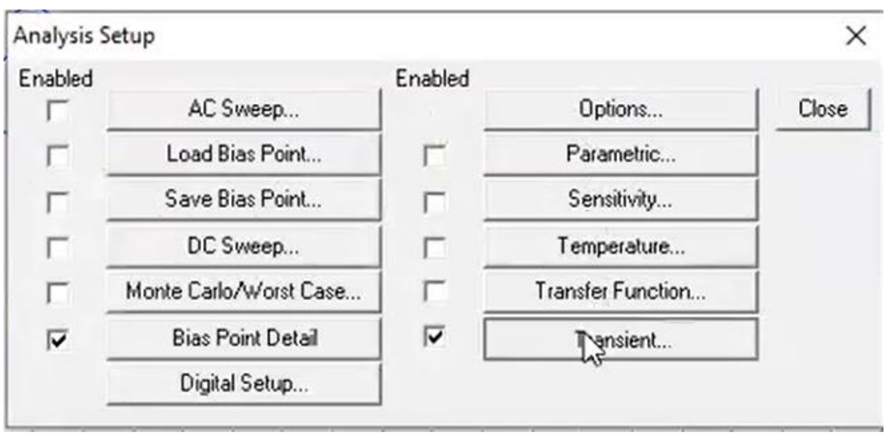


*Figure 8: Transient simulation for the circuit*

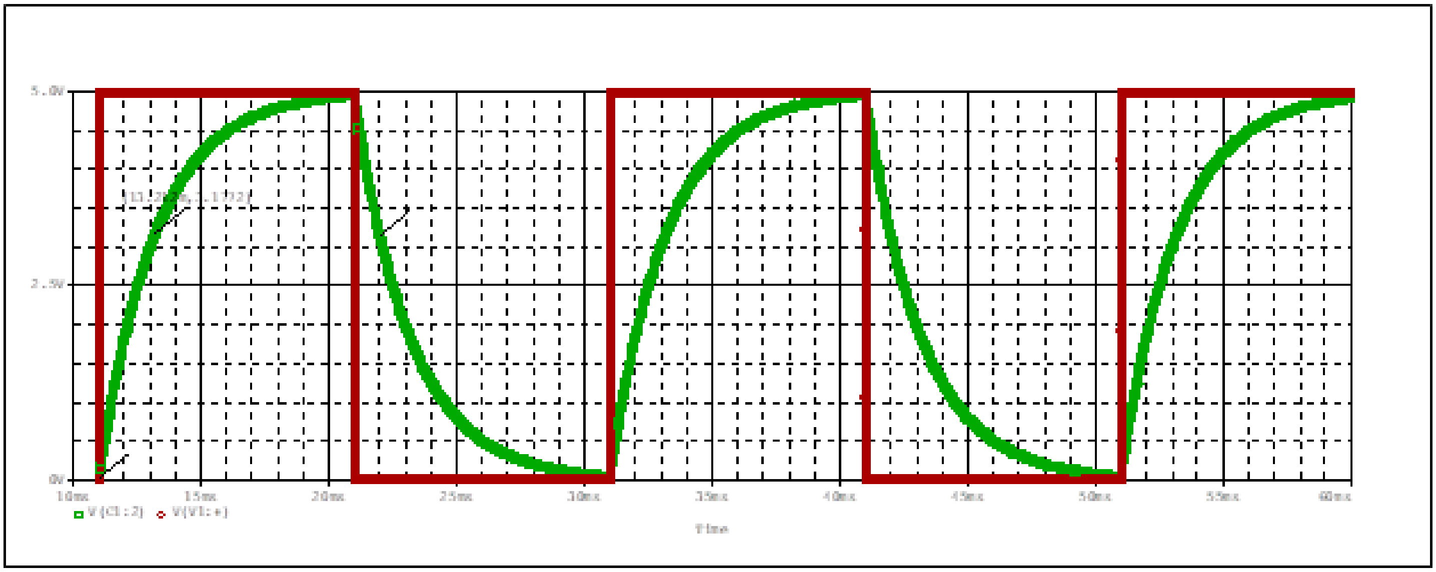


*Figure 9: Simulation of Rc circuit*

In order to find the time constant:

Steady state voltage value on the capacitor [equal to the final max value of the square pulse] = 5V.

Let us take 0.63 of Vsteady when charging: $0.63 \times 5 = 3.15\ volt$

So, searching for this point in the curve give that $t = 13.2\ ms$.

After taking this delay in consideration, we get that

$$\tau = 13.2\ ms - 11ms = 2.2ms$$

This is the value from PSPICE simulation, we know in advance that:

$\tau = RC = 22k\Omega \times 100nF = 2.2\ ms$

Therefore, the simulation result is close to the expected.

Finally, to determine the value of capacitance we use the equation below:

$$\mathrm{C} = \frac{\tau}{\mathrm{R}}$$

So **C = 2.2/ 22k = 100nF**

## 3.2 RL Circuit:

Firstly we draw the circuit shown in figure 10 on Pspice as shown in figure 11, note that we set the content values as the following:

- R = 2.2kΩ
- L = 500mH
- square wave 10Vp-p and 500Hz as shown in figure 12

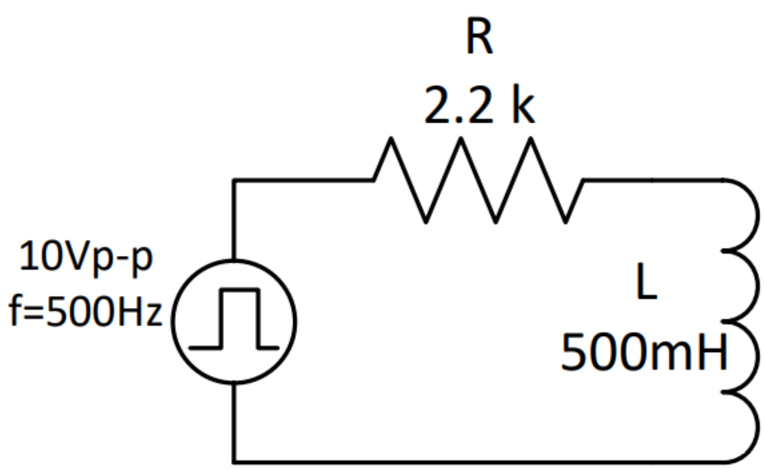


*Figure 10: RL Circuit*

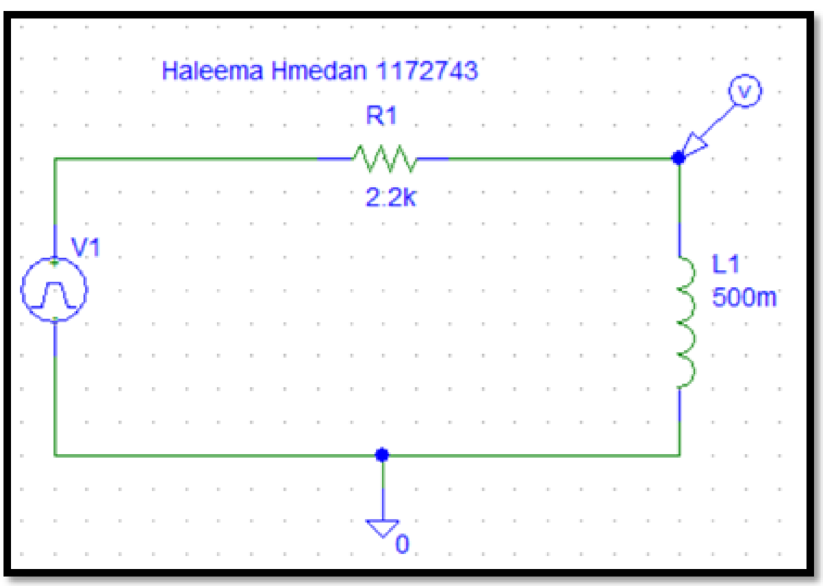


*Figure 11: RL circuit connection*

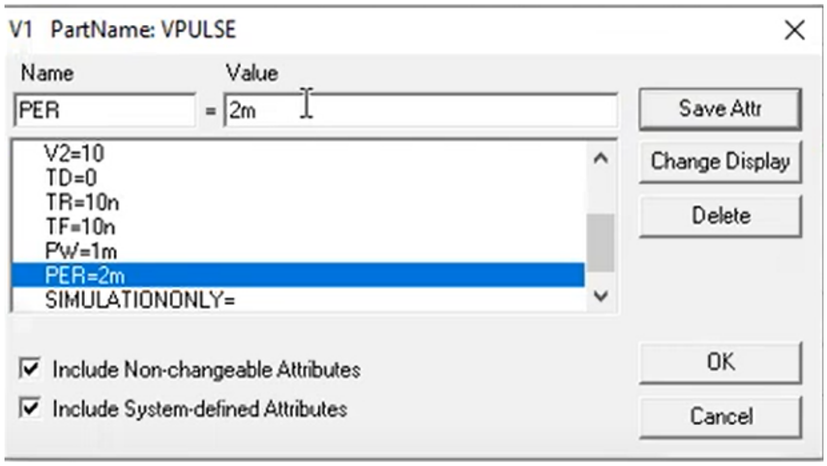


*Figure 12: square wave 10Vp-p and 500Hz*

Then we simulated this circuit by using Bias point detail ->Transient as shown in Fig.8, the Simulation of voltage response of RL circuit was shown on Fig.13

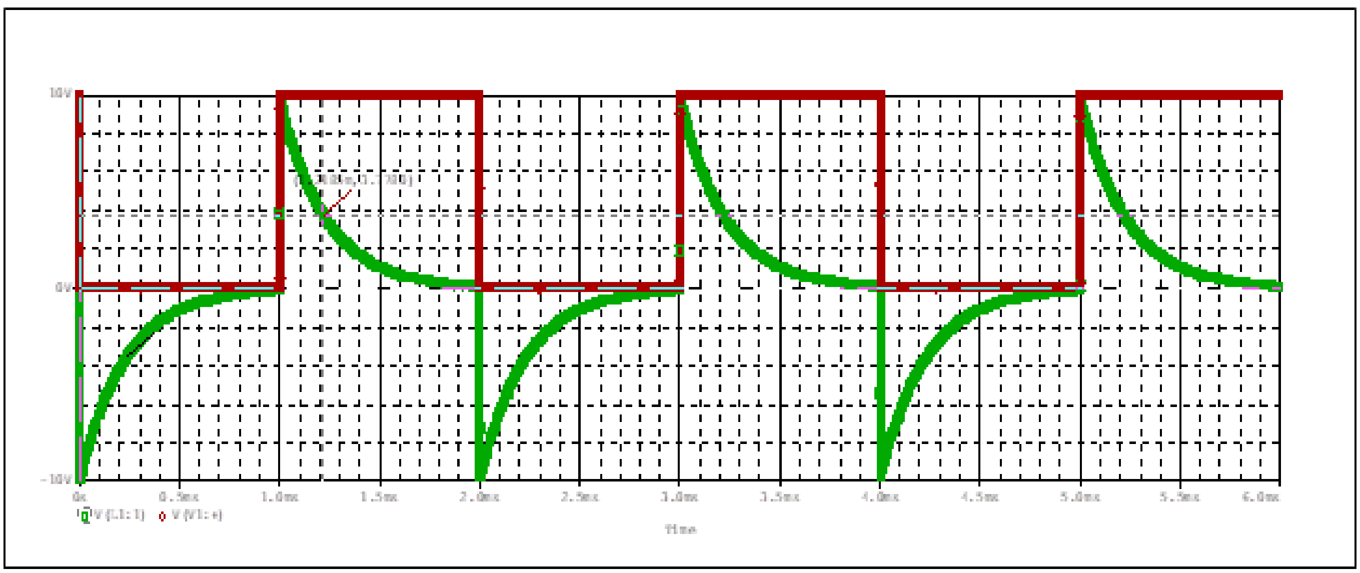


*Figure 13: Simulation of voltage response*

In order to find the time constant, let us take 0.37 of Vp-p (discharge): $0.37 \times 10 = 3.7\ volt$

$$\tau = 1.21ms - 1ms = 0.21ms$$

The simulation of current response of RL circuit was shown on Fig.14

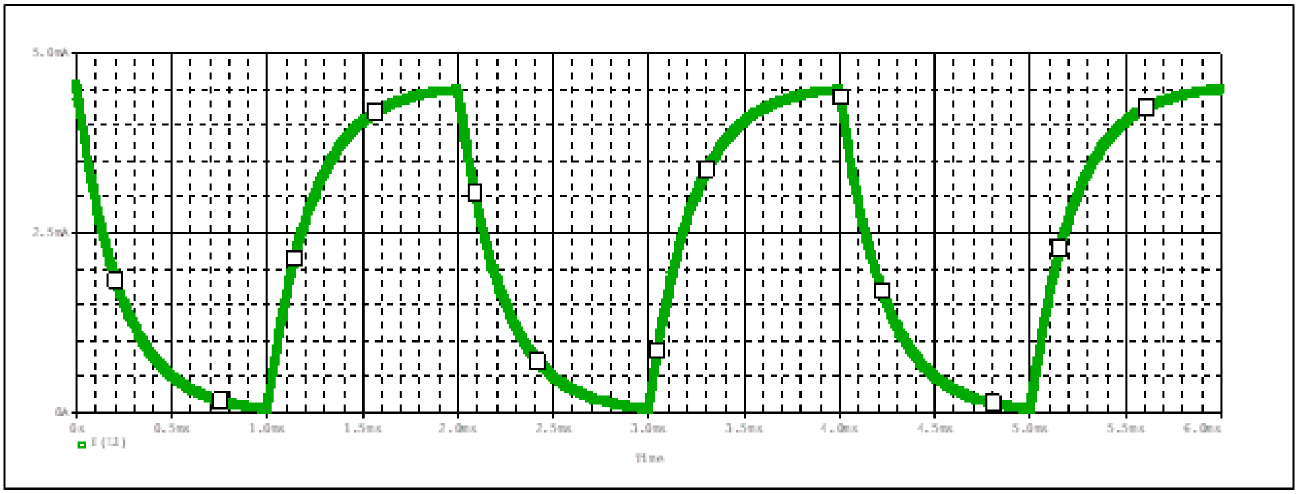


*Figure 14: Simulation of current response in RL circuit*

In order to find the time constant, let us take 0.37 of Ip-p (discharge):

$$0.37 \times 4.5m = 1.665mA$$

$\tau = 1.2292$ m = 0.2292 ms which almost match the previous value.

In theoretical, $\tau = \frac{L}{R} = \frac{500mH}{2.2\ K\Omega}$ = 0.227 ms which all close to each other.

With Vpulse period = 2$\tau$ = $454\ \mu s$ and so PW = $227$ µ the voltage response become as shown in the figure below:

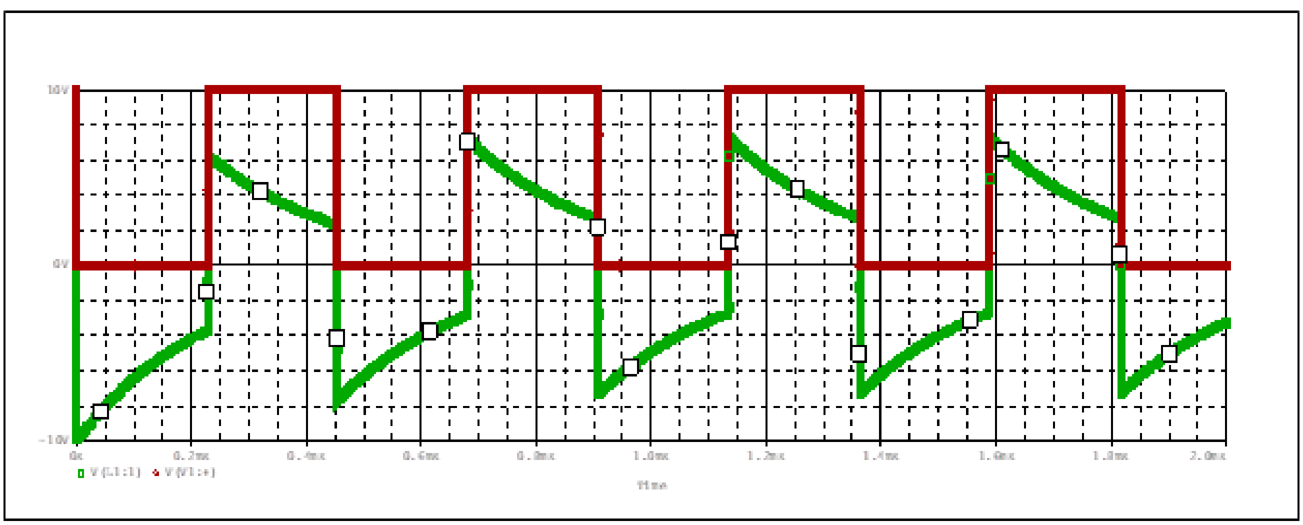


*Figure 15: The voltage response after changing the period time*

## 3.3 RLC Circuit:

We was drawn the circuit shown in figure 16 on Pspice as shown in figure 17, note that we set the content values as the following:

- R = 22kΩ
- C = 100nF
- L = 500mH
- square wave 5Vp-p and 30Hz as shown in Fig.18

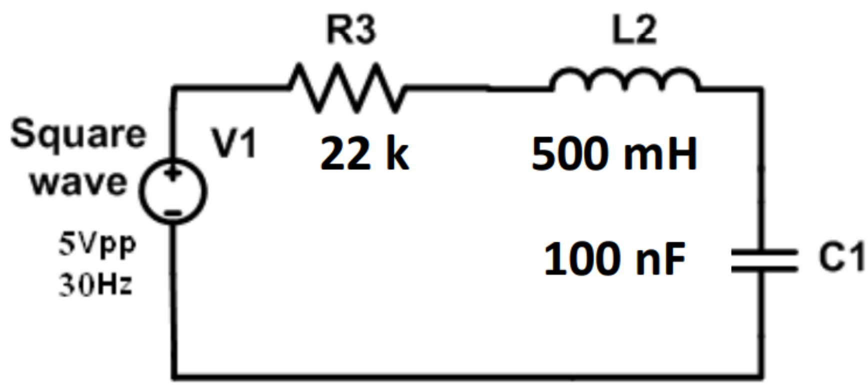


*Figure 16: RLC Circuit*

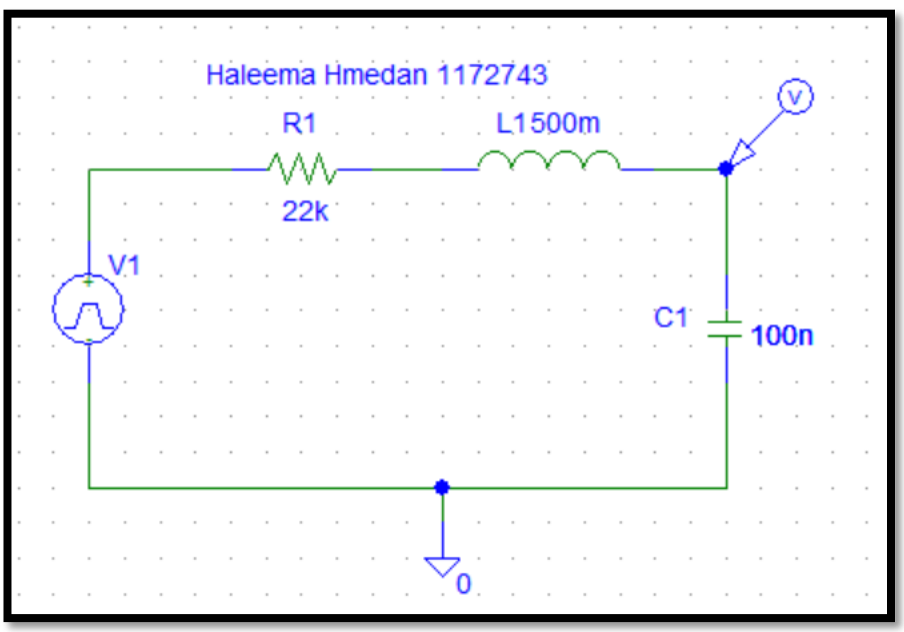


*Figure 17: Circuit connection of RLC circuit*

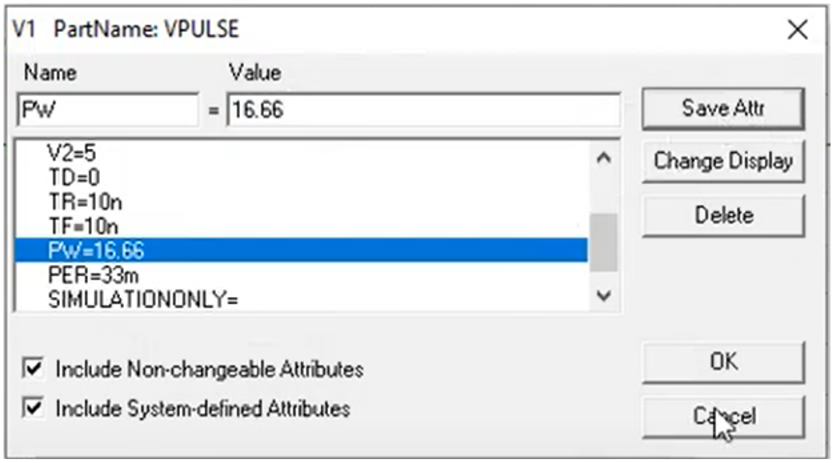


*Figure 18: Square wave 5Vp-p and 30Hz*

## ➢ Response type

We simulated this circuit by using Bias point detail ->Transient as shown in Fig.8, the Simulation of RLC circuit was shown on Fig.19

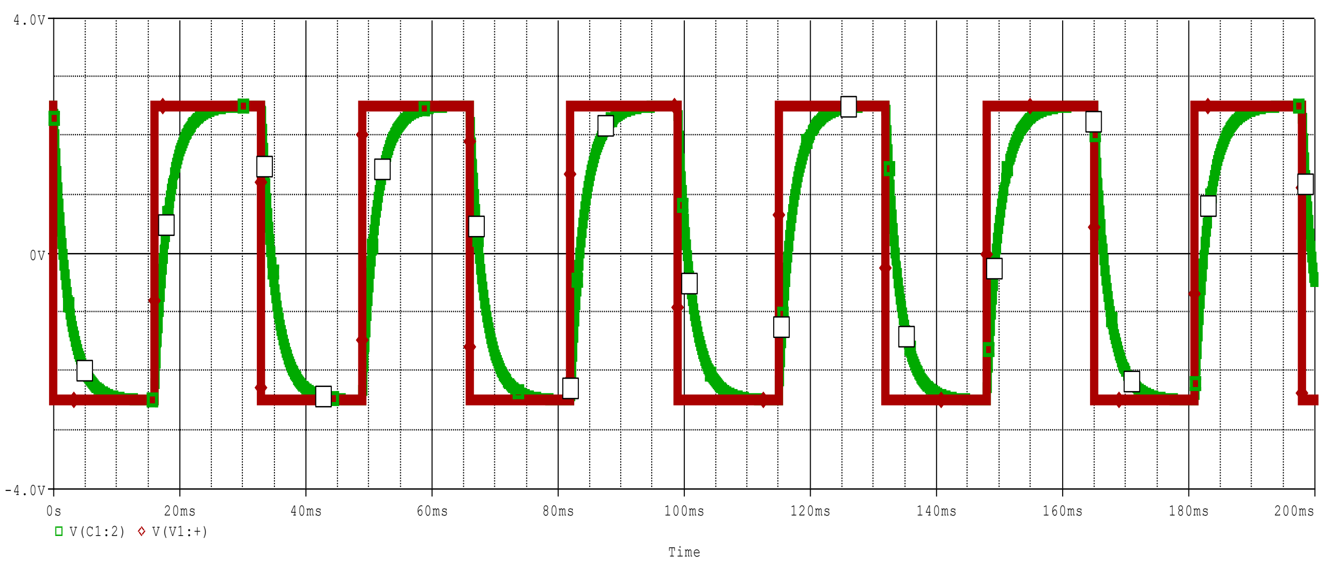


*Figure 19: Simulation of RLC circuit*

This case is over damping case.

$R_{critical} = 2 \times \sqrt{\frac{L}{C}} = 2 \times \sqrt{\frac{500\ mH}{100nF}} = 141\ \Omega.$

For critical damping case, we need to set R = 4.47 KΩ.

For under damping case we need R < 4.47 KΩ.

For over damping case we need R > 4.47 KΩ.

If we set the value of resistor equal 10 KΩ the simulation of RLC circuit was over damping response as shown on the figure below:

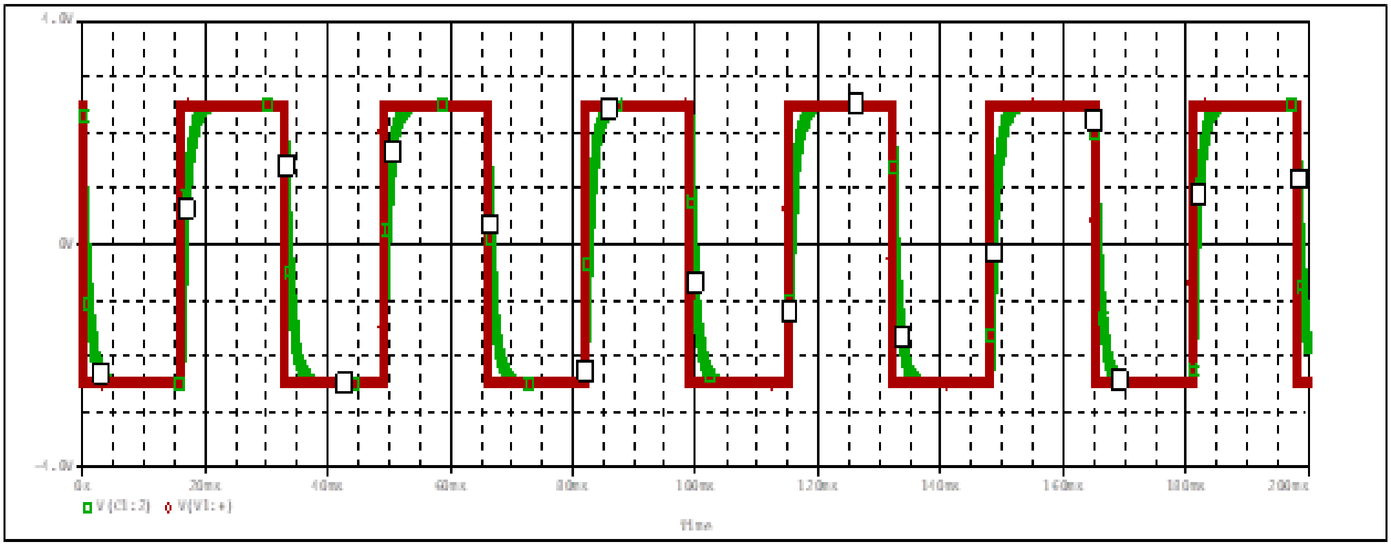


*Figure 20: Over damped response when R=10k*

When set the value of resistor equal 4.7 KΩ the simulation of RLC circuit was on critical damping response as shown on the figure below:

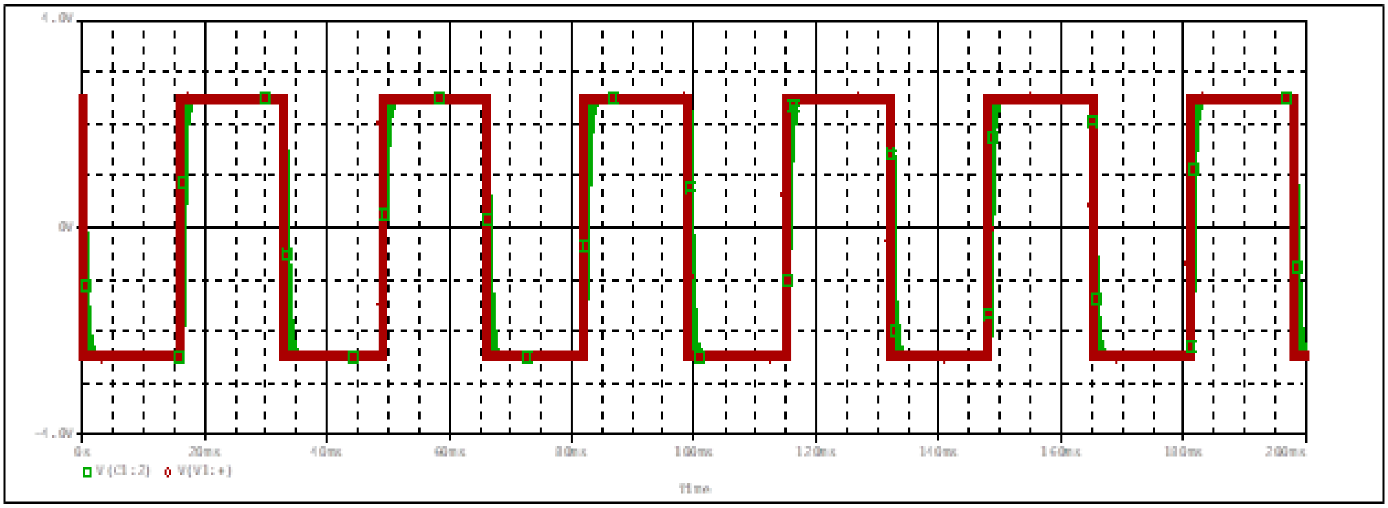


*Figure 21: Critical damped response when R=4.7k*

After set the value of resistor equal 1 KΩ the simulation of RLC circuit was on critical damping response as shown on the figure below:

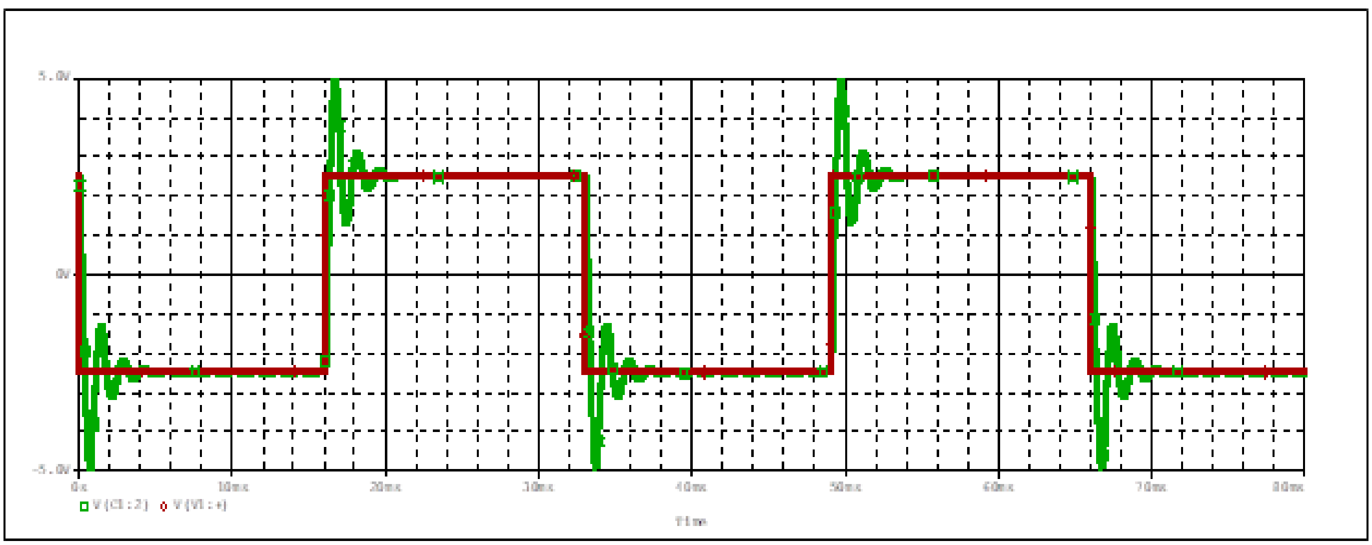


*Figure 22: Under damped response when R=1k*

## ➢ Response parameters

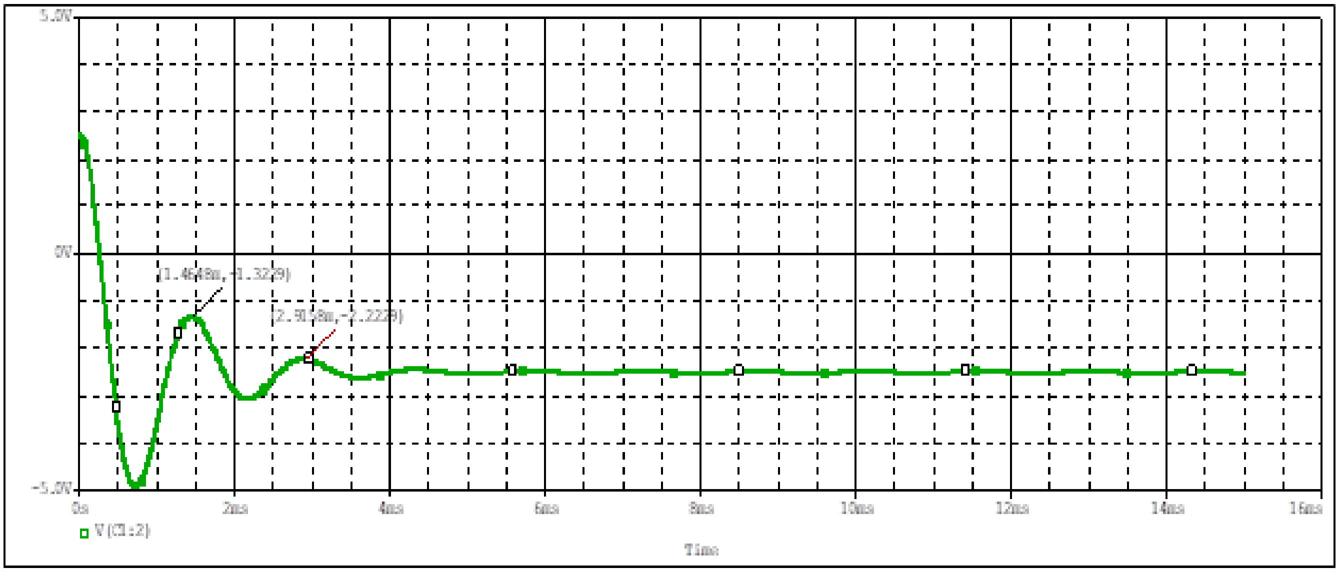


*Figure 23: Under damped response to measure the response parameter*

We can see that: [R=1KΩ]

$t_a$ = 1.46 ms

$t_b$ = 2.915

$V_a$ = -1.3229 volt

$V_b$ = -2.2229 volt

$V_0(\infty)$ = -2.5

Decay constant $\tau = \frac{t_b - t_a}{ln\left(\frac{V_a - V_{o(\infty)}}{V_b - V_{o(\infty)}}\right)}$ = 1.005 msec.

Damping Coefficient $\alpha = \frac{1}{\tau}$ = 994 $sec^{-1}$

Damped radian frequency $\omega_d = \frac{2\pi}{t_b - t_a}$ = 4318.34 rad/sec

Theoretical $\alpha = \frac{R}{2L}$ = 1000 so error = 6

After making C = 200 nF, the simulation was as shown in the figure below:

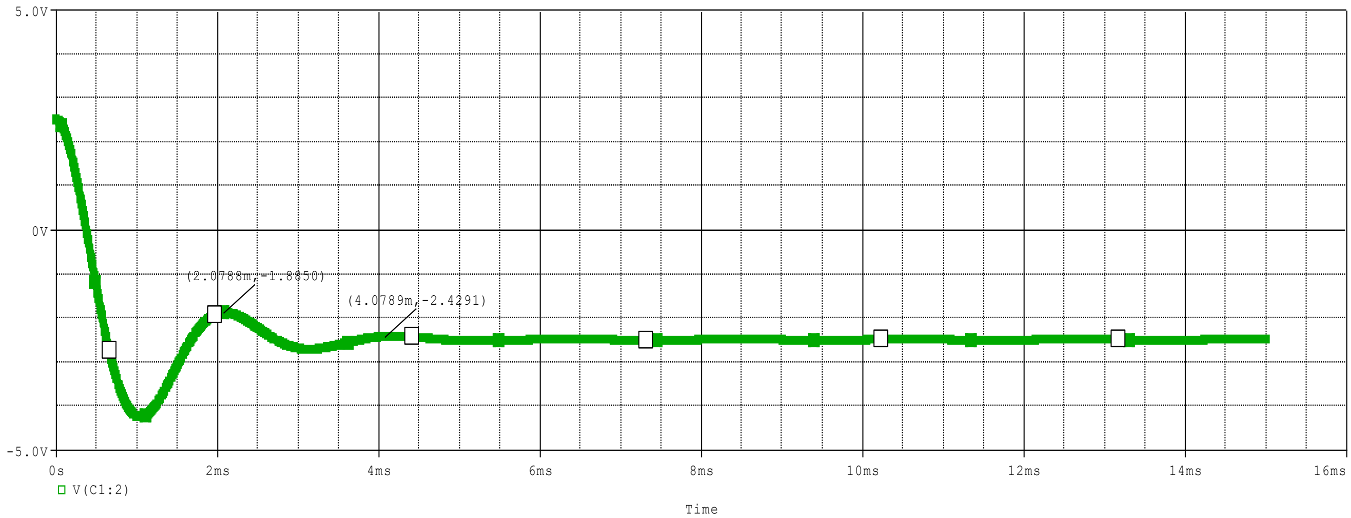


*Figure 24: Under damped response to measure the response parameter after changing c*

We can see that: [R=1KΩ]

$t_a$ = 2.078 ms

$t_b$ = 4.07 ms

$V_a$ = -1.885 volt

$V_b$ = -2.42 volt

$V_0(\infty)$ = -2.5

Decay constant $\tau = \dfrac{t_b - t_a}{ln\left(\dfrac{V_a - V_{o(\infty)}}{V_b - V_{o(\infty)}}\right)}$ = 0.976 msec.

Damping Coefficient $\alpha = \dfrac{1}{\tau}$ = 1023.8 sec-1

Damped radian frequency $\omega_d = \dfrac{2\pi}{t_b - t_a}$ = 3154.2 rad/sec

Theoretical $\alpha = \dfrac{R}{2L}$ = 1000 so error = 23.8

# 4. Conclusion

Four types of circuit was connected in this experiment ,first order(RL&RC)circuit and second-order (series &parallel)RLC circuit Some measurement was talked in the (RC & RL)circuit like $\tau$ and noticed that the theoretical value was differed from the experimental value and the error was measured above. the RLC circuit (series and parallel) was connected and the three cases of response(over damped , critical damped, under damped) was explained and some measurement was talked ($V_a$ ,$t_a$ ,$V_b$ ,$t_b$ , $V(\infty)$).

# 5. References


1. RC Charging Circuit Tutorial & RC Time Constant (electronics-tutorials.ws)accessed on 3/9/2021
2. What is RL Series Circuit? - Phasor Diagram & Power Curve - Circuit Globe accessed on 3/9/2021
3. Series RLC Circuit | Analysis | Phasor Diagram | Impedance Triangle (electricalacademia.com) accessed on 3/9/2021
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