Department

Of electrical and computer

Engineering

ENEE2103

CIRCUITS AND ELECTRONICS LABORATORY

Experiment No.3 Report

Report#3

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Abstract

The aim of the report is to discuss the results of analyzing and testing the time response on the RL, RC and RLC circuits and to observe the effect of the initial state on the circuits.

It also aims to check the practical values with the theoretical one.

Components used in the experiment:

1. Signal generator
2. Oscilloscope
3. Digital multimeter
4. 22kohm and 2.2kohm resistors
5. 100nF capacitor
6. Resistance Decade Box
7. Inductance Decade Box

Contents

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Theory

In this part of the report, the theory behind the circuits connected in the experiment is going to be explained.

The circuits are categorized in 2 types, which are:

1. First order circuits

For a circuit to be categorized as first order circuit, it has to have only one storage element, either a capacitor or an inductor connected with a resistor.

The 2 circuits in the experiment are:

- RC circuits

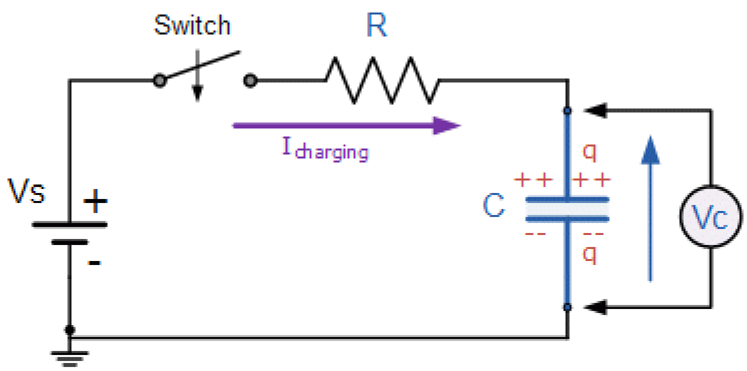

Figure 1. 1 RC circuit

The capacitor in the circuit gets charged until its voltage equals the source's voltage.

To analyze such circuit the time for the capacitor voltage to reach full charge has to be found.

To find the time for full charge, graph of Vc vs t while charging and discharging needs to be analyzed.

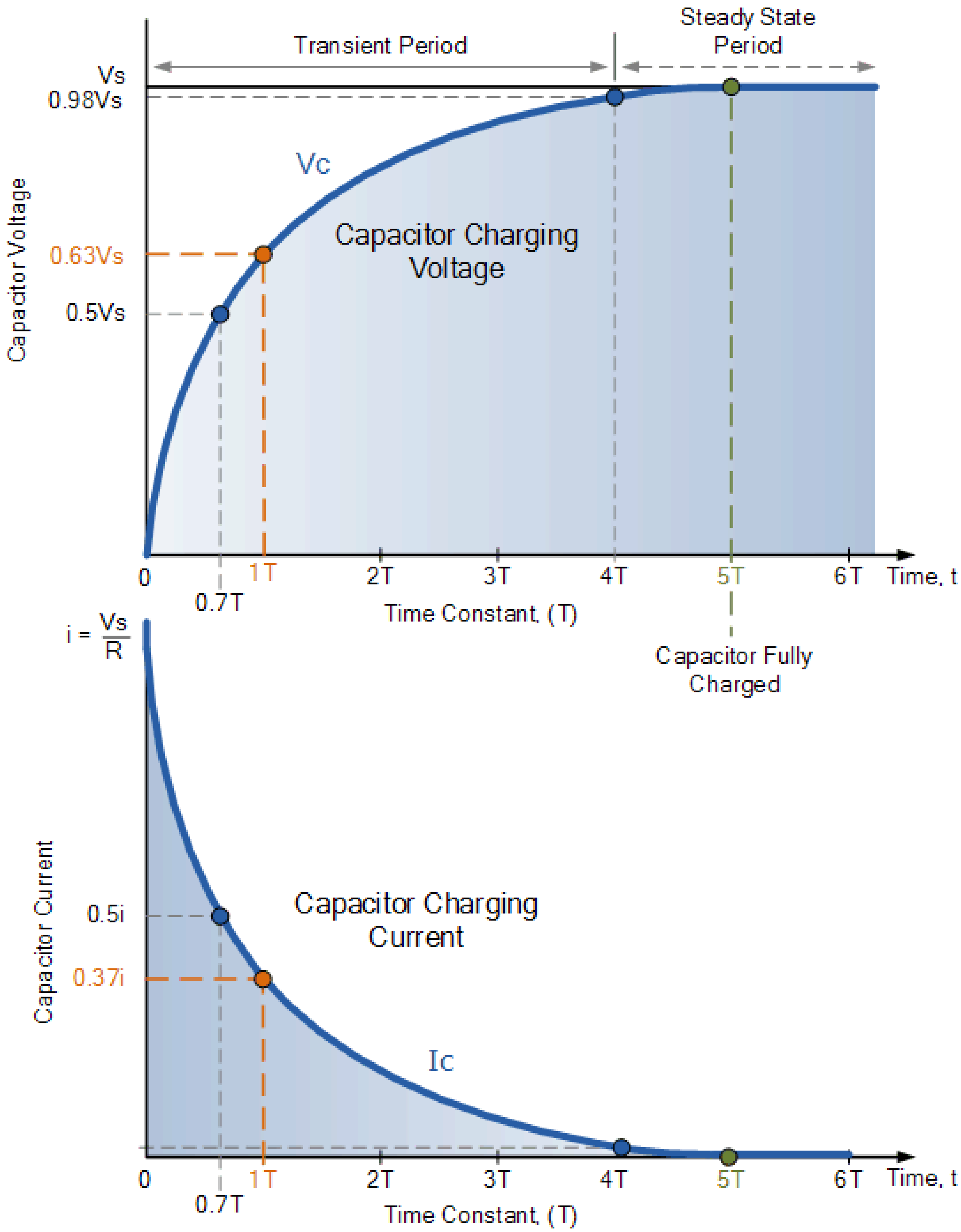

Figure 1. 2 Vc vs time while charging and discharging

From the graph, it can be seen that the time for the capacitor voltage to reach 63% of the sources voltage is the fastest then it slows down to be exponential. So a time constant (τ) is defined, which is the time for the capacitor to reach 63% of the source's voltage.

It's also seen that the time for the capacitor voltage to reach 99% is 5τ.

$$\tau = RC$$

$$Vc = Vs(1 - e^{-t/RC})$$

- RL circuits

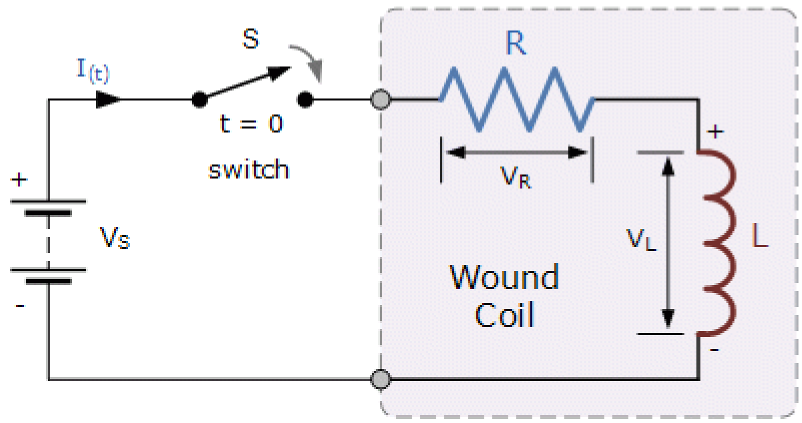

Figure 1. 3 RL circuit

The inductor is a device that stores current. The time for it to reach the maximum current from the source needs to be analyzed.

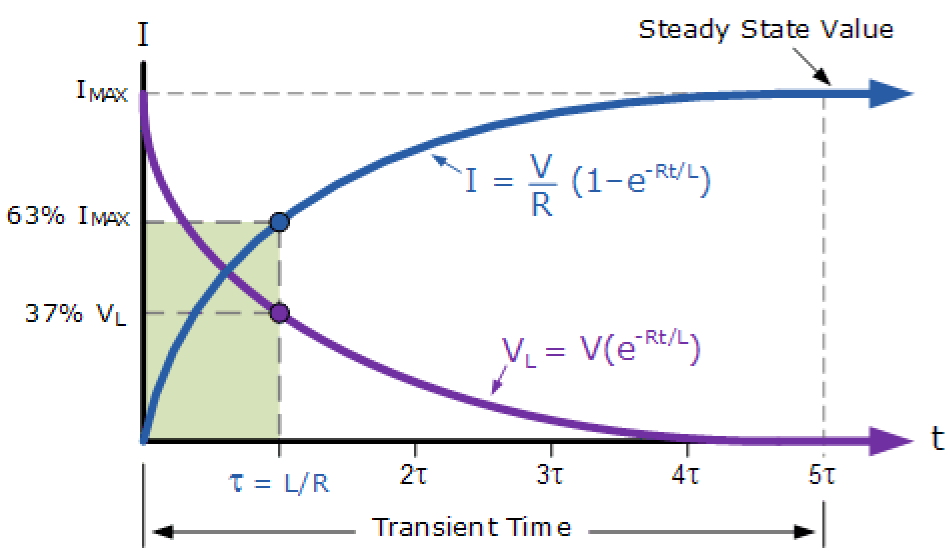

Figure 1. 4 IL vs time for LC circuits

$$\text{Is} = \frac{Vs}{R}$$

The time for the current of the inductor to reach 63% Is called τ

$$\tau = \frac{L}{R}$$

The current in IL:

$$I(t) = \frac{Vs}{R}(1 - e^{-Rt/L})$$

It's also seen that the time for the inductor to reach maximum current is 5τ.

2. Second order circuits

For a circuit to be categorized as second order circuit it has to have a capacitor, an inductor and a resistor

series RLC circuits:

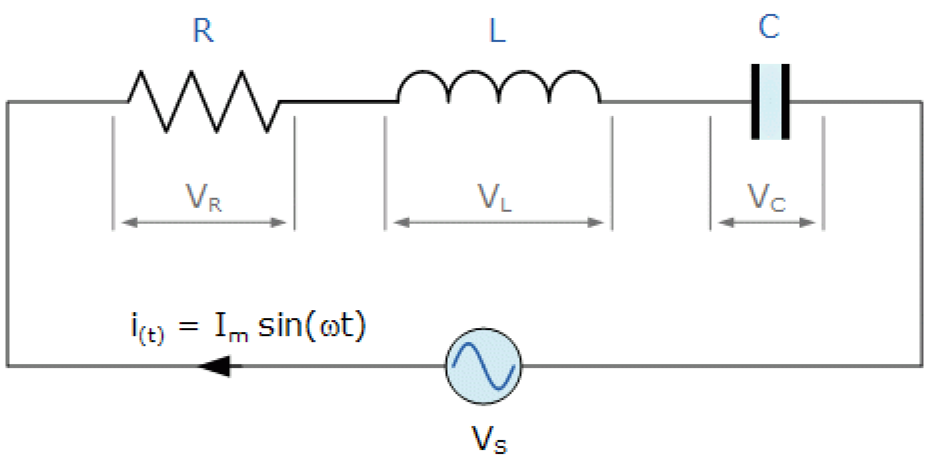

Figure 1. 5 RLC circuit

In such circuit the capacitor and inductor are storing so the voltage and the current is harder to find

For such circuit the damping factor and the resonant frequency need to be found

Damping factor: $\alpha = \frac{R}{2L}$

Resonant frequency: $\omega o = \frac{1}{\sqrt{LC}}$

It can be known from those 2 values if the output is:

- overdamped, $\alpha > \omega$ leads to the sum of two decaying exponentials

- critically damped, $\alpha=\omega$ leads to t times decaying exponential
- underdamped, $\alpha<\omega$ leads to a decaying sine

Procedure and data analysis

In this part of the report, the experiment is going to be done and analyzed to compare the actual values with the theoretical ones.

Three circuits are going to be connected, those circuits are:

A. RC Circuit

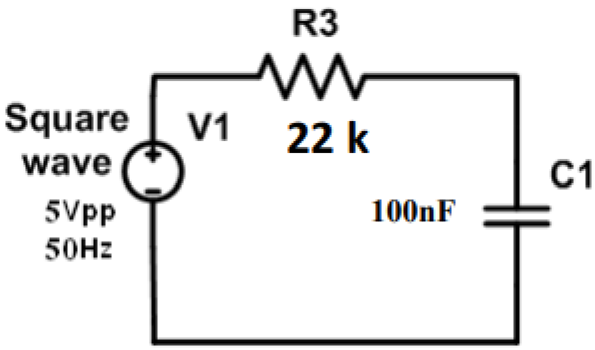

Figure 2. 1 RC circuit in the experiment

1. The circuit should be connected as shown in figure 2.1
2. The resistance decade box should be set to 22kΩ
3. The capacitor should be checked on the RLC meter to make sure its 100nF
4. The signal generator should be set to generate a square wave of 5Vp-p and 50Hz with DC offset= 2.5V (5V high , 0V low)
5. The oscilloscope should be connected to the terminals of the capacitor
6. The value of the system time constant should be measured from the Vc on the oscilloscope

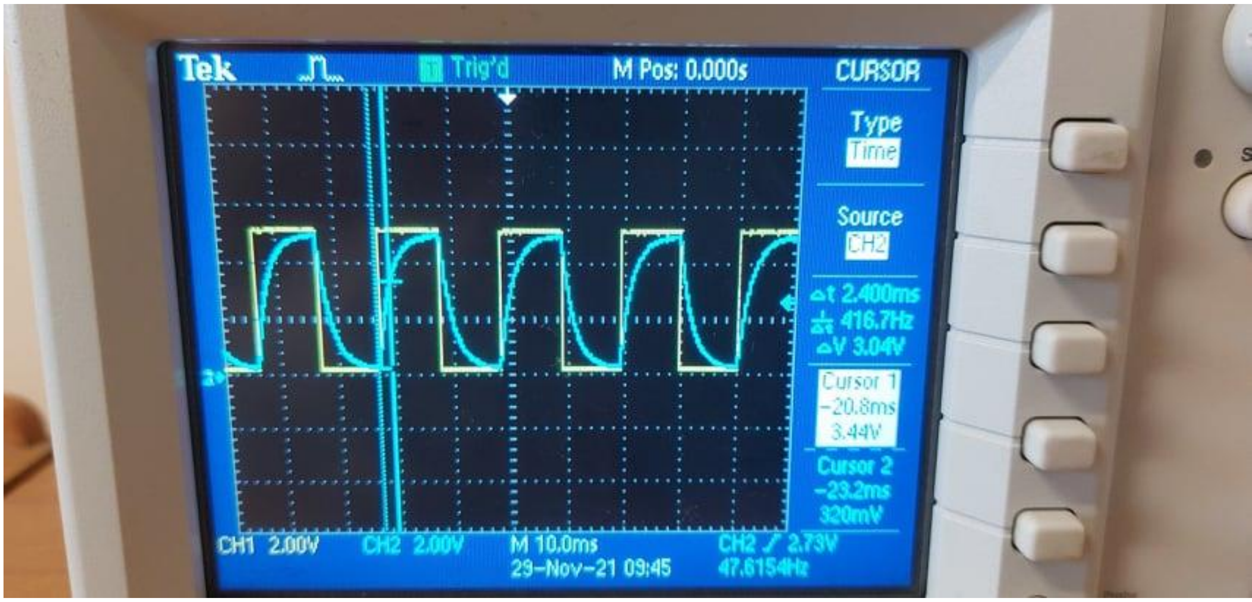

Figure 2. 2 RC circuit value of the measured time constant

$$\tau_{practical} = 2.4ms$$
$$\tau_{theoritical} = RC$$
$$\tau_{theoritical} = 2.2ms$$

The values of the time constant are close which confirms that the experiment was successful

7. The value of the steady state voltage should be measured from the oscilloscope

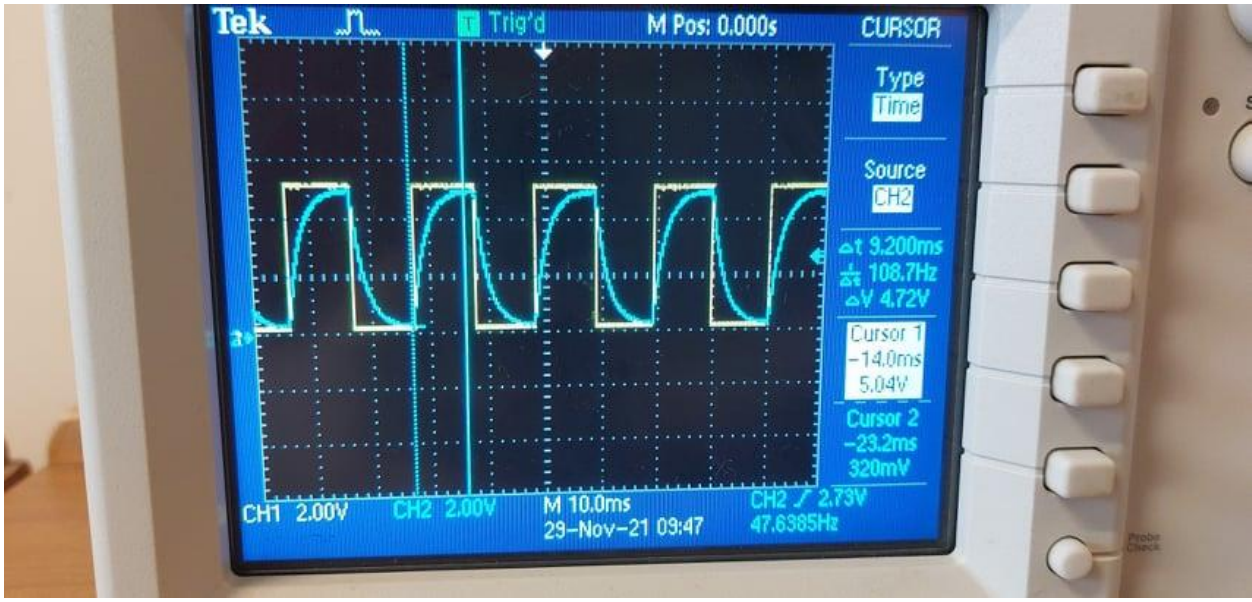

Figure 2. 3 RC circuit value of the measured steady state voltage

$$steady\ state\ voltage = 4.72V$$

8. The value of the capacitance should be calculated from the measured time constant

$$C = \frac{\tau}{R}$$
$$C = 109nF$$

The value of the calculated capacitance is close to the actual capacitance

B. RL Circuit

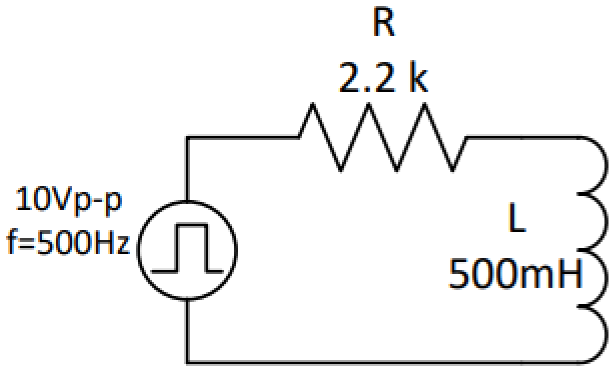

Figure 2. 4 RL circuit from the experiment

1. The circuit should be connected as shown in figure 2.4
2. The signal generator should be set to provide a square wave with 10Vp-p, frequency 500Hz and DC offset=5V
3. The oscilloscope should be connected to the terminals of the inductor
4. The time constant and the steady state voltage and current should be measured

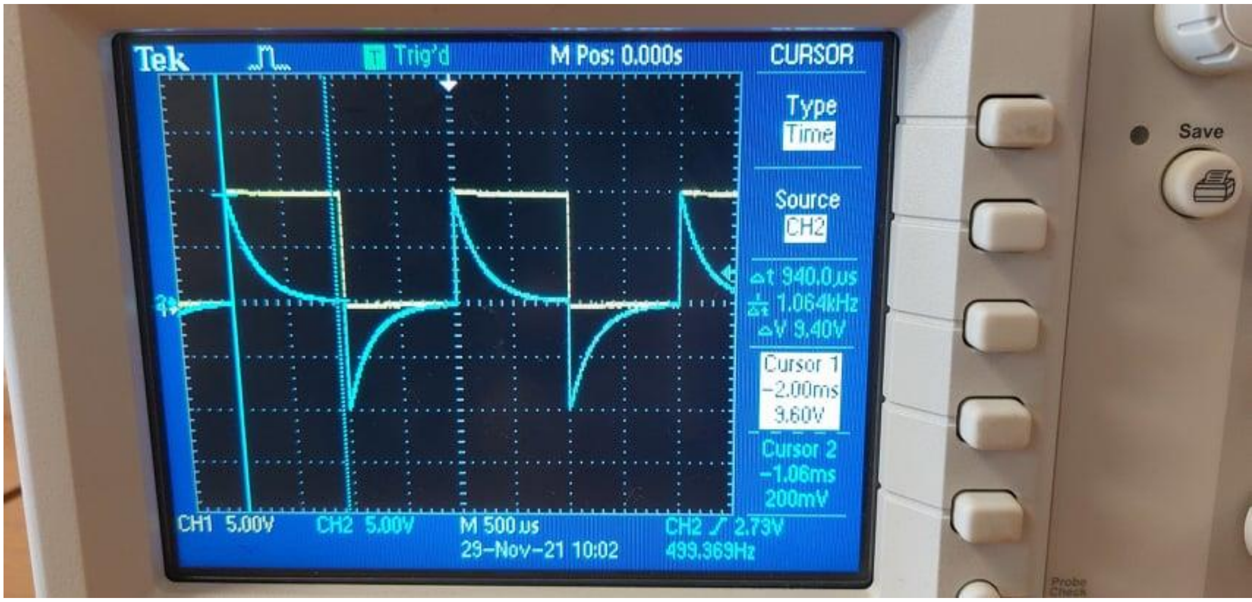

Figure 2. 5 RL circuit value of the measured steady state voltage

$$V\ steady\ state_{practical} = 9.6$$

$$V\ steady\ state_{theoritical} = 10$$

The steady state theoretical voltage is very close to the practical one.

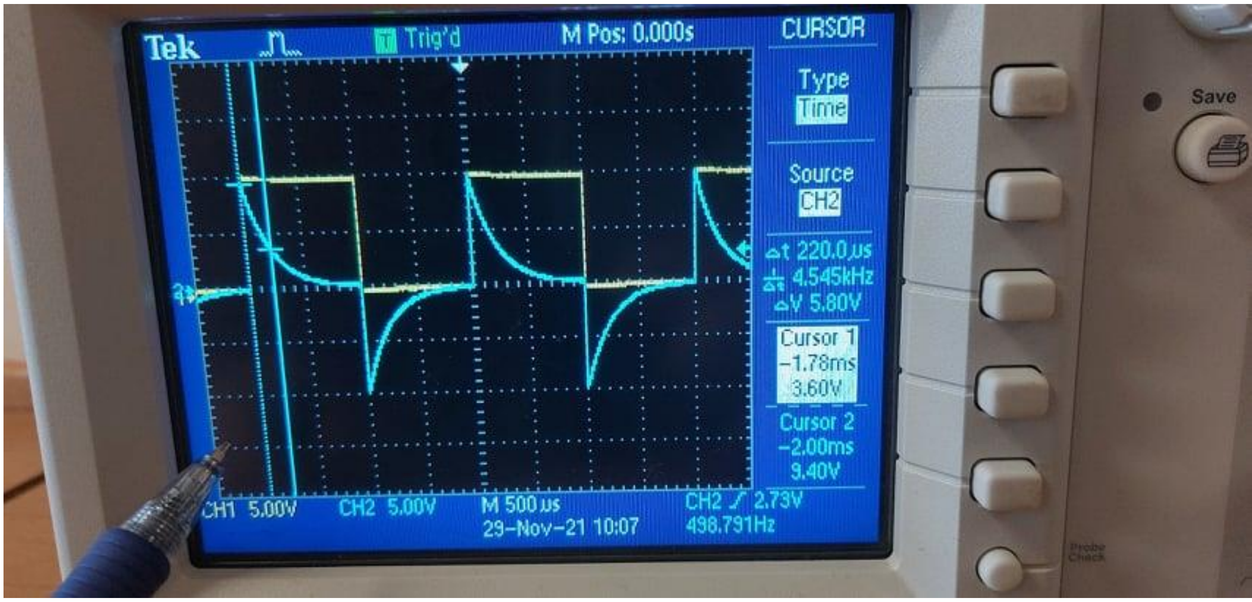

Figure 2. 6 RL circuit value of the measured time constant

$$\tau_{practical} = 220us$$

$$\tau_{theoritical} = 227us$$

The values of the time constant are close which confirms that the experiment was successful

5. The behavior of the voltage and current responses should be determined in relation to the element characteristic equation
   The behavior is charging and discharging of the current in the circuit
   4.36mA$\geq I \geq 91uA$
6. The period of the square wave should be changed to 2τ and displayed

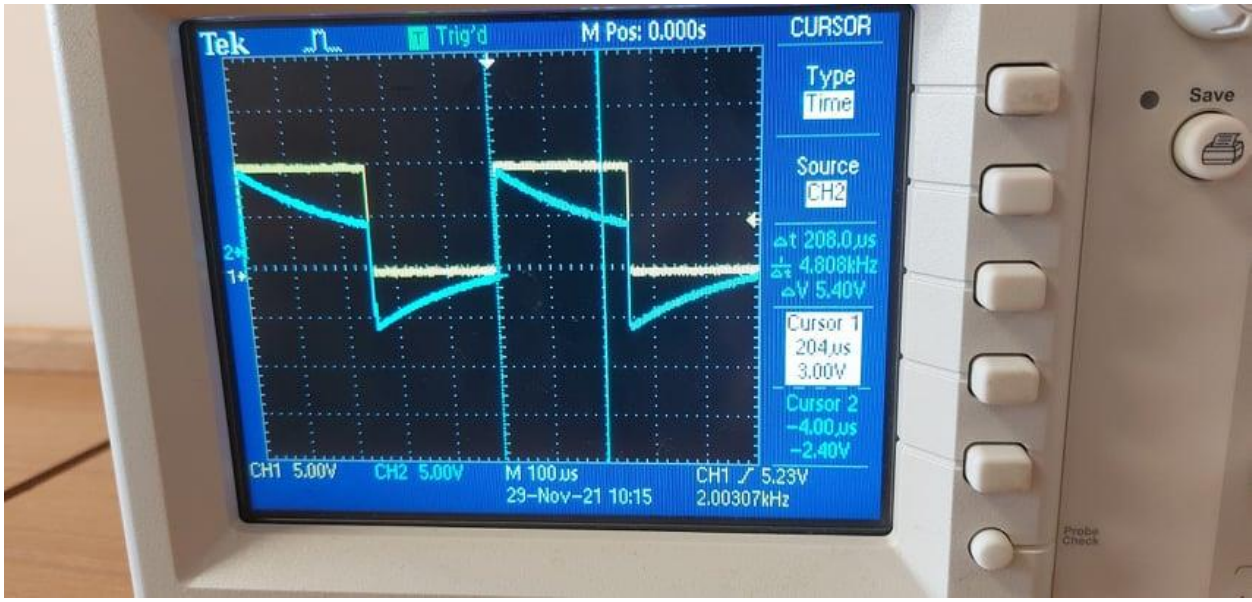

Figure 2. 7 RL circuit inductor voltage when T=2τ

The waveform shown in figure 2.7 shows that when T=2τ, the inductor is not able to charge for to the maximum I and it can't also discharge to the minimum I (0)

C. RLC Circuit

I. Response type

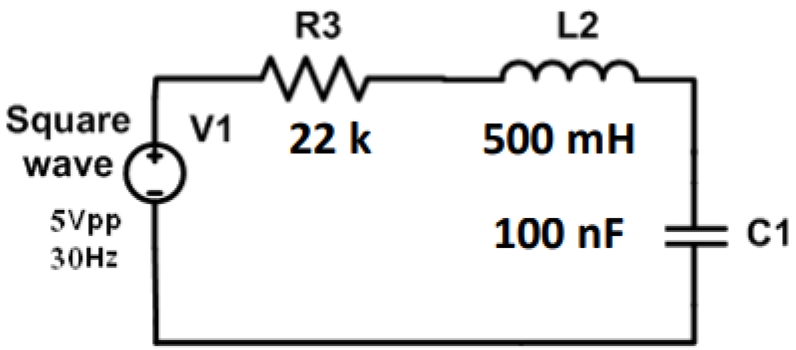

Figure 2. 8 RLC circuit from the experiment

1. The circuit in figure 2.8 should be connected
2. The oscilloscope should be connected to measure the voltage on the capacitor
3. The signal generator should be set to provide a square wave with +-2.5V, f=30Hz and DC offset= 2.5
4. The response type should be determined

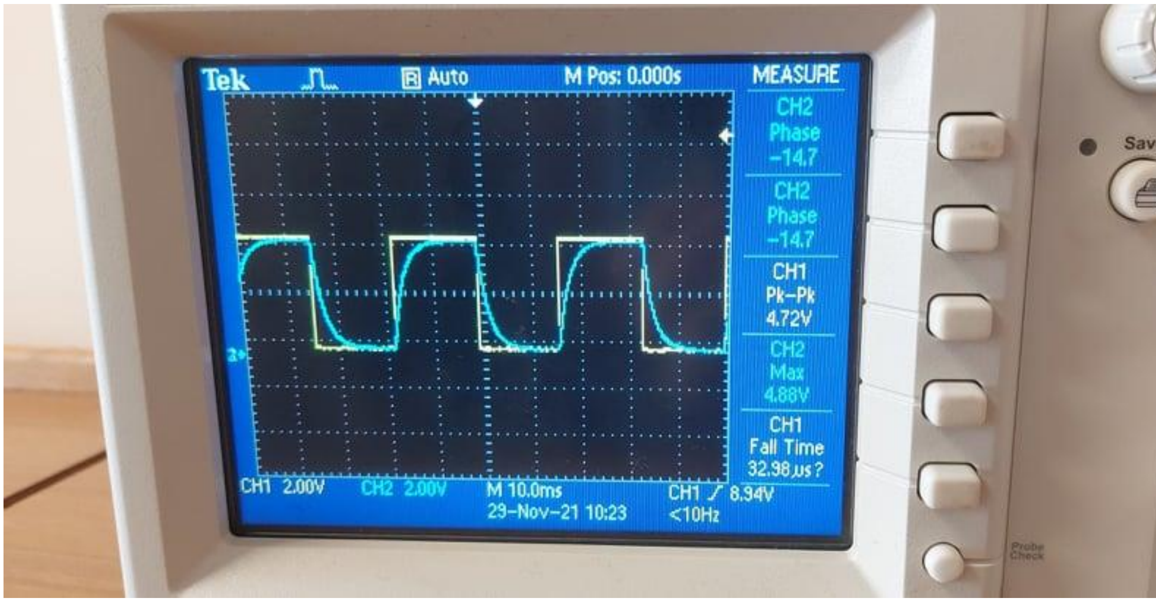

Figure 2. 9 RLC circuit in an over-damped state

The system is over-damped

5. R3 should be replaced with a resistance value that provides a critically damped system
   For a system to be critically-damped alpha should equal omega o.

$$\alpha = \omega$$
$$\frac{R}{2L} = \frac{1}{\sqrt{LC}}$$
$$R = 4472\Omega$$

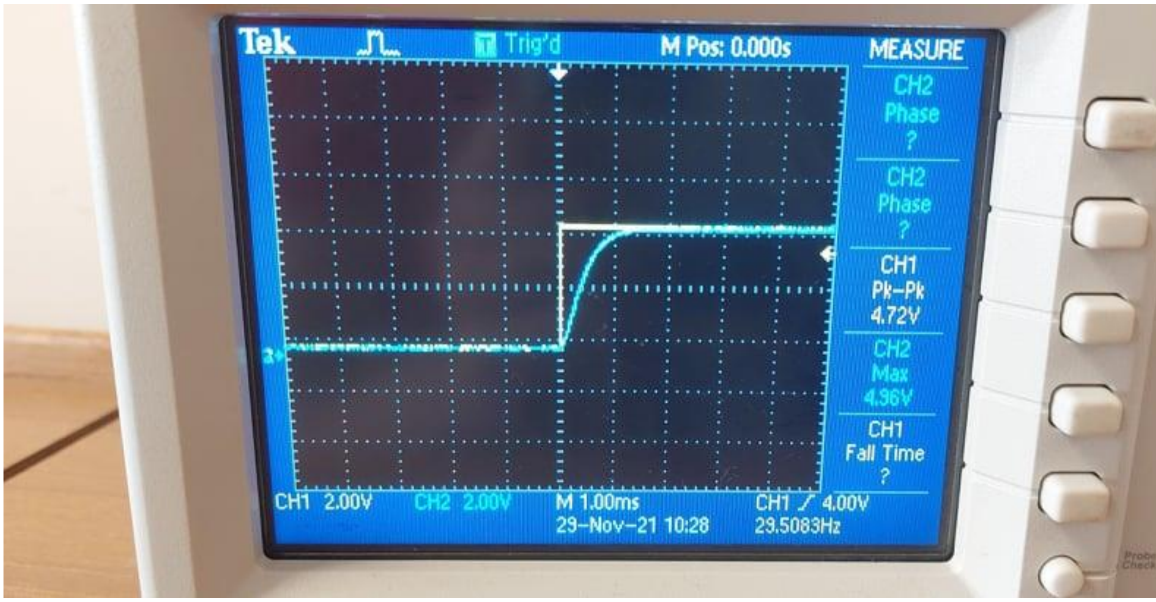

Figure 2. 10 11 RLC circuit in a critically-damped state

6. R3 should be replaced with a resistance value that provides an under-damped system

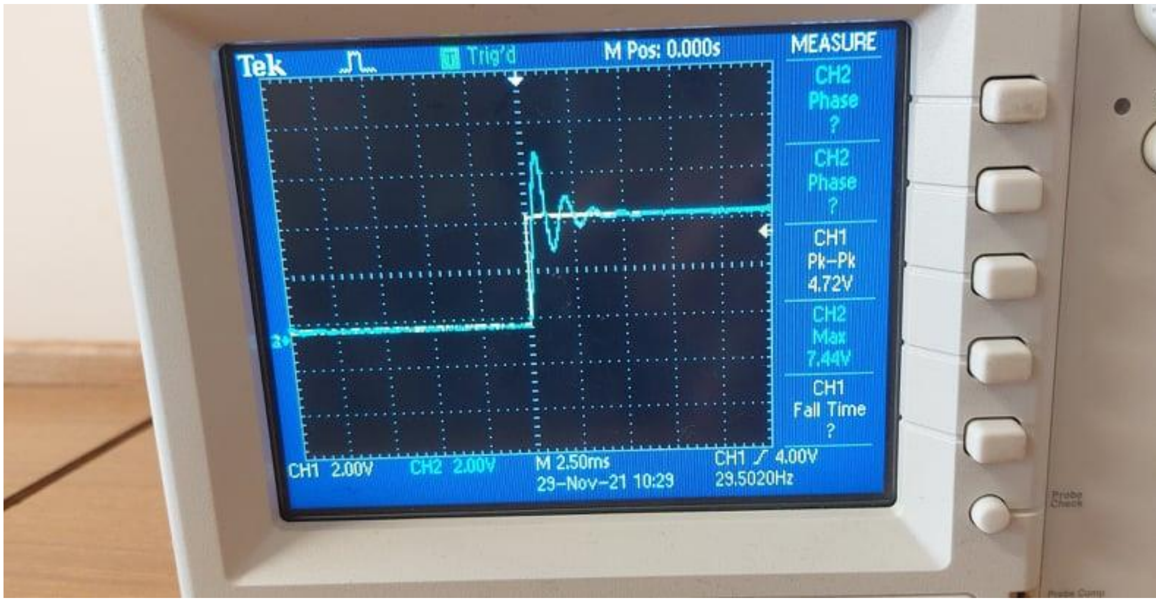

Figure 2. 12 13 RLC circuit in an under-damped state

7. The variable resistance should be changed in steps to observe the change from one damping condition to another, and then it should be refined to detect the transition point
8. The type of response should be determined in each case

Parts 7 and 8 where observed by the team but it was not captured

II. Response parameters

1. The circuit should be kept as its connected but some values need to be changed
2. R should be set to 750Ω
3. The value of the capacitor should be doubled
4. The value of the inductor should be halfed
5. The coefficients α, ω and τ can be measured as shown in figure 12.10

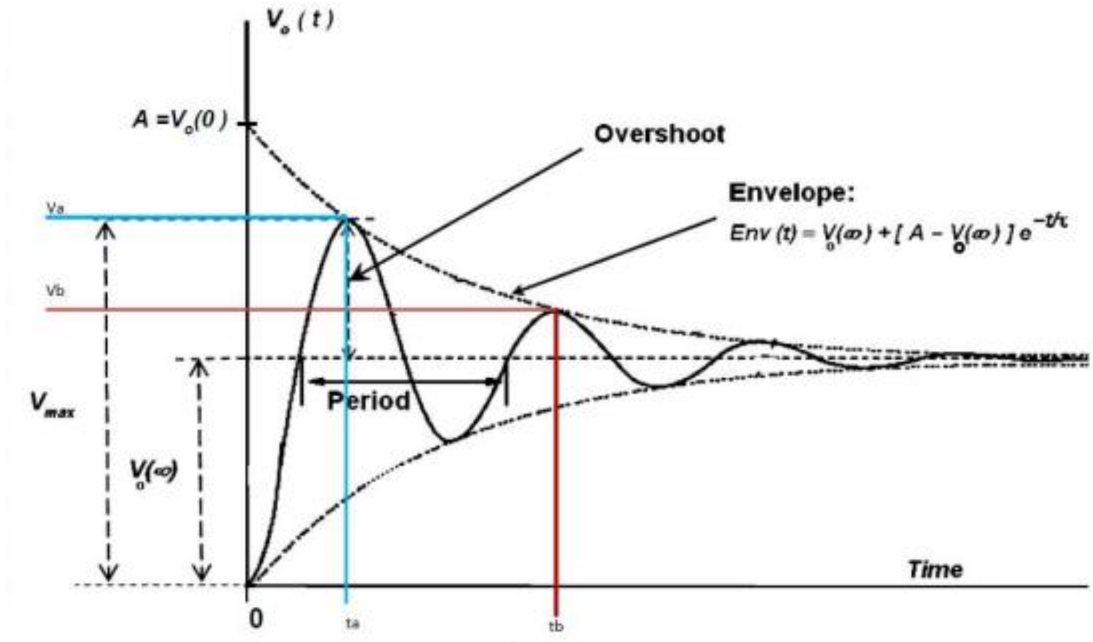

Figure 2. 14 measuring damping coefficients for under-damped

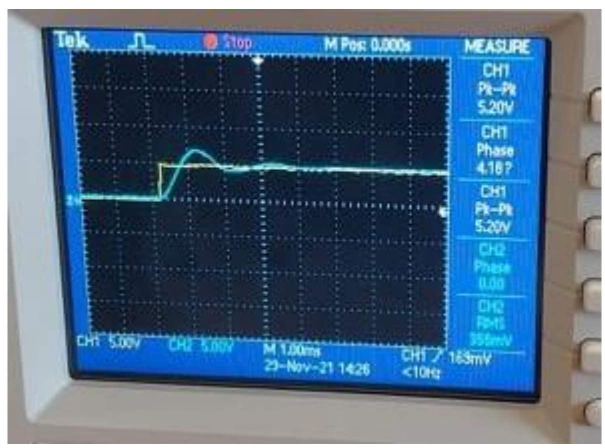

Figure 2. 15 the under-damped response used to measure damping coefficients

$$\tau = \frac{tb - ta}{\ln\left(\frac{Va - V0(\infty)}{Vb - V0(\infty)}\right)}$$

$$\tau = \frac{1.44}{\ln\left(\frac{7.44 - 4.64}{5.44 - 4.64}\right)}$$

$$\tau = 1.15$$

$$\alpha = \frac{1}{\tau}$$

$$\alpha = 0.87$$

$$\omega d = \frac{2\pi}{tb - ta}$$

$$\omega d = 4.363$$

Conclusion

The experiment showed how first order an second order responses look like and how to calculate the time for each to reach the full or 63% of the maximum.

It also showed how to calculate certain parameters from the graph of the voltage of current vs time.

References

Theory: all the figures in the theory were taken from **electronics-tutorials.ws,** the material was also understood from the mentioned site

Procedure: the circuit's figures and the experiment were taken from the circuits and electronics laboratory manual of Birzeit University