BIRZEIT UNIVERSITY

Faculty of Engineering & Technology
Department of Electrical & Computer Engineering
ENEE2103-Circuit And Electronics Laboratory
Report exp#3:First and second order circuit

Prepared by:

Saja Asfour 1210737

Partners Names and IDs:

Fatima Dawabsheh 1210827

Yara Khattab 1210520

Instructor:

Mr.Nasser Ismail

Assistance:

Eng. Hazem Awaysa

Section:

Sec1

Date:

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Place:

Masri203

1.Abstract:

In this experiment we want to connect RC ,RL and the second order RLC circuit to the Oscilloscope then test and analyze the time response of the circuit and see how does charging and discharging processes works. And we want to test the effect of the dynamic elements on the time response . and finally, determine the first and second order circuits parameters from the circuit response.

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2.Theory:

2.1 RC Circuit:

*An RC circuit combines a resistor (R) which is measured in ohms (Ω),and a capacitor (C) which is measured in Farad (F) and it is commonly found in electronic devices.

*The capacitor in the circuit stores energy, and when a resistor is connected in series, it regulates the charging and discharging rates. This produces a characteristic time dependence that turns out to be exponential. A key parameter that characterizes this time behavior is the "time constant " denoted as τ. Notably, the time constant is inherently defined by the product of the resistance (R) and the capacitance (C), and it possesses the dimensions of time, as evidenced by its unit (Ohm × Farad = second).

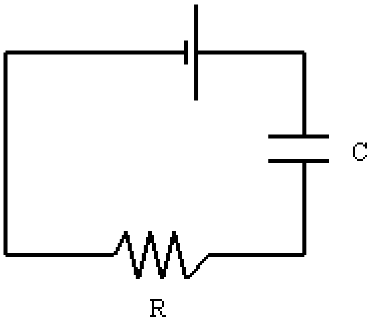

Figure1 : RC circuit

*Figure 1 shows a capacitor in series with a resistor, forming a RC Charging circuit connected across a DC battery supply. 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 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.

*The voltage across the capacitor, which is time-dependent, can be found by using Kirchhoff's current law. The current through the resistor must be equal in magnitude (but opposite in sign) to the time derivative of the accumulated charge on the capacitor. This results in the linear differential equation

$C\frac{dV}{dt} + \frac{V}{R} = 0$ where C is the capacitance of the capacitor.

Solving this equation for V yields the formula for exponential decay:

$V(t) = V_0 e^{-\frac{t}{RC}}$ where V_0 is the capacitor voltage at time t = 0.

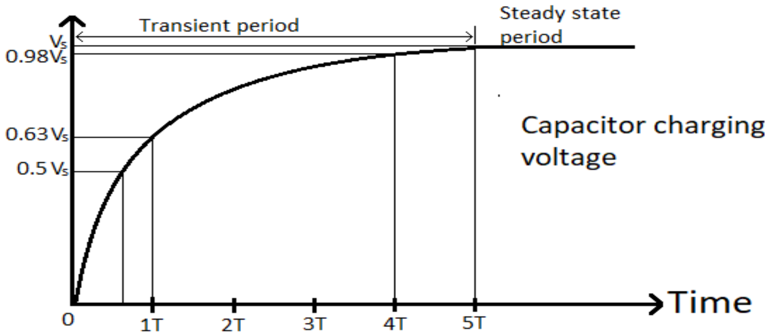

Figure 2: Capacitor charging voltage

*The time constant (τ) of an RC circuit is the time that takes to charge almost 63% of the capacitor's maximum voltage or to discharge almost 37% of the same voltage, and both are equal to the multiplication of the R & C.

2.2 RL Circuit

***RL Circuits** (resistor – inductor circuit), also called RL network or RL filter, is a type of circuit having a combination of inductors and resistors and voltage source. As such, an RL circuit has the inductor and a resistor connected in series combination with each other.

*The role of an inductor in the circuit is to oppose the change in the magnetic flux, i.e., the inductor does not allow the spontaneous changes in the current.

*When a supply voltage (V) is applied across the current element I flowing in the circuit. IL and IR are the currents flowing in the inductor and resistor, but the current flowing across both the elements are the same as they are said to be connected in the series connection with each other.

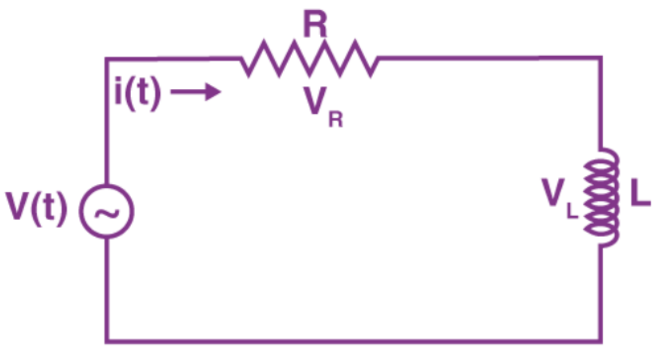

Figure 3: RL Circuit

*IL = IR = I. Consider V_L and V_R to be the voltage drops across the inductor and resistor. By the application of Kirchhoff voltage law to this circuit, we get, $V(t) = V_R + V_L$ .Thus, this is the equation for the voltage across the RL series circuit.

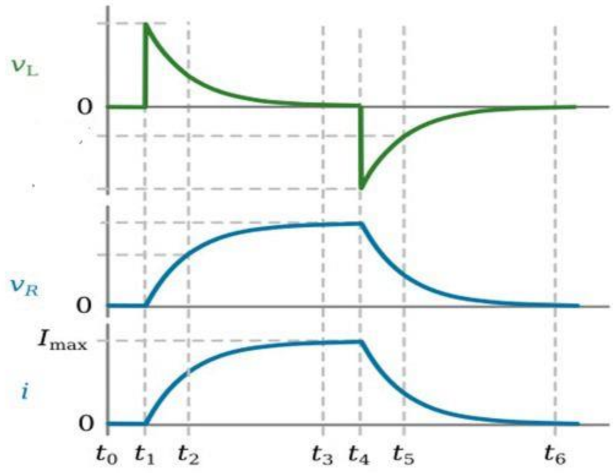

Figure4 : inductor and resistor voltage and current curve in RL circuit

2.3 RLC Circuit:

*Series RLC circuits consist of a resistance, a capacitance and an inductance connected in series across an alternating supply.

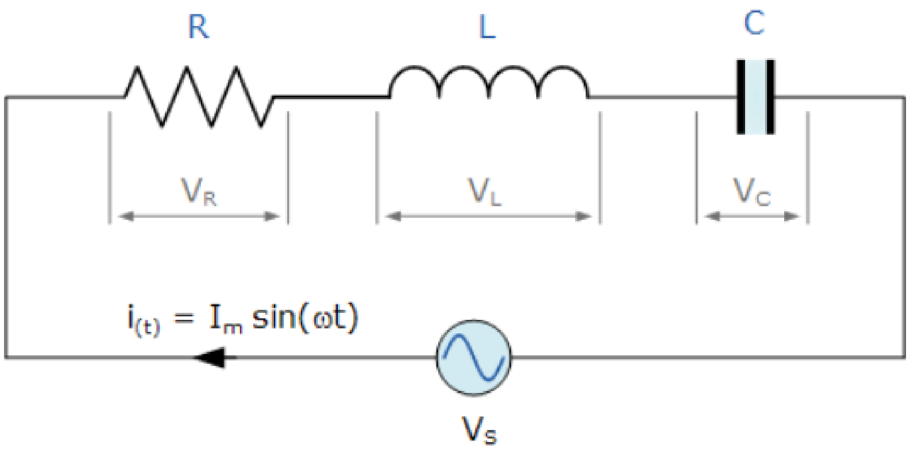

Figure 5: RLC circuit

*From the KVL $V_R + V_L + V_C = V(t)$ where V_R, V_L and V_C are the voltages across R, L, and C, respectively, and $V(t)$ is the time-varying voltage from the source.

*The current is the same through all components, but the voltage drops across the elements are out of phase with each other while The voltage dropped across the resistance is in phase with the current , The voltage dropped across the inductor leads the current by 90 degrees and The voltage dropped across the capacitor lags the current by 90 degrees.

*The resistor increases the decay of the oscillations (damping) and it also reduces the peak resonant frequency ($\omega o = 1/ \sqrt{LC}$).

*Let define a=R/2L and ωo = 1/ √LC then:

→To be over damped→a>w (its happens when the resistant is high relative to the response frequency).

→To be under damped→a<w (its happens when the resistant is low relative to the response frequency).

→To be critical damped → a=w (is caused when the resistance is on the edge of ringing).

* The damped radian frequency (ωd) is equal to 2π/(tb−ta) and the decay time constant is equal to (tb−ta)/ln [(va−vo(∞))/(vb−vo(∞))]

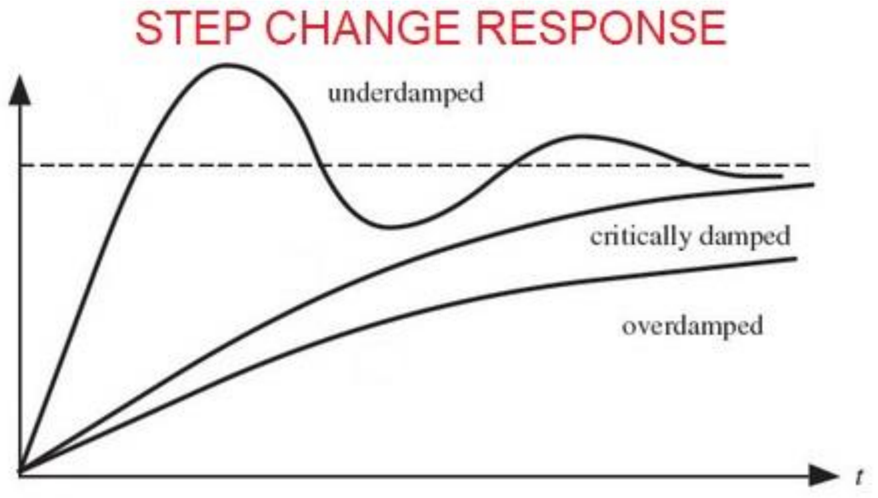

Figure 6: Transition respone of second order RLC circuit

3. Procedure And Data Analysis:

3.1 RC circuit:

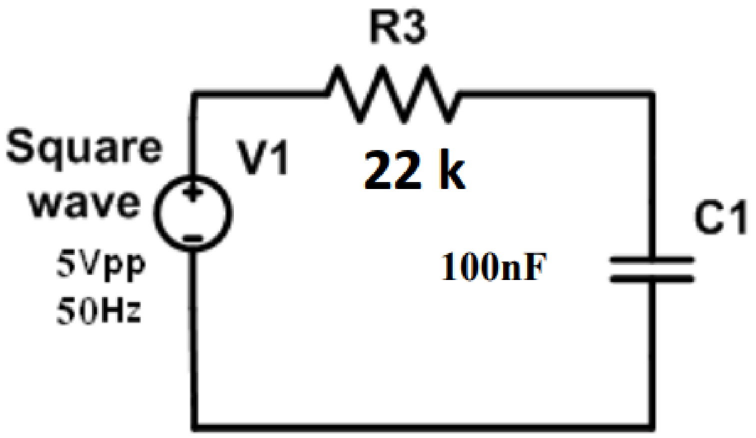

Figure 7: The RC circuit that should be connected

We first set the signal generator to square wave 5Vp-p and 50HZ with dc offset=2.5V, then connect it with other component in the circuit which is Resistor with value 22k and capacitor with value 100nF , then we connect the Oscilloscope in parallel with the Capacitance terminals and have a response displayed on the oscilloscope .

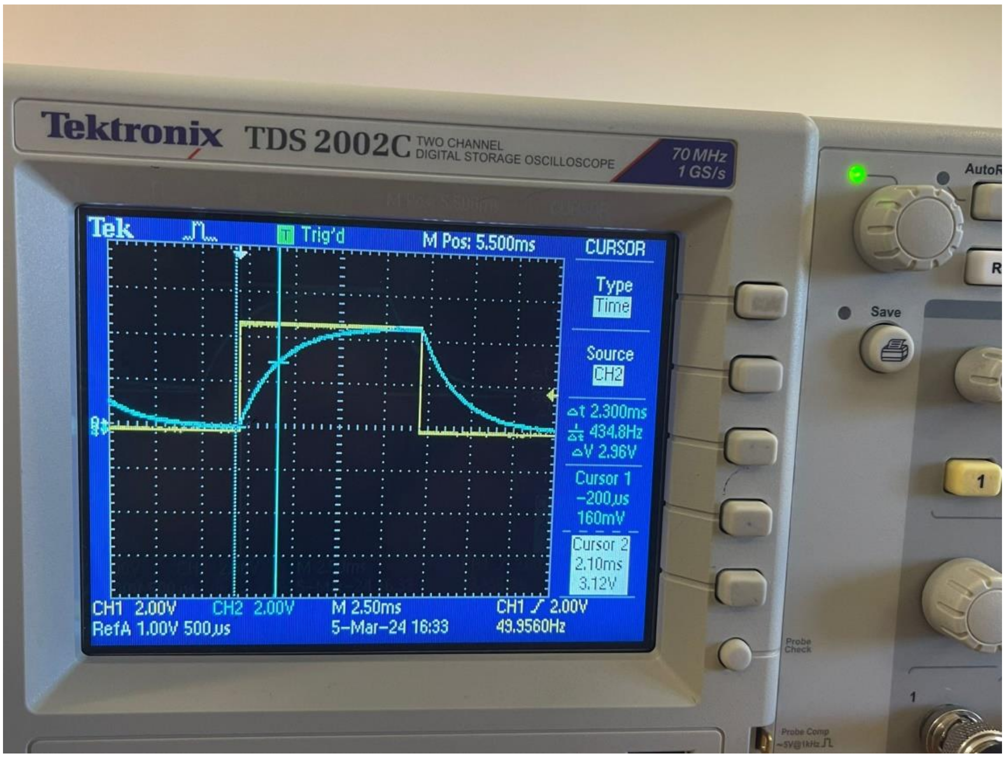

Figure 8: response displayed on the Oscilloscope in RC circuit

From the response displayed on the oscilloscope :
→ the steady state voltage value on the capacitor is 4.64V and its charging so we multiple it by 0.63 and have 2.92volt , so we changed the cursors to have ^v equal to 2.92, we set it to 2.96v then the time constant in it is equal 2.3ms

→ by the measurement of the time constant we can determine the value of the capacitance : C=time constant/R=2.3ms/22k=104nF which is closer to the original value in the circuit Theoretically we can find time constant by multiple the R and C→time constant=RC=2.2ms which is closer to the value we find from the graph.

3.2 RL circuit:

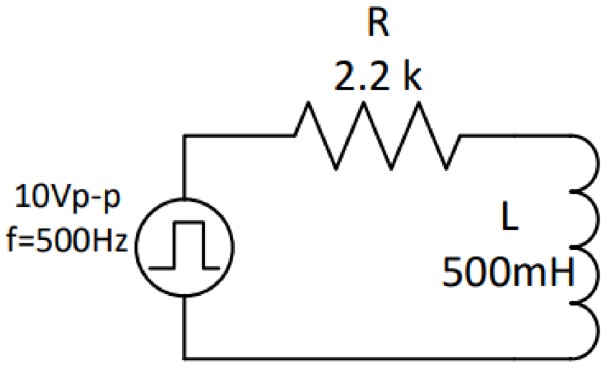

Figure 9: The RL circuit that should be connected

We first set the signal generator to square wave 10Vp-p and 500HZ with dc offset=5V, then connect it with other component in the circuit which is Resistor with value equal 2.2k and inductor with value 500mH that we chose it from the inductance decade box , then we connect the Oscilloscope in parallel with the inductor terminals and have a response displayed on the oscilloscope .

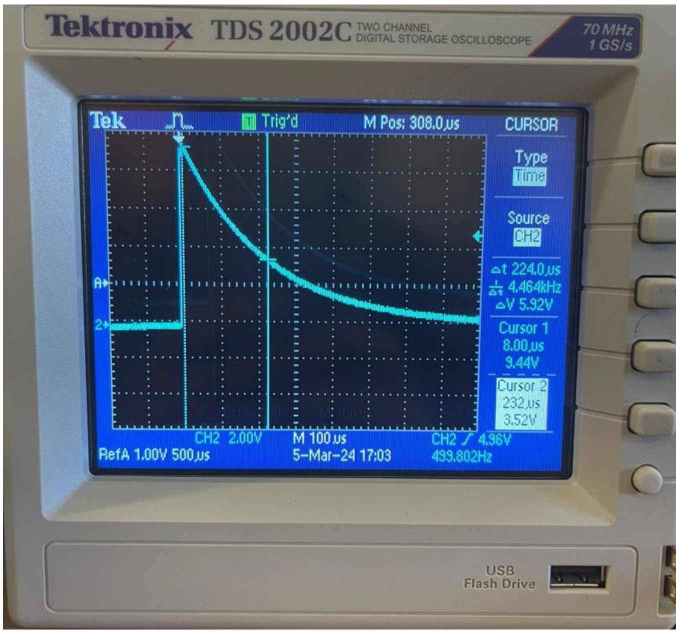

Figure 10: response displayed on the Oscilloscope in RL circuit

In figure 10 we see that is discharging curve but in fact it must be charging like I curve for it but we can not display the current curve in oscilloscope so instead of this we but connect the oscilloscope on the resistor terminal (resistor and inductor have the same current becouse they are connecting in series.

→time constant in figure10 is equal to 224us

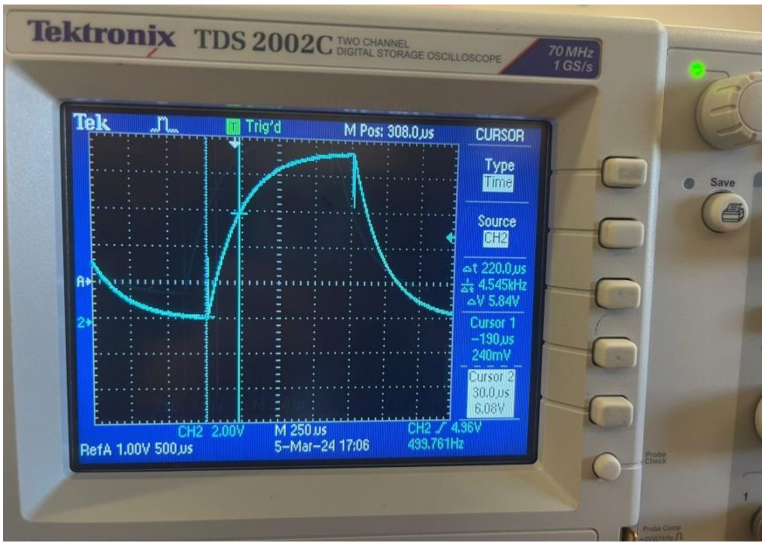

Figure 11: response displayed on the Oscilloscope in RL circuit for R

From Figure 11 :

→The steady state voltage is 9.20V so we multiple it by 0.637 and ^v=5.86V and try to set it equal this , we set it to 5.86volt and this at time constant=220us.

→ we can find the time constant theorticlly which equal L/R=500mH/2.2k=227us which is close to that we find from two graph.

Then we change the period of the periodic square wave to T=2 τ , so we change the frequency to 1/2 τ which equal 2.2kHz .

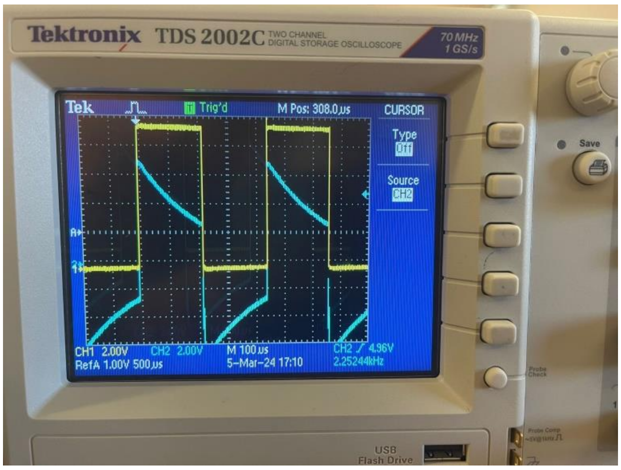

Figure 12: response displayed on the Oscilloscope in RL circuit when double the period

We note that the graph are become smaller and this because the actual time that must have is 5τ but we give it τ.

3.3 RLC Circuit:

3.3.1 Response type:

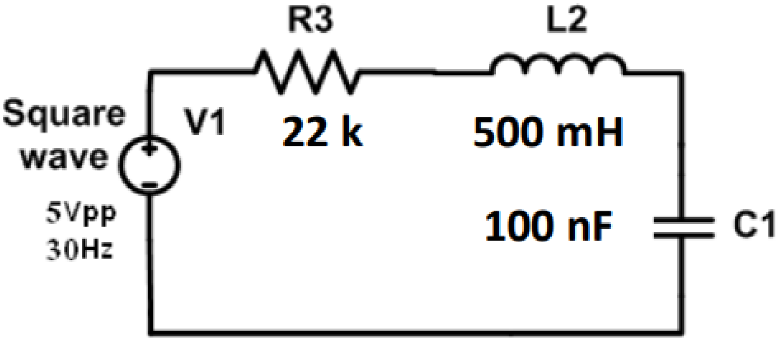

Figure 13: The RLC circuit that should be connected

We first set the signal generator to square wave 5Vp-p and 30HZ with dc offset=2.5V, then connect it with other component in the circuit which is Resistor with value equal 22k,inductor with value 500mH that we chose it from the inductance decade box and capacitor with value 100nF in series , then we connect the Oscilloscope in parallel with the capacitance terminals and have a response displayed on the oscilloscope .

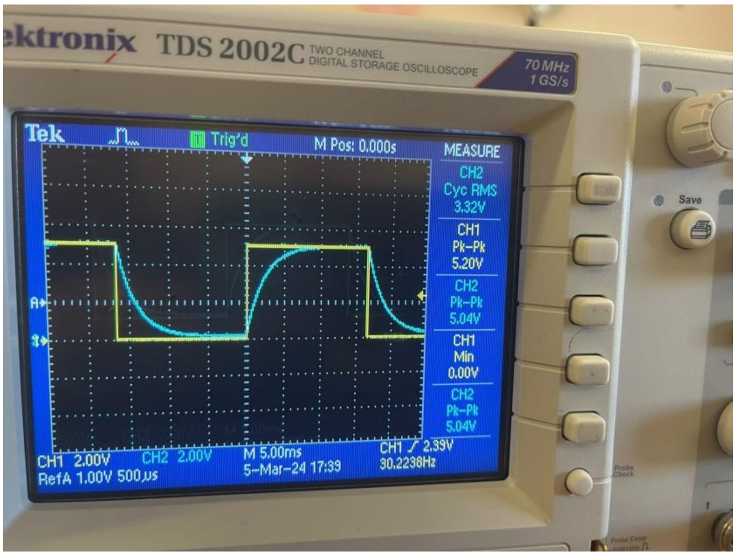

Figure 14: response displayed on the Oscilloscope in RLC circuit

→From figure14 we can Determine the type of the response which is over damped response so we see that 22k resistor case the over damped response .

Then we replace R3 by resistance decade box and change the variable resistor with steps so we can decade the change in the type of the response.

→when we change the resistor and set to 4k it be a critical damped response which clear in figure 15

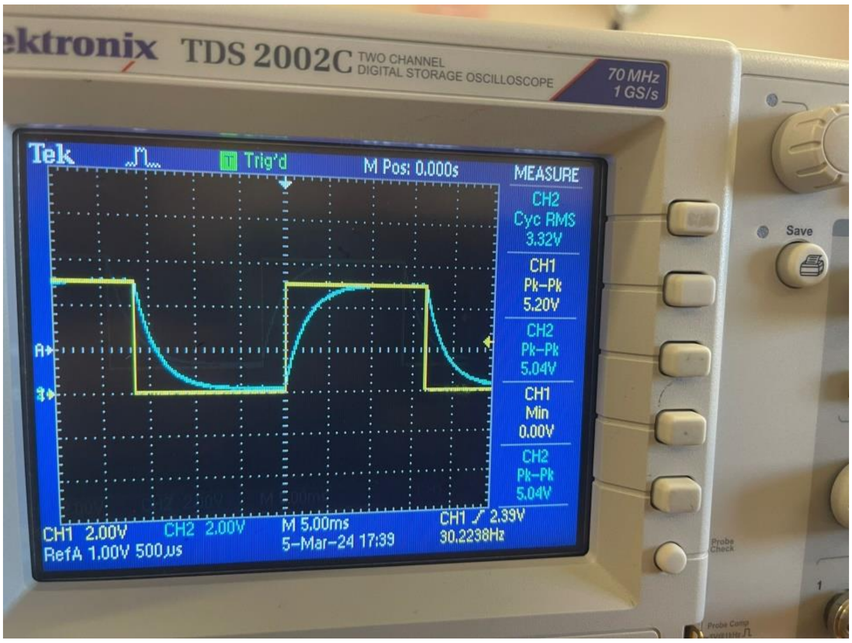

Figure 15: critical damped response displayed on the Oscilloscope in RLC circuit

It's clear in figure 15 that the response is critical damped response and it case from resistor equal 4k.

Then we still change the resistor and set it to 1k which case the under damped response

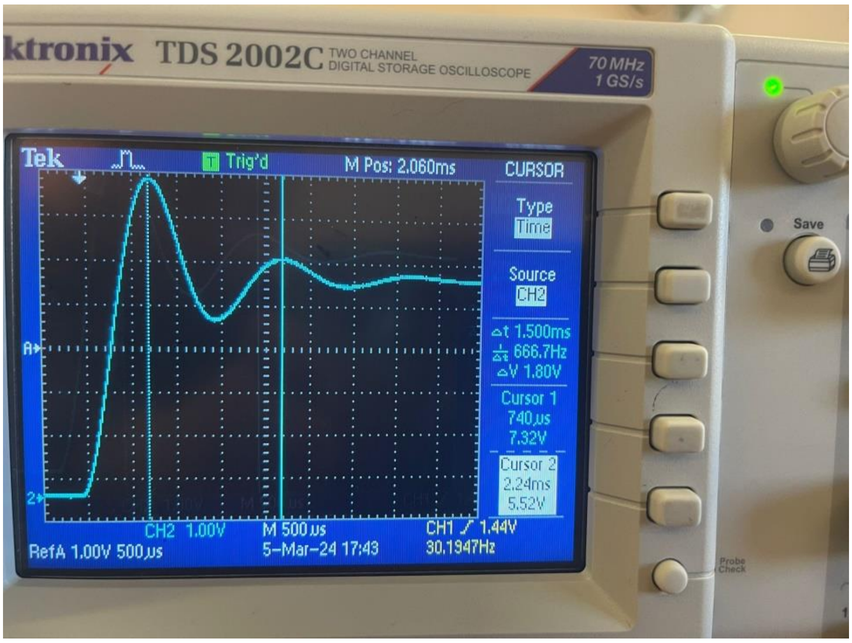

Figure 16: under damped response displayed on the Oscilloscope in RLC circuit

We conclude from the experiment that :

→if R=4k we have a critical damped response

→if R>4k we have over damped response

→if R<4k we have under damped response

Theoretically:
To be over damped→a>w
To be under damped→a<w
To be critical damped → a=w
a=w
R/2L=1/ √LC→R=2L/ √LC
So :
To be over damped→R>4.47k
To be under damped→R<4.47k
To be critical damped→R=4.47k
Which is closed to the R cases in the experiment.

3.3.2 Response parameters:

From the last step which conclude over damped response that in figure 16:
→(tb,Vb)=(2.24ms,5.52V)
→(ta,Va)=(740us,7.32V)
→ $Vo(\infty)$=5V

Decay time constant →τ =($tb-ta$) /[ln($Va-Vo(\infty)$ /$Vb-Vo(\infty)$)]=1.003ms
Damping Coefficient →α = 1 / τ→997.009rad/sec
Damped radian frequency→ ωd = 2π/($tb-ta$)=4188.79rad/sec

Then we put 2 capacitor each of them has value equal 100nF in parallel to have capacitor with value 200nF which is the double of the original case.

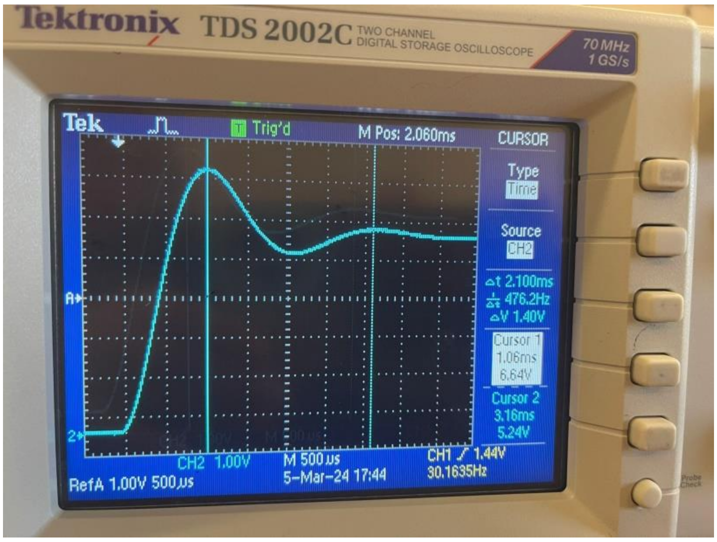

Figure 17: under damped response displayed on the Oscilloscope in RLC circuit when double the C value

From the figure 17:

→(tb,Vb)=(3.16ms,5.24V)

→(ta,Va)=(1.06ms,6.64V)

→ $Vo(\infty)$=5V

Decay time constant →τ =($tb-ta$) /[ln($Va-Vo(\infty)$ /$Vb-Vo(\infty)$)]= 1.093ms →is increased a few

Damping Coefficient →α = 1 / τ→914.913rad/sec→ is decreased

Damped radian frequency→ ωd = 2π/($tb-ta$)=2991.993rad/sec → is decreased

Then we reset the capacitor to its initial value and reduce the value of inductor to half of its initial value which equal 250mH.

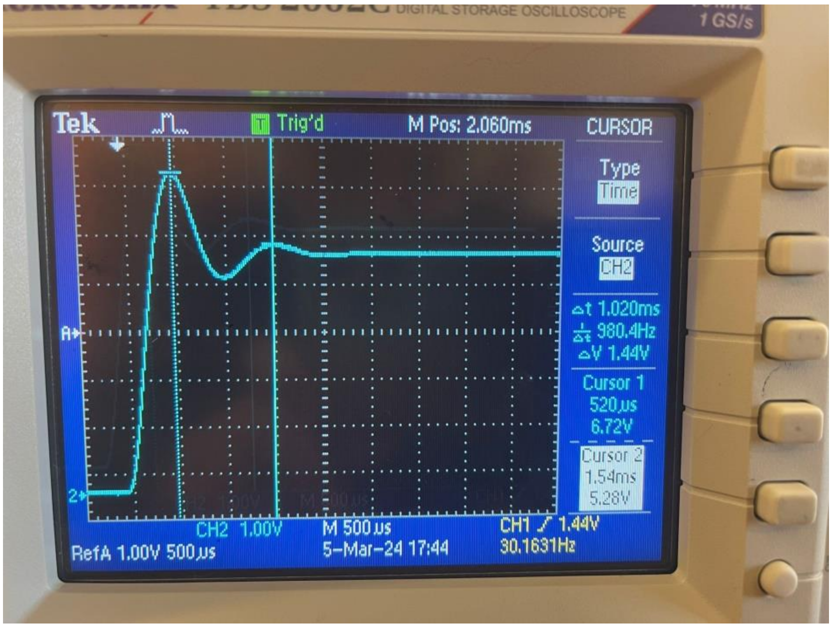

Figure 18: under damped response displayed on the Oscilloscope in RLC circuit when reduce the L to its half value

From the figure 18:

→(tb,Vb)=(1.54ms,5.28V)

→(ta,Va)=(520us,6.72V)

→ $Vo(\infty)$=5V

Decay time constant →τ =($tb-ta$) /[ln($Va-Vo(\infty)$ /$Vb-Vo(\infty)$)]= 0.562ms →is decreased

Damping Coefficient →α = 1 / τ→1779.359rad/sec→ is increased

Damped radian frequency→ ωd = 2π/($tb-ta$)=6159.986rad/sec → is increased

4. Conclusion:

In conclusion it was shown how to connect the RC, RL, RLC circuit and how they work and how do they effect the wave of the voltage and current .and how to get the time constant theoretically and by check the values using oscilloscope .and how the resistance might make change on the damping while its value change the damping from over to critical or under damping. And finally , we know a lot about under damped response and find the response parameter from the curve in oscilloscope which is decay time constant, damping coefficient and Damped radian frequency , then we see the effect in this parameter when we change the capacitor or inductor value.

5. References:

- https://web.pa.msu.edu/courses/2000fall/phy232/lectures/rccircuits/rc.html
- https://en.wikipedia.org/wiki/RC_circuit
- https://byjus.com/jee/rl-circuit/
- https://drive.google.com/drive/folders/13hl1Fi-XR6VWcHRmZU75Lbq6u4gtnOQG
- lab manual

6. Appendix:

Experiment#3 **ENEE2103**

First and Second Order Circuit

Objectives:

1. To use the Oscilloscope to measure electric values.
2. To test and analyze the time responses of RL and RC circuits.
3. To test and analyze the time response of the second order RLC circuit.
4. To test the effect of the initial state of the dynamic elements on the time response.
5. To determine the first and second order circuits parameters from the circuit response.

Equipment:

1. Digital Multimeter.
2. Oscilloscope (TDS-2002B).
3. Power supply.
4. Signal generator.
5. **Discrete Capacitors and Resistors, Inductance decade box, Resistance decade box**

Pre-lab:

3. Simulate the circuits in the procedure section and determine the required values (set the parameters that must be assigned by the instructor in the procedure to proper values).
4. Verify if Simulation Results match the expected results

Procedure:

A. RC Circuit:

1. Set the resistance Decade Box to the value of R3 then measure Value of C1 using the RLC meter.
2. Connect the circuit of Fig (3.1)
3. Set the signal generator to square wave 5Vp-p and 50Hz **with dc offset=2.5V**
4. Connect the Oscilloscope to the Capacitance terminals.
5. From the response displayed on the oscilloscope, determine the value of the system time constant. $\tau = 2.3ms$
6. Determine the steady state voltage value on the capacitor. $\approx 4.64V$
7. Use your measurements of the time constants to determine the value of the capacitance.

$C = \tau / R = 2.3m / 22k = 104nF$

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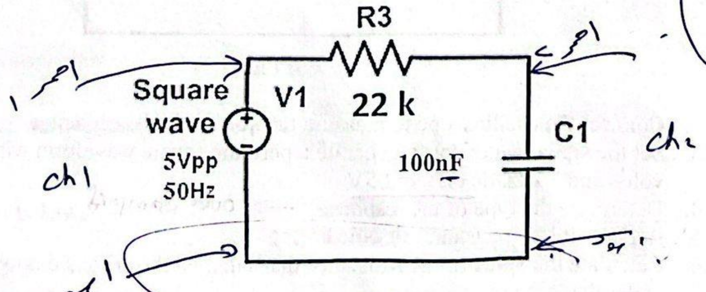
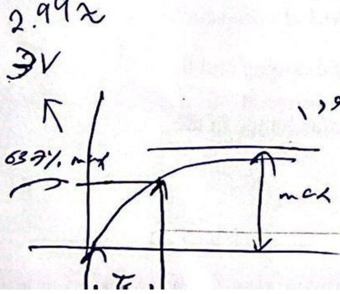


Fig (3.1)



B. RL Circuit:

1. Connect the circuit of Fig (3.2)
2. Set the signal generator to generate a periodic square waveform with 10Vp-p and frequency=500Hz , dc offset=5V.
3. Connect the oscilliscope to display the voltage response of the inductor.
4. Measure the time constant of the circuit and the steady state values of the voltage and current responses.
5. Determine the behavior of the voltage and current responses in relation to the element characteristic equation. discharge charge
6. Change the period of the periodic square wave to T=2τ_L and display the result.
7. Write your conclusion about the displayed waveform.

9.20

0.637 *9.20

ΔV = 5.86

τ = 224μ

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

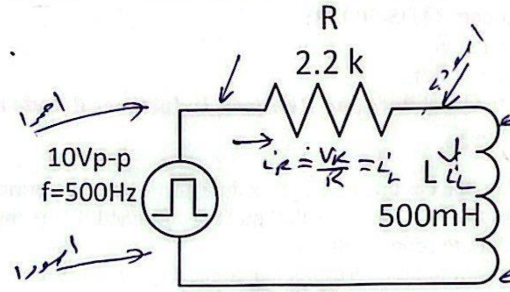


Fig (3.2)

5

-5

2.2 KHZ

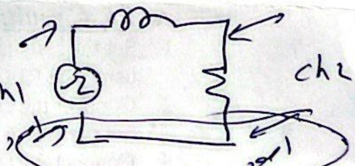
$= \frac{1}{2(220\mu s)}$

= 1/T

C. RLC Circuit:

I. Response type:

1. Connect the circuit of Fig (3.3)



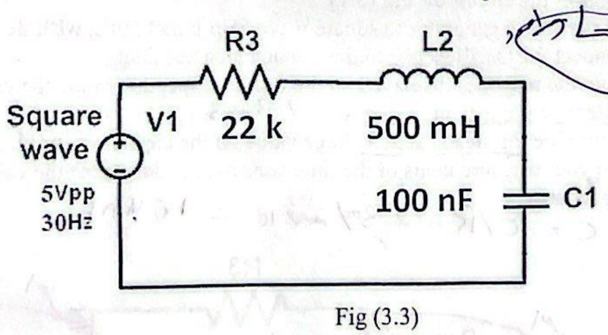


Fig (3.3)

2. Connect the oscilloscope to measure the voltage in the capacitor.
3. Set the signal generator to generate a periodic square waveform with ± 2.5 volts and 30Hz, dc offset=2.5V
4. Determine the type of the response. → over damped
5. Replace R3 by resistance decade box
6. Calculate the value of the resistance that satisfied the critical damping and the under damping conditions. R= 4.472k
7. Change the variable resistor with steps so that you can detect a change in the type of the response.

8. Refine your steps around the value for which the transition occurs so that to detect the transition point.
9. Determine the type of the response in each case.

II. Response parameters:

1. Set the value of R_x to (define value through test and confirm it with lab instructor) so that to get an under damped response
2. Use the cursor to measure the decay-envelope time constant (τ), the damping coefficient (α) and the damped frequency (ω_d) as shown in Figure 3.3.
3. Double the value of C1 and Measure the parameters defined in step2 noting the effect.
4. Reset the capacitance to its initial value
5. Reduce value of L2 to half its value and note the effect on previous parameters.

100 nF 2 in parallel

$V_o(\infty) = 5.08$ steady state.

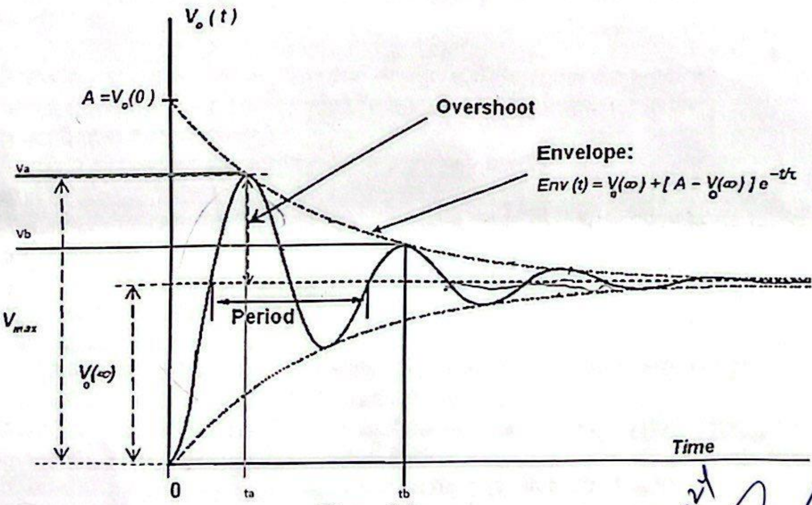


Figure 3.3

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

Damping Coefficient $\alpha = \dfrac{1}{\tau}$

Damped radian frequency $\omega_d = \dfrac{2\pi}{t_b - t_a}$

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Components List:

22kohm , 2.2kohm

100nF (2)
Resistance Decade Box
Inductance Decade Box