Lab Report 4

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February 24, 2025

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1 Objective

- Transient response of an LC circuit.
- Observation and Analysis of Damped Frequency from the Oscilloscope with Natural Frequency.
- Calculating Damping ratio (ζ) from observation.

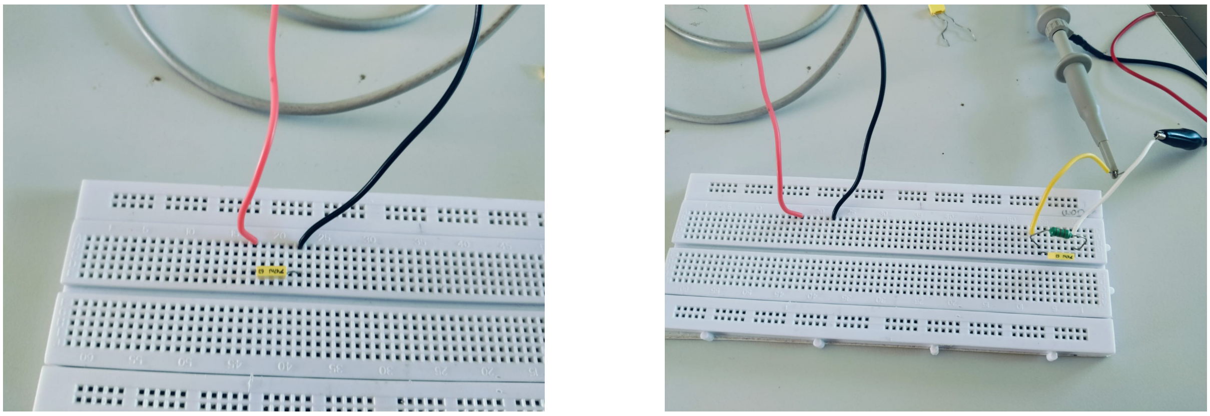
2 Apparatus and procedure

2.1 Materials

- Cathode ray Oscilloscope
- DC Voltage Generator
- Probes
- Connecting wires
- Breadboard
- Capacitor ($47nF$)
- Inductor ($2.2mH$)

2.2 Procedure

1. Connect the probe to DC Voltage generator and turn it on.
2. Set the Potential Difference to $5V$ and charge the Capacitor by applying Voltage across it.
3. Press Mode/Coupling button and then change sweep mode from auto to normal.
4. In the Trigger menu, press Mode until "Edge" is selected.
5. Then select Single mode. Wait until mode will initiate.
6. Carefully and quickly connect the capacitor in parallel to the inductor and capture the event response.
7. Using cursors, measure the time taken for each LC oscillations at one cycle in Oscilloscope.



(a) Charging the capacitor (b) Capacitor in parallel with the inductor

Figure 1: Experiment setup

3 Results

Using probe, the current in the circuit is recorded and following is displayed on the oscilloscope.

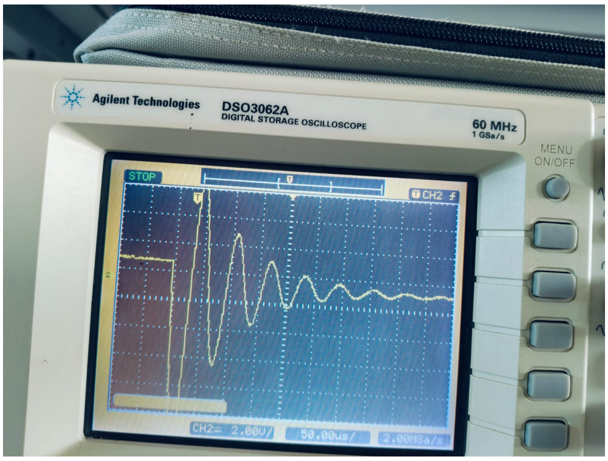


Figure 2: Current response of the circuit.

4 Theory

According to the chosen values of L, C and considering ideal conditions, i.e., net Resistance $= R = 0$, The value of Natural Frequency is

$$\Omega_N = \frac{1}{\sqrt{LC}} \approx 98.34 \times 10^3$$

But in the experiment, the circuit contains implicit Resistance. Its measured value is $\approx 24.2\Omega$. Considering a practical series RLC circuit, by applying KVL loop in RLC circuit and differentiating, we get

$$L\frac{d^2i}{dt^2} + R\frac{di}{dt} + \frac{1}{C}i = 0$$

The roots of the following differential equation are also roots of the following Characteristic equation:

$$s^2 + \frac{R}{L}s + \frac{1}{LC} = 0$$

Solving this Quadratic equation, we get roots as :

$$s = \frac{-R \pm \sqrt{R^2 - \frac{4L}{C}}}{2L}$$
$$s = -\alpha \pm \sqrt{\alpha^2 - \Omega_n^2}$$

where

$$\alpha = \frac{R}{2L} \approx 5.5 \times 10^3$$
$$\Omega_n = \frac{1}{\sqrt{LC}} \approx 98.34 \times 10^3$$

are damping factor and natural frequencies of the circuit respectively.
For the values of R, L and C, the roots are complex in nature $(\alpha < \Omega_n)$.Hence the current in the circuit as a function of time is in the form:

$$i(t) = e^{-\alpha t}(A\cos\omega t + B\sin\omega t)$$

From the above function, we can surely say that current is in Decaying Sinusoidal form as depicted by the oscilloscope, with the decay rate α. Here,

$$\omega = \sqrt{\Omega_n^2 - \alpha^2} = \sqrt{\frac{1}{LC} - \frac{R^2}{4L^2}}$$

Which is called as **Damped Frequency.** The theoretical value of Damped Frequency for our experiment is $\omega \approx 98.19 \times 10^3$

From the oscilloscope, time period of one cycle is $T = 6 \times 10^{-5}$. We know that $\omega = \frac{2\pi}{T}$. The observed value of damped frequency is $\omega = \frac{2\pi}{T} = \frac{2\pi}{6\times10^{-5}} \approx 104.71 \times 10^3$.

4.1 Impact of resistance on damping and oscillations:

Damping Factor is defined as a dimensionless quantity that measures how much the system is damped relative to its natural frequency.

$$\zeta = \frac{\alpha}{\Omega_n} = \frac{R}{2}\sqrt{\frac{C}{L}}$$

Depending on the value of Damping Ratio, which again depends on values of R, L and C, 3 types of Damping oscillations are classified:

- **Under Damped**$(\zeta < 1)$
- **Critically Damped**$(\zeta = 1)$
- **Over Damped**$(\zeta > 1)$

The damping ratio is directly proportional to the Resistance present in the circuit. Depending on the value of R, the circuit can undergo any of the 3 mentioned oscillations.

- For **Under Damped Oscillations**, $R < 2\sqrt{\frac{L}{C}}$, for our chosen inductor and capacitor, it should be less than 432.66 Ω. In this case the current varies sinusoidally along with decay.
- For **Critically Damped Oscillations**, $R = 2\sqrt{\frac{L}{C}}$, for our chosen inductor and capacitor, it should be equal to 432.66 Ω. In this case the current undergoes fastest non-oscillatory return to equilibrium.
- For **Over Damped Oscillations**, $R > 2\sqrt{\frac{L}{C}}$, for our chosen inductor and capacitor, it should be greater than 432.66 Ω. In this case the current varies slowly showing non-oscillatory behavior.

In our circuit, the value of R is 24.2Ω, which is less than 432.66Ω. Hence, the type of Oscillations the circuit has undergone are **Underdamped Oscillations**.

5 Precautions

1. Handle charged capacitors carefully to avoid accidental discharges.
2. Use appropriate rated components to prevent damage.
3. Ensure proper oscilloscope grounding to avoid erroneous readings.