UNIVERSITY
OF WOLLONGONG
IN DUBAI

LAB REPORT 6

LC AND RLC CIRCUITS

Subject: PHYS143 (DB123) Physics for Engineers
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PART A

1) Understanding faradays law

The occurrence of an emf or current in a conductor as a result of changes in the magnetic field surrounding the conductor is known as electromagnetic induction.

A coil, an ammeter, and a bar magnet can be used to show this in a simple way.

Faraday observed that exposing a length of wire to changing intensities of a perpendicular magnetic field flux produced a voltage across the wire.

Putting a permanent magnet adjacent to a wire or coil can produce magnetic field of changing intensity. When the ammeter deflects, it indicates that a current has been induced, and the direction and speed of the deflection can provide information about the direction and rate of the induced current. The induced emf is caused by a change in magnetic flux passing through the coil. The induced current is the current caused by the relative motion of the magnet and the coil. The current is related to the number of coils turns and the magnetic flux rate of change, and inversely proportional to the resistance.

2) Making a motor

1) Gather the necessary materials which include a battery or power source, a long copper wire, a magnet, a metal rod, and a piece of cardboard.

2) Cut a rectangular piece of cardboard, then firmly wrap wire around it to form the armature. Leave two long wire ends hanging from the cardboard's sides.

3) Place the metal rod on a flat surface and connect the magnet to one of the ends of the rod.

4) Put the armature onto the metal rod perpendicularly to the magnet. Make sure the two ends of the wire are in contact with the metal rod.

5) Connect the two ends of the wire to the power source or battery. The current will flow through the wire and create a magnetic field, which will create a force resulting in the rotation of the armature.

When an electric current flow through a coil of wire, it generates a magnetic field around the coil. The direction of the magnetic field is perpendicular to the direction of the current flow and can be determined using the right-hand rule.

In the simple electric motor shown in the video, an external permanent magnet is placed beneath the coil. When current is passed through the coil, the magnetic field generated by the coil interacts with the static magnetic field of the external magnet. This interaction creates a force that causes the coil to rotate. As the coil continues to rotate, the mechanical output can be extracted by connecting the coil to a shaft, which will also rotate.

3) Current generator

A current generator, also known as an electrical generator, is a device that converts mechanical energy into electrical energy by inducing an electromotive force (EMF) in a conductor. This EMF is produced due to the relative motion between a magnetic field and a conductor.

The basic principle behind all electrical generators is the same: a conductor is moved through a magnetic field, inducing a voltage or EMF across the conductor. This EMF can then be used to produce an electric current, which can be used to power various electrical devices.

Part B

The behaviour of a series RL circuit when a DC voltage is applied to it can be described by the following equations:

$$I_{max} = V_0 / R$$

Where Imax is the steady state current, V_0 is the applied voltage, and R is the total resistance of the circuit. However, in reality, the current does not reach its steady state immediately due to the inductor generating a back emf in response to the rising current. As a result, it takes some time for the current to reach its steady state value. This can be derived by the following equation:

$$I(t) = I_{max} (1 - e^{-t/\tau})$$

Where I(t) is the current at time t, Imax is the maximum current, and $\tau = L/R$ is the time constant of the circuit. The time constant represents the time it takes for the current to reach 63.2% of its steady state value.

The voltage across the resistor in the circuit can be described by the following equation:

$$V_R = V_0 - V_L$$

Where V_R is the voltage across the resistor and V_L is the voltage across the inductor. As the current exponentially increases, the voltage across the resistor also increases, while the voltage across the inductor decreases. It is important to note that this derivation assumes that there is no internal resistance in the inductor.

When the voltage is turned off, the inductor continues to maintain the current flow by generating a back emf in the opposite direction of the applied voltage. The voltage across the resistor and the current in the circuit both decrease exponentially with time, and the rate of decrease is determined by the time constant τ of the circuit. The behaviour of the circuit after the voltage is turned off can be described by the following equation:

$$V_R = V_0(e^{-t/\tau})$$

Where V_R is the voltage across the resistor at time t after the voltage is turned off and V_0 is the maximum voltage.

Part C (RL Circuit)

Purpose

The objective of this experiment was to observe how an RL circuit works and how the voltages across the resistor and inductor changes over time.

Hypothesis

It is expected that the sum of the voltage across the resistor and the voltage across the inductor will be equal to the max input voltage.

Materials

- Pulse voltage source
- Oscilloscope
- Resistor (150 Ω)
- Inductor (400 µH)
- Wires

Procedures

1) Calibrate the oscilloscope and function generator by setting the function generator to produce a square wave.
2) Read the values of the time period and voltage from the oscilloscope.
3) Connect a resistor of 150 Ω to the pulse voltage in series and connect channel A of the oscilloscope to the resistor.
4) Connect an inductor of 400 µH in series to the circuit and connect channel B of the oscilloscope to the inductor.
5) Complete the circuit by connect the inductor to the AC voltage.
6) The frequency of the input signal = $\frac{1}{f_{signal}} = T >> \tau = L / R$

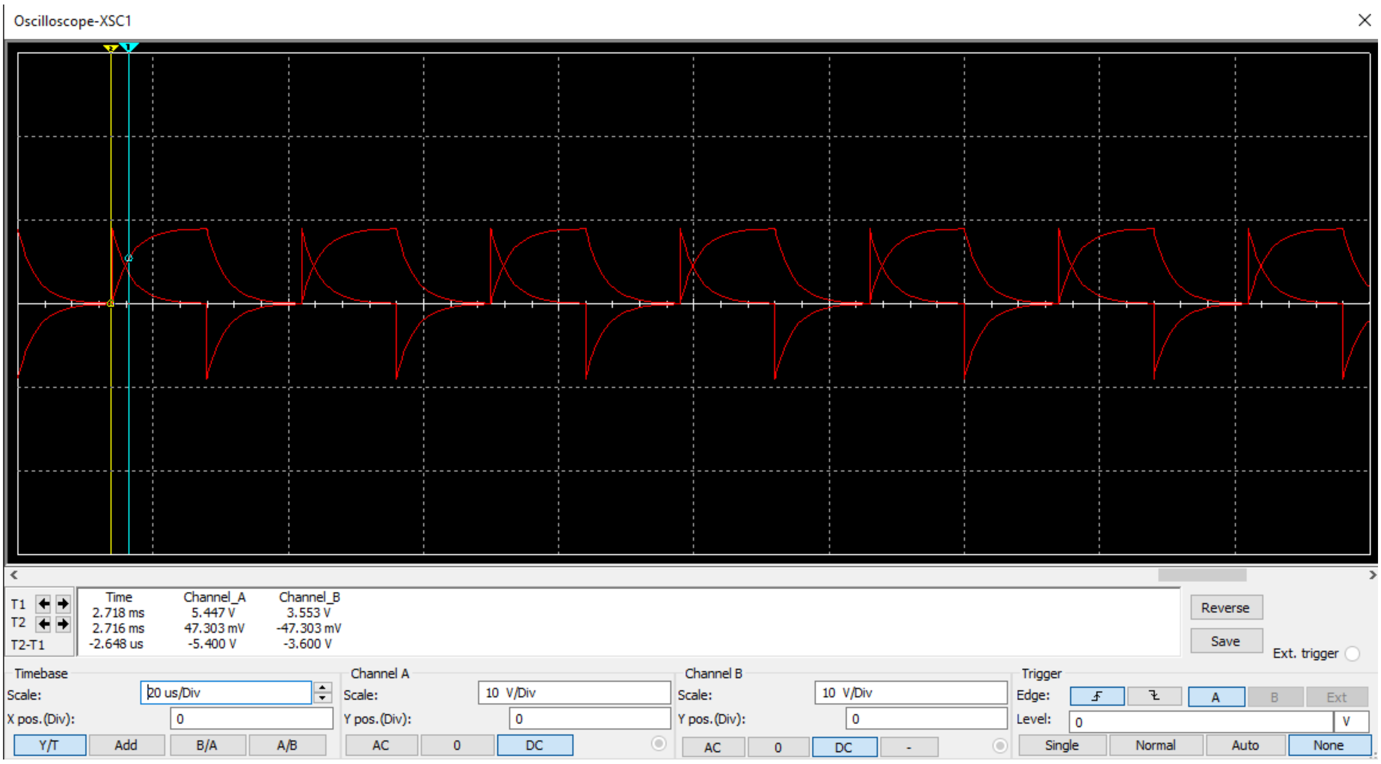
Data

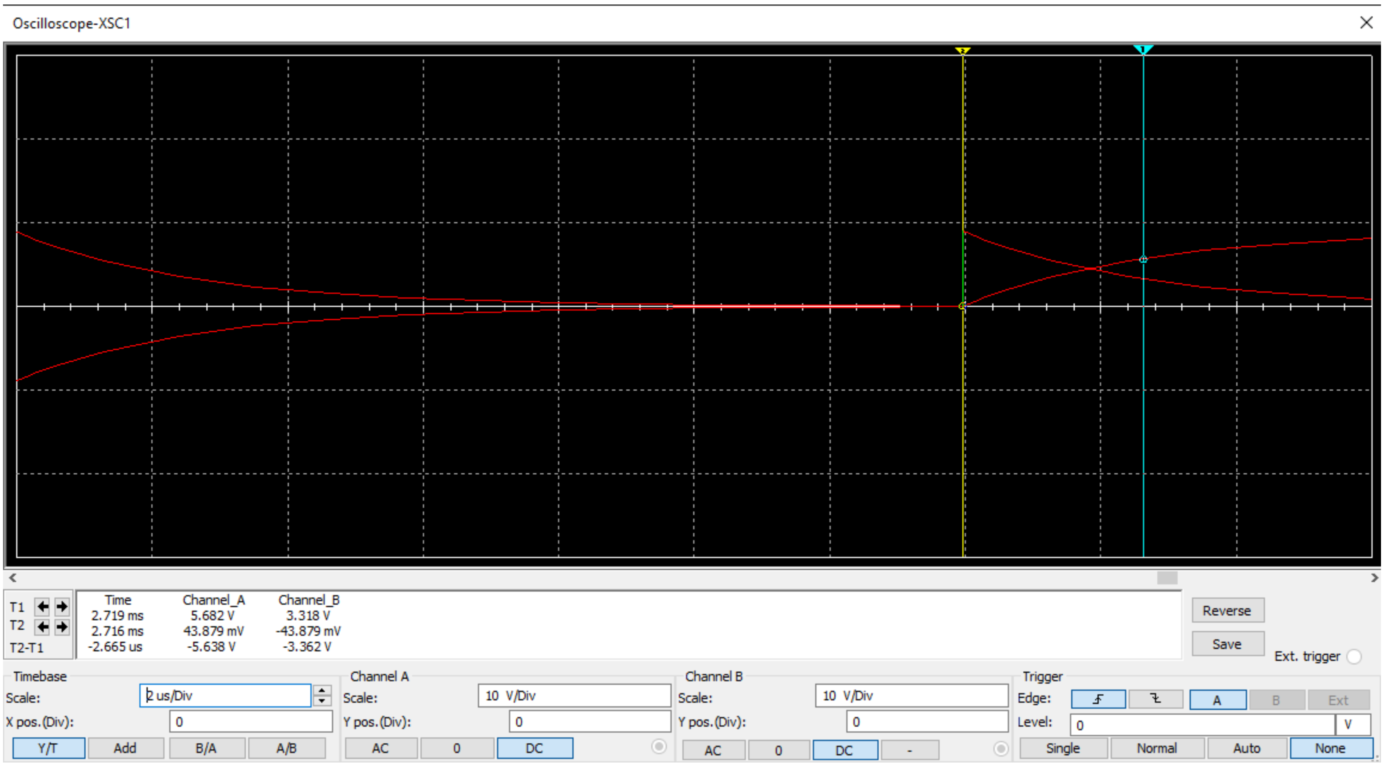
Recorded TIME/DIV on oscilloscope = 50 µs

Recorded VOLTS/DIV on oscilloscope = 10V

	R (Ω)	L (H)	τ (µs)	Input Voltage Max V_{max} (V)	Frequency (KHz)	T (µs)	Max Voltage (V_R)	Max Voltage (V_L)	$V_{max} - V_R$	$V_{max} - V_L$
EXP 1	150	0.4	2.67	9	37.5	28	8.955	8.766	0.045	0.234

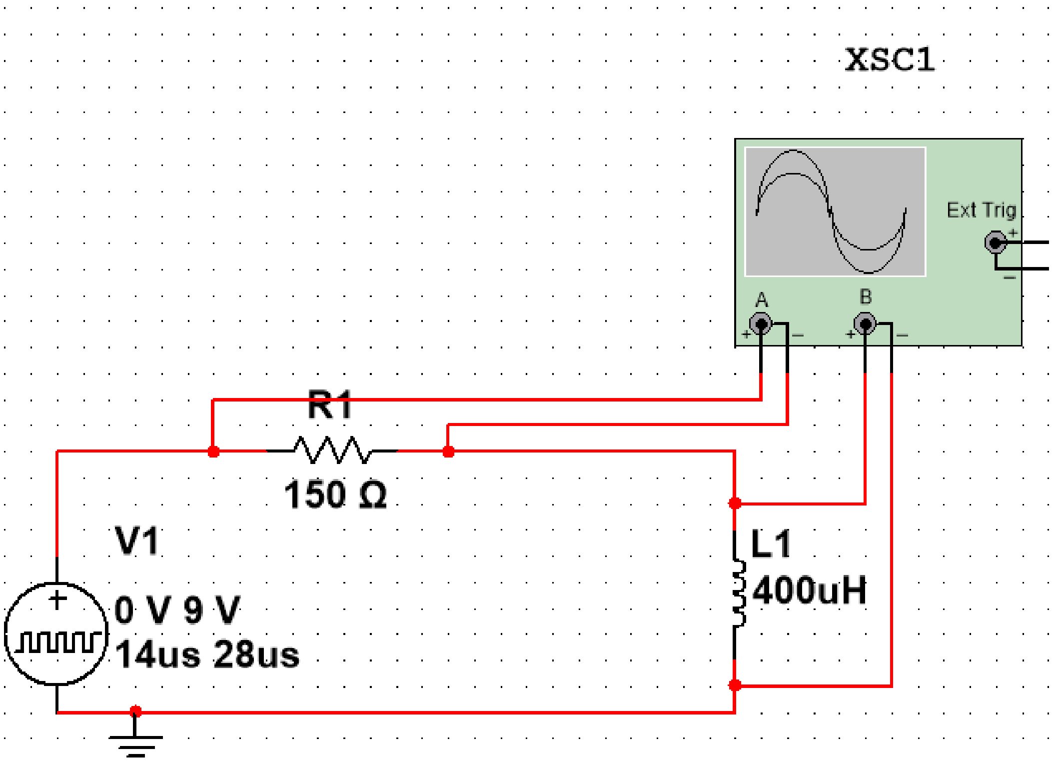
Graph





We took the value of V_R and V_L from the second graph since the value of τ is more accurate than the first graph.

Circuit



Calculations

τ = L/R = 0.0004/150 = 2.67 * 10^{-6}= 2.67 µs

Recorded value of V_R at time = τ is 5.682 V

Recorded value of V_L at time = τ is 3.318 V

Theoretical value of $V_R = V_{max}(1-e^{-t/\tau})$

V_R = 5.689 V; Recorded value of V_R similar to the theoretical V_R.

Theoretical value of $V_L = V_{max}(e^{-t/\tau})$

V_L = 3.311 V; Recorded value of V_L is similar to the theoretical V_L.

V_{max} = 9V

At τ the sum of V_R and V_L = V_{max}

5.682V + 3.318V = 9V

Frequency = 1/T and T= τ so, frequency = 1/2.67 * 10^{-6} = 37.5 KHz

Observations

As we can see from the calculations, theoretical values of V_R and V_L are similar to its calculated values.

Conclusion

The purpose of the experiment is to observe the behaviour of an RL circuit and the changes in voltage across the resistor and inductor over time. The hypothesis is that the sum of the voltage across the resistor and the voltage across the inductor will be equal to the maximum input voltage. The materials used include a pulse voltage source, oscilloscope, resistor, inductor, and wires. The procedures involve calibrating the equipment, connecting the resistor and inductor in series with the pulse voltage source, and measuring the voltage across each component using the oscilloscope. Finally, the circuit is completed by connecting the inductor to the AC voltage and the frequency of input signal is set. There were no sources of error in this experiment as we did this experiment on a simulation software called Multisim. The results of the experiment did make sense as the values obtained were closer to theoretical value.

We learnt how an RL circuit works and how time affects the voltages of the resistor and the inductor. If this experiment was repeated, then take different values of the resistor or inductor and observe if the sum of the V_R and V_L is equal to the input voltage.

In conclusion, the experiment was successful in demonstrating the behaviour of an RL circuit and how the voltages across the resistor and inductor change over time. Overall, the experiment provides a useful introduction to RL circuits and demonstrates how they can be used to control and manipulate electrical signals.

Part D (RLC Circuit)

Purpose

This experiment aims to understand the underdamped and overdamped oscillations in RLC circuits.

Hypothesis

From ohms law, we know that if resistance is high then we would have a low current which results in a larger damping ratio which means that it is more damped. So, we expect that the higher resistance graph will be more damped.

Materials used

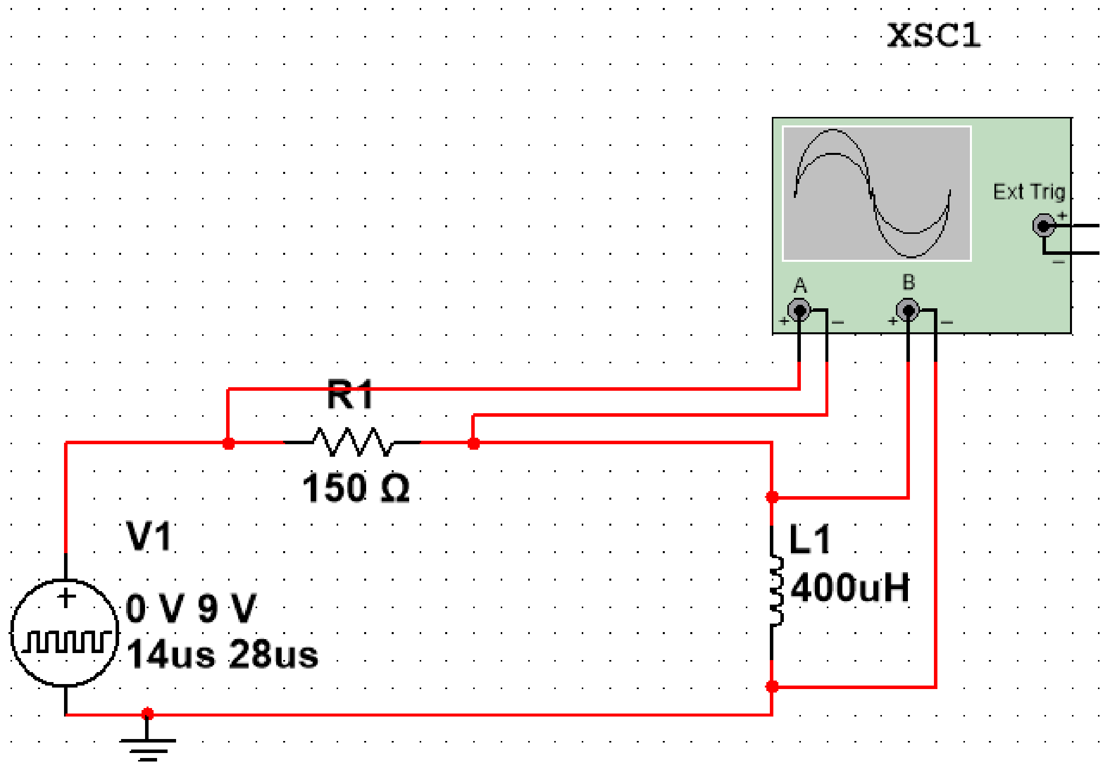
- Function generator
- Oscilloscope
- Resistors (50 Ω, 200 Ω, 300 Ω)
- Inductor (100 mH)
- Capacitor (10 μF)
- Wires

Procedures

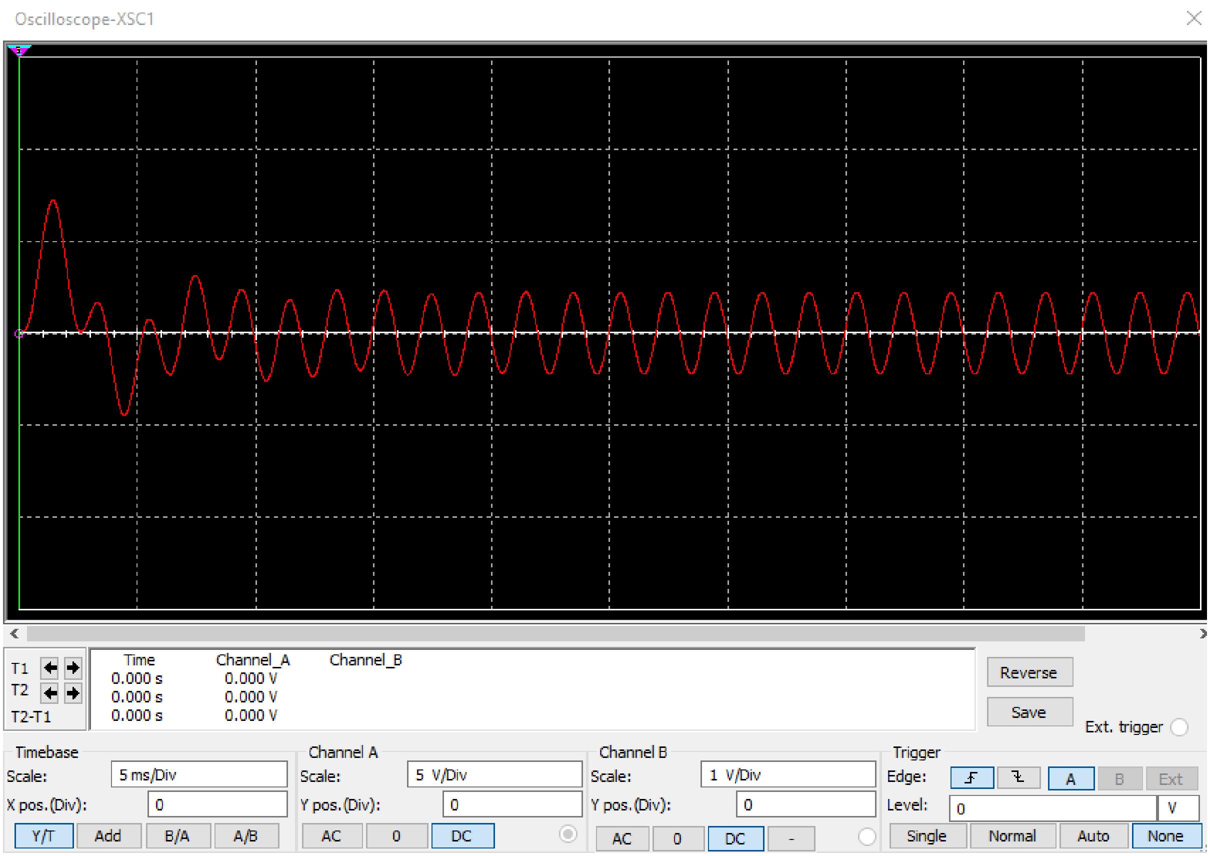
1) Gather the necessary equipment: RLC circuit, function generator, oscilloscope, and connecting wires.
2) Set up the RLC circuit by connecting the resistor (R), inductor (L), and capacitor (C) in series.
3) Set the values of R, L, and C to the desired values. For this experiment, use 3 values for R (50, 200, 300 ohms), a value for L (100mH), and a value for C (10 μF).
4) Connect the function generator to the circuit. Connect channel A of the oscilloscope to the capacitor to measure the voltage across it as a function of time.
5) Turn on the function generator and observe the oscillations on the oscilloscope. Adjust the time scale and voltage scale as necessary to obtain a clear view of the oscillations.
6) Record the values of R, L, C, and the maximum charge used. The maximum charge used can be calculated using the formula $Q = Q_{max}\, e^{-Rt/2L} \cos(\omega t)$.
   $\omega = \sqrt{[}\left(\frac{1}{LC} - \left(\frac{R}{2L}\right)^2\right]$
7) Plot the oscillations as a function of time, with voltage on the vertical axis and time on the horizontal axis. Make sure to label the axes and include units.

Graphs

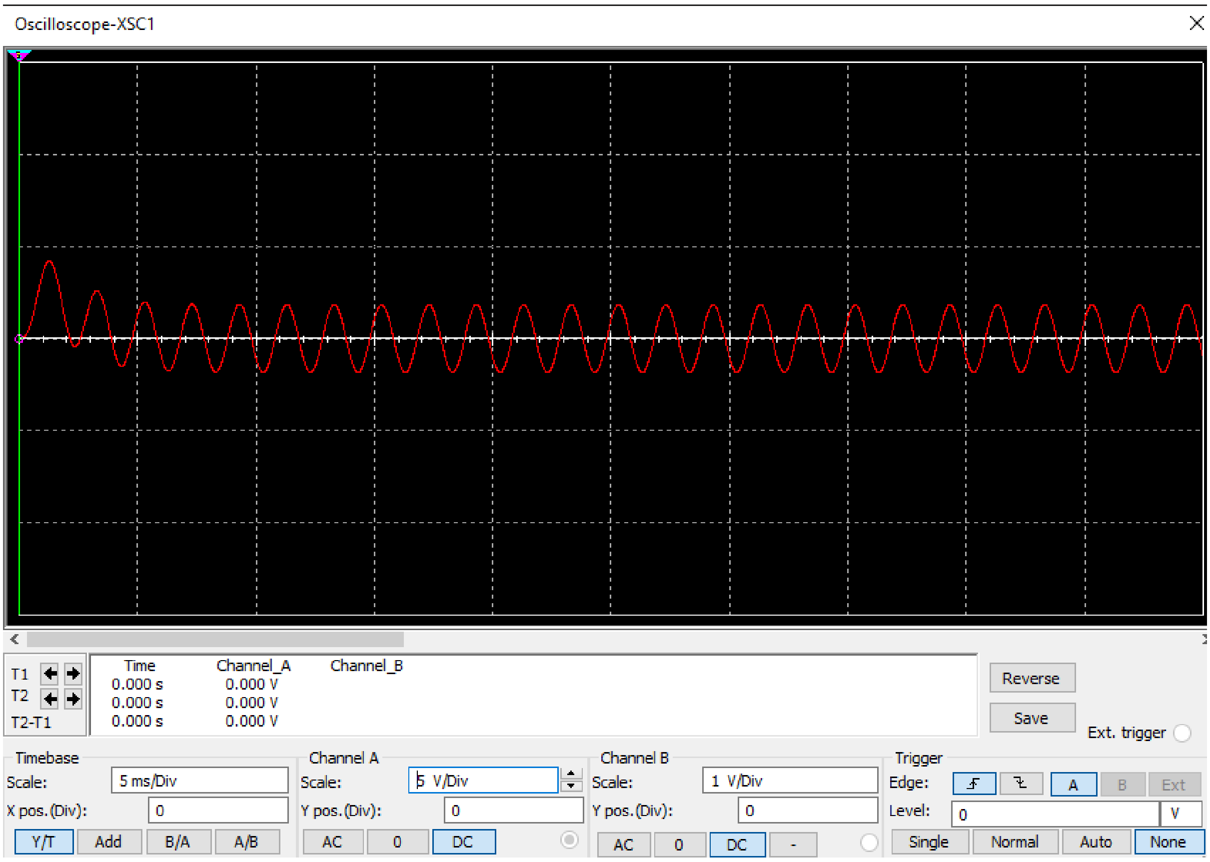
Circuit



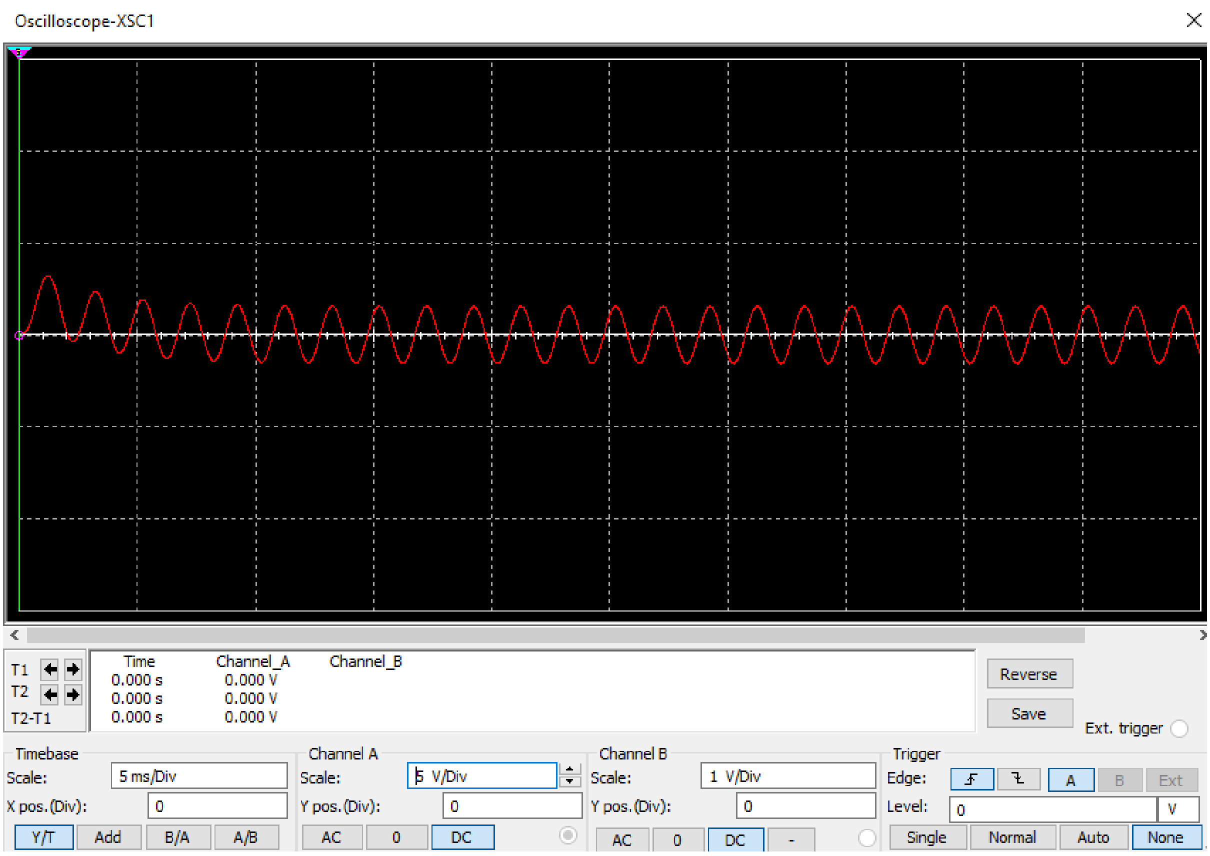
Graph for 50 Ω



Graph for 200 Ω



Graph for 300 Ω



Observation

As we can see from the graphs above, the 50 Ω graph is the underdamped graph. The graph showing the system's reaction to the disturbance in an underdamped system often resembles a series of oscillations that are fading, where each oscillation is less than the one before it. The graph will oscillate repeatedly around the equilibrium point, but as time passes, the oscillations' amplitude will steadily decrease.

Since the 300 Ω graph has a smaller amplitude, we can say that it is more damped than the 200 Ω graph. From ohms law, we know that if resistance is high then we would have a low current which results in a larger damping ratio which means that it is more damped. Since 300>200, 300 Ω graph will be more damped than the 200 Ω graph.

Conclusion

The objective of this experiment is to investigate the various types of oscillations in RLC circuits and to compare the resulting graphs.

The materials used in this experiment include a function generator, an oscilloscope, resistors, inductors, capacitors, and wires. T

he experimental procedures involve setting up the RLC circuit, connecting the function generator and oscilloscope, adjusting the time and voltage scales, recording data, and plotting the oscillations as a function of time. The maximum charge in the circuit can be calculated using the formula $Q = Q_{max}\, e^{-Rt/2L} \cos(\omega t)$ where $\omega = \sqrt{[}\left(\frac{1}{LC} - \left(\frac{R}{2L}\right)^2\right]$.

The experiment was later repeated using two different resistors of different resistances.

The aim of the experiment is to develop a better understanding of normal, underdamped, and overdamped oscillations in RLC circuits. No errors were encountered as the experiment was simulated using Multisim software. The results of the experiment were consistent with the anticipated outcomes based on theoretical predictions.

We learnt that the circuit with a resistor of higher resistance will have a more damped graph than a circuit with a resistor of lower resistance which can be shown on the oscilloscope.