Experiment 12: AC Circuits - RLC Circuit

Introduction

An inductor (L) is an important component of circuits, on the same level as resistors (R) and capacitors (C). The inductor is based on the principle of inductance - that moving charges create a magnetic field (the reverse is also true - a moving magnetic field creates an electric field). Inductors can be used to produce a desired magnetic field and store energy in its magnetic field, similar to capacitors being used to produce electric fields and storing energy in their electric field. At its simplest level, an inductor consists of a coil of wire in a circuit. The circuit symbol for an inductor is shown in Figure 1a.

So far we observed that in an RC circuit the charge, current, and potential difference grew and decayed exponentially described by a time constant τ. If an inductor and a capacitor are connected in series in a circuit, the charge, current and potential difference do not grow/decay exponentially, but instead oscillate sinusoidally. In an ideal setting (no internal resistance) these oscillations will continue indefinitely with a period (T) and an angular frequency ω given by

$$\omega = \frac{1}{\sqrt{LC}} \tag{1}$$

This is referred to as the circuit's natural angular frequency.

A circuit containing a resistor, a capacitor, and an inductor is called an RLC circuit (or LCR), as shown in Figure 1b. With a resistor present, the total electromagnetic energy is no longer constant since

(a) (b)

Figure 1: (a) Inductor circuit symbol. (b) An RLC circuit.

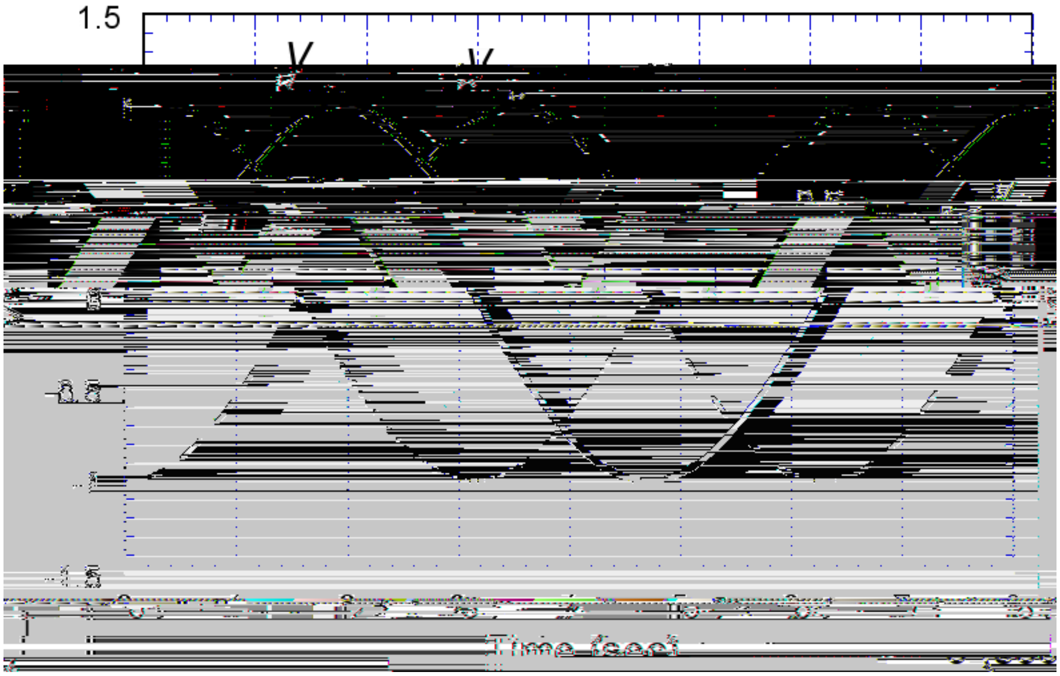

Figure 2: Phase relationships between voltages across the components of an RLC circuit. Using V_R as a reference, V_L leads by 90° while V_C lags by 90°. Note that the amplitude of the voltage for each component may not be equal as depicted but depend on the specific values of L, R and C.

In this lab we will only discuss *series* RLC circuits. Since the R, L, and C components are in series, the same current passes through them. The current in the circuit can be expressed in the form of Ohms Law as

$$I = \frac{E_0}{Z} \tag{6}$$

where Z is the *impedence* of the circuit defined as

$$Z = \sqrt{R^2 + (\omega L - \frac{1}{\omega C})^2} \tag{7}$$

The impedance of a circuit is a generalized measurement of the resistance that includes the frequency

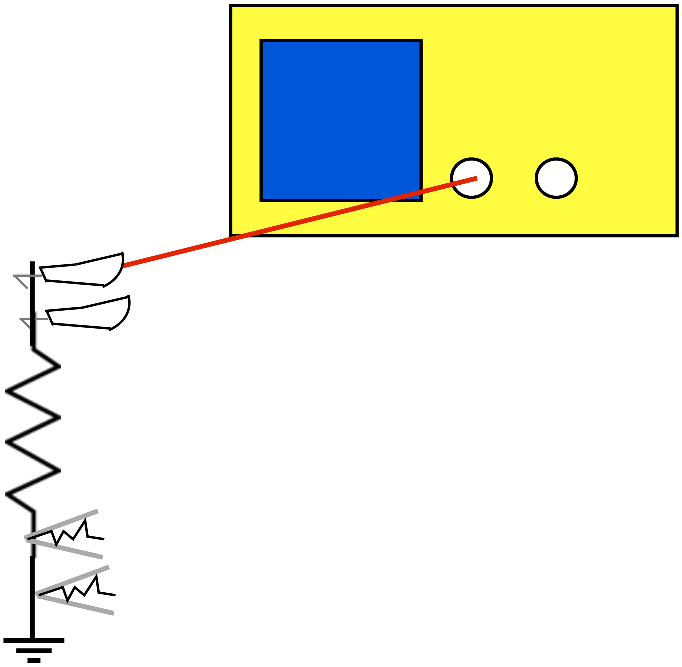

Figure 3: Oscilloscope connection for alternating current circuit. Note that only the resistor part of the RLC circuit is shown.

8. Change the settings to obtain the signal as in Procedure 5-6. Disconnect CH2 from the circuit and connect it to Point A as shown in Figure 1b. In this position, CH1 is still measuring the voltage across the resistor (V_R), but CH2 is now measuring the voltage across all three components (V_{RLC}). Adjust the vertical and horizontal scales to obtain the best display.
9. Are the two signals in phase with each other? Does V_{RLC} lead or lag V_R,and by how much? Sketch this in your report.
10. Observe the Lissajous figure for these two signals by repeating Procedure 7. Is this identical to the one you observed before? Sketch this in your report. You should now know what the Lissajous figure should look like when the signals are in phase and out of phase with each other.
11. Change the settings back to obtain the signal as in Procedure 8-9 (using the format button), but this time, set the display to show only the signal from CH1, which is V_R. You should, however, leave CH2 connected as is.
12. Change the frequency of the signal generator (hint: you may 0,]TJV_R/F19i08pe358(o8pe358inc9sst43181 cb346k

($X_C = 1/\omega C$) should cancel each other so that the impedence of the circuit just depends on the resistor. This means that V_{RLC} should be in phase with V_R. Is this what you observe?

14. Check this by observing the Lissajous figure at the resonant frequency. If the figure does not quite