

A Series RLC Circuit

This lab will let you learn the characteristics of both amplitude and phase of a series RLC circuit.

Theory

Inductors and Capacitors

Resistors (R), inductors (L) and capacitors (C) are passive components commonly used in AC electrical circuits. An inductor shown in Figure 1a is usually constructed as a coil of conducting material, typically copper wire, wrapped around a core either of air or of ferromagnetic material. Figure 1b shows several large inductors seen commonly in AC circuits.

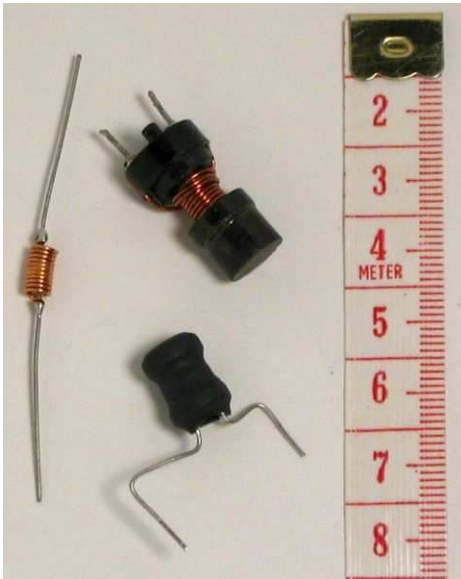


Figure 1a Three small inductors are shown to show what inductors look like



Figure 1b Three large inductors

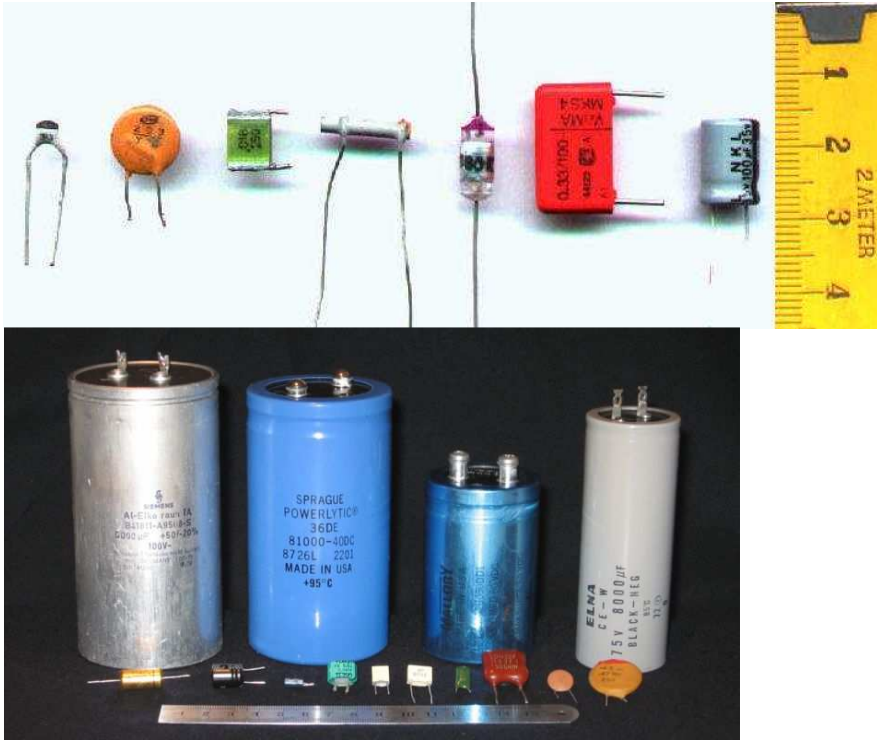


Figure 2 Various types of capacitors. From left in the up part: multilayer ceramic, ceramic disc, multilayer polyester film, tubular ceramic, polystyrene, metallized polyester film, aluminium electrolytic. Major scale divisions are cm. The lower part shows various capacitors with high values of capacitances.

A capacitor is an electrical/electronic device that can store energy in the electric field between a pair of conductors (called "plates"). Figure 2 shows various types of capacitors.

RLC series circuit

If the angular frequency of an AC signal applied from the function generator is ω ($=2\pi f$) the impedance Z of a RLC series circuit is thus:

$$Z = R + i(\omega L - \frac{1}{\omega C}) \quad (1)$$

where R -the resistance in Ω of the resistor, L -the inductance in H of the inductor and C -the capacitance in F of the capacitor and $i = \sqrt{-1}$. The current passing through the circuit is equal to:

$$I = \frac{V_0}{R + i(\omega L - \frac{1}{\omega C})} \quad (2)$$

There are two kinds of characteristics, of amplitude and of phase, we need to study for the RLC circuit. The amplitude of I equals to

$$|I| = \frac{V_0}{\sqrt{R^2 + (\omega L - \frac{1}{\omega C})^2}} \quad (3)$$

Certainly, when the frequency f equals to the resonant frequency $f_0 = \frac{1}{2\pi\sqrt{LC}}$ the Equation (3) is simplified just to V_0/R . The phase θ of I is determined by

$$\theta = \tan^{-1}\left(\frac{\omega L - \frac{1}{\omega C}}{R}\right) \quad (4)$$

We can conclude from Equation (3) and (4) that the amplitude $|I|$ reaches a maximum value while the phase θ becomes zero when the frequency f equals to the resonant frequency f_0 . Also, we can find that the phase of I is negative (capacitance) if f is less than f_0 and is positive (inductance) if f is greater than f_0 (see Figure 4b).

Pre-Lab

1. Using PSpice, draw a RLC circuit as pictured as Figure 1 and choose $R=38\Omega$, $C=0.1\mu\text{F}$ and $L=1.2\text{mH}$ and VSIN source (AC=5, DC=0, VAMPL=5, FREQ=10K). Simulate it by using of *AC Sweep*. Find what the resonant frequency $f_0 (= \frac{1}{2\pi\sqrt{LC}})$ is.
2. Simulate the above RLC circuit by using of Transient. Find the phase different between V_0 and I , or between V_0 and V_R .

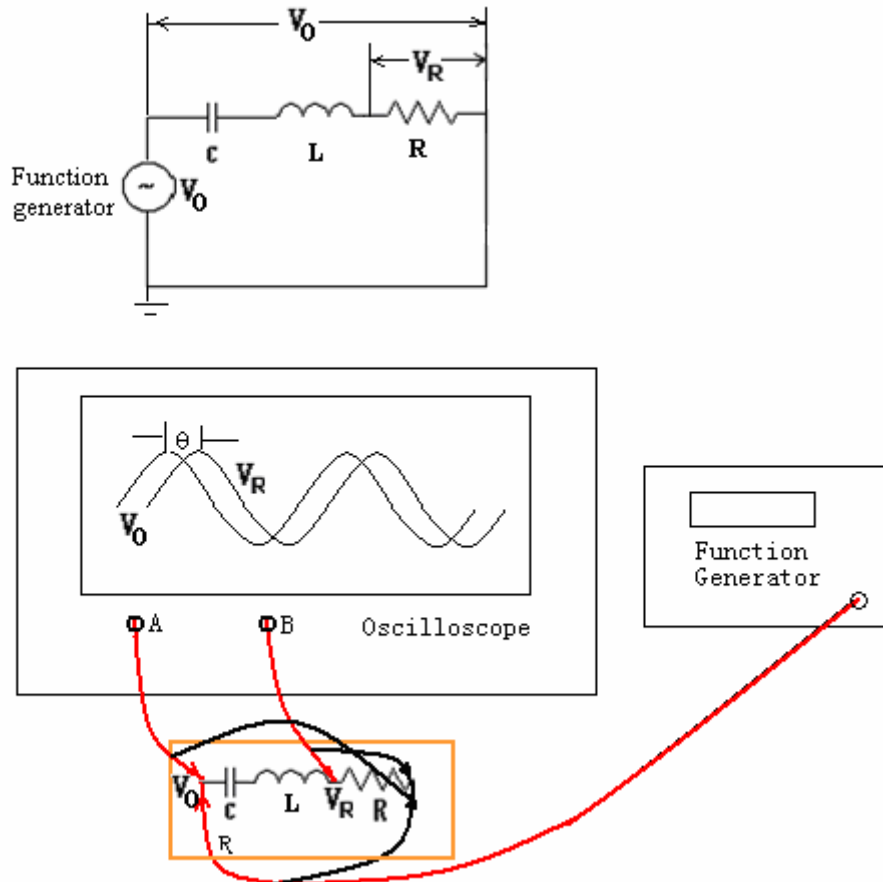


Figure 3 A series RLC circuit with a sinusoidal source applied for measuring its amplitude and phase characteristics

Procedure

1. Construct a circuit as shown in Figure 3. Pay attention to the positive and negative terminals of the cables from the function generator, and also to that of the cables to connect to the oscilloscope.
2. Drive the circuit by a sine wave from a function generator and connect the oscilloscope channel 1 to the function generator V_0 and channel 2 to the resistor R .
3. Change the frequency of the function generator from 2 KHz up to 30 KHz. Measure and fill the voltages on R (the curves I and V_R versus the frequency f are exactly same) for 15 different frequencies into the following table. Try to keep V_0 as constant as you can. Find where the resonant frequency is.

$f(KH)$	2	4	6	8	9	10	11
I							
$f(KH)$	12	13	14	15	16	17	18
I							
$f(KH)$	19	20	22	24	26	28	30
I							

4. Change the frequency of the function generator from 2 KHz up to 30 KHz. Measure the phase difference between V_R and V_0 for 15 different frequencies and fill them into following table. Your results should be similar to Figure 4. The method of measuring the phase difference between two waves is demonstrated in Figure 5 and is by using of following equation

$$\theta = (AB / AC) \cdot 360^\circ \quad (5)$$

Try to keep V_R and V_0 having equal amplitudes (peak-to-peak) so that you will be easy to measure AB and AC . Find what θ are at all 15 frequencies, especially find what θ is at the resonant frequency.

$f(KH)$	2	4	6	8	9	10	11
θ (degree)							
$f(KH)$	12	13	14	15	16	17	18
θ (degree)							
$f(KH)$	19	20	22	24	26	28	30
θ (degree)							

5. Draw two curves ($|I|$ and θ versus f) and submit them with your lab report. Compare your measurement with your simulation of pre-lab and discuss your results. If they don't coincide with each other discuss where the error comes from.

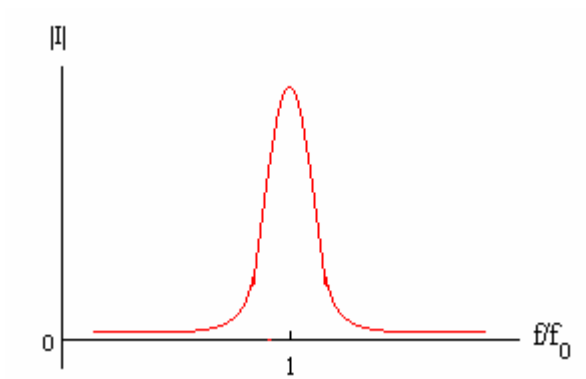


Figure 4a The amplitude characteristics of I versus f/f_0

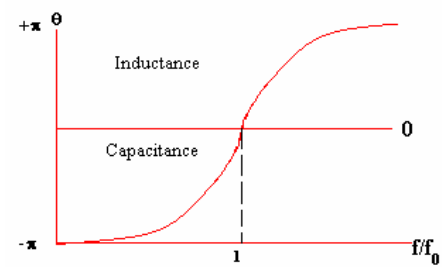


Figure 4b The phase characteristics of I versus f/f_0 .

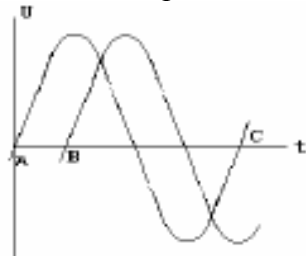


Figure 5 Measuring phase between two waves