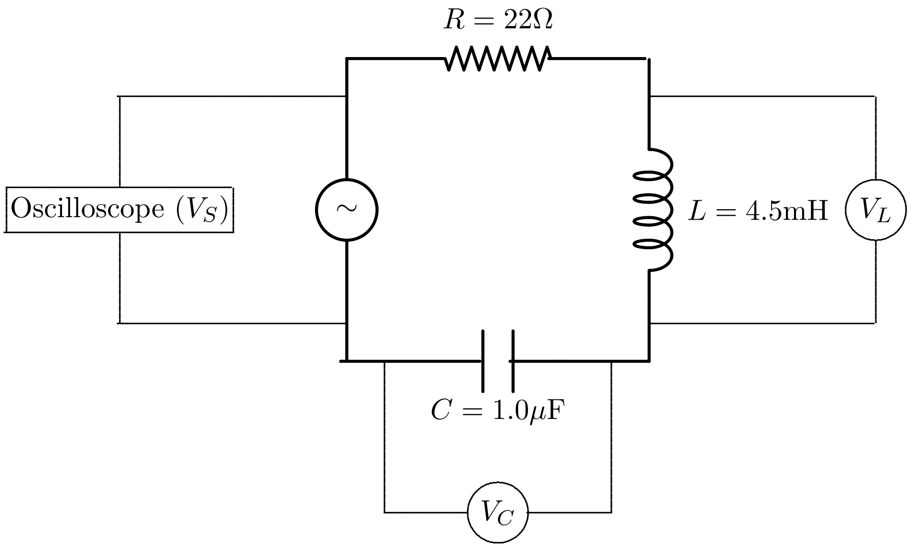
AC RLC Circuit*

Object

To measure frequency dependence of voltages across components of a series RLC circuit with AC input.

Theory



A series RLC circuit with AC input is shown above. A voltmeter is connected across the inductor to measure the rms voltage V_L across it. Similarly, another voltmeter measures the rms voltage V_C across the capacitor. An oscilloscope is connected across the source function generator to observe the waveform as well as measure the rms voltage V_S delivered. A sinusoidal input voltage from the source is written as follows.

$$V = V_m \sin(\omega t), \quad V_m = \sqrt{2} V_S, \quad \omega = 2\pi f,$$

where V_m is the maximum voltage, t is time, ω is the angular frequency of the source and f is the frequency in cycles/sec (or Hertz or Hz). From theory, it is known that

$$V_L = X_L V_S / Z, \quad \text{and} \quad V_C = X_C V_S / Z,$$

where

$$X_L = \omega L, \quad X_C = 1/(\omega C), \quad Z = \sqrt{R^2 + (X_L - X_C)^2},$$

R is the resistance of the resistor, L the inductance of the inductor and C the capacitance of the capacitor. V_L and V_C, being rms values, do not give instantaneous values of voltages. The actual voltages across the capacitor and inductor are instantaneously always opposite to each other. Hence, when $V_L = V_C$, they cancel each other and the circuit has a maximum current. This is the condition of resonance. From the above formulas, it can be seen that resonance occurs for $\omega = \omega_R$ ($f = f_R$) where

$$\omega_R = 1/(\sqrt{LC}), \quad f_R = 1/(2\pi\sqrt{LC}).$$

The measurement method

The AC source voltage V_S is provided by a function generator. For the present experiment, the sinusoidal function needs to be chosen and the frequency range of 1kHz is appropriate. The "frequency" knob and the "fine" knob are used to select frequency. The oscilloscope measures V_S and displays its waveform. The "voltage measure" button displays measurement options on the screen. Choose the V_{rms} option to measure V_S. Use "input channel 1" for the measurement. V_L and V_C are measured by two voltmeters. Use Microsoft Excel to plot the three voltages against frequency.

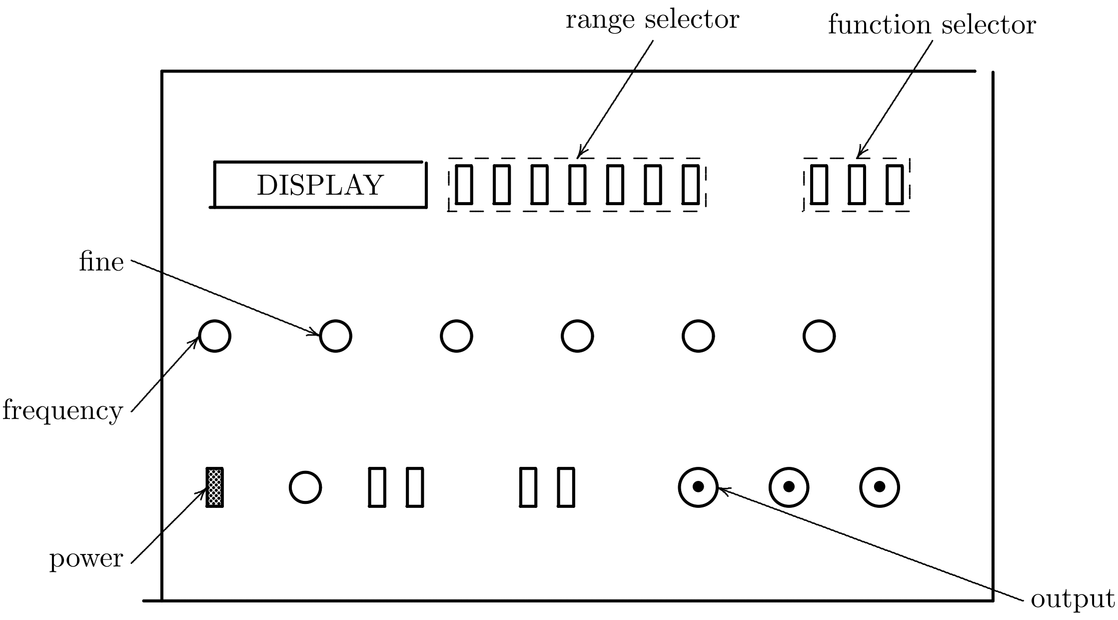
Some trials

Experimental measurement of f_R can be made by measuring V_L and V_C for a range of frequencies and plotting them on the same graph against frequency. Choose the range of frequencies so it covers a significant region on either side of the theoretically computed value for f_R. The frequency at which the V_L and V_C curves intersect must be the resonant frequency by definition. To locate the intersection point accurately, fit a straight line to each curve for data points close to the intersection. The fitted straight line equations can be used to find the intersection point. Compare the experimental and theoretical values of f_R.

You could also plot $(V_L - V_C)$ against frequency. This curve should intersect the frequency axis at the resonant frequency.

It is interesting to note that the voltage source has a small internal resistance. Hence, at resonance, when the current is a maximum, there is a maximum drop of voltage across this internal resistance. This makes the measured voltage V_S across the source to be a minimum at resonance. This provides a second method for determining f_R. In a plot of V_S versus frequency the minimum point gives f_R. To locate the minimum point accurately, it is useful to fit a polynomial of second degree (a parabola) to a small range of data points around the minimum. The minimum of the parabola can be found from its equation.

Function Generator



Oscilloscope