Experiment 4
Resonance and Maximum Power Transfer

PART 1: To find the resonance frequency and Q factor of RLC circuit.

In RLC circuit, the frequency at which the inductive reactance of the inductor becomes equal to the capacitive reactance of the capacitor is called resonance frequency (f_c) of the circuit. At the resonance frequency maximum current I_{max} will flow through the circuit.

At resonance frequency:-

$$X_L = -X_C \text{, or, } X_L + X_C = 0$$

where $|X_L| = 2\pi f L$ and $|X_C| = \frac{1}{2\pi f C}$. Therefore,

$$2\pi f L = \frac{1}{2\pi f C} \text{, so that } f_c = \frac{1}{2\pi\sqrt{LC}}. \quad (1)$$

The frequency response curve (Figure 1) of a series resonance circuit (Figure 2) shows that the magnitude of the current is a function of frequency and plotting this onto a graph shows that the response starts at near to zero, reaches maximum value at the resonance frequency and then drops again to nearly zero as *f* becomes infinite. The voltages across the inductor *L* and the capacitor *C* can become many times larger than the supply voltage, when the circuit is close to and at resonance, but as they are equal and in opposition, they cancel each other, leaving behind only the resistive voltage drop, which will equal the supply voltage in magnitude. Thus the Kirchhoff voltage Law is not violated. The sharpness of the peak of frequency response curve is measured quantitatively by the so-called Quality Factor, *Q* of the circuit.

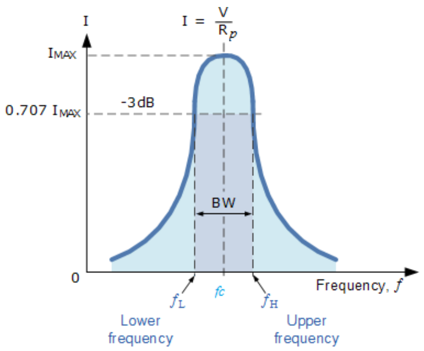

Fig.1: Frequency response of RLC circuit

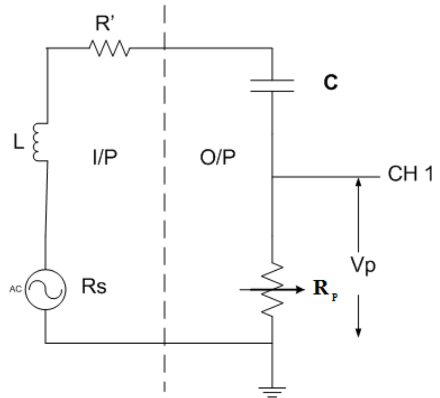

Fig.2: RLC circuit

Experiment.

A. Find the resonance frequency: (4 marks)

1. Wire the RLC circuit of Figure 2. The value of the circuit components are taken as: $L = 1$mH, $C = 0.1\mu$F and $R' = 500\Omega$, and a 1$k\Omega$ potentiometer.
2. Set the value of potentiometer (variable resistance) $R_p = 500\Omega$, using a digital multimeter to adjust its resistance.
3. Connect the channel 1 of DSO to the point CH 1 of circuit. It gives the voltage V_p across the potentiometer R_p.
4. Apply an input through the function generator whose internal resistance is $R_s = 50\Omega$.
5. Now vary the frequency of the function generator from 500 Hz to 500 kHz and calculate the value of circuit current $I = V_p/R_p$ for each frequency. Plot I vs f to get a curve similar to Fig.1 on semi log paper.
6. Find the frequency at which current *I* is maximum. This frequency is called the resonance frequency f_c. of the

circuit.

7. Now, verify the observed resonance frequency with the frequency calculated by equation 1.

B. Find the Q factor of the circuit. (4 marks)

1. Set the potentiometer value: $R_p = 500\Omega$
2. From the I vs f response plot made above. Vertical axis is the current value and horizontal axis is the log of the corresponding frequency value.
3. Q factor is defined as: $Q = \frac{f_C}{BW}$. where $BW = f_H - f_L$. f_H is the higher cut off frequency, the frequency above f_C when the current is equal to $\left(\frac{1}{\sqrt{2}}\right) \times I_{max}$. Similarly, f_L is the lower cut off frequency, the frequency below f_C when the current is equal to $\left(\frac{1}{\sqrt{2}}\right) \times I_{max}$.
4. Verify the calculated Q factor value against the theoretical value $Q = \frac{X_L}{R} = \frac{X_C}{R}$, where

   $R = R_p + R' + R_s$ is the total resistance of circuit,.

5. Repeat the step B for one more potentiometer values (say $R_p = 250\Omega$) and draw the

   resonance curve I vs. f again.

PART **2: Maximum Power Transfer**

The power transferred from a source to a load is at its maximum when the resistance of the load is equal to the internal resistance of the source and the circuit reactance is zero.

Experiment.

A. RLC circuit: (7 marks)

1. Use the already wired circuit of Fig.2. Retain the frequency of the source at resonance frequency f_C found in Part 1 for the rest of the experiment.
2. Vary the value of R_p and calculate the power $P = V_p^{\,2}/R_p$ for each value of R_p. For this, keep a jumper to connect Rp to the rest of the circuit. Each time, open the jumper to take the resistor out of the circuit, put it across the multimeter, and adjust the value by turning the potentiometer knob until you read the resistance you wanted to set. Now, remove the multimeter and restore the jumper, putting the potentiometer Rp back in the circuit. Note the new values of Vp nd Rp. Repeat and tabulate Vp, Rp and P.
3. Find R_p at which power P is maximum and verify that this happens at $R_p = R_s + R'$.

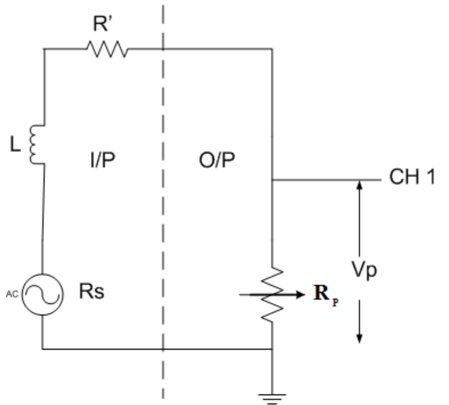

Fig.3: RL circuit

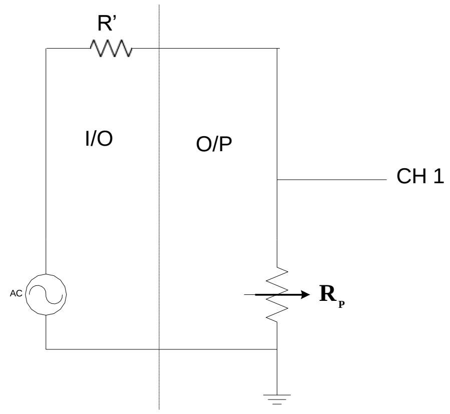

Fig.4: R circuit.

B. RL circuit:

1. Get the circuit of Fig.3 by removing the capacitor in Fig.2 (and substituting it with a shorting wire). Keep the frequency of the source at f_C .
2. Vary the value of R_p and calculate the power $P = {V_p}^2/R_p$ for each value of R_p.
3. Find R_p at which power *P* is maximum and verify that $R_p = \sqrt{(R' + R_s)^2 + X_L^2}$

C. R circuit:

1. Get the circuit of Fig.4 by removing the inductor in Fig.3 (and substituting it with a shorting wire).. Keep the frequency of the source at f_C .
2. Vary the value of R_p and calculate the power $P = {V_p}^2/R_p$ for each value of R_p.
3. Find R_p at which power *P* is maximum and verify that $R_p = R' + R_s$