Experiment: 8

FREQUENCY RESPONSE OF LCR CIRCUIT

AIM: To study the frequency response of the series and parallel resonance circuits. And to determine the resonant frequency, bandwidth and quality factor

APPARATUS: Signal generator, Inductor, Capacitor, resistor, ammeter

INTRODUCTION:

LCR circuit is an electrical circuit consisting of a resistor, an inductor, and a capacitor, connected in series or in parallel. Resonance in AC circuits implies a special frequency determined by the values of the resistance , capacitance , and inductance . For series resonance the condition of resonance is straightforward and it is characterized by minimum impedance and zero phase. For Parallel resonance , impedance is maximum at resonance.

Series resonance circuit

The resonance of a series RLC circuit occurs when the inductive and capacitive reactance are equal in magnitude but cancel each other because they are 180 degrees apart in phase. The sharp minimum in impedance which occurs is useful in tuning applications.

In a circuit containing R, L and C connected in series the impedance is given by

$$|Z| = \sqrt{R^2 + (X_L - X_C)^2} \quad \text{Or} \quad |Z| = \sqrt{R^2 + (\omega L - \frac{1}{\omega C})^2}$$

The effective reactance is inductive or capacitive depending upon $X_L > X_C$ or $X_L < X_C$. The inductive reactance X_L is directly proportional to the frequency and increases as the frequency increases from zero onwards. The capacitive reactance is inversely proportional to the frequency, decreases from an infinite value downwards. At certain frequency both reactances become equal and this frequency is called resonant frequency (f_r). At resonant frequency the two reactances are equal i.e., $X_L = X_C$ (or) $X_L - X_C = 0$.

Therefore $$\mathbf{f_r} = \frac{1}{2\pi}\sqrt{\frac{1}{LC}} \ \mathbf{Hz}$$

The sharpness of the minimum depends on the value of R and is characterized by the "Q" of the circuit. Q- factor of LCR circuit is defined as the ratio of energy stored to the energy dissipated across resistance .i.e.

$$Q = \frac{2\pi f_r L}{R} = \frac{1}{R}\sqrt{\frac{L}{C}} = \frac{f_r}{f_2 - f_1}$$

Parallel resonance circuit:

Here a coil (L) and capacitor (C) are connected in parallel with an AC power supply. When X_L equals X_C, the reactive branch currents are equal and opposite. Hence they cancel out each other to give minimum current in the main line. Since total current is minimum, in this state the total impedance is maximum. The resonant frequency of a parallel LCR circuit is given by,

$$\mathbf{f_r} = \frac{1}{2\pi}\sqrt{\frac{1}{LC} - \frac{R^2}{L^2}} \ \mathbf{Hz}$$

If $(R/L)^2$ is negligible in comparison to (1/LC) then

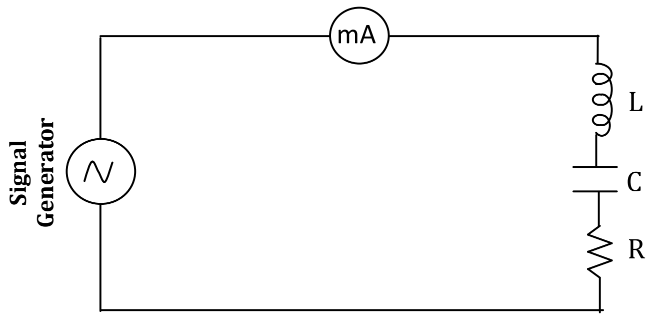
$$\mathbf{f_r} = \frac{1}{2\pi}\sqrt{\frac{1}{LC}} \ \mathbf{Hz}$$

This is same as for series circuit. For parallel LCR circuits, the current at resonance is minimum.

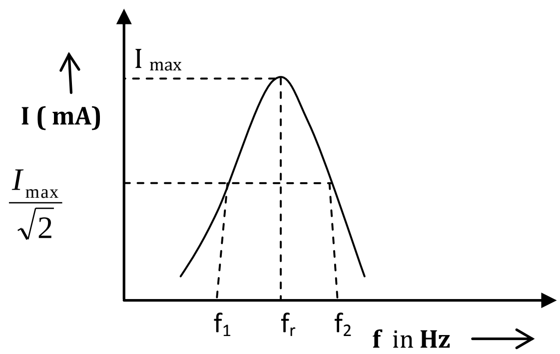
There are many applications for this circuit. An important property of this circuit is its ability to resonate at a specific frequency, the resonance frequency. They are used in many different types of oscillator circuit. Another important application is for tuning, such as in radio receivers or television sets, where they are used to select a narrow range of frequencies from the ambient radio waves. An RLC circuit can be used as a band-pass filter or a band-stop filter.

<u>CIRCUIT DIAGRAM</u>:

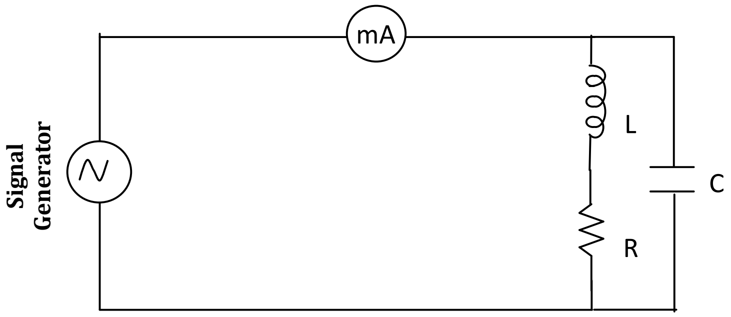
Series LCR circuit:



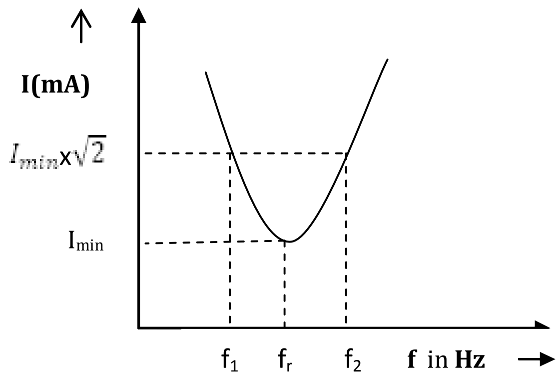
Nature of graph:



Parallel LCR circuit:



Nature of graph:



FORMULAE:

1. $L = \dfrac{1}{4\pi^2 f_r^2 C}$

2. $\Delta f = f_2 - f_1$

3. Quality factor (Series LCR) (Theoretical) = **Q** = $\dfrac{1}{(R+r)}\sqrt{\dfrac{L}{C}}$

4. Quality factor (Experimental) = **Q** = $\dfrac{f_r}{f_2 - f_1}$

Where,

C is the capacitance of the capacitor in F
Δf is the bandwidth in Hz
r is the internal resistance of the inductor in Ω
L is the inductance of the inductor in H
R is the resistance of the resistor in Ω
f_r is the resonant frequency in Hz
f_1 is the upper cut off frequency in Hz
f_2 is the lower cut off frequency in Hz

PROCEDURE:

1. The connections for series LCR circuit are made as shown in the circuit diagram.
2. The frequency of ac signal is increased in the steps given and corresponding current readings are tabulated.
3. A plot of frequency v/s current is drawn.
4. From the graph, the resonant frequency (fr) and bandwidth are calculated.
5. The Quality factor (Q) and inductance (L) are calculated using the given formulae.
6. The same procedure is repeated for parallel LCR circuit as well.

TABULAR COLUMN :

Series LCR circuit

Frequency (f) (Hz)	Current (I) (mA)
1000	
1500	
2000	
2500	
3000	
3500	
4000	
4100	
4200	
4300	
4400	
4500	
4600	
4700	
4800	
4900	
5000	
5100	
5200	
5300	
5400	
5500	
6000	
6500	
7000	
7500	
8000	
8500	
9000	
9500	
10000	

Parallel LCR circuit

Frequency (f) (Hz)	Current (I) (mA)
1000	
1500	
2000	
2500	
3000	
3500	
4000	
4100	
4200	
4300	
4400	
4500	
4600	
4700	
4800	
4900	
5000	
5100	
5200	
5300	
5400	
5500	
6000	
6500	
7000	
7500	
8000	
8500	
9000	
9500	
10000	

RESULT:

The frequency response of series and parallel LCR circuits are studied.

Parameter	Series LCR	Parallel LCR
Inductance	H	H
Resonant frequency	Hz	Hz
Bandwidth	Hz	Hz
Quality factor (graph)		
Quality factor (calculation)		

References:

1. Electricity & Magnetism, Chattopadhyay, P.C.Rakshit, New Central Publn, 5th Edn, 1998,(Page 345)

2. University Physics, Hugh D Young, Pearson Education, Eleventh Edition, 1999, (Page 114 - 128).

3. 2. An advanced course in Practical Physics, Chattopadyay, Central Publn, 2002, 6th Edn, (Page 461)