Expt. No.7 Series and Parallel Resonance

Aim:

1. To calculate the resonance frequency, quality factor and band width of a given LCR circuits which are connected in series/parallel.
2. Compare the theoretically calculated resonance frequency and experimentally calculated resonance frequency and comment on the result.
3. To interpret the variation in the output in response to the variation in frequency

Apparatus:

Audio frequency oscillator, a. c. millimeters (0-20 mA) or millimeter, Inductance, resistor and capacitor of known values, connecting cords.

Theory:

Resistance, inductance and capacitance in series A C circuit. Consider a circuit containing inductance L, capacitor C and resistor R in series as shown in fig.1. When an alternate e.m.f. V ($=V_{max}\sin\omega t$) is applied to the circuit an alternate current flows in the circuit. Let 'I' be the current, at any instant. Let voltage drop across resistance R be V_R in phase with current, voltage drop across inductance L be V_L leading the current by 90^o and voltage drop across capacitance C be V_C lagging the current by 90^o. The resultant of V_L and V_C, (V_L- V_C) leads the current by 90^0, provided (V_L-V_C) and will lag current by 90^0 if $V_C>V_L$ (fig 2)

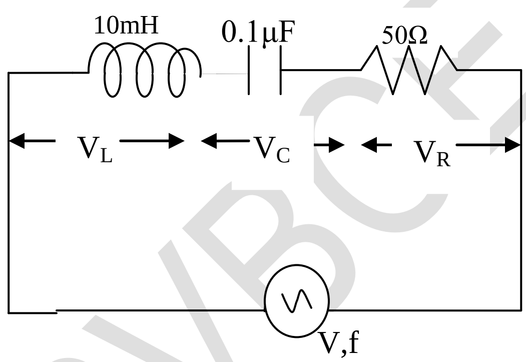


Fig: 1

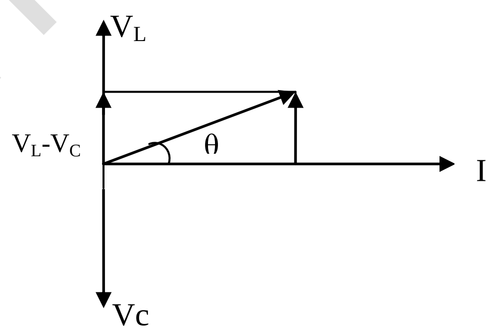


Fig: 2

$V_R = IR$ in phase with current
$V_L = IX_L$ leading the current by 90^0
$V_C = IX_C$ lagging by 90^0
The applied potential difference will be given by

$$V^2 = V_R^2 + (V_L - V_C)^2$$

$$V^2 = (IX_L - IX_C)^2 + (IR)^2 \quad \text{as } V_L = IX_L,\ V_C = IX_C \ \&\ V_R = IR$$

$$= I^2 (X_L - X_C)^2 + I^2R^2$$

$$= I^2 ((X_L - X_C)^2 + R^2)$$

There force I= V/ $((X_L - X_C)^2 + R^2))^{1/2}$
Where 'Z' is the impedance of the circuit
Or $Z=\sqrt{R^2+(X_L-X_C)^2}$

Where X_L---- inductive reactance and X_C---- capacitive reactance

<u>Series and resonance circuit</u>

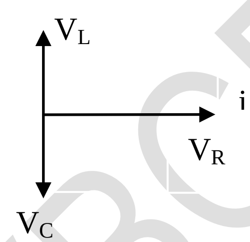
In a circuit containing R, L and C connected in series the impedance is given by

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

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 <u>resonant frequency (</u>f_r). At resonant frequency the two reactances are equal.

i.e., $X_L = X_C$ (or) $X_L - X_C = 0$. Then $V_L = V_C$ (fig3)
$\therefore \omega L = 1/\omega C$ Therefore $2\pi f_r L=1/2\ \pi f_r C$ because $\omega = 2\pi f$

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



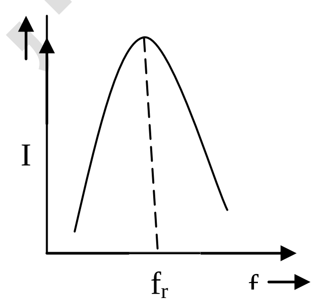


Fig -3a Where $V_L = V_C$ net voltage = V_R **Fig: 3b**

When $X_L = X_C$ at resonant Frequency the impedance is minimum and equal to the resistance. i.e., Z = R. In an Ac circuit containing R, Land C the supply voltage is magnified at resonant frequency as V_C reaches a value far excess of the supply voltage. The ratio of V_L or V_C with applied voltage at resonant frequency is called voltage magnification and denoted by Q factor i.e.,quality factor

$Q = V_L / V = iX_L / iR$ (as Z = R)
Or $Q = 2\pi f_r (L / R)$

As fr = $\frac{1}{2\pi}\sqrt{\frac{1}{LC}}$

$Q = 2\pi\frac{1}{2\pi}\frac{L}{R}\sqrt{\frac{1}{LC}}$

$$\boxed{Q=\frac{1}{R}\sqrt{\frac{L}{C}}}$$

Parallel Resonant Circuit:

A parallel resonance circuit is shown in fig-4. It is assumed that the resistance of the inductance coil is negligible. The current in the inductance I_L will lag in phase by 90^0 to the applied Voltage V. while the current in the capacitor I_C will lead in phase by 90^0 the applied voltage V. These currents being out of phase can be considered equivalent to an AC. If the supply current is "I" then

$I = I_L + I_C$ If I_C is greater than I_L at a particular frequency, then

$I = I_C – I_L = V/X_C – V/X_L$

Since I leads by 90^o on V in this case the circuit is 'net capacitive.'

If I_L is greater than I_C at a particular frequency, then

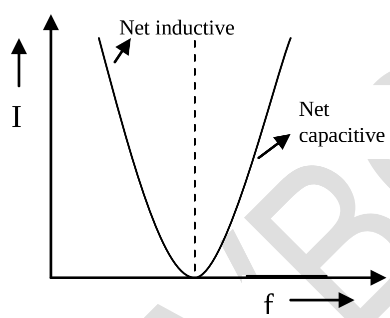
$I = I_L – I_C = V/X_L – V/X_C$

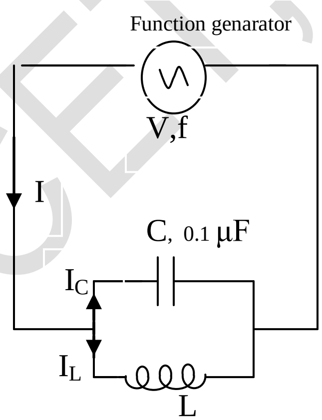
Since I lags by 90^o on V in this case the circuit is 'net inductive'.

Suppose V, L, C are kept constant & frequency f of supply is varied from low to high , the magnitude of I varies according to the relative magnitudes of $X_L(2\pi fL)$ & X_C $(1/2\pi fC)$.A special case occurs when $X_L = X_C$, then $I_L = I_C$ & so,I=0 at a particular frequency called resonant frequency f_r.

$$2\pi f_r L = 1/ 2\pi f_r C$$

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





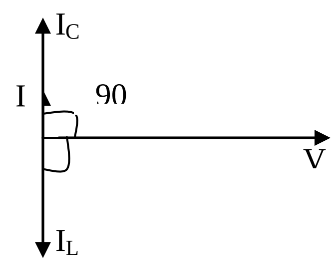


Fig:4a For L,C in parallel **Fig: 4b** Variation of I with 'f '

Since Z=V/I ,& I is zero at f_r , it follows that Z=infinity at f_r for a parallel inductor-capacitor circuit.

In practice when resistance R is taken in series with L, a similar variation of Z with f is obtained. But the maximum value of Z is finite now. & Z=L/CR. In this case also the resonant frequency is practically still given by

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

PROCEDURE:

1. **Series resonance**

The circuit connection is made as shown in the fig 5(a). The supplied points are switched on, and the output of the oscillator is adjusted suitably, which is kept constant throughout the experiment. The frequency ‘f’ is increased in appropriate steps and the corresponding readings of the current ‘I’ in mA as read from the milliammeter are entered in tabular column 1 under series resonance. The frequency for which current reaches its maximum value (I_{max}) is called resonant frequency (f_r). The readings including f_r and I_{max} are plotted with frequency in Hz along X-axis and the current in mA along the Y-axis. A resonance curve as shown in fig 6(a) will be obtained in which f_r and I_{max} are marked. The value of R, C, L and f_r are entered in tab. column 2 against Series resonance. The quality factor Q of the circuit is evaluated by using the equation,

$$Q = \frac{1}{R}\sqrt{\frac{L}{C}}$$

$Q_{graphically} = (f_r / \Delta f)$ where,

$\Delta f = (f_b - f_a)$ is the bandwidth

2. **Parallel Resonance**

The circuit connection is made as shown in the fig 5(b). The frequency f is varied and the corresponding circuit currents are noted. The readings are entered in tab. column 1 under parallel resonance. In this case the resonance frequency ‘f_r’ corresponds to the minimum value of current (Imin) in the circuit. The readings are plotted as earlier, and resonance curve as shown in fig 6(b) will be obtained. f_r and I_{min} are marked. The values of R, C, f_r and L are entered in tab. column 2 against parallel resonance and the Quality factor is determined.

Circuit Diagrams:

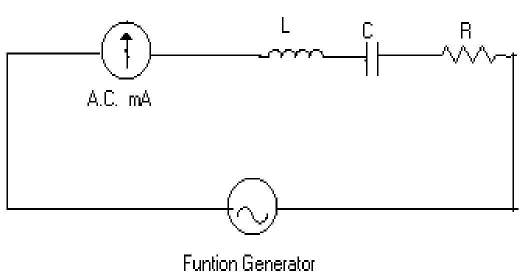


Fig: 5a Series resonance circuit

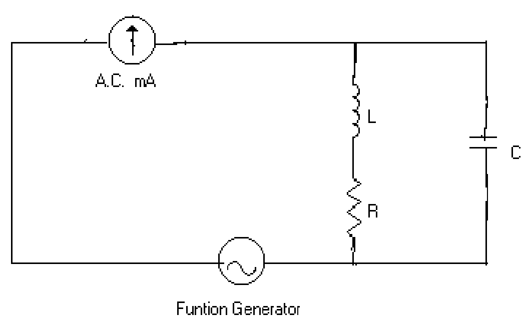
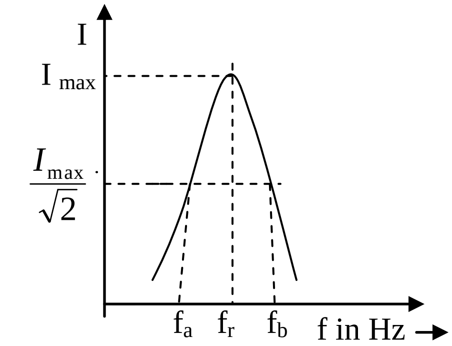


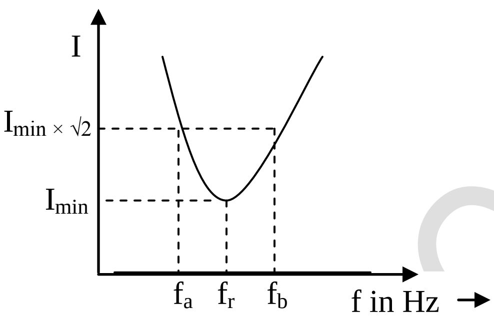
Fig: 5b Parallel resonance circuit

Nature of Graphs:



Series resonance frequency f_r = ………Hz.
I_{max}= ………mA
Band width $\Delta f = f_a - f_b$ =…….Hz.

Fig: 6a For series resonance.



Parallel resonance frequency f_r = ………Hz
I_{min} = ………..mA.
Band width $\Delta f = f_a - f_b$ =…….Hz.

Fig: 6b For parallel resonance

Record of Observations:

Resistance R =. …… ± Ω
Capacitance C =…….±. μF
Inductance L= ……... ± mH

Tabulation 1.

Series ckt

Sl.No	Frequency 'f ' in Hz.	Current 'I' in mA.
Error	±	±

Parallel ckt

	Frequency 'f ' in Hz.	Current 'I' in mA.
Error	±	±

Tabulation 2:

Type Of Resonance	'R' in Ω	L' in mH	'C' in μF	$f_r = \frac{1}{2\pi}\sqrt{\frac{1}{LC}}$ in Hz	f_r (experimental)
Series Resonance					
Parallel Resonance					

Results: a) $f_r \approx f_{exptl}$

There is an agreement between theoretical and experimental value.

Viva questions:

1) What is Resonance?
2) How the resonance takes place in LCR circuit?
3) How do we identify the resonance in LCR circuit?
4) Why the series resonance circuit is called an acceptor circuit and the parallel resonance circuit is called rejector circuit?
5) What is the potential difference across L and C at resonance?
6) What is the role of resistance in LCR circuit?
7) What is reactance?
8) What is impedence?
9) What is meant by band width?
10) What is quality factor?
11) What is the impedence of the LCR series circuit at resonance frequency?
12) How do you change the resonance frequency in LCR circuit?