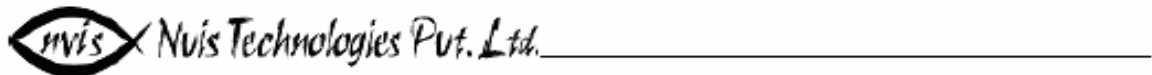


RLC Resonance Trainer
NV7009

Learning Material
Ver 1.2

Designed & Manufactured by:



141-A, Electronic Complex, Pardesipura, Indore- 452 010 India, **Tel.:** 91-731-4211500,

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CERTIFICATE OF COMPLIANCE



INTERNATIONAL CERTIFICATION SERVICES PVT. LTD.

This is to certify that the
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**141-B, Electronic Complex, Pardesipura, Indore – 452 010,
Madhya Pradesh, India.**

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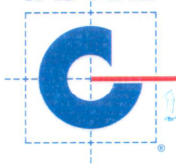
The Quality Management System applicable to:

**Scope: Design And Manufacture Of Clean Technology And Didactic
Products In Science And Technology.**

Registration No. : RQ91/7763
Registered Date : 17th June, 2012
Expiry Date : 16th June, 2015



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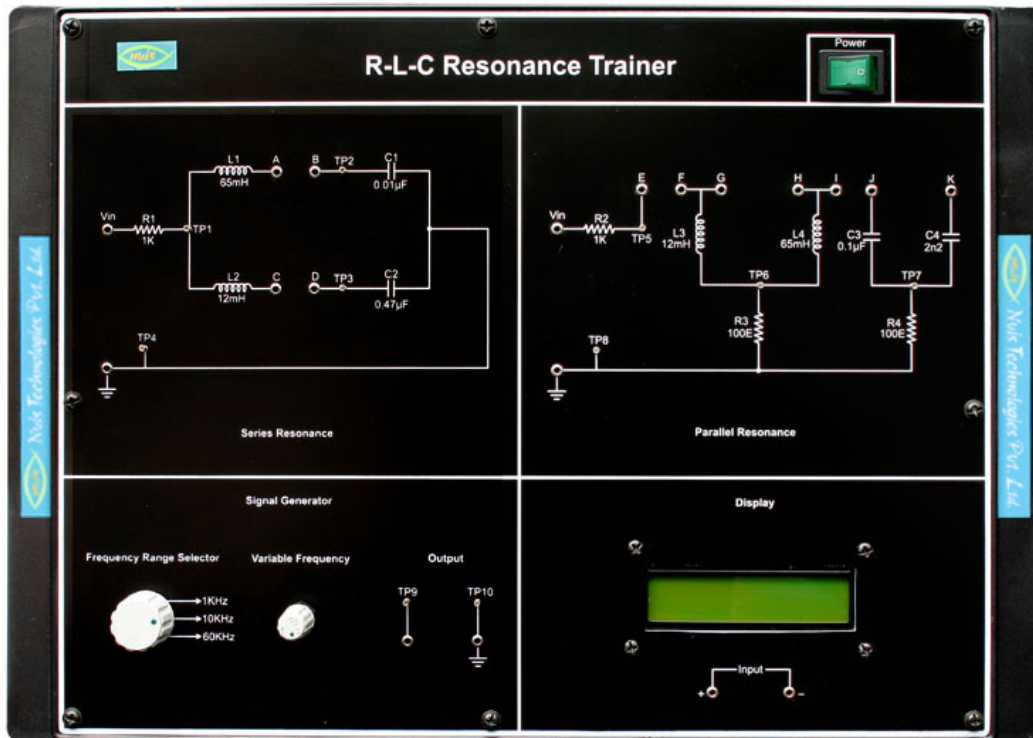
*Validity of this certificate is based on periodic audits of the management system defined by the above scope and is contingent upon prompt, written notification of significant changes to the management system and/or its components thereof shall be immediately communicated to ICS.
Further clarifications regarding the scope of this certificate and the applicability of ISO 9001:2008 requirements may be obtained at www.icsasian.com*

RLC Resonance Trainer
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Introduction

NV7009 RLC Resonance Trainer is very exclusive training system provides complete learning content for both series and parallel resonance. Resonance is an interesting phenomenon in electrical circuits in which inductive and capacitive elements behave to be like zero impedance circuit. This explanation is given with the help of passive circuits on the trainer. Multiple combination of components has been provided so that students can calculate resonance frequencies for these different combinations. Concept of Resonance frequency is explained very clearly which can be easily elaborated either on Oscilloscope or by on board display.



Features

- **Low cost trainer demonstrating both Series and Parallel Resonance.**
- **Designed with considering all safety standards.**
- **Series and Parallel Resonance RLC circuits are given on the same board.**
- **Provided with attractive LCD display.**
- **Provided with inbuilt Function Generator.**
- **Experiments can be performed with or without Oscilloscope**
- **Learning Material**
- **2 Year Warranty**

Technical Specifications

Mains Supply	:	230V, 50Hz.
Output of Generator	:	5 Vpp
Frequency ranges	:	1KHz, 10KHz, 60KHz.

Theory

In many of the electrical circuits, resonance is a very important phenomenon. The study of resonance is very useful particularly in the area of communications. For example, the ability of a radio receiver to select a certain frequency, transmitted by a station and to eliminate frequencies from other stations is based on the principle of resonance. The resonance condition can be achieved by connecting RLC components either in series or parallel depending on requirement.

Before starting the study of RLC circuit we should get familiar with the components which keeps a great importance in the resonance.

- Resistance (R)
- Inductance (L)
- Capacitance (C)

Resistance :

Electrical resistance is a ratio of the degree to which an object opposes an electric current through it, measured in ohms. Its reciprocal quantity is electrical conductance measured in siemens. Assuming a uniform current density, an object's electrical resistance is a function of both its physical geometry and the resistivity of the material it is made from:

$$R = \frac{l \cdot \rho}{A}$$

where

"l" is the length

"A" is the cross sectional area, and

" ρ " is the resistivity of the material

Discovered by Georg Ohm in the late 1820s, electrical resistance shares some conceptual parallels with the mechanical notion of friction. The SI unit of electrical resistance is the ohm, symbol Ω . The resistance of an object determines the amount of current through the object for a given potential difference across the object.

$$R = \frac{V}{I}$$

where

R is the resistance of the object, measured in ohms, equivalent to $J \cdot s / C^2$

V is the potential difference across the object, measured in volts

I is the current through the object, measured in amperes

For a wide variety of materials and conditions, the electrical resistance does not depend on the amount of current through or the amount of voltage across the object, meaning that the resistance R is constant.

DC resistance :

As long as the current density is totally uniform in the insulator, the DC resistance R of a conductor of regular cross section can be computed as

$$R = \frac{l \cdot \rho}{A}$$

where

l is the length of the conductor, measured in meters

A is the cross-sectional area, measured in square meters

(Greek: rho) is the electrical resistivity (also called specific electrical resistance) of the material, measured in ohm · meter. Resistivity is a measure of the material's ability to oppose electric current.

For practical reasons, almost any connections to a real conductor will almost certainly mean the current density is not totally uniform. However, this formula still provides a good approximation for long thin conductors such as wires.

AC resistance :

If a wire conducts high-frequency alternating current then the effective cross sectional area of the wire is reduced because of the skin effect. This causes the wire resistance to increase at a rate of 10dB/decade for wire radius much greater than skin depth.

In a conductor close to others, the actual resistance is higher than that predicted by the skin effect because of the proximity effect.

Inductance :

An electric current i flowing around a circuit produces a magnetic field and hence a magnetic flux through the circuit. The ratio of the magnetic flux to the current is called the inductance, or more accurately self-inductance of the circuit. The term was coined by Oliver Heaviside in February 1886. It is customary to use the symbol L for inductance, possibly in honour of the physicist Heinrich Lenz but perhaps simply from the word Loop. The quantitative definition of the inductance in SI units (webers per ampere) is

$$L = \frac{\Phi}{i}$$

In honour of Joseph Henry, the unit of inductance has been given the name henry (H): $1\text{H} = 1\text{Wb}/\text{A}$. In the above definition, the magnetic flux is that caused by the current flowing through the circuit concerned. There may, however, be contributions from other circuits. Consider for example two circuits C_1 , C_2 , carrying the currents i_1 , i_2 . The magnetic fluxes Φ_1 and Φ_2 in C_1 and C_2 , respectively, are given by

$$\Phi_1 = L_{11}i_1 + L_{12}i_2,$$

$$\Phi_2 = L_{21}i_1 + L_{22}i_2,$$

According to the above definition, L_{11} and L_{22} are the self-inductances of C_1 and C_2 , respectively. It can be shown (see below) that the other two coefficients are equal: $L_{12} = L_{21} = M$, where M is called the mutual inductance of the pair of circuits.

Self and mutual inductances also occur in the expression for the energy of the magnetic field generated by N electrical circuits carrying the currents i_n . This equation is an alternative definition of inductance, also valid when the currents don't flow in thin wires and when it thus is not immediately clear what the area encompassed by a circuit is and how the magnetic flux through the circuit is to be defined. The definition $L = \Phi / i$, in contrast, is more direct and more intuitive. It may be shown that the two definitions are equivalent by equating the time derivative of W and the electric power transferred to the system.

$$W = \frac{1}{2} \sum_{m,n=1}^N L_{m,n} i_m i_n$$

$$W_{\text{charging}} = \int_0^Q \frac{q}{C} dq = \frac{1}{2} \frac{Q^2}{C} = \frac{1}{2} CV^2 = W_{\text{stored}}$$

$$W_{\text{stored}} = \frac{1}{2} CV^2 = \frac{1}{2} \frac{A}{d} V^2$$

Capacitance : Capacitance is a measure of the amount of electric charge stored (or separated) for a given electric potential. The most common form of charge storage device is a two-plate capacitor. If the charges on the plates are $+Q$ and $-Q$, and V gives the voltage difference between the plates, then the capacitance is given by

$$C = \frac{Q}{V}$$

The SI unit of capacitance is the farad; 1 farad = 1 coulomb per volt.

Energy :

The energy (measured in joules) stored in a capacitor is equal to the work done to charge it. Consider a capacitance C , holding a charge $+q$ on one plate and $-q$ on the other. Moving a small element of charge dq from one plate to the other against the potential difference $V = q/C$ requires the work dW :

$$dW = \frac{q}{C} dq$$

where

W is the work measured in joules

q is the charge measured in coulombs

C is the capacitance, measured in farads

We can find the energy stored in a capacitance by integrating this equation. Starting with an uncharged capacitance ($q=0$) and moving charge from one plate to the other until the plates have charge $+Q$ and $-Q$ requires the work W :

$$W_{\text{charging}} = \int_0^Q \frac{q}{C} dq = \frac{1}{2} \frac{Q^2}{C} = \frac{1}{2} CV^2 = W_{\text{stored}}$$

Combining this with the above equation for the capacitance of a flat-plate capacitor, we get:

$$W_{\text{stored}} = \frac{1}{2} CV^2 = \frac{1}{2} \epsilon \frac{A}{d} V^2$$

where

W is the energy measured in joules

C is the capacitance, measured in farads

V is the voltage measured in volts

Series RLC resonance circuit :

Series RLC circuit is as shown in figure 1. In a series RLC circuit, the current lags behind, or leads the applied voltage depending upon the values of X_L and X_C . X_L causes the total current to lag behind the applied voltage, while X_C causes the total current to lead the applied voltage. When $X_L > X_C$, the circuit is predominantly inductive, and when $X_C > X_L$, the circuit is predominantly capacitive. However, if one of the parameters of the series RLC circuit is varied in such a way that the current in the circuit is in phase with the applied voltage, then the circuit is said to be in resonance.

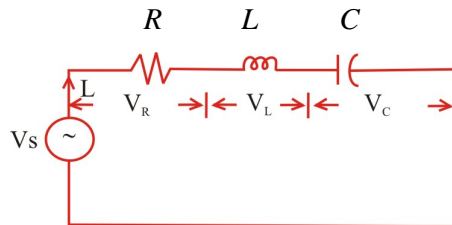


Figure 1

The total impedance for the series RLC circuit is

$$Z = R + j(X_L - X_C) = R + j(\omega L - \frac{1}{\omega C})$$

It is clear from the circuit that the current $I = \frac{V_S}{Z}$

$$W_{\text{stored}} = \frac{1}{2} CV^2 = \frac{1}{2} \epsilon \frac{A}{d} V^2$$

The circuit is said to be in resonance if the current is in phase to the applied voltage. In a series RLC circuit, series resonance occurs when $X_L = X_C$. The frequency at which the resonance occurs is called resonant frequency.

Since $X_L = X_C$, the impedance in a series RLC circuit is purely resistive. At the resonant frequency, f_r , the voltages across capacitance and inductance are equal in magnitude. Since they are 180° out of phase with each other, they cancel each other and, hence, at resonance frequency the amplitude of signal across LC combination will be minimum.

At resonance,

$$X_L = X_C$$

Solving for resonance we have,

$$f_r^2 = \frac{1}{4\pi^2 LC}$$

$$f_r = \frac{1}{2\pi\sqrt{LC}} \quad \dots\dots\dots(1)$$

In a series RLC circuit, the resonance may be produced by varying frequency, keeping L and C constant; otherwise, resonance may be produced by varying either L or C for a fixed frequency.

Impedance and phase angle of a series Resonant circuit :

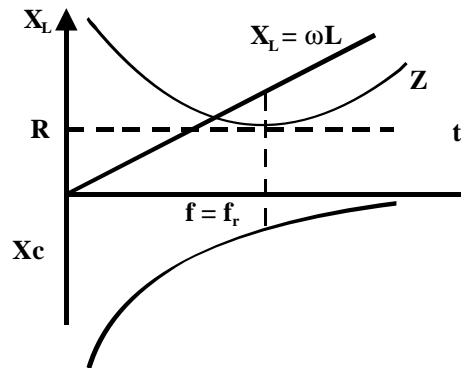
The impedance in series RLC circuit is,

$$Z = \sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2} \quad \dots\dots\dots(2)$$

The variation of X_C and X_L with frequency is shown in figure 2

At zero frequency, both X_C and Z are infinitely large, and X_L is zero because the capacitor acts as an open circuit at zero frequency and the inductor acts as a short circuit at zero frequency. As the frequency increases, X_C decreases and X_L increases. Since X_C is larger than X_L , at frequencies below resonant frequency f_r , Z decreases along with X_C . At resonant frequency f_r , $X_C = X_L$, and $Z = R$. At frequencies above the resonant frequency f_r , X_L is larger than X_C , causing Z to increase. The phase angle as a function of frequency is shown in figure 2

At a frequency below the resonant frequency, the current leads the source voltage because the capacitive reactance is greater than the inductive reactance. The phase angle decreases as the frequency approaches the resonant value, and is 0° at resonance. At frequencies above resonance, the current lags behind the source voltage, because the inductive reactance is greater than capacitive reactance. As the frequency goes higher, the phase angle approaches 90° .



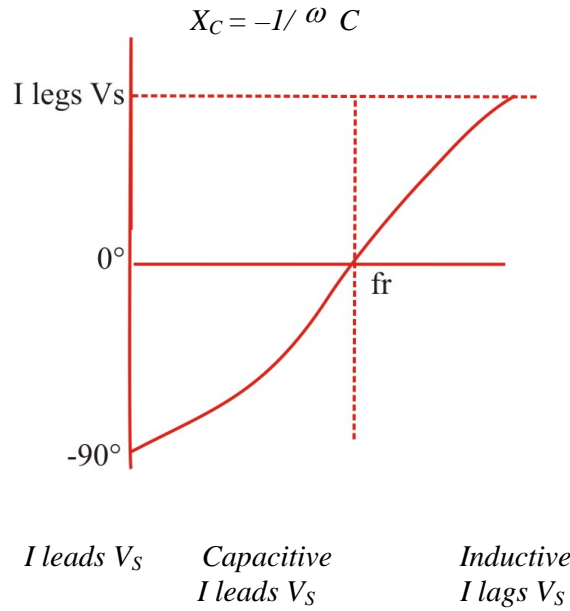


Figure 2

Voltages and current in a series resonant circuit :

The variation of impedance and current with frequency is shown in figure 3 at resonant frequency, the capacitive reactance is equal to inductive reactance, and hence the impedance is minimum. Because of the minimum impedance, maximum current flows through the circuit. The current variation with frequency is plotted.

The voltage drops across resistance, inductance and capacitance also varies with frequency. At $f = 0$, the capacitor acts as an open circuit and blocks current. The complete source voltage appears across the capacitor. As the frequency increases, X_C decreases and X_L increases, causing total reactance $X_C - X_L$ to decrease. As a result, the impedance decreases and the current increases. As the current increases, V_R also increases, and both V_C and V_L increase.

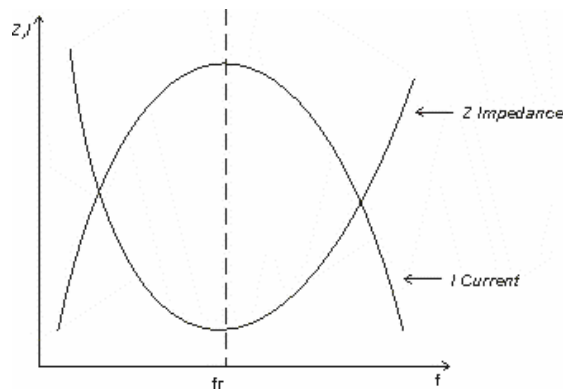


Figure 3

When the frequency reaches its resonant value f_r , the impedance is equal to R, and hence, the current reaches its maximum value, and V_R is at its maximum value.

As the frequency is increased above resonance, X_L continues to increase and X_C continues to decrease, causing the total reactance, $X_L - X_C$ increase. As a result there is an increase in impedance and a decrease in current. As the current decreases, V_R also decreases, and V_C and V_L decrease. As the frequency becomes very high, the current approach zero, both V_R and V_C approaches zero, and V_L approaches V_s .

The response of different voltages with frequency is shown in figure 4

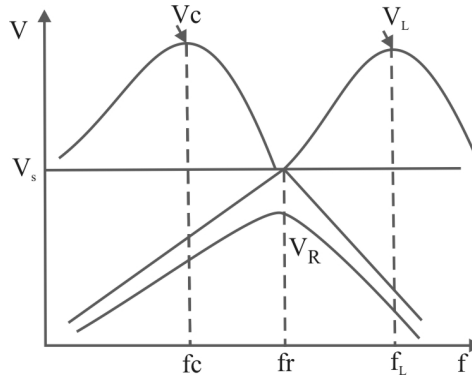


Figure 4

The drop across resistance reaches its maximum when $f = f_r$. The maximum voltage across capacitor occurs at $f = f_c$. Similarly, the maximum voltage across inductor occurs at $f = f_L$.

The voltage drop across inductor is

$$V_L = IX_L$$

Where,

$$I = \frac{V}{Z}$$

The maximum voltage across inductor is obtained at

$$f_L = \frac{1}{2\pi\sqrt{LC}} \sqrt{\frac{1}{1 - \frac{R^2 C}{2L}}}$$

The maximum voltage across capacitor is obtained at

$$f_c = \frac{1}{2\pi} \sqrt{\frac{1}{LC} - \frac{R^2}{2L}}$$

The maximum voltage across the capacitor occurs below the resonant frequency, and the maximum voltage across the inductor occurs above the resonant frequency.

Here the frequency f_1 is the frequency at which the current is 0.707 times the current at resonant value, and it is called the lower cut off.

Bandwidth :

The bandwidth of any system is the range of frequencies for which the current or the output voltage is equal to 70.7% of its value at resonant frequency, and is denoted by BW. Figure 5 shows the response of series RLC circuit frequency. The frequency f_2 is the frequency at which the current is 0.707 times the current at resonant value (i.e. maximum value), and is called the upper cut off frequency. The bandwidth, or BW, is defined as the frequency difference of f_2 and f_1 .

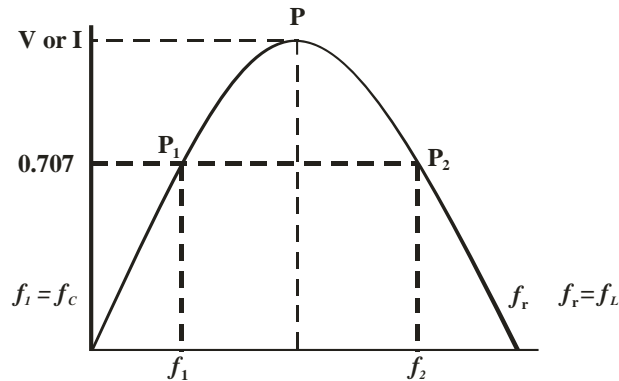


Figure 5

$$BW = f_2 - f_1$$

The unit of BW is the hertz (Hz).

If the current at P_1 is $0.707I_{max}$, the impedance of the circuit at this point is $\sqrt{2} R$, and hence

$$BW = \frac{R}{2\pi L}$$

Parallel RLC resonance circuit :

Basically, parallel resonance occurs when $X_C = X_L$. The frequency at which resonance occurs is called the resonant frequency. When $X_C = X_L$, the two branch-currents are equal in magnitude and 180° out of phase with each other. Therefore, the two currents cancel each other and the total current is zero. Consider the circuit shown in figure 6. The condition for resonance occurs when $X_L = X_C$.

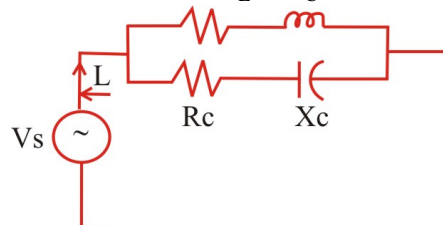


Figure 6

At resonance $X_L = X_C$

Solving for resonance we have,

$$f_0 = \frac{1}{\sqrt{LC}} \left[\frac{R_L^2 C - L}{R_L^2 C - L} \right]^{\frac{1}{2}}$$

or, when $R_L = R_C$

$$f_r = \frac{1}{2\pi\sqrt{LC}} \dots\dots\dots (1)$$

Variation in impedance with frequency :

The impedance of parallel resonant circuit is maximum at the resonant frequency and decreases at lower and higher frequencies, as shown in figure 7. So the amplitude of the given signal across the LC circuit will be maximum at the resonance frequency.

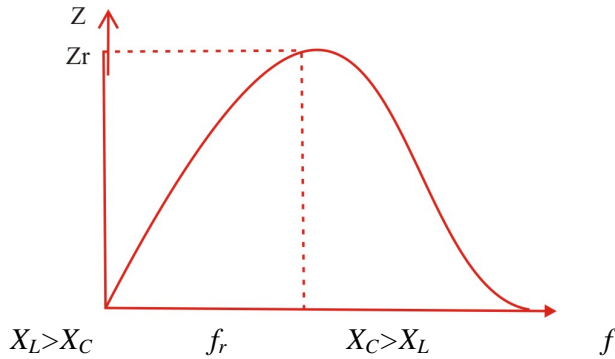


Figure 7

At very low frequencies, X_L is very small and X_C is very large, so the total impedance is essentially inductive. As the frequency increases, the impedance also increases, and the inductive reactance dominates until the resonant frequency is reached. At this point $X_L = X_C$ and the impedance is at its maximum. As the frequency goes above the resonance, the capacitive reactance dominates and the impedance decreases.

Reactance Curves in Parallel Resonance :

The effect of variation of frequency on the reactance of the parallel circuit is shown in the figure 8

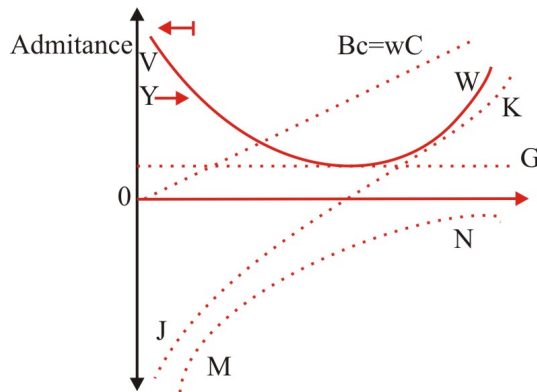


Figure 8

The effect of inductive susceptance,

$$B_L = \frac{-1}{2\pi fL}$$

Inductive susceptance is inversely proportional to the frequency or (ω). Hence it is represented by a rectangular hyperbola, MN. It is drawn in forth quadrant, since B_L is negative. Capacitive susceptance, $B_C = 2\pi fC$. It is directly proportional to frequency f or (ω). Hence it is represented as OP, passing through the origin. Net susceptance $B=B_C-B_L$. it is represented by the curve JK, which is a hyperbola. At point ω_r , the total susceptance is zero, and the resonance takes place. The variation of the admittance Y and the current I is represented by curve VW. The current will be minimum at resonant frequency.

Applications of resonance effect :

- Most common application is tuning. For example, when we tune a radio to a particular station, the LC circuits are set at resonance for that particular carrier frequency.
- A series resonant circuit provides voltage magnification.
- A parallel resonant circuit provides current magnification.
- A parallel resonant circuit can be used as load impedance in output circuits of RF amplifiers. Due to high impedance, the gain of amplifier is maximum at resonant frequency.
- A parallel resonant circuit can be used in induction heating.

Experiment 1

Objective :

Study of Resonance in Series RLC Circuit and to find its resonance frequency

Equipment Needed :

1. Oscilloscope

Circuit Diagram :

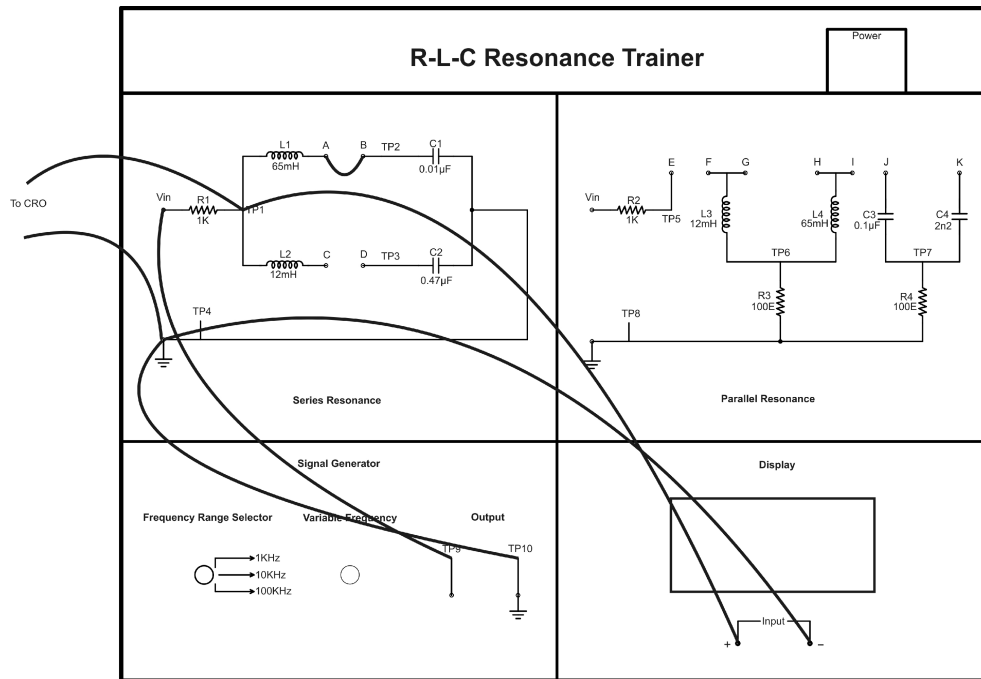


Figure 9

Procedure :

1. Connect terminals A and B so that inductor L1 and capacitor C1 will be in series.
2. Now connect generator output to this series combination, for this connect TP9 and TP10 to Vin and TP4 (Ground) respectively.
3. To observe the output of circuit, connect TP1 and TP4 to + and – terminals of display.
4. Switch ON the power supply.
5. Select 1KHz range from Frequency Range Selector.
6. Vary the frequency by Variable Frequency knob and observe the change in output voltage on display.
7. Apply same process for other two frequency ranges and note the minimum voltage.
8. Now connect the CRO across TP9 and TP10 and find the frequency for which the output voltage is minimum among these three ranges. This frequency will be the resonance frequency of this RLC circuit.
9. Similarly select other combinations like L1-C2, L2-C1, L2-C2 by connecting terminals A-D,C-B and C-D respectively one by one and apply same procedure to find the resonance frequency.
10. Record your observations in the observation table.

Observation Table :

S. No.	Combination	Minimum output Voltage	Resonance Frequency
1	L1-C1		
2	L1-C2		
3	L2-C1		
4	L2-C2		

Result :

Theoretical value of resonant frequency = $f_r = \frac{1}{2\pi\sqrt{LC}} = \dots\dots\dots\text{Hz}$

Experiment 2

Objective :

Study of Resonance in Parallel RLC Circuit and to find its resonance frequency

Equipment Needed :

1. Oscilloscope

Circuit Diagram :

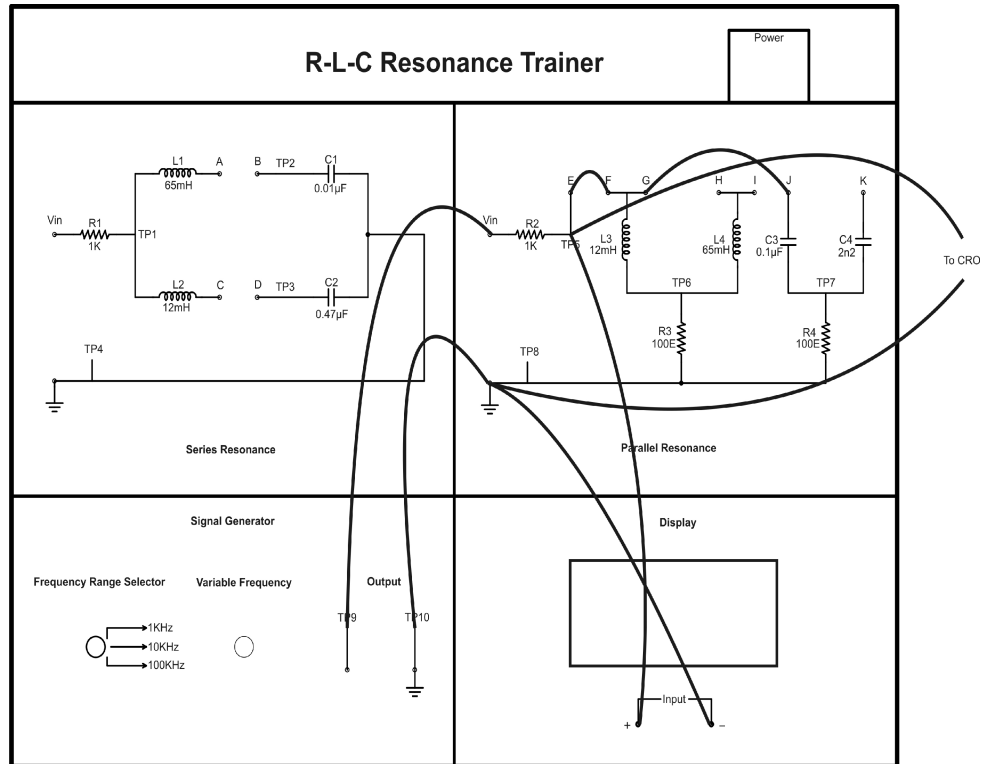


Figure 10

Procedure :

- Connect terminals E and F, G and J, so that L3 and C3 will be in parallel.
- Now connect generator output to this parallel combination, for this connect TP9 and TP10 to Vin and TP8 (Ground) respectively.
- To observe the output of circuit, connect TP5 and TP8 to + and – terminals of display.
- Switch ON the power supply.
- Select 1 KHz range from Frequency Range Selector.
- Vary the frequency by Variable Frequency knob and observe the change in output voltage on display.
- Apply same process for other two frequency ranges and note the maximum voltage.
- Now connect the CRO across TP9 and TP10 and find the frequency for which the output voltage is maximum among these three ranges. This frequency will be the resonance frequency of this RLC circuit.
- Similarly select other combinations like L3-C4, L4-C3, L4-C4 by connecting terminals G-K,H-J and J-K respectively one by one and apply same procedure to find the resonance frequency.
- Record your observations in the observation table.

Observation Table :

S. No.	Combination	Minimum output Voltage	Resonance Frequency
1	L3-C3		
2	L3-C4		
3	L4-C3		
4	L4-C4		

Result :

Theoretical value of resonant frequency = $f_r = \frac{1}{2\pi\sqrt{LC}}$ =Hz.

Warranty

- 1) We guarantee the product against all manufacturing defects for 24 months from the date of sale by us or through our dealers. Consumables like dry cell etc. are not covered under warranty.
- 2) The guarantee will become void, if
 - a) The product is not operated as per the instruction given in the learning material.
 - b) The agreed payment terms and other conditions of sale are not followed.
 - c) The customer resells the instrument to another party.
 - d) Any attempt is made to service and modify the instrument.
- 3) The non-working of the product is to be communicated to us immediately giving full details of the complaints and defects noticed specifically mentioning the type, serial number of the product and date of purchase etc.
- 4) The repair work will be carried out, provided the product is dispatched securely packed and insured. The transportation charges shall be borne by the customer.

List of Accessories

1. 2mm Patch Cord 8" 12 Nos.
2. Learning Material CD 1 No.
3. Mains Cord..... 1 No.