

Name of Student: \_\_\_\_\_

Enrollment No.: \_\_\_\_\_

Class: \_\_\_\_\_

Section: \_\_\_\_\_

Session: \_\_\_\_\_

# Department of Electronics & Communication Engineering

## EMI Lab Manual

Prepared By  
Dr. L N Gahalod



# LAKSHMI NARAIN COLLEGE OF TECHNOLOGY

Kalchuri Nagar, Raisen Road, Bhopal (MP) - 462023

## **Vision & Mission of the Department**

### **Vision**

To be recognized as Center of Academic Excellence by imparting quality teaching and strengthening research and development activities with world class infrastructure in the field of Electronics and Communication Engineering.

### **Mission**

**M1** To establish a quality teaching learning process to provide application oriented, in-depth knowledge consistently.

**M2** To establish state-of-the-art laboratories for academic excellence and to develop infrastructure through collaboration for quality research.

**M3** To equip the students by blending theoretical knowledge and practical skills with employability and entrepreneurship traits for a bright successful career.

**M4** To inculcate team spirit and leadership qualities to produce socially acceptable, eco-friendly and responsible citizens.

### **Program Educational Objectives (PEO's)**

- PEO1 Apply knowledge of mathematics, science and engineering as appropriate in the field of Electronics & Communication Engineering as proficient learners in the domains such as Electronic Circuits, Embedded Systems, Communication Systems, Digital Signal Processing, VLSI Design, Data Networks, IOT, and Simulation etc.
- PEO2 Seek admissions at Institutes of repute for higher education in Engineering & Technology and Management to the tune of 10%, seek employment in core and IT domains to the extent of 80% with remaining 10% opting for entrepreneurship.
- PEO3 Use the skills, latest techniques, tools for modern engineering and ICT which are necessary to analyze industrial problems related to Electronics & Communication Engineering with focus to Global, Economical and Environmental Issues.
- PEO4 Understand engineering solutions, exhibit professionalism, ethical attitude, team work, effective written and oral communication skills to practice in their profession with high regards to societal issues and responsibilities.

### **Program Specific Outcomes (PSO's)**

- PSO1 Apply basic concepts of science and engineering, to undertake theoretical learning of Electronic Devices and Circuits, Analog & Digital Communication, Signals & Systems, Embedded Systems, VLSI Design etc.
- PSO2 Develop the ability to acquire hands-on skills such as Circuit Simulation, MATLAB, HDL Programming, Embedded Systems, DSP and PCB Designing etc.
- PSO3 Develop team spirit and professional ethics to undertake research oriented projects, especially developmental projects and a few industry sponsored projects.
- PSO4 Learn extra-curricular courses such as soft-skills, personality development, and groom them as responsible citizen with professional ethics blended with human values, engineering economics and ability to handle real life issues.

### **Course Outcomes (CO's)**

**Student will be able to**

- CO1** Measure Amplitude, frequency and Phase of unknown signal using CRO.
- CO2** Measure unknown AC parameters using bridges.
- CO3** Draw the input output characteristics of various transducers.
- CO4** Generate various signals used in electronics circuits.
- CO5** Determine digital output for given analog signal and vice versa.

## Code of Conducts for the Laboratories

- All bags must be left at the indicated place.
- The lab timetable must be strictly followed.
- Be **PUNCTUAL** for your laboratory session.
- Noise must be kept to a minimum.
- Workspace must be kept clean and tidy at all time.
- Handle the experiment kit and interfacing kits with care.
- All students are liable for any damage to the accessories due to their own negligence.
- Students are strictly **PROHIBITED** from taking out any items from the laboratory.
- Students are **NOT** allowed to work alone in the laboratory without the Lab Supervisor
- Report immediately to the Lab Supervisor if any malfunction of the accessories, is there.
- Before leaving the lab Place the stools properly.

Please check the laboratory notice board regularly for updates.

### Rubrics for Assessment of student performance during Experiments

Area of Direct Assessment	Poor (0-2 Marks)	Fair (3-4 Marks)	Average (5-6 Marks)	Good (7-8 Marks)	Excellent (9-10 Marks)
<b>Aim &amp; Theory</b>	Aim is not clear and irrelevant theory written. Concept was not explained.	Aim is clear and Incomplete theory written. Concept could not be explained.	Aim is clear and Theory written but is unorganised. Concept is explained.	Aim is clear and Theory written properly. Concept is explained.	Aim is clear and Theory written properly. Concept is explained with neat diagrams.
<b>Performance and Working with Others</b>	Did not conduct the experiment and none of the member recorded the observations.	Followed few steps to conduct the experiment. But few members recorded the observations.	Followed few steps to conduct the experiment. Few members recorded the observations.	Followed step by step method to conduct the experiment. Sufficient observations recorded by all team members.	Followed step by step method to conduct the experiment. Many observations recorded by all team members.
<b>Safety Measures</b>	None of the team member knew safety measures and did not followed.	Team members had knowledge of safety measures and followed few of them.	Team members had fair knowledge of safety measures and followed them.	Team members were well acquainted with safety measures and followed.	Team members were well acquainted with safety measures and followed all of them.
<b>Result and Conclusion</b>	No data recorded. Conclusion can not be drawn.	Analysis does not follow data the data. Conclusion can not be drawn.	Analysis as recorded somewhat lacks in insight. Results is poorly recorded to make sense. Conclusion can not be drawn.	Analysis as recorded somewhat lacks in insight. But clearly recorded as Results. Conclusion is properly drawn.	Observations are analysed accurately and clearly recorded as Results. Conclusion is properly drawn.
<b>Observations and Calculations</b>	No observations recorded and no calculation done.	Insufficient number of observations recorded. So calculations are Inaccurate.	Sufficient number of observations recorded but calculations are Inaccurate.	Almost all observations recorded. Calculations are accurate and well organised.	Many observations recorded in the table. Calculations are accurate and well organised.
<b>Internal Viva</b>	Student does not have grasp on the experiment and could not answer the questions about the experiment.	Student mumbles incorrectly, pronouns terms and speak too quietly for teachers to hear.	Student is uncomfortable but is able to answer basic questions about the experiment.	Student is at ease and able to answer expected questions, but fails to elaborate.	Student demonstrated full knowledge by answering all questions with explanations and elaboration.

## INDEX

**Name of Student:** \_\_\_\_\_ **Enrollment No.:** \_\_\_\_\_

S. No.	Title of the Experiment	Date of Experiment	Date of Submission	Remark
1	Measurement of Amplitude and frequency of various waveforms using CRO. (CO1)			
2	To measure unknown frequency with comparison of known frequency using Lissajous Patterns of Cathode Ray Oscilloscope. (CO1)			
3	Measurement of self-inductance of an inductor using Maxwell's Bridge. (CO2)			
4	Measurement of unknown inductance of an inductor using Hay's Bridge. (CO2)			
5	Measurement of unknown capacitance of a capacitor using Schering Bridge. (CO2)			
6	Measurement of frequency using Wien Bridge. (CO2)			
7	Displacement measurement by LVDT. (CO3)			
8	Force measurement by strain gauge. (CO3)			
9	Temperature measurement by thermistor, RTD and thermocouple. (CO3)			
10	Study of Optical Transducer- Photo conductive, Photo voltaic, Photo-diode, Photo-Transistor. (CO3)			
11	Convert analog voltage into equivalent digital voltage using Analog-to-Digital convertor. (CO5)			
12	Convert digital voltage into equivalent analog voltage using Digital-to-Analog convertor. (CO5)			



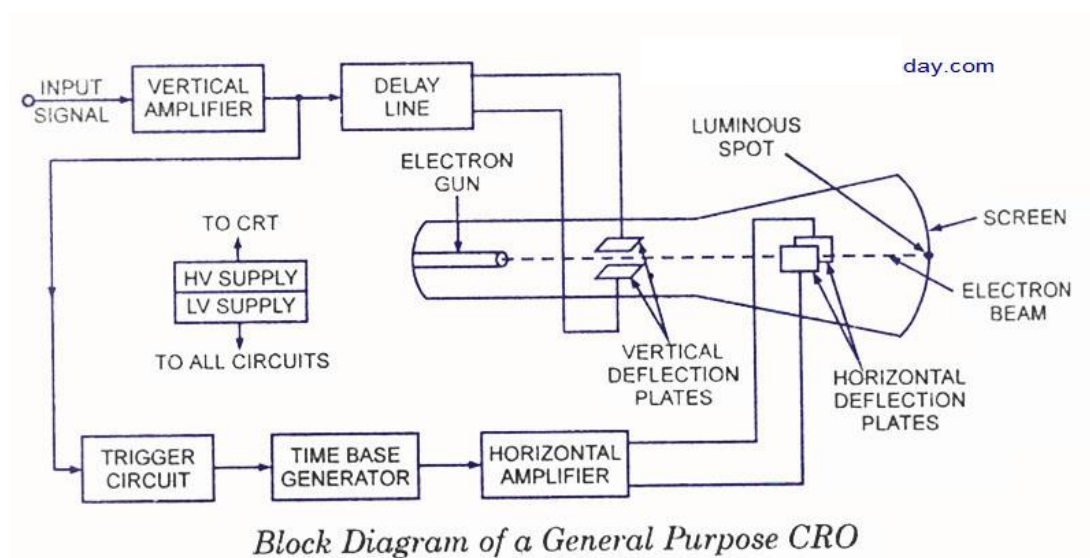
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## EXPERIMENT NO: 1

**Aim:** Measurement of Amplitude and frequency of various waveforms using CRO.

**Apparatus Required:** Function generator, CRO, Patch chord.

**Circuit Diagram:**



**Theory:** The Cathode Ray Oscilloscope is a very useful and versatile laboratory instrument used for display, measurement and analysis of waveforms and other phenomena in electrical and electronics circuit.

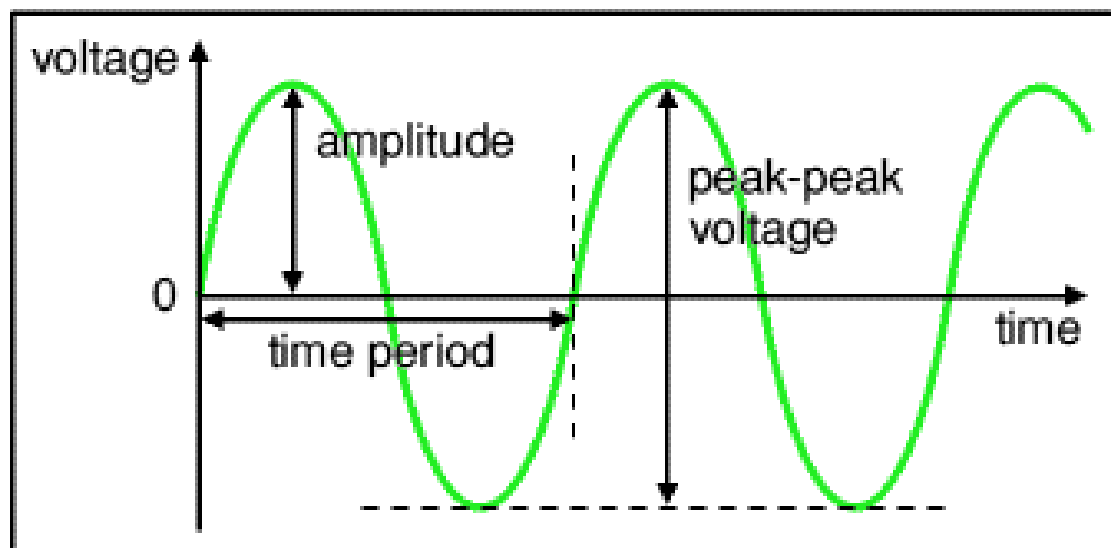
CRO is a fast X-Y plotter, displaying an input signal versus another signal or versus time. The “stylus” of this plotter is a luminous spot which moves over the display area in response to the input signal. The luminous spot is produced by a beam of electrons striking a fluorescent screen.

The signal to be analyzed is applied to the **vertical amplifier** which contains amplifier and attenuator to provide desired output voltage for vertical deflection plate. The vertical signal applied to vertical deflection

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plate passes through **delay line**, which delays input signal for few times until the time base start sweep of the beam. A sample of input waveform is fed to the **trigger circuit** which produce a trigger pulse synchronize to the input frequency, this trigger pulse is used to start time base generator. **Time base generator** generates a saw tooth waveform that is used as horizontal deflecting signal of CRT. Saw tooth wave form of time base generator amplified by **horizontal amplifier**, which amplifies the horizontal signal and make suitable to deflect the horizontal deflection plate.

## Measurement of Voltage and frequency:



**Voltage Measurement:** Peak-to-peak voltage of unknown signal can be measured as:

$$V_{pp} = \text{No. of division on Y axis} \times \frac{\text{Volt}}{\text{div}} \text{Multiplier}$$

$$V_m = \frac{V_{pp}}{2}$$

$$V_{rms} = \frac{V_m}{\sqrt{2}} = \frac{V_{pp}}{2\sqrt{2}}$$

**Frequency Measurement:** Time period of unknown signal can be measured as

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$$T = \text{No. of division on X axis} \times \frac{\text{Time}}{\text{div}} \text{ Multiplier}$$

$$\text{Frequency is given by } f = \frac{1}{T} \text{ Hz}$$

## Observation Table:

Sr. No	Type of Waveform	Signal Frequency (Hz)	Amplitude Measurement			Frequency Measurement			
			No. of division on Y Axis	Volt/Div Multiplier	Amplitude (Volt)	No. of division on X Axis	Time/ Div Multiplier	Time T (Sec.)	Frequency $f = 1/T$ (Hz)
1	Sine Wave								
2	Square Wave								
3	Triangular Wave								

**Result:** Various waveforms are plotted in graph paper.

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## EXPERIMENT NO: 2

**Aim:** To measure unknown frequency with comparison of known frequency using Lissajous Patterns of Cathode Ray Oscilloscope.

### **Apparatus Required:**

Sr. No	Apparatus	Quantity
1	Cathode ray Oscilloscope	1
2	Function Generator	2
3	CRO Probes	2

### **Theory:**

It is interesting to consider the characteristics of the patterns that appear on the screen of a CRT when sinusoidal voltages are simultaneously applied to horizontal & vertical plates. These patterns are called 'Lissajous Patterns'. A Lissajous figure is produced by taking two sine waves of the same frequency produce a Lissajous pattern which may be a straight line, a circle or an ellipse depending upon the phase and magnitude of voltages. This is easily done on an oscilloscope in XY mode. In the following examples the two sine waves have equal amplitudes.

- When the two voltages are of equal frequency and in-phase, you get a diagonal line to the right.
- When the two voltages are of equal frequency and 180 degrees out-of-phase you get a diagonal line to the left.
- When the two voltages are of equal frequency and phase angle of  $\phi$  (not equal to 0 or 90 degrees) you get an ellipse.

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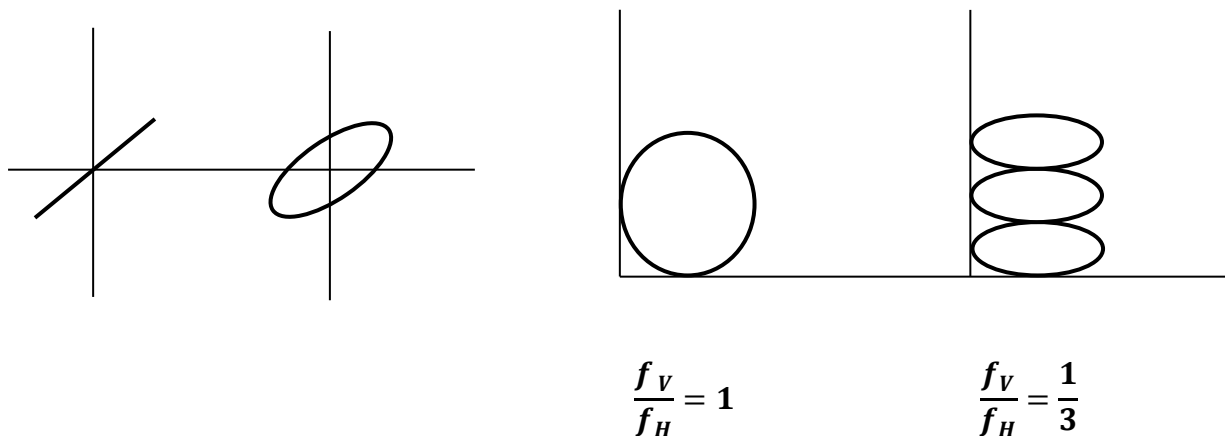
- When the two voltages are of equal frequency and 90 degrees out-of-phase you get a circle see figure1.

Two lines are drawn, one horizontal and the other vertical so that they do not pass through any intersections of different parts of the Lissajous curve. The number of intersections (or touches) of the horizontal and the vertical lines with the Lissajous curve are individually counted (see Figure2). The frequency ratio is given by

$$\frac{f_V}{f_H} = \frac{\text{No. of intersections of the horizontal line with the curve}}{\text{No. of intersections of the vertical line with the curve}}$$

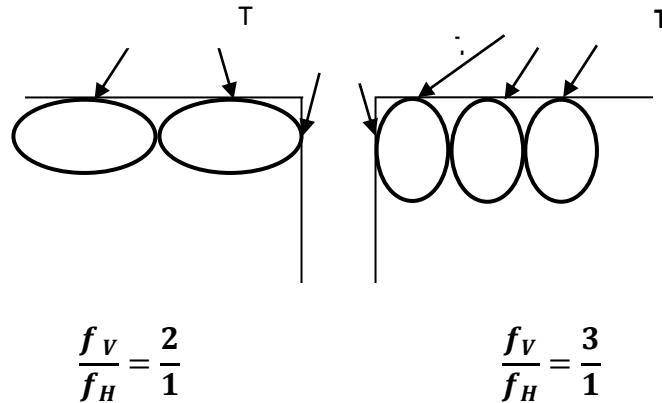
or

$$\frac{f_V}{f_H} = \frac{\text{No. of Horizontal Tangencies}}{\text{No. of Vertical Tangencies}}$$



**Figure1: Lissajous Patterns**

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**Figure 2: Lissajous Patterns**

## **Procedure:**

1. Switch on the CRO. Rotate the intensity control clockwise. After some time either a bright spot or a line will be appeared on the screen. If you see none, adjust X-POS and Y-POS controls to get the display in the centre of the screen.
2. Operate the INTEN and FOCUS controls and observe the effect on the spot (or line). Adjust them suitably.
3. For measuring the frequency of the signal feed the unknown signal (taken from the signal generator) to the Y-INPUT terminals. Take a standard signal generator, and connect its output to the X-INPUT terminals of the CRO. Put the TIME-BASE or HORIZONTAL-AMPLIFIER knob at EXT position. Change the frequency of the standard signal generator till you get a stable Lissajous pattern. For the various frequency ratios,  $f_H/f_V$ , the Lissajous patterns are shown in Fig. The unknown frequency can thus be determined using the relationship.



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$$\frac{f_V}{f_H} = \frac{\text{No. of Horizontal Tangencies}}{\text{No. of Vertical Tangencies}}$$

**Result:** Thus, obtained unknown frequency of given signal using Lissajous pattern of cathode ray oscilloscope.

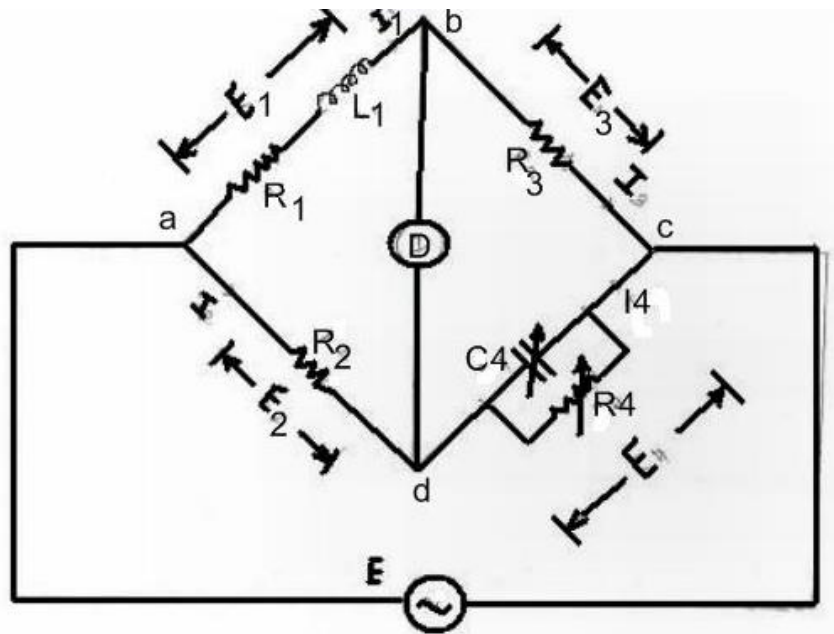
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## EXPERIMENT NO: 3

**Aim:** Measurement of Inductance of coil using Maxwell's inductance capacitance Bridge.

**Apparatus Required:** Maxwell's Bridge kit, LCRQ meter, Patch chord etc.

**Circuit Diagram:**



**Introduction:** Bridges are used for accurate measurement of electrical quantities viz; Resistances, inductances, capacitances, frequency etc.

Maxwell's inductance-capacitance bridge is used for measurement of inductance of coil having low Q factor (1-10).

**Theory:** Let

$L_1$  = unknown inductance,

$R_1$  = effective resistance of inductor  $L_1$ ,

$R_2, R_3, R_4$  = known non-inductive resistances,

$C_4$  = variable standard capacitor.



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Writing the equation for balance

$$(R_1 + j\omega L_1) \left( \frac{R_4}{1 + j\omega C_4 R_4} \right) = R_2 R_3$$

$$R_1 R_4 + j\omega L_1 R_4 = R_2 R_3 + j\omega R_2 R_3 C_4 R_4$$

Separating the real and imaginary terms, we have

$$R_1 = \frac{R_2 R_3}{R_4}$$

And

$$L_1 = R_2 R_3 C_4$$

Thus we have two variables  $R_4$  and  $C_4$  which appear in one of the two balance equations and hence the two equations are independent.

The expression for **Q factor**

$$Q = \frac{\omega L_1}{R_1} = \omega C_4 R_4$$

**Observation Table:**

Sr. No	Unknown Inductance $L_1$	$R_2$ (ohm)	$R_3$ (ohm)	$C_4$ (Farad)	$L_1 = R_2 R_3 C_4$ (Henry)	True value of L (Henry)	% Error
1	$L_{11}$						
2	$L_{12}$						

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**Result:** The inductance of coils is measured using Maxwell's bridge and their inductances are

$$L_{11} = \dots\dots\dots H$$

$$Q_1 = \dots\dots\dots$$

$$L_{12} = \dots\dots\dots H$$

$$Q_2 = \dots\dots\dots$$

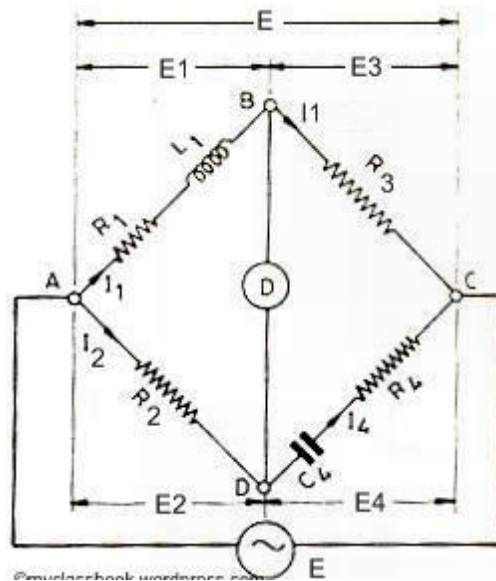
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## EXPERIMENT NO: 4

**Aim:** Measurement of Inductance of coil using Hay's bridge.

**Apparatus Required:** Hay's bridge kit, LCRQ meter, multimeter, Patch chord etc.

**Circuit Diagram:**



**Theory:** The Hay's bridge is the modification of the Maxwell Bridge. This bridge uses a resistance in series with the standard capacitor. The bridge has four resistive arms in which the arms 1 consists of the resistor  $R_1$ , in series with unknown inductor  $L_1(L_x)$ . The arm 2 and arm 3 consists of the variable resistance  $R_2$  and  $R_3$ . Arm 4 has a standard capacitor  $C_4$  in series with resistor  $R_4$ .

By using the unknown inductance having a resistance  $R_1$ .  $R_2$ ,  $R_3$ ,  $R_4$  is the known non-inductive resistance and  $C_4$  is standard value of the capacitor. The unknown value of inductance and Quality factor of the Bridge is obtained by formula.

$$L_x = \frac{R_2 R_3 C_4}{1 + \omega^2 R_4^2 C_4^2}$$

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Quality factor

$$Q = \frac{1}{\omega R_4 C_4}$$

## Procedure:-

- Study the circuit provided on the front panel of the kit.
- Connect unknown inductance  $L_{X1}$  in the circuit. Make all connections to complete the bridge.
- Put the supply ON
- Set the null point of galvanometer by adjusting variable resistance  $R_3$ .
- Note value of  $R_2$ ,  $R_3$ , and  $C_4$  by removing connection by patch cords.
- Calculate theoretical value of  $L_{X1}$ .
- Measure value of  $L_{X1}$  by LCRQ meter and compare it.
- Repeat process for  $L_{X2}$ .

## Observation Table:

Sr. No	Unknown Inductance $L_x$	$R_2$ (ohm)	$R_3$ (ohm)	$C_4$ (Farad)	$L_x = R_2 R_3 C_4$ (Henry)	True value of L (Henry)	% Error
1	$L_{x1}$						
2	$L_{x2}$						

**Result:** - The unknown inductance is measured using Hay's bridge and is found to be:

$L_{x1} = \text{----- Henry,}$                        $Q_1 = \text{-----}$

$L_{x2} = \text{----- Henry,}$                        $Q_2 = \text{-----}$

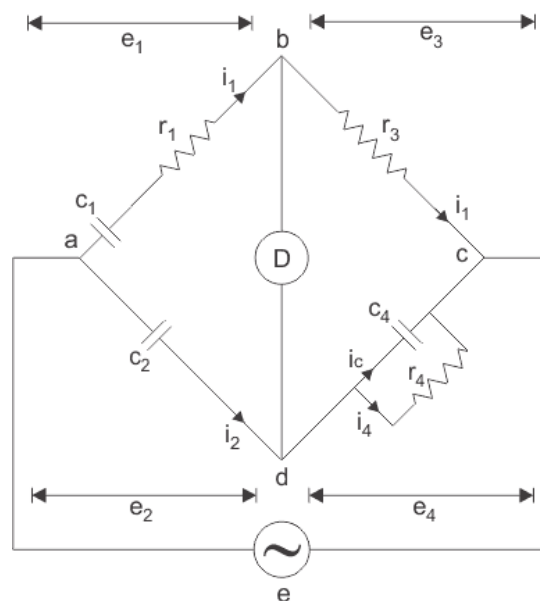
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## EXPERIMENT NO: 5

**Aim:** Measurement of Capacitance of a capacitor using Schering Bridge.

**Apparatus Required:** Schering bridge kit, LCRQ meter, Multimeter, Patch chord etc.

**Circuit Diagram:**



**Theory:**

Schering bridge is used to measure the capacitance of the capacitor, dissipation factor and measurement of relative permittivity. Let us consider the circuit of Schering bridge as shown above:

Here,  $c_1$  is the unknown capacitance whose value is to be determined with series electrical resistance  $r_1$ .

$c_2$  is a standard capacitor.

$c_4$  is a variable capacitor.

$r_3$  is a pure resistor (i.e. non inductive in nature).

And  $r_4$  is a variable non inductive resistor connected in parallel with variable capacitor  $c_4$ .

Now the supply is given to the bridge between the points a and c. The detector is connected between b and d.

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At balanced condition the value of unknown capacitance  $C_1$  and series resistance  $r_1$  is given as:

$$C_1 = C_2 \frac{r_4}{r_3} \qquad r_1 = r_3 \frac{C_4}{C_2}$$

The dissipation factor is given by

$$D = \omega r_1 C_1$$

**Observation Table:**

Sr. No	Unknown Inductance $C_x$	$R_3$ (ohm)	$R_4$ (ohm)	$C_2$ (Farad)	$C_x = C_2 \frac{r_4}{r_3}$ (Farad)	True value of C (Farad)	% Error
1	$C_{x1}$						
2	$C_{x2}$						

**Result:** - The unknown capacitance and dissipation factor is measured using Schering bridge and is found to be:

$$C_{x1} = \text{----- Farad,} \qquad D_1 = \text{-----}$$

$$C_{x2} = \text{----- Farad,} \qquad D_2 = \text{-----}$$

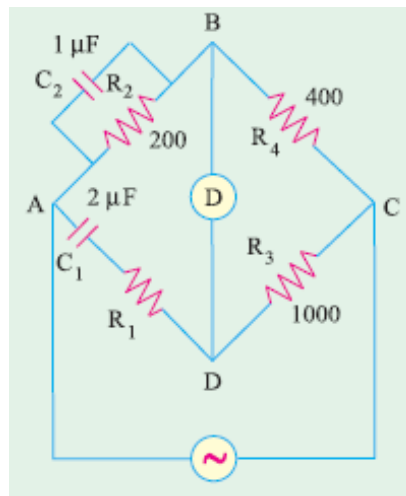
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## EXPERIMENT NO: 6

**Aim:** Measurement of Frequency of signal using Wien Bridge.

**Apparatus Required:** Wien bridge kit, LCRQ meter, Multimeter, Patch chord etc.

**Circuit Diagram:**



Wien Bridge is commonly used for the measurement of frequency in audio frequency (20 Hz – 20 kilo Hz) range. It consist a series RC combination in one and a parallel combination in the adjoining arm.

At balance condition

$$Z_1 Z_4 = Z_2 Z_3$$

Where

$$Z_1 = R_1 - \frac{j}{\omega C_1}, Y_2 = \frac{1}{R_2} + j\omega C_2, Z_3 = R_3, \text{ and } Z_4 = R_4$$

$$Z_3 = \frac{Z_1 Z_4}{Z_2} = Z_1 Z_4 Y_2$$

$$R_3 = \left( R_1 - \frac{j}{\omega C_1} \right) R_4 \left( \frac{1}{R_2} + j\omega C_2 \right)$$

Equating real parts we have

$$\frac{R_3}{R_4} = \frac{R_1}{R_2} + \frac{C_2}{C_1}$$



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If  $R_1 = R_1$  and  $C_1 = C_2$

$$R_3 = 2R_4$$

Equating imaginary parts we have

$$\omega C_2 R_1 = \frac{1}{\omega C_1 R_2}$$

This gives

$$f = \frac{1}{2\pi\sqrt{R_1 R_2 C_1 C_2}}$$

If  $R_1 = R_1 = R$  and  $C_1 = C_2 = C$

$$f = \frac{1}{2\pi RC}$$

## Measurement:

1. Value of Resistance  $R_1 = \dots\dots\dots$  Ohm
2. Value of Resistance  $R_2 = \dots\dots\dots$  Ohm
3. Value of Capacitance  $C_1 = \dots\dots\dots$  Farad
4. Value of Capacitance  $C_2 = \dots\dots\dots$  Farad

**Result :** Frequency of signal is  $\dots\dots\dots$  Hz



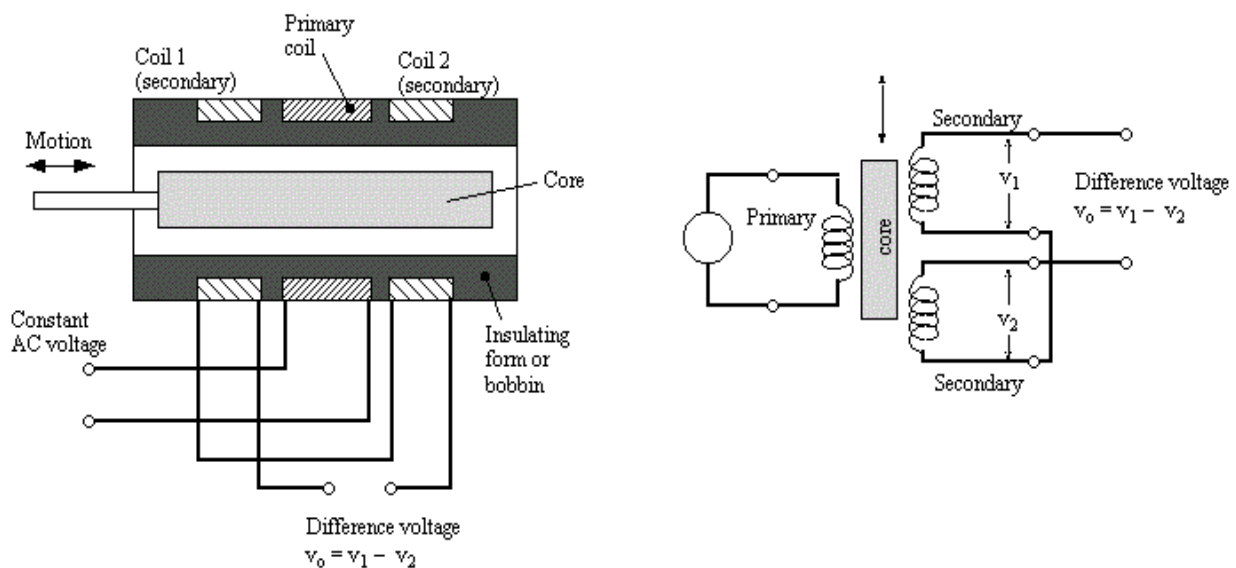
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## EXPERIMENT NO: 7

**Aim:** Displacement measurement using LVDT.

**Apparatus Required:** LVDT kit, Screw gauge, connecting chords etc.

**Circuit Diagram:**



### Theory:

LVDT stands for linear variable differential transformer. It works on the principle of mutual induction. LVDT illustrated in figure consists of three symmetrically spaced coils wound on and illustrated bobbin. A magnetic core, which moves through the bobbin, provides a path for magnetic flux linkage between coils. The position of the magnetic core controls the mutual inductance between the primary coils and two secondary coils. When a carrier excitation is applied to the primary coil, voltage is induced in the two secondary coils that are wired in series opposing circuit. When the core is centered between the two secondary coils, the voltage induced in secondary coils are equal but out of phase by  $180^\circ$ . With series opposing circuit, the voltage in two secondary coils cancels each other and the O/P voltage is zero. When the core is moved from the center position, an imbalance in the mutual inductance between the

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primary and secondary coils occurs and an o/p voltage develops. The o/p voltage is linear function of core position as long as the motion of the core is within the operating range of LVDT. The direction of motion can be determined from the phase of o/p voltage.

## Features :

1. The frequency of voltage applied to the primary winding can range from 50-25000 kHz.
2. Dynamic measurement is possible if the carrier frequency is 10 times greater than the highest frequency component in dynamic signal.
3. The I/P ranges from 5 – 15 watts / amp i.e. volts.
4. The power required is less than 1 watt.
5. Range of sensitivity is from 0.02 – 0.2 V / mm.
6. Available in operating range  $\pm 2$  to  $\pm 150$  mm.

## Procedure:

Make the connection between LVDT sensor and the digital display unit as directed in manual. Switch 'ON' the circuit. Advance the LVDT core on one side with screw gauge. Record the o/p, repeat the procedure for possible range of i/p in regular steps on one side. Withdraw the LVDT core to the null position in same steps it was advanced. Take o/p while drawing i/p. Repeat same on other side of null. Plot I/P v/s O/P graph using least square fit method. Calculate linearity of instrument.

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## Observation Table:

Correction Factor (if any): .....

Sr. No	Displacement (in mm)	Output Voltage (in Volts)	Corrected Output Voltage (in Volts)
1	10 mm		
2	8 mm		
3	6 mm		
4	4 mm		
5	2 mm		
6	0 mm		
7	-2 mm		
8	-4 mm		
9	-6 mm		
10	-8 mm		
11	-10 mm		

- Result:**
- 1.The graph between displacement and output voltage is plotted in the graph paper.
  2. The graph shows that output voltage is linearly related with the displacement.

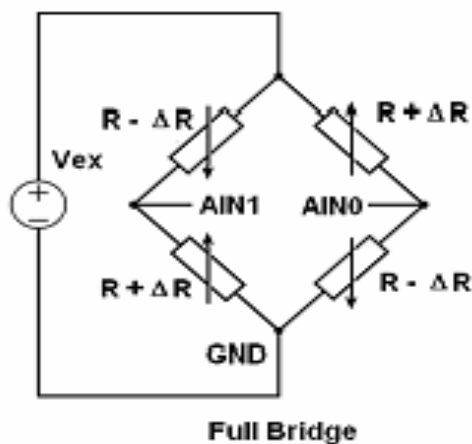
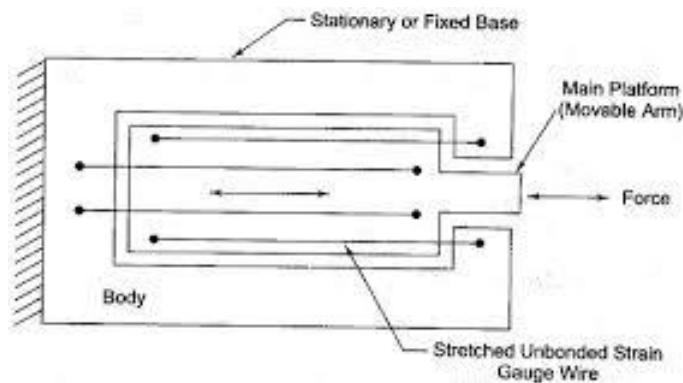
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## EXPERIMENT NO: 8

**Aim:** Force measurement using strain gauge.

**Apparatus Required:** Strain measurement kit, load cell, weights of various value, connecting chords etc.

**Circuit Diagram:**



**Theory:** The strain gauge is an example of a primary passive analog transducer that converts force or small displacement into a change of resistance. Since many other quantities such as torque, pressure, weight, and tension also involve force or displacement effects, they can also be measured by strain gauges. Strain gauges are so named because when they undergo a strain (defined to be a fractional change in linear dimension tension or compression caused by an applied force); they also undergo a change in electrical resistance. The strain

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takes the form of a lengthening of the special wire from which the gauge is constructed. The change in resistance is proportional to the applied strain and is measured with a specially adopted Wheatstone bridge.

The gauge factor ( $k$ ) is given by:

$$k = \frac{\Delta R/R}{\Delta l/l}$$

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

Since strain is given as  $\sigma = \frac{\Delta l}{l}$

Hence  $\Delta R = kR\sigma$

Or  $\Delta R \propto \sigma$

## Observation Table:

Sr. No	Weight (in Gram)	DPM Reading (in Volts)
1		
2		
3		
4		
5		
6		
7		
8		

**Result:** The graph between weight and output voltage is plotted in graph paper, and found linear.

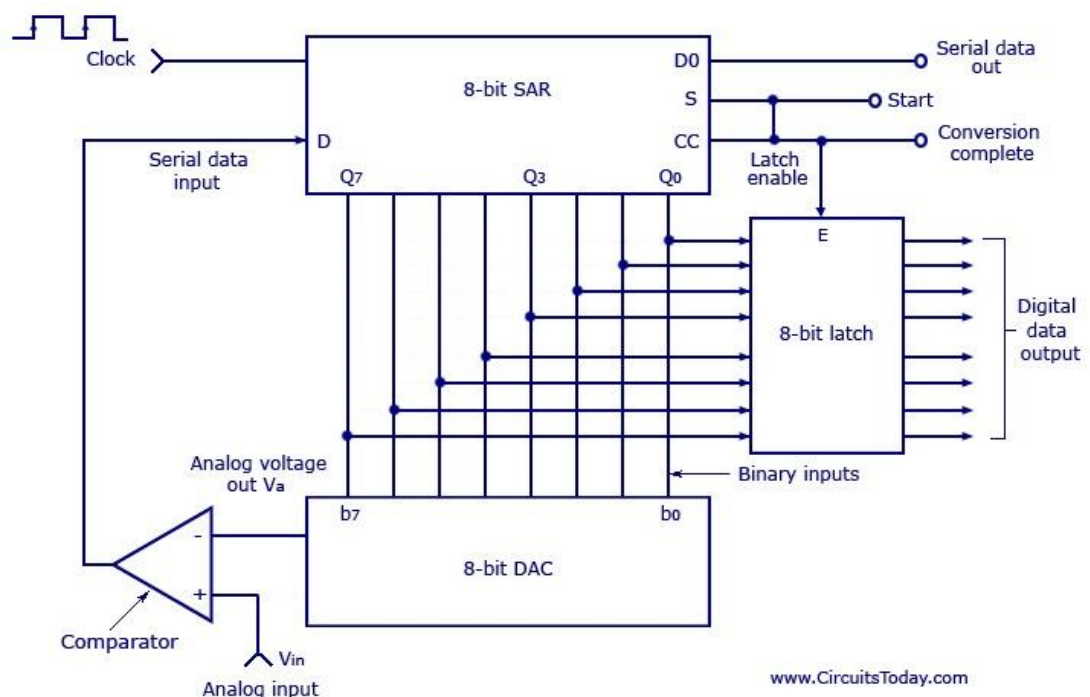
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## EXPERIMENT NO: 11

**Aim:** To convert Analog voltage into equivalent Digital voltage using Analog-to-Digital converter.

**Apparatus Required:** A/D Converter kit, connecting chords etc.

**Circuit Diagram:**



**Principle & Working:** A successive approximation A/D converter consists of a comparator, a successive approximation register (SAR), output latches, and a D/A converter. The main part of the circuit is the 8-bit SAR, whose output is given to an 8-bit D/A converter. The analog output  $V_a$  of the D/A converter is then compared to an analog signal  $V_{in}$  by the comparator. The output of the comparator is a serial data input to the SAR. Till the digital output (8 bits) of the SAR is equivalent to the analog input  $V_{in}$ , the SAR adjusts itself. The 8-bit latch at the end of conversation holds onto the resultant digital data output.

At the start of a conversion cycle, the SAR is reset by making the start signal (S) high. The MSB of the SAR (Q7) is set as soon as the first transition from LOW to HIGH is introduced. The output is given to the D/A converter which



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produces an analog equivalent of the MSB and is compared with the analog input  $V_{in}$ .

If comparator output is LOW, D/A output will be greater than  $V_{in}$  and the MSB will be cleared by the SAR. If comparator output is HIGH, D/A output will be less than  $V_{in}$  and the MSB will be set to the next position (Q7 to Q6) by the SAR.

According to the comparator output, the SAR will either keep or reset the Q6 bit. This process goes on until all the bits are tried. After Q0 is tried, the SAR makes the conversion complete (CC) signal HIGH to show that the parallel output lines contain valid data. The CC signal in turn enables the latch, and digital data appear at the output of the latch. As the SAR determines each bit, digital data is also available serially. As shown in the figure above, the CC signal is connected to the start conversion input in order to convert the cycle continuously.

The biggest advantage of such a circuit is its high speed. It may be more complex than an A/D converter, but it offers better resolution.

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## Observation Table:

Sr. No.	Analog I/P Voltage	Digital O/P Voltage
1		
2		
3		
4		
5		
6		
7		
8		
9		

## Result & Discussion:



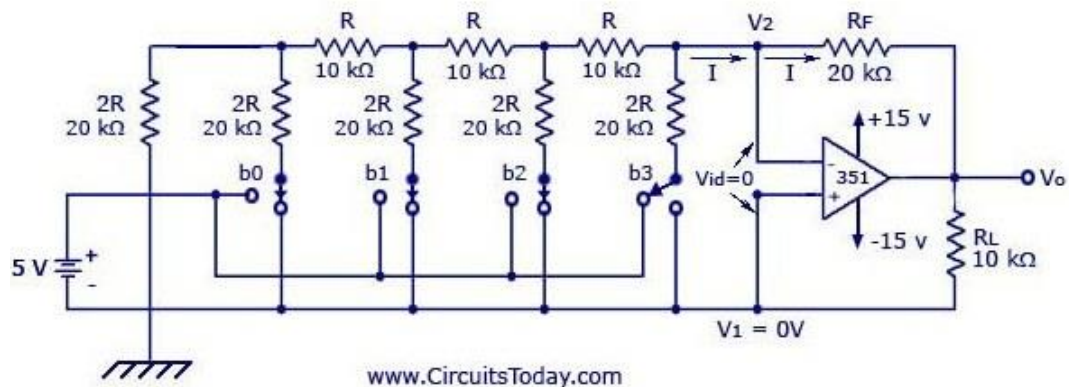
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## EXPERIMENT NO: 12

**Aim:** To convert Digital voltage into equivalent Analog voltage using Digital-to-Analog converter.

**Apparatus Required:** D/A Converter kit, connecting chords etc.

**Circuit Diagram:**



**Principle:** A R-2R ladder type D/A Converter is designed by resistors having two values and thus overcome the disadvantage of Binary Weighted resistor DAC.

From the above circuit we can calculate the value of voltage on different nodes as  $V_R/2$ ,  $V_R/4$ ,  $V_R/8$  and  $V_R/16$ . The total current entering on current to voltage converter is given by

$$I = I_1 + I_2 + I_3 + I_4$$

$$I = \frac{V_R}{4R} + \frac{V_R}{8R} + \frac{V_R}{16R} + \frac{V_R}{32R} = \frac{V_R}{2R} \left[ \frac{1}{2} + \frac{1}{4} + \frac{1}{8} + \frac{1}{16} \right]$$

The output voltage of digital to analog converter is given by

$$V_o = -IR_F \quad (\text{Since } R_F = 2R)$$

$$V_o = V_R [D_{n-1}2^{-1} + D_{n-2}2^{-2} + \dots \dots D_12^{-(n-1)} + D_02^{-n}]$$

Which can be written as

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$$V_o = \frac{V_{ref} \times \text{Digital bit value}}{2^n}$$

**Observation Table:** Reference voltage  $V_{Ref} = \dots$  Volts

Sr. No.	Digital Input (Binary Bits)	Analog Output (Measured)	Analog Output (Calculated)
1	00000001		
2	00000010		
3	00000100		
4	00001000		
5	00010000		
6	00100000		
7	01000000		
8	10000000		
9	11111111		

**Result and Discussion:**