SRM VALLIAMMAI ENGINEERING COLLEGE

(An Autonomous Institution)

SRM NAGAR, KATTANKULATHUR – 603 203

1907304 MEASUREMENTS AND TRANSDUCERS LABORATORY MANUAL

Regulation 2019

(For III semester B.E – EIE Academic Year 2022-2023(Odd Sem))

Department of Electronics and Instrumentation Engineering

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SYLLABUS

1907304 MEASUREMENTS AND TRANSDUCERS LABORATORY **LTPC**
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COURSE OBJECTIVES

- To make the students aware of basic concepts of measurement and operation of different types of transducers.
- To make the students conscious about static and dynamic characteristics of different types of transducer.
- To make the students to analyze step response of RTD
- To make the student to measure resistance using bridge circuits.
- To make the students to calibrate the electrical instruments

LIST OF EXPERIMENTS:

1. Displacement versus output voltage characteristics of a potentiometric transducer.
2. Characteristics of Strain gauge and Load cell.
3. Characteristics of LVDT, Hall Effect transducer and Photoelectric tachometer.
4. Characteristics of LDR, thermistor and thermocouple.
5. Step response characteristic of RTD and thermocouple.
6. Temperature measurements using RTD with three and four leads.
7. Wheatstone and Kelvin's bridge for measurement of resistance.
8. Schering Bridge for capacitance measurement and Anderson Bridge for inductance measurement.
9. Measurement of Angular displacement using resistive and Capacitive transducer.
10. Calibration of Single-phase Energy meter and wattmeter.
11. Calibration of Ammeter and Voltmeter using Shunt type potentiometer.

Minimum of ten experiments to be offered from the list. Additional one or two experiments can be framed beyond the list or curriculum

TOTAL : 60 PERIODS

COURSE OUTCOMES (COs)

1. Understand the concepts of measurement, error and uncertainty.
2. Understand the static and dynamic characteristics of measuring instruments.
3. Gain knowledge about the principle of operation and characteristics of different types of resistance, capacitance and inductance transducers.
4. Acquire knowledge of analyzing different stages of signal conditioning units.
5. Ability to work as a member of a team while carrying out experiments

CONTENTS

CYCLE OF EXPERIMENTS

Exp. No.	Name of the Experiment
	CYCLE-I
1	Displacement versus output voltage characteristics of a potentiometric transducer.
2	Characteristics of a) Strain gauge b) Load cell.
3	Characteristics of a) LVDT b) Hall Effect transducer c) Photoelectric tachometer
4	Characteristics of a) LDR b) Thermistor c) Thermocouple.
5	a) Wheatstone bridge for measurement of resistance. b) Kelvin's bridge for measurement of resistance.
6	Calibration and range extension of a) Ammeter. b) Voltmeter.
	CYCLE-II
7	Step response characteristic a) RTD b) Thermocouple
8	Temperature measurements using RTD with three and four leads
9	a) Schering Bridge for capacitance measurement b) Anderson Bridge for inductance measurement
10	Calibration of a) Single-phase Energy meter b) Wattmeter
11	Measurement of angular displacement using a) Resistive b) Capacitive transducer.
	ADDITIONAL EXPERIMENTS
12	Temperature measurement using Filled System Thermometer.

Exp No.:1 **Date:**

CHARACTERISTICS OF A POTENTIOMETRIC TRANSDUCER

Aim:

To obtain the displacement versus output voltage characteristics of potentiometer.

Apparatus required:

S. No.	Components / Equipments	Specification	Quantity
1.	Power Supply	(0-30V)	1
2.	Voltmeter	(0-30V), MC	1
3.	Potentiometer	---	1
4.	Connecting Wires	----	Few

Theory:

The potentiometer is used to find the unknown voltage, current & power. It is effectively utilized for calibrating voltmeter, ammeter & wattmeter. Its principle is comparing the unknown voltage with the known voltage. Unlike the deflecting methods, the errors occurred in measurement using potentiometer were found to be minimum.

Construction:

Potentiometers comprises of a resistive element and a sliding contact (wiper) that moves along the element making good electrical contact with it. The wiper mechanism moves from one end to the other there by producing change of resistance.According to the position of the wiper shaft the output voltage is produced.

Formula:

The true value of voltage is given by$V_o = - \left[V_i \right]$

Where, V_o = Voltage to be measured in volts

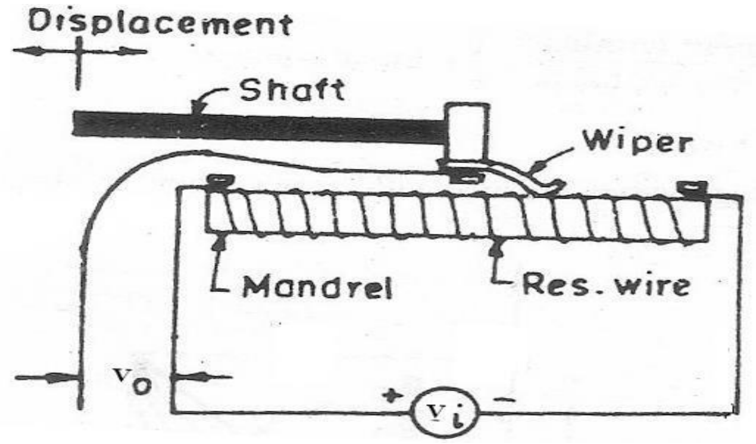
R = Standard resistance in Ω.

X = Length of the potentiometer at which the deflection occurs in cm.

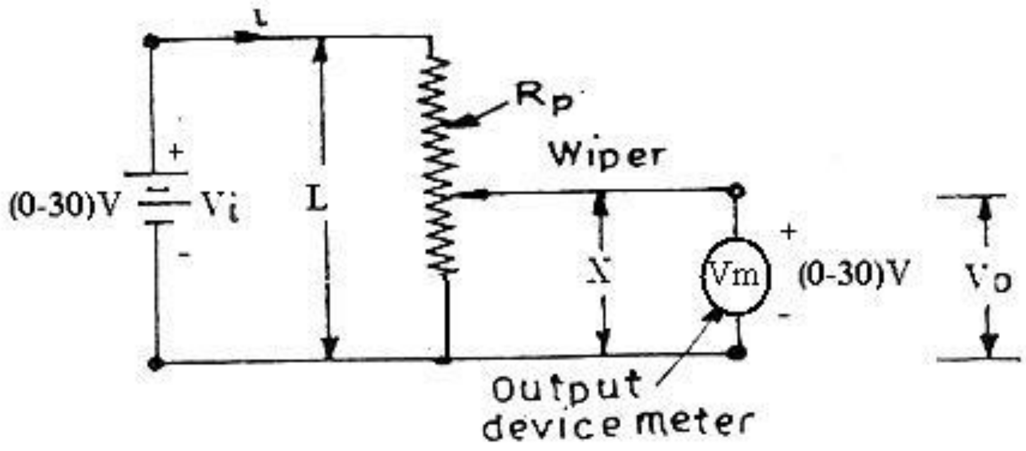
V_i = Voltage applied across the Potentiometer in volts.

L = Length of the potentiometer wire in cm.

Generalized Diagram:



Circuit Diagram:



Procedure:

1. Connections are given as per the circuit diagram.
2. Keep the potentiometer in the minimum position.
3. Switch on the power supply.
4. Measure the Input Voltage (V_i), Output Voltage (V_o) using voltmeter.
5. Measure the total Length (L) and the displacement length (X) of the potentiometer.
6. Measure the Output Voltage (V_o) by keeping the sliding contact at different positions (X,lengths).
7. Calculate the theoretical voltage using the given formula.

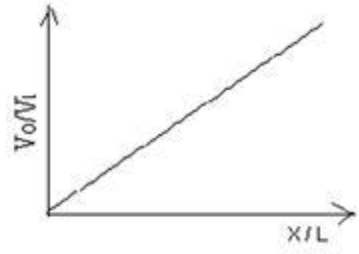
Graph: Plot the graph between X/L (X-axis) and V_o/V_i (Y-axis).

Tabulation:

Input Voltage V_i(Volts) :_______ **Total Length L(cm):________**

S. No.	Displacement X (cm)	OutputVoltage V_o (Volts)		–	—
		Theoretical	Practical		

Model Graph:



Space for Calculation:

Result:

Thus the characteristic of potentiometer was obtained**.**

Inference:

Review Questions:

1. Define transducer.
2. Classify transducers.
3. Name some resistive transducers.
4. What are active and passive transducers?
5. Name some active and passive transducers.
6. Define linearity of a transducer.
7. Define sensitivity of a transducer.
8. What are the materials used in potentiometers?
9. State the advantages & disadvantages of potentiometers.

CHARACTERISTICS OF STRAIN GAUGES

Aim:

To study the characteristics of strain gauges.

Apparatus required:

S. No.	Components / Equipments	Specification	Quantity
1.	Strain Gauge Kit	---	1
2.	Digital Multimeter	---	1
3.	Standard weights	100g, 200g & 500g	1,2&1

Theory:

If a metal conductor is stretched or compressed, its resistance changes on account of the fact that both length and diameter of conductor change. Also there is a change in the value of resistivity of the conductor when it is strained and this property is called piezoresistive effect. Therefore resistance strain gauge is also known as piezoresistivegauges. The strain gauges are used for measurement of strain and associated stress in experimental stress analysis.

The change in the value of resistance by straining the gauge may be partly explained by the normal dimensional behavior of elastic material. If a strip of elastic material is subjected to tension or in other words positively strained, its longitudinal dimension will increase while there will be reduction in the lateral dimension. So, when a gauge is stretched to a positive strain, its length increases while its area of cross section decreases. Since the resistance of the conductor is proportional to its length and inversely proportional to its area of cross section the resistance of the gauge increases with positive strain. The extra change in the value of resistance is attributed to a change in the value of resistivity of a conductor when strained.

Let us consider in the case the value of resistance is attributed to a change in the value of resistivity. Length = L, area = A, diameter = D before strained. The material of the wire has a resistivity ρ Therefore resistance of a strained gauge R = ρL/A. Let a tensile stress S be applied to the wire. This produces a positive strain. The length is to increase and area to decrease. Let ΔL = change in length, ΔA = change in area, ΔD = change in diameter and ΔR = change in resistance

$$\frac{dR}{ds} = \frac{\rho}{A}\cdot\frac{\partial L}{\partial s} - \frac{\rho L}{A^2}\cdot\frac{\partial A}{\partial s} + \frac{L}{A}\frac{\partial \rho}{\partial s} \quad \text{...(1)}$$

Divide by resistance $R = \frac{\rho L}{A}$, we have

$$\frac{1}{R}\frac{dR}{ds} = \frac{1}{L}\cdot\frac{\partial L}{\partial s} - \frac{1}{A}\cdot\frac{\partial A}{\partial s} + \frac{1}{\rho}\frac{\partial \rho}{\partial s} \quad \text{...(2)}$$

It is evident from the equation 2, that the per unit change resistance is due to

(i) per unit change length in length =ΔL/L
(ii) per unit change in area =ΔA/A
(iii) per unit change in resistivity= $\partial\rho/\rho$

Area A = $\frac{\pi}{4}D^2 \quad \therefore \frac{\partial A}{\partial s} = \frac{\pi}{4}2D.\frac{\partial D}{\partial s}$ ....(3)

$$\frac{1}{A}\frac{dA}{ds} = \frac{(2\pi/4)D}{(\pi/4)D^2}\frac{\partial D}{\partial s} = \frac{2}{D}\frac{\partial D}{\partial s} \quad (4)$$

Equation 2 can be written as

$$\frac{1}{R}\frac{dR}{ds} = \frac{1}{L}\frac{\partial L}{\partial s} - \frac{2}{D}\frac{\partial D}{\partial s} + \frac{1}{\rho}\frac{\partial \rho}{\partial s} \quad \text{......................... (5)}$$

Now poisson's ratio = $\frac{\text{lateral strain}}{\text{longitudinal strain}} = -\frac{\partial D/D}{\partial L/L}$ …………………..... (6)

$$\frac{\partial D}{D} = -\nu \times \frac{\partial L}{L}$$

$$\frac{1}{R}\frac{dR}{ds} = \frac{1}{L}\cdot\frac{\partial L}{\partial s} + \nu\frac{2}{L}\cdot\frac{\partial L}{\partial s} + \frac{1}{\rho}\frac{\partial \rho}{\partial s} \quad (7)$$

For a small variation, the above relationship can be written as

$$\frac{R}{R} = \frac{L}{L} + 2v\frac{L}{L} + \frac{\rho}{\rho} \qquad ....(8)$$

The gauge factor is defined as the ratio of per unit change in resistance to per unit change in length.Gauge factor $G_f = \frac{R/R}{L/L}$ ....(9)

$$\frac{R}{R} = G_f \frac{L}{L} = G_f \times \in \; ....(10)$$

$\in = Strain = \frac{L}{L}$ .The gauge factor can be written as

$$G_f = \frac{R/R}{L/L} = 1 + 2v + \frac{\rho/\rho}{L/L} \qquad (11)$$

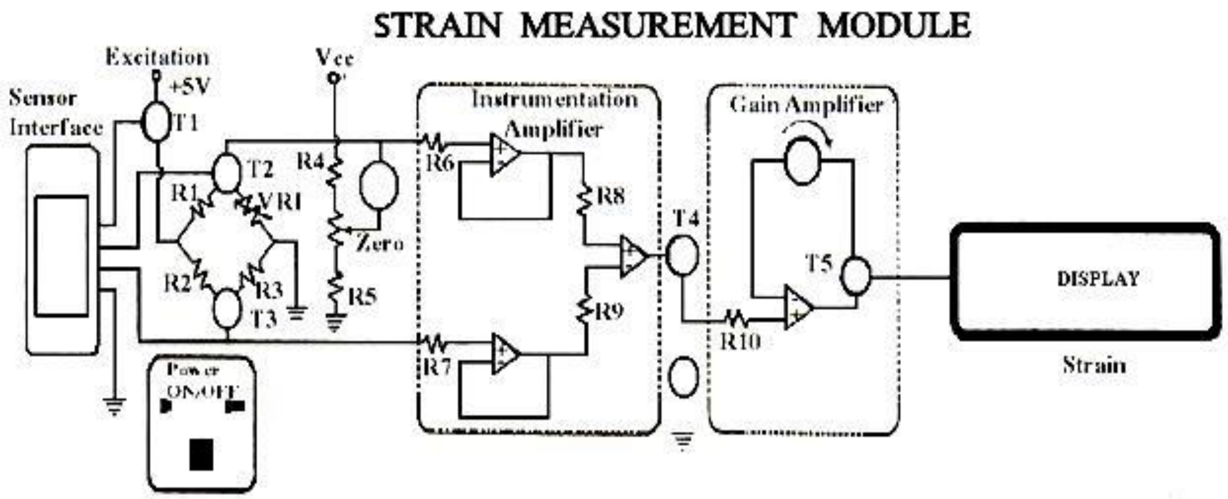
If the change in the value of resistivity of a material when strained is neglected, the gauge factor is

G_f= 1 + 2V ……………………………………….……..…..…(12)

The equation 12 is valid only for piezo electric effect. The poisson ratio for all metals is found to be between 0 and 0.5. This gives a gauge factor of approximately 2. The common values of gauge factor for wire wound strain gauges are:

Material	Gauge factor	Material	Gauge factor
Nickel	- 12.1	Platinum	+ 4.8
Manganin	+ 0.47	Carbon	+ 20
Nichrome	+ 2.0	Doped crystals	100 to 5000
Constantan	+ 2.1	Soft iron	+ 4.2

Module Diagram:



Procedure:

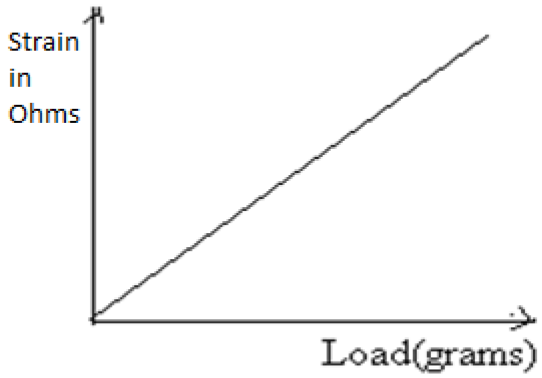
1. Connect the trainer with the load applying column.
2. Connect the multimeter at the output terminal.
3. Switch ON the kit.
4. Initially at no load, zero adjustment has to be done.
5. Gradually increase the load and note down the corresponding output voltage.

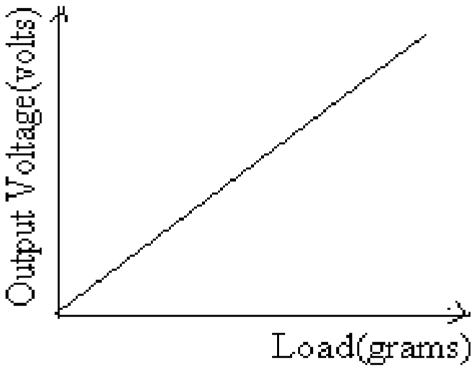
Graph: Plot the graph Strain Vs Load and Output Voltage Vs Load.

Tabular column:

S.No.	Load in gm	Strain in Ω		% error	Output Voltage in Volts
		Theoritical	Practical		

Model graph:





Result:

Thus the characteristics of strain gauge were studied and the graphs were plotted for different weights.

Inference:

Review Questions:

1. State piezoreistive effect.
2. Define Poisson's ratio.
3. Define Gauge factor of a strain guage.
4. What is the importance of gauage factor of a strain gauge?
5. What are the types of strain gauges?
6. What are the advantages of semiconductor strain gauge?
7. What are the disadvantages of semiconductor strain gauges?
8. What is Rosettes?

Exp No.:2(b) **Date:**

CHARACTERISTICS OF LOAD CELL

Aim:

To study the characteristics of load cell.

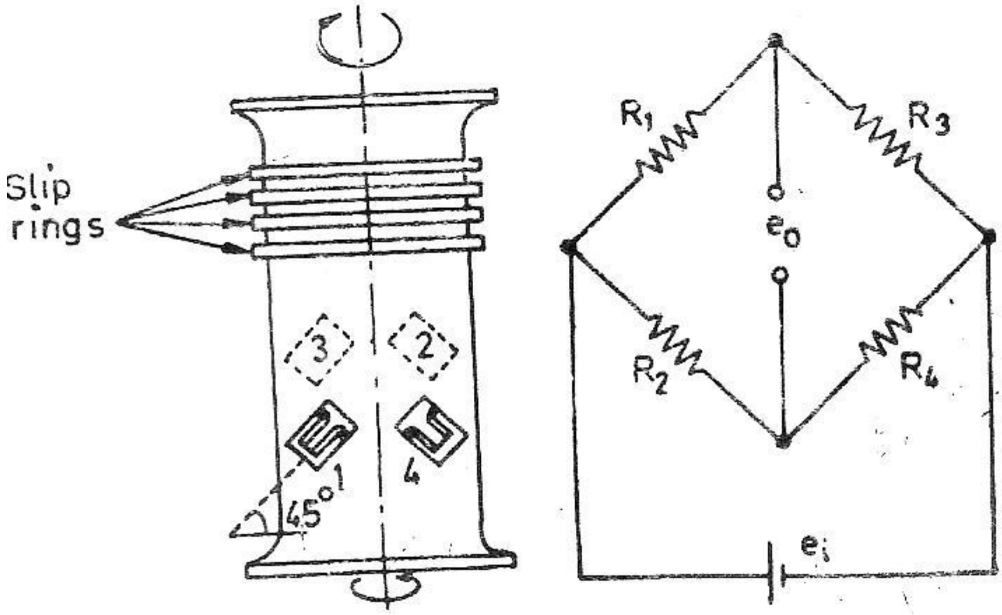
Apparatus Reuired:

S. No.	Components / Equipments	Specification	Quantity
1.	Load cell with indicator Kit	---	1
2.	Digital Multimeter	---	1
3.	Standard weights	100g, 200g & 500g	1,2&1

Theory:

Single channel digital load meter is designed for use with strain gauge type load transducer and load cell for most of the load. The instrument displays load values directly in kgs. This instrument is equipped with internal calibration setting which enables the operator to calibrate any load with the instrument. The physical parameter which is to be measured is issued by load cell and converted to a proportional electric signal. The signal after suitable processing is fed to a high accuracy digital voltmeter. Strain gauges are bonded on the surface of a cantilever which is used as the active element. The guages are connected in the form of a wheatstone network. When a load is applied to the cantilever beam, it expands thus straining the gauges and thus resistance changes.

Generalized Diagram:

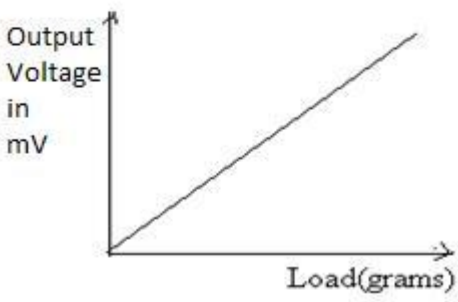


Procedure:

1. Connect the load cell with the digital meter.
2. Switch ON the power supply.
3. Adjust the meter for zero reading initially.
4. Place various weights over the load cell and note down the corresponding values of the output voltage using a digital multimeter.

Graph: Plot the graph with input load in gm on X-axis and output voltage e_0 in mV on the Y-axis.

Model graph:



Tabular Column:

S.No.	Load (gm)	Output Volatge, e_0 (mV)

Result:

Thus the characteristics of Load cell were studied.

Inference:

Review Questions:

1. Define transducer.
2. What are active and passive transducers?
3. What is the principle used in load cell?
4. What are the different designs of load cells with strain guage?
5. What are the factors affecting response characteristics of the load cell?
6. What are the types of Load cells?

Exp No.:3(a) **Date:**

CHARACTERISTICS OF LVDT

Aim:

To study the operation and characteristics of Linear Variable Differential Transformer (LVDT).

Apparatus Required:

S. No.	Components / Equipments	Specification	Quantity
1.	LVDT Trainer Kit	---	1
2.	Digital Multimeter	---	1

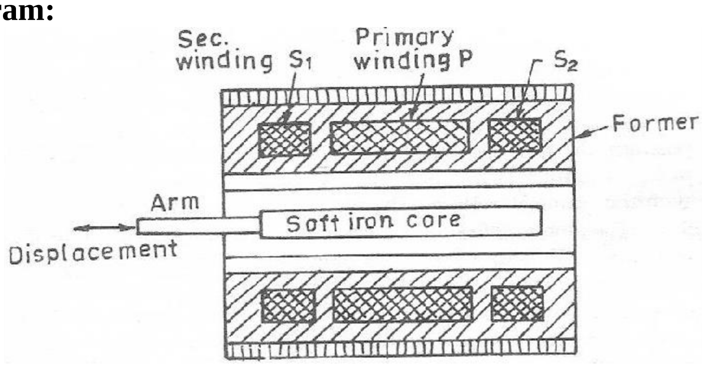
Theory:

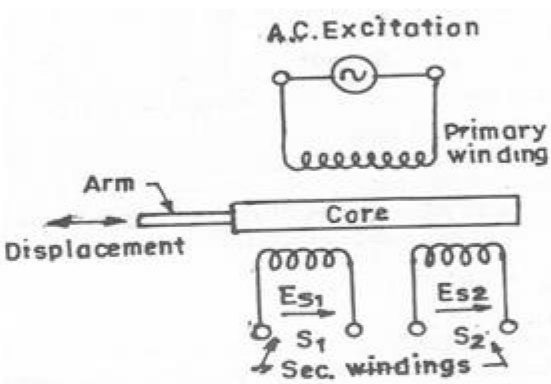
LVDT is the most commonly and extensively used transducer, for linear displacement measurement. The LVDT consists of three symmetrical spaced coils wound onto an insulated bobbin. A magnetic core, which moves through the bobbin without contact, provides a path for the magnetic flux linkage between the coils. The position of the magnetic core controls the mutual inductance between the primary coil and with the two outside or secondary coils. When an AC excitation is applied to the primary coil, the voltage is induced in secondary coils that are wired in a series opposing circuit. When the core is centered between two secondary coils, the voltage induced in the secondary coils are equal, but out of phase by 180°. The voltage in the two coils cancels and the output voltage will be zero.

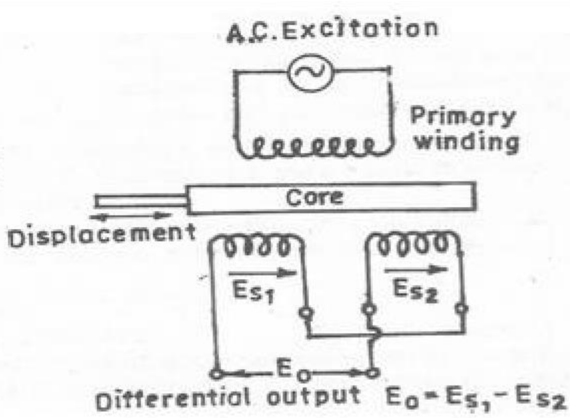
Circuit Operation:

The primary is supplied with an alternating voltage of amplitude between 5V to 25V with a frequency of 50 cycles per sec to 20 K cycles per sec. The two secondary coils are identical & for a centrally placed core the induced voltage in the secondariesE_{s1}&E_{s2} are equal. The secondaries are connected in phase opposition. Initially the net o/p is zero. When the displacement is zero the core is centrally located. The output is linear with displacement over a wide range but undergoes a phase shift of 180°. It occurs when the core passes through the zero displacement position.

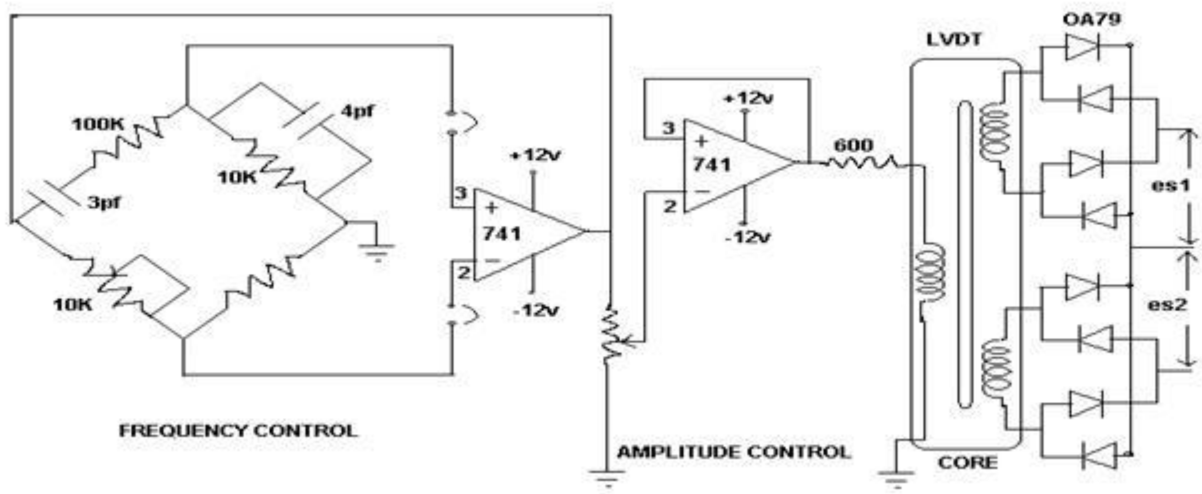
Generalized Diagram:







Trainer kit Diagram:



Procedure:

1. Connect the multimeter at the output terminal of the LVDT kit.
2. Switch ON the LVDT kit.
3. Move the core to different positions using screw guage and measure thesecondary voltages E_{S1}&E_{S2}).
4. Tabulate the readings & calculate the output voltage (E_0).

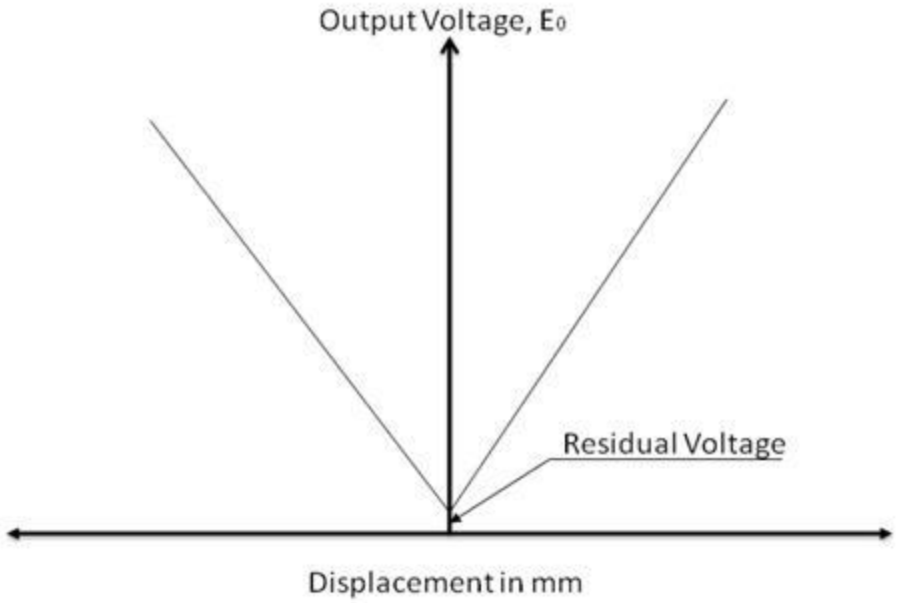
Graph: Plot the graph between core displacement (X-axis) and Output Voltage (Y-axis).

Tabular column:

Screw Guage Reading	**Core displacement (mm)**	**LVDT Output in mV**
		E_0 = (E_{S1} - E_{S2})
0	**-10**	
2	**-8**	
4	**-6**	
6	**-4**	
8	**-2**	
10	**0**	
12	**2**	
14	**4**	
16	**6**	
18	**8**	
20	**10**	

Note : -ve Sign indicates the direction of displacement.

Model graph:



Result:

Thus the operation and characteristics of LVDT was studied.

Inference:

Review Questions:

1. What are primary and secondary transducers?
2. What are the different types of displacement transducers?
3. Explain working principle of LVDT.
4. What is Null voltage?
5. What are the advantages of LVDT?
6. What are the applications of LVDT?

Exp No.:3(b) **Date:**

HALL EFFECT TRANSDUCER

Aim:

To study the characteristics of Hall Effect transducer.

Apparatus Required:

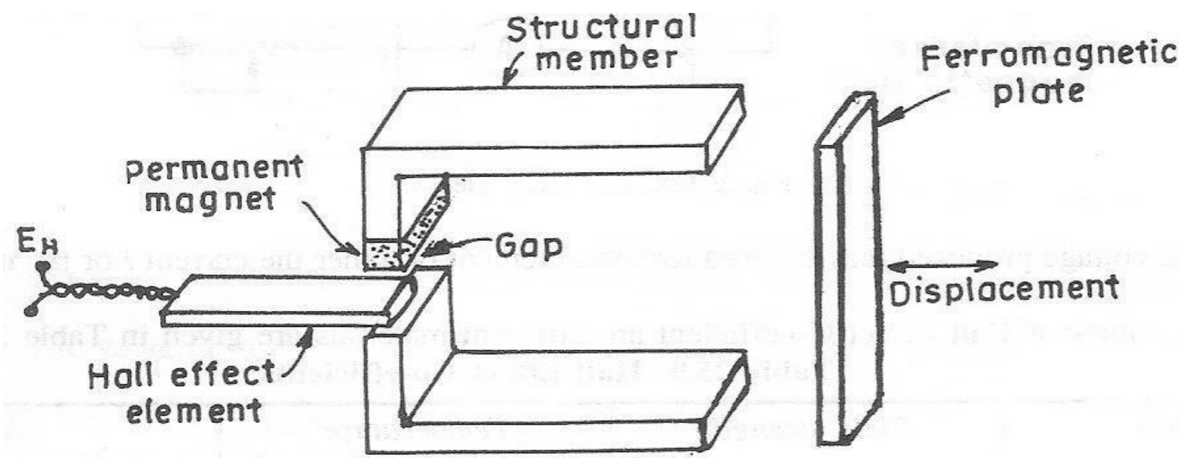
S. No.	Components / Equipments	Specification	Quantity
1.	Hall Effect characteristics trainer	---	1
2.	Digital Multimeter	---	1
3.	Magnet	---	1

Theory:

A Hall Effect sensor is a transducer that varies its output voltage in response to a magnetic field. Hall Effect sensors are used for proximity switching, positioning, speed detection, and current sensing applications.With a known magnetic field, its distance from the Hall plate can be determined. Using groups of sensors, the relative position of the magnet can be deduced.

Electricity carried through a conductor will produce a magnetic field that varies with current, and a Hall sensor can be used to measure the current without interrupting the circuit. Typically, the sensor is integrated with a wound core or permanent magnet that surrounds the conductor to be measured.

Generalized Diagram:



Procedure:

1. Connect the multimeter at the output terminal of the Hall Effect kit.
2. Switch ON the kit.
3. Place the North Pole of the magnet near the hall sensor.
4. Measure the halleffect voltage for different magnetic intensities. (The magnetic intensity can bevaried by varying the distance between the halleffect element & the magnet).
5. Repeat the step (4) for the South Pole also.

Graph: Plot the graph between displacement (X-axis) and Output voltage (Y-axis).

Model Graph:

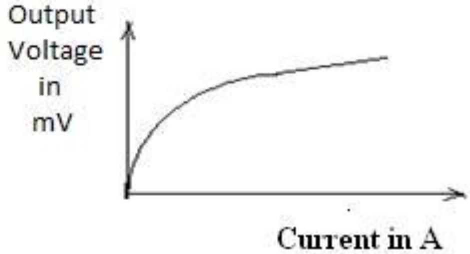


Table:

S.No.	**Ammeter** (A)	**Output Voltage (mV)**

Result:

Thus the characteristic of the Hall Effect transducer is studied.

Inference:

Review Questions:

1. Name the different displacement transducers.
2. What is Hall Effect?
3. How will you measure magnetic field?
4. What are the applications of Hall Effect transducers?
5. Write the expression for the voltage induced in a Hall Effect transducer.

Exp No.:3(c) **Date:**

PHOTOELECTRIC TACHOMETER

Aim:

To study the characteristics of photoelectric tachometer.

Apparatus Required:

S. No.	Components / Equipments	Specification	Quantity
1.	Tachometer	---	1
2.	DC Motor	---	1

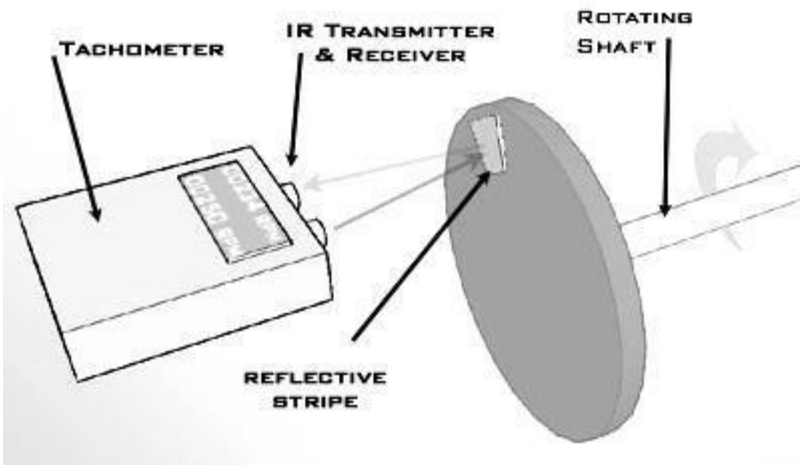
Theory:

A **tachometer** is an instrument measuring the rotation speed of a shaft or disk, as in a motor or other machine. The device usually displays the revolutions per minute (RPM) on digital display.

This is a device that produces a voltage proportional to the speed of a rotating shaft. Common examples include the rev' counter found in many vehicles. This measures the rotation of the engine crank shaft. The speedometer in vehicles measures the wheel rotation speed. Wind speed gauges use a similar system.Here is a convenient way to detect the rotation of a shaft.

As the notched wheel rotates, the light beam is interrupted. This appears as a small square(ish) wave output from the photodiode. When the shaft rotates faster, more pulses are produced but the pulses are also shorter. This means that the average output remains constant. To make a useful measuring device, the variable length pulses from the photodiode need to be converted into fixed length pulses. A monostable circuit achieves this. The monostable needs to be triggered by short pulses

Generalized Diagram:



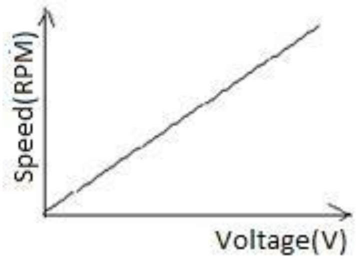
Procedure:

1. Switch ON the DC motor.
2. Keep the photoelectric tachometer against the shaft of the DC motor and note down the speed (RPM) of the disc, which displays on tachometer display.
3. Repeat the same for different speeds by varying the DC motor supply.

Tabular column:

DC motor supply voltage (Volts)	Photoelectric Tachometer Reading (RPM)		% error
	Observed	Actual	

Model graph



Result:

Thus the characteristics of photoelectric tachometer was studied.

Inference:

Review Questions:

1. State the different types of photoelectric transducer.
2. What are the advantages of photoelectric transducers?
3. What are the disadvantages of photoelectric transducers?
4. State the working principle of Stroboscope.
5. Name the other methods used to find the speed of the shaft.

Exp No.:4(a) **Date:**

CHARACTERISTICS OF LDR

Aim:

To study the characteristics of Light DependantResistor (LDR).

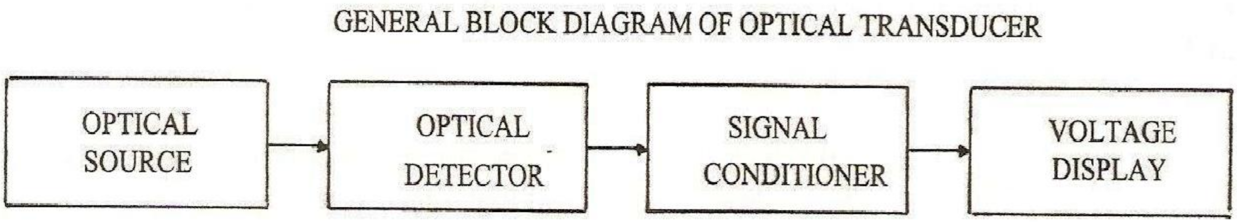
Apparatus Required:

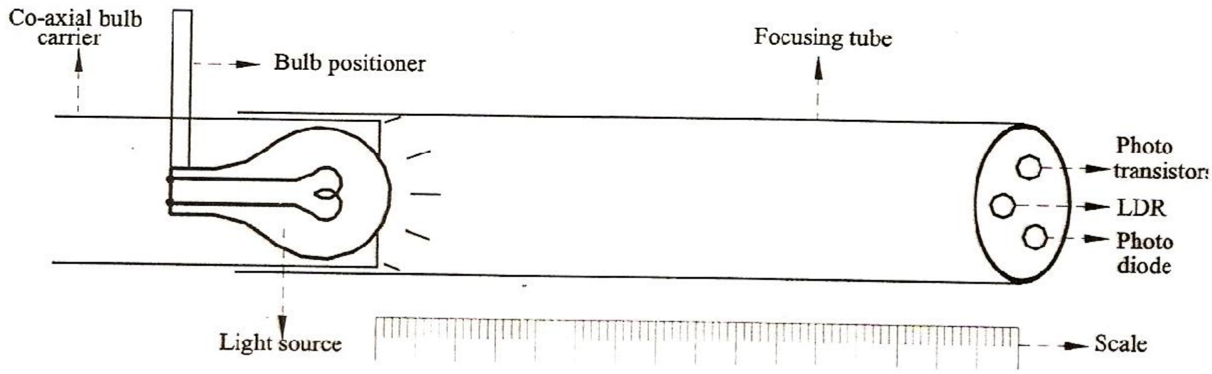
S. No.	Components / Equipments	Specification	Quantity
1.	LDR Trainer Kit	---	1
2.	Digital Multimeter	---	1

Theory:

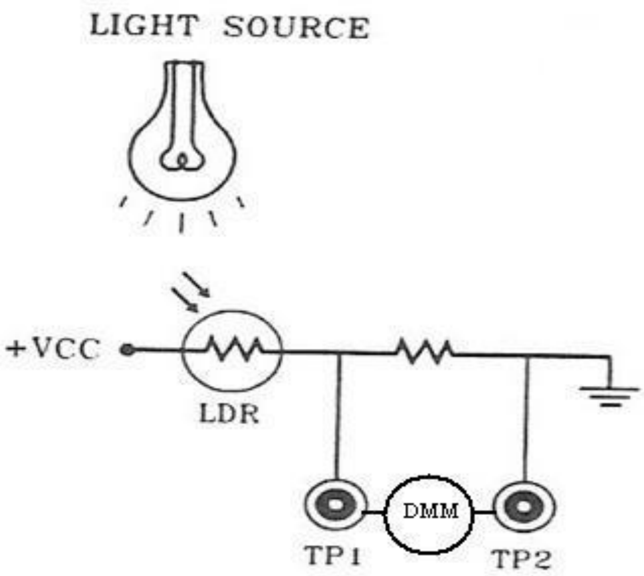
LDR is a photosensitive material whose resistance changes when light falls on it. The resistance of LDR is linearly proportional to the light intensity on it. It is made of non-reflective material usually a semiconductor. If radiation falls upon a semiconductor its conductivity increases. The radiant energy supplied to the semiconductor. This increases the number of current carriers. These increased current carriers decrease the resistance of the material and hence this device is called a LDR orPhotoresistor. Due to this property LDR is used in many applications.Cadmiumsulphidecell, Lead sulphide cell and selenium cells are used for the manufacturing of LDR. But cadmium sulphide due to their high dissipation capacity and their excellent sensitivity are mostly preferred.

Block Diagram:





Circuit Diagram:



Procedure:

Variation of LDR resistance with respect to the distance between source and LDR for aconstant voltage:

1. Connnect the multimeter at the output terminal of the LDR kit.
2. Switch ON the kit.
3. The distance of LDR from the light source is varied and the voltage of LDR is measured using amultimeter.

Graph: A graph is drawn between Voltage Vs Distance. The graph follows the below relation.

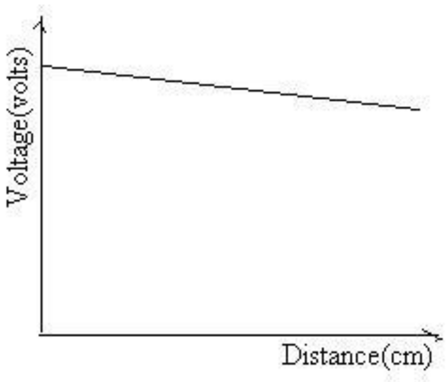
$R_{LDR} \alpha 1 / \sqrt{I_{LIGHT}}$.

Where I_{LIGHT} - Intensity of Light.

Tabular Column:

S.No.	**Distance between source & LDR (cm)**	**Voltage across LDR (Volts)**	**Resistance Rf = -(V0 * Ri/Vi) (Kilo ohms)**

Model Graph



Result:

Thus the characteristics of LDR was obtained.

Inference:

Review Questions:

1. Name some resistive transducers.
2. What is the principle of LDR?
3. What are the applications of LDR?
4. State the advantages of LDR.
5. State the disadvantages of LDR

Exp No.:4(b) **Date:**

CHARACTERISTICS OF THERMISTOR

Aim:

To determine the characteristics of thermistor.

Apparatus Required:

S. No.	Components / Equipments	Specification	Quantity
1.	Thermistors	---	1
2.	Digital Multimeter	---	1
3.	Thermometer	Max. 100°C	1
4.	Water Bath	---	1

Theory:

Thermistors are semiconductors with high negative temperature coefficient of resistance. The high sensitivity of the thermistor makes it useful for precision temperature measurement. Oxides of titanium and nickel are among the materials used. They are very sensitive with temperature coefficients that range from -2 to -6Ω /°C. They are capable of detecting minute changes in temperature. Their resistance at 25°C ranges from 100Ω to 100KΩ with 5000Ω being a very common value. Their linearity is the poorest of those of all temperature sensors. The usual range of thermistors is from - 200°C to 1000°C. A single thermistor cannot be used over such a large range.

For Thermistor

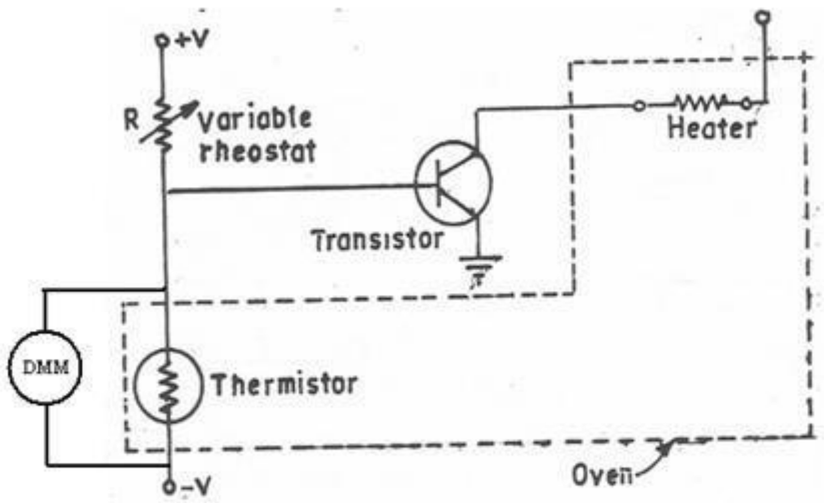
$$R_T = R_0\, e^{\beta} \left[(1 / T) - (1 / T_0) \right]$$

R_T - Resistance of thermistor at T deg K

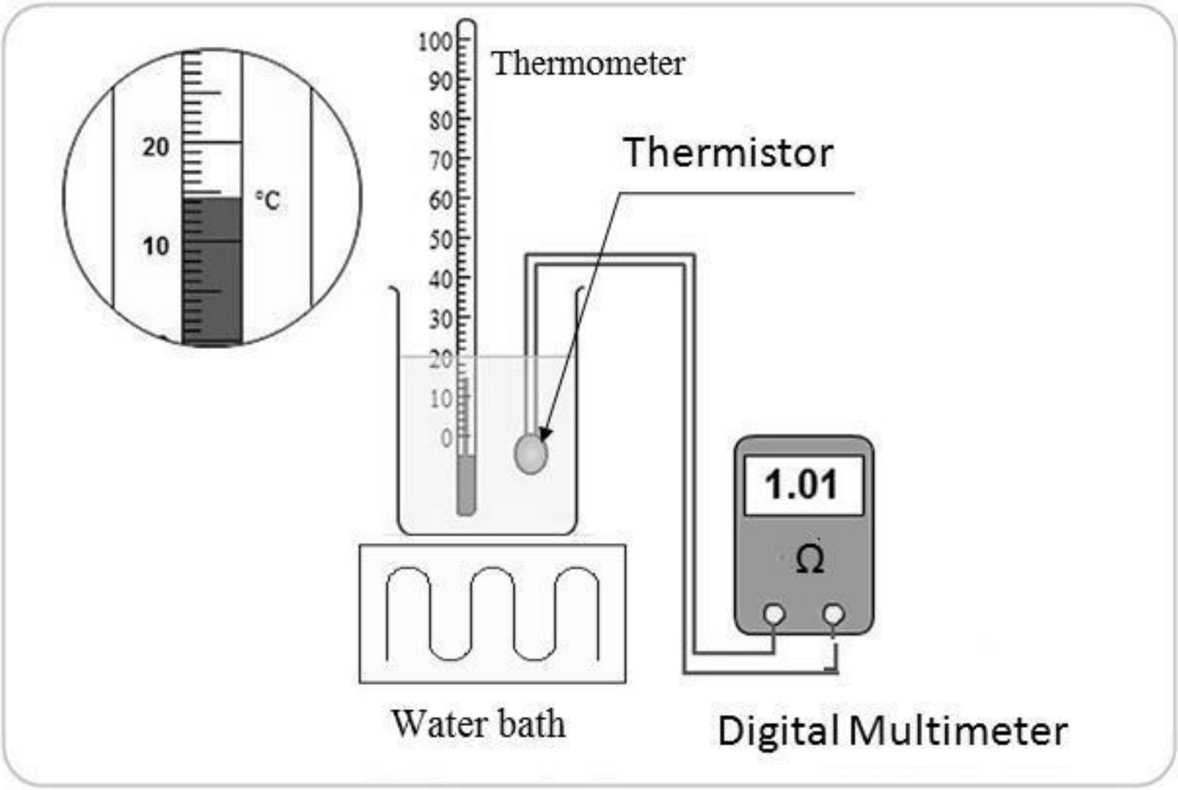
R_0 - Resistance at room temperature

β - Thermistor constant

Circuit Diagram:



Experiment setup:



Procedure:

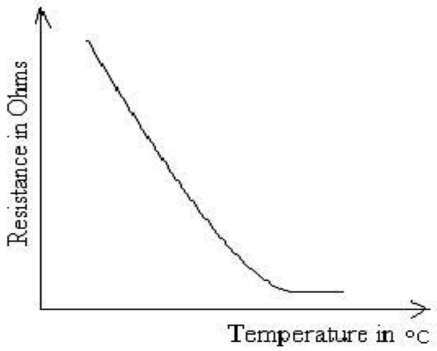
1. Immerse the thermistor & thermometer into the water bath.
2. Connect the leads from the thermistor to the multimeter.
3. Switch ON the water bath.
4. Measure the temperature using the thermometer of water and the corresponding resistance of thermistor using multimeter.
5. For every 5 °C rise, the reading on the thermistor and thermometer are noted until the temperature reaches the max.temperature(100 °C).

Graph: Plot the graph betweenTemperature (X-axis) and Output Resistance (Y-axis).

Tabular Column:

S.No.	Temperature (°C)	Output Resistance (KΩ)

Model graph:



Result:

Thus the characteristics of thermistor is determined.

Inference:

Review Questions:

1. Name the different temperature transducers.
2. What is thermistor?
3. What is the temperature range of thermistor?
4. What is the difference between RTD and thermistor?
5. What are the materials used to manufacture thermistor?

Exp No.:4(c) **Date:**

CHARACTERISTICS OF THERMOCOUPLE

Aim:

To study the characteristics of Thermocouple.

Apparatus Required:

S. No.	Components / Equipments	Specification	Quantity
1.	Thermocouple	---	1
2.	Digital Multimeter	---	1
3.	Thermometer	Max. 100°C	1
4.	Water Bath	---	1

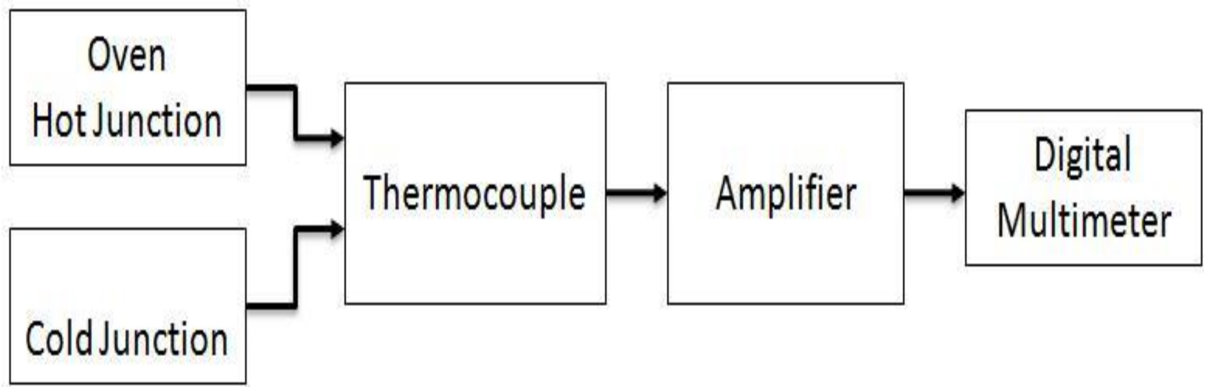
Theory:

Thermocouple is a temperature transducer based on seebeck effect. It is the most common and widely used single device for temperature measurement in industrial applications. Its measurements cover the temperature range of 0°F to 4000°F. Thermocouple is a self generating transducer and it has a pair of dissimilar metallic conductors .If this dissimilar metallic conductor are connected in a circuit with one junction at T_1 and the other at T_2, an emf is developed due to difference in temperature. The relation between E, T_1 and T_2 is called the Seebeck effect. Commonly used materials in the thermocouple are Platinum, Rhodium, Chromel, Alumel, Copper–Constantan and Iron–Constantan.The range of chromel- constantan is 700 to 1200 °C.

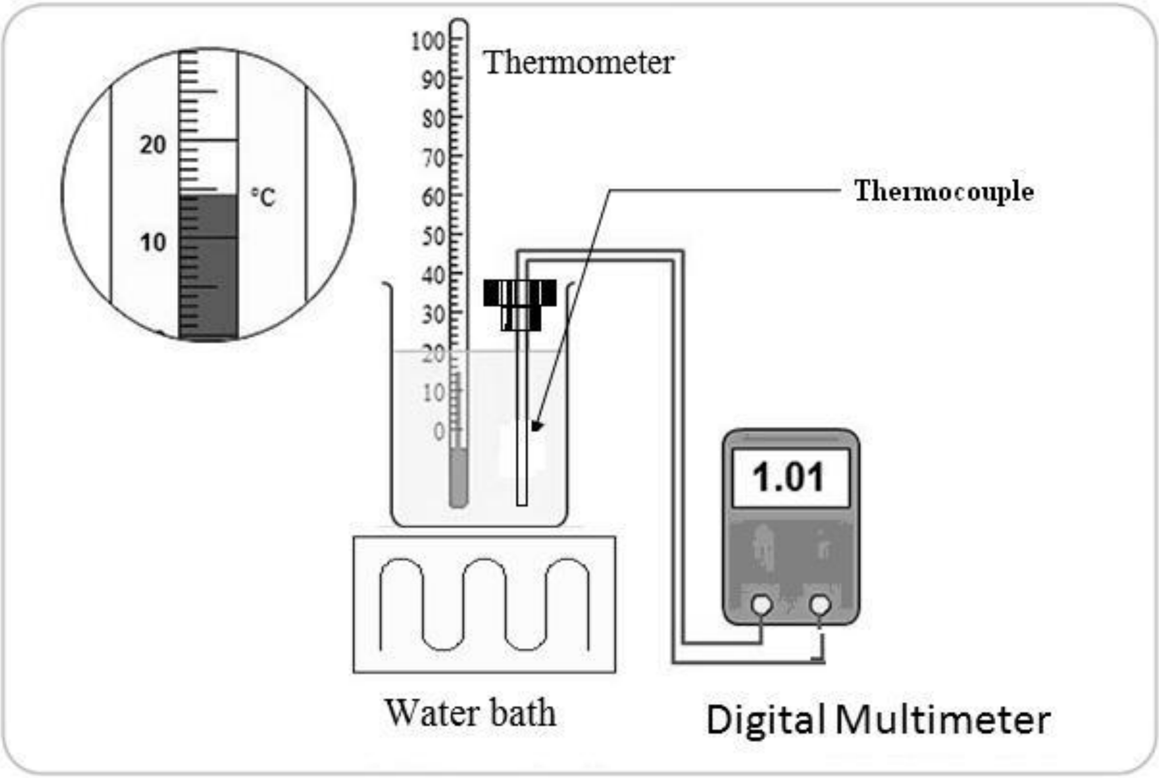
The cold junction of thermocouple is taken as the reference junction and its temperature is kept constant. The hot junction is kept at the place where temperature is to be measured. In lab, it is possible to keep the temperature of cold junction constant but in industries it is not possible. So the variation in thermoemf of thermocouple due to variation in cold junction temperature is to be compensated for exact temperature measurement. Here the compensation is made using Wheatstone bridge in which RTD is placed at one of its arms. Thermocouple output is connected to the non-inverting terminal of operational amplifier. The gain of the amplifier is set to be 10. The bridge excitation comes from a separate D.C. Supply. Finally about 50mV of excitation is made available to the bridge. As the ambient temperature goes changing, the RTD's resistance also changes and small output voltage is developed across the bridge. The bridge output is fed to the inverting input of the amplifier. With higher ambient temperature thermocouple transducer tends to produce lower output voltage.

The RTD bridge circuit automatically takes care of this tendency of the thermocouple by applying a small voltage of proper polarity to the inverting terminal of the amplifier. That is how cold junction compensation is achieved. Condenser connected across the terminals of IC suppresses any unwanted disturbances coming to amplifier. The output of operational amplifier is connected to a pot (MAX.) on the panel and is useful for carrying out the calibration operation. Offset Null Pot is useful for zero adjustment.

Block Diagram:



Experiment Setup:



Procedure:

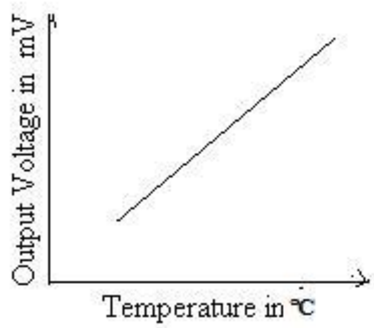
1. Immerse the thermocouple & thermometer into the water bath.
2. Connect the leads from the thermocouple to the respective meter.
3. Switch ON the water bath.
4. Measure the temperature of water using thermometer and the corresponding output voltage of thermocouple using multimeter.
5. For every 5°C rise, the reading of the thermocouple are noted until the temp reaches the maximumtemperature (100 °C).Tabulate the readings.

Graph: Plot the graph between temperature (X-axis) and thermocouple Output voltage (Y-axis).

Tabular column:

S. No.	Thermometer Reading (°C)	Thermocouple Output voltage (mV)

Model Graph:



Result:

Thus the characteristics of thermocouple was studied.

Inference:

Review Questions:

1. What is the principle of thermocouple?
2. What are the different types of thermocouples?
3. What is the temperature range of thermocouple?
4. What is cold junction compensation of thermocouple?
5. State the industrial applications of Thermocouples.

Exp No.:5(a) **Date:**

STEP RESPONSE CHARACTERISTICS OF RTD

Aim:

To analyse the step response characteristics of Resistance Temperature Detector (RTD).

Apparatus Required:

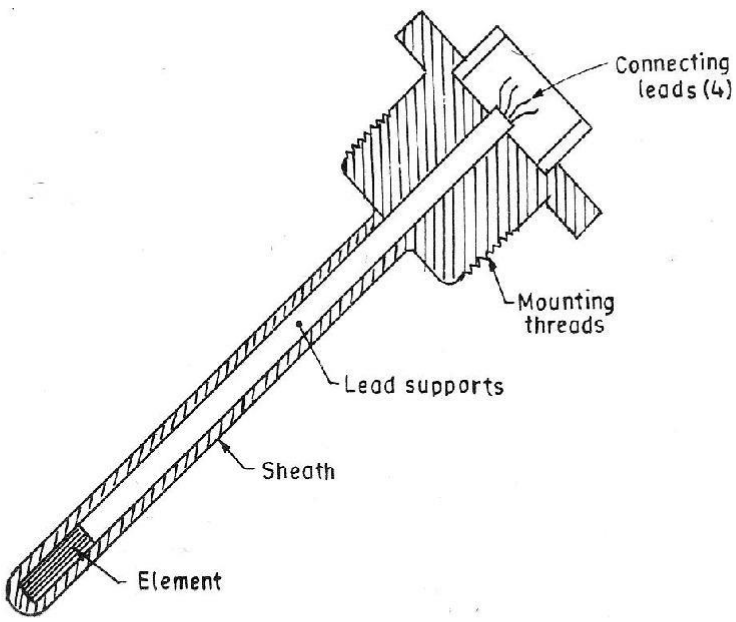
S. No.	Components / Equipments	Specification	Quantity
1.	RTD	PT100	1
2.	Digital Multimeter	---	1
3.	Thermometer	Max. 100°C	1
4.	Water Bath	---	1
5.	Stop Clock	---	1

Theory:

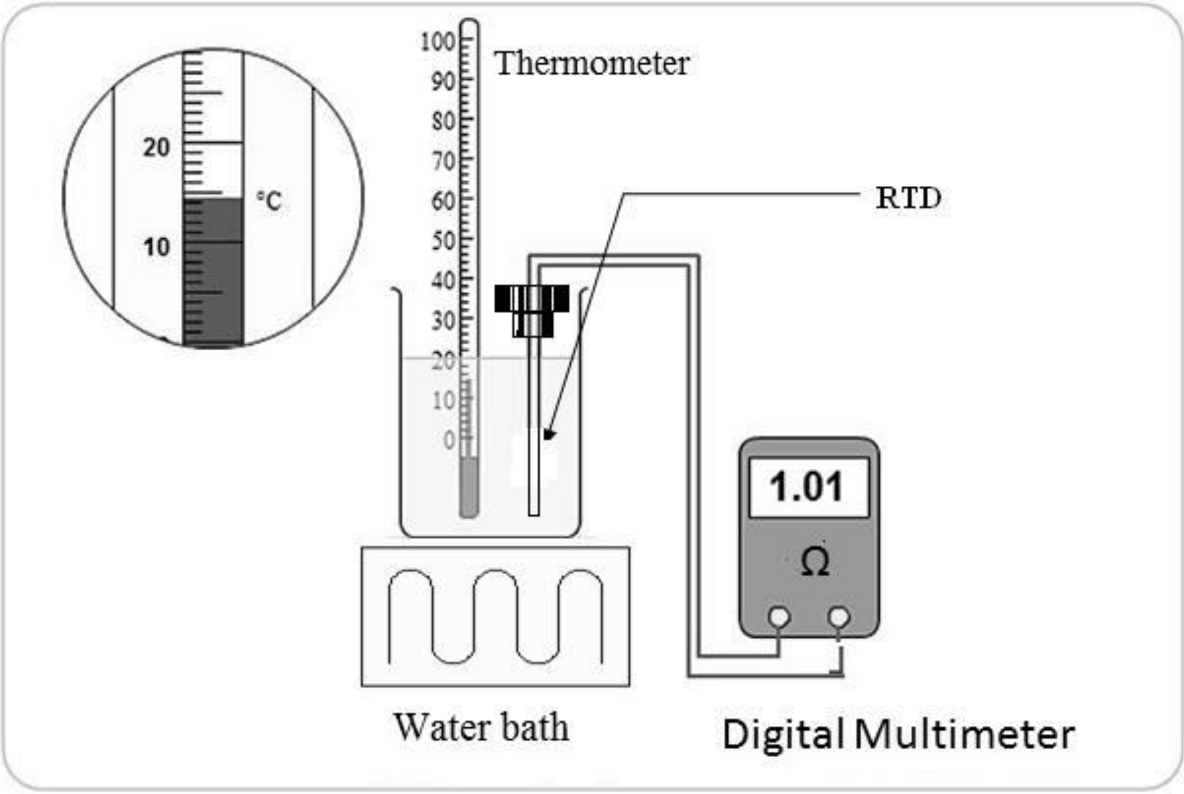
The principle of operation of RTD is based on the fact that electrical resistance of many metals increases almost directly to the temperature and gives high degree of accuracy. These characteristics are well known as Co-efficient of resistance and is defined by the approximate formula $R_t = R_o (1+\alpha t)$ Where, α - Temperature Co-efficient of resistance and R_o. - Resistance of wire at 0°c.

RTD is connected to one of the arms of a bridge circuit. The other two arms are connected by constant resistance. An adjustment and a fixed resistance are attached to the adjacent arm of the bridge. When the RTD is at 0°C the helical potentiometer is set to 0 position by adjusting the MIN control on the panel. The bridge output is given to the meter which also initially indicates zero. The resistance of the RTD changes due to the temperature change.The resistance of the adjacent arm is changed by the introduction of corresponding amount of known resistance until balance is achieved. The change in the resistance of RTD can be measured by noting the revolution of the helical pot.

Generalized Diagram:



Experiment setup:



Procedure:

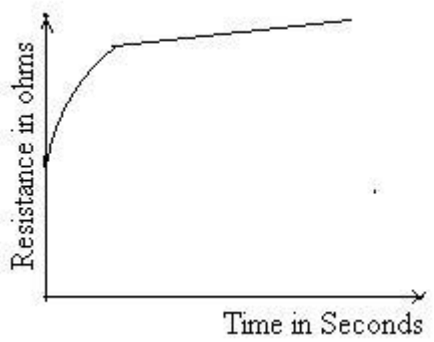
1. Connect the leads from the RTD to the respective meter.
2. The water bath heater is switched ON.
3. When the water temperature reaches the 100 ° C, insert the RTD into the water bath. (That is theRTD is provided a sudden change of input temperature to boiling point (100 ° C) from the roomtemperature, which is the step response observed).
4. Start the stop clock and tabulate the resistance of RTD for every 5 seconds.

Graph: Draw the graph between time in seconds (X – axis) and RTD resistance in ohms(Y – axis).

Tabular Column:

S.No.	Time in Seconds	RTD Resistancein Ohms

Model Graph:



Result:

Thus the step response characteristic of RTD was analysed.

Inference:

Review Questions:

1. What do you mean by step response?
2. What is the principle of RTD?
3. What are the requirements of a conductor to be used in RTD?
4. RTD has _______________ temperature coefficient.
5. What are the materials used for constructing RTD?
6. State the industrial applications of RTD.

Exp No.:5(b) **Date:**

STEP RESPONSE CHARACTERISTICS OF THERMOCOUPLE

Aim:

To analyse the step response characteristics of thermocouple.

Apparatus Required:

S. No.	Components / Equipments	Specification	Quantity
1.	Thermocouple	PT100	1
2.	Digital Multimeter	---	1
3.	Thermometer	Max. 100°C	1
4.	Water Bath	---	1
5.	Stop Clock	---	1

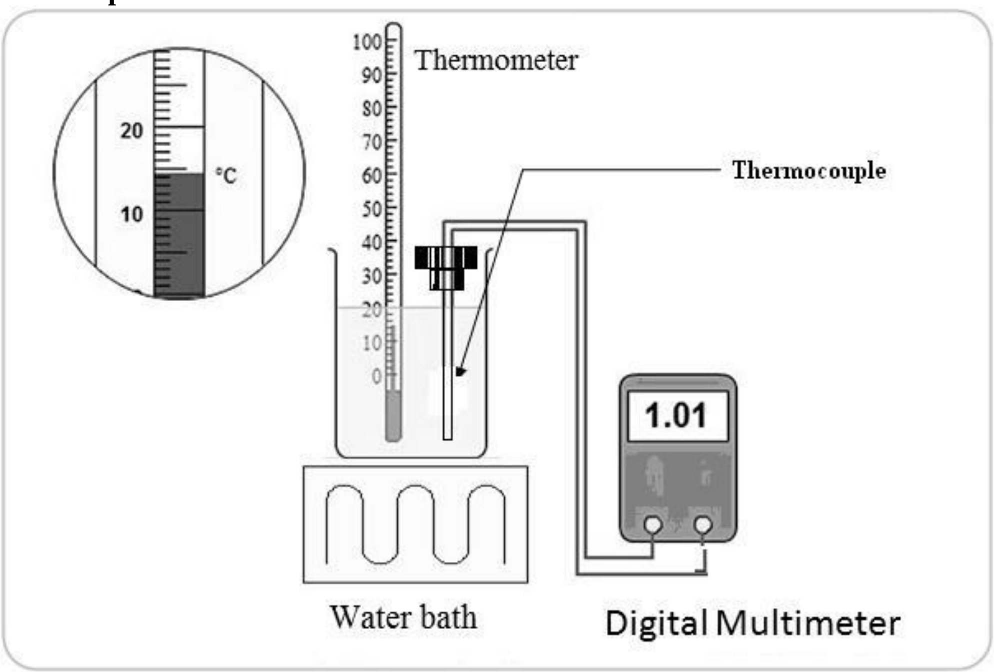
Theory:

Thermocouple is a temperature transducer based on seeback effect. It is the most common and widely used single device for temperature measurement in industrial applications. Its measurement cover the temperature range off 0 °C to 4000°C. Thermocouple is a self generating transducer and it has a pair of dissimilar metallic conductors. If this dissimilar metallic conductor are connected in a circuit with one junction at T_1 and the other at T_2. An emf is developed due to difference in temperature. The relation between E, T_1 and T_2 is called the Seeback effect. Commonly used materials in the thermocouple are Platinum, Rhodium, Chromel, Alumel, Copper –Constantan and Iron
–Constantan. The range of chromel- constantan is 700 to 1200°C.

The cold junction of thermocouple is taken as the reference junction and its temperature is kept constant. The hot junction is kept at the place where temperature is to be measured. In lab, it is possible to keep the temperature of cold junction constant but in industries it is not possible . So the variation in thermoemf of thermocouple due to variation in cold junction temperature is to be compensated for exact temperature measurement. Here the compensation is made using Wheatstone bridge in which RTD is placed at one of its arms. Thermocouple output is connected to the non-inverting terminal of op. amp. And gain of the amplifier is set to be 10. To the inverting terminal of the op. amp output from a Wheatstone bridge is supplied.

As the ambient temperature goes changing, the RTD's resistance also changes and small output voltage is developed across the bridge. The bridge output is fed to the inverting input of the amplifier. With higher ambient temperature thermocouple transducer tends to produce lower output voltage. The RTD bridge circuit automatically takes care of this tendency of the thermocouple by applying a small voltage of proper polarity to the inverting terminal of the amplifier. This is how cold junction compensation is achieved.

Experiment Setup:



Procedure:

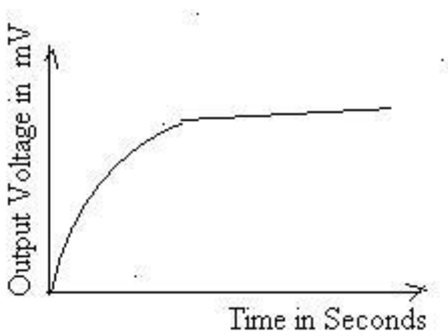
1. Connect the leads from the thermocouple to the multimeter.
2. Note down the initial temperature and the corresponding thermocouple output.
3. Switch ON the bath.
4. When the water temperature reaches the 100 °C, insert the thermocouple into the water bath. (That is the thermocouple is provided a sudden change of input temperature to boiling point (100° C) from the room temperature, which is the step response observed).
5. Start the stop clock and tabulate the thermocouple output for every 5 seconds.

Graph: Draw the graph between time in seconds and thermocouple output voltage in mV.

Tabular Column:

S. No.	Time (Seconds)	Thermocouple Output (mV)

Model graph:



Result:

Thus the step response characteristic of Thermocouple was analysed.

Inference:

Review Questions:

1. What is Seeback effect?
2. State Peltier effect?
3. What is Thermopile?
4. What is cold junction compensation? Why it is required?
5. What are the different types of thermocouples?

Exp No.:6 **Date:**

TEMPERATURE MEASUREMENTS USING RTD WITH THREE AND FOUR LEADS

Aim:

To measure the temperature using RTD with three and four leads configuration

Theory:

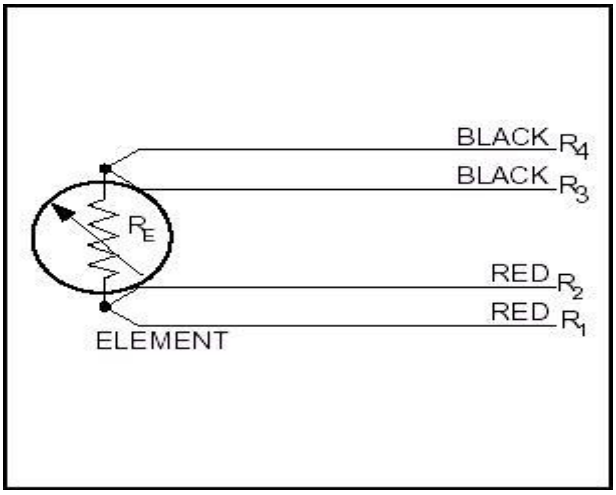
3 Wire RTD configuration:

In order to minimize the effects of the lead resistances, a three-wire configuration can be used. Using this method the two leads to the sensor are on adjoining arms. There is a lead resistance in each arm of the bridge so that the resistance is cancelled out, so long as the two lead resistances are accurately the same.

In a three-wire circuit two constant current sources are used, in order to compensate for the disadvantages described above for the two-wire circuits. Similar to the two-wire circuit the current source IK2 is used to measure the temperature dependent resistance RT including the lead and terminal contact resistances. The additional current source IK1 together with a third lead is used to separately compensate the lead and terminal contact resistances. Assuming the exact same lead and terminal contact resistances for all three leads, the effect on the accuracy of the temperature measurements can be eliminated. But practice has shown that it is not always possible to assure that the terminal contact resistances are always identical.

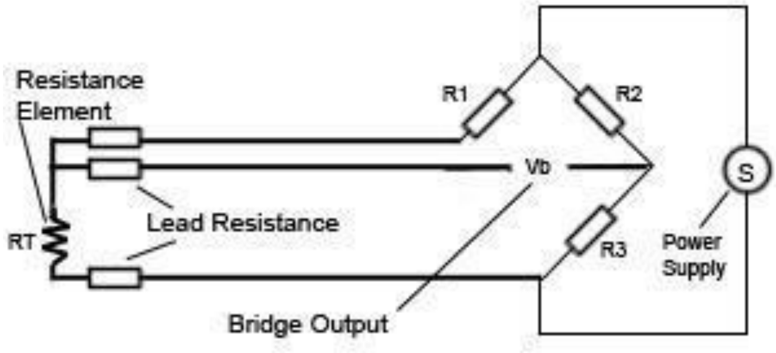
4 Wire RTD Configuration Temperature Sensor

The four-wire resistance thermometer configuration increases the accuracy and reliability of the resistance being measured: the resistance error due to lead wire resistance is zero. In the diagram above a standard two-terminal RTD is used with another pair of wires to form an additional loop that cancels out the lead resistance. The above wheatstone bridge method uses a little more copper wire and is not a perfect solution. Below is a better configuration, four wire kelvin connection. It provides full cancellation of spurious effects; cable resistance of up to 15 Ω can be handled.

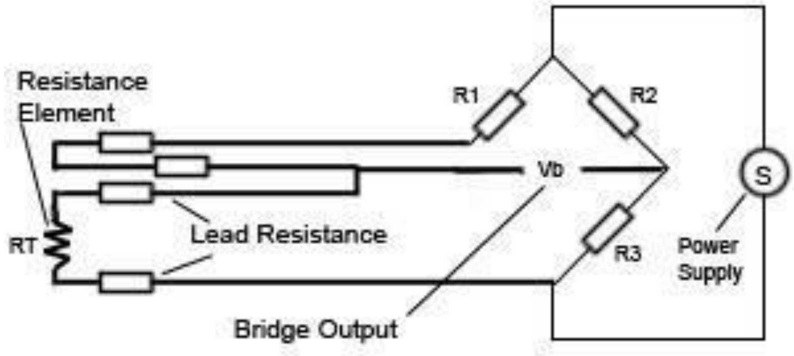


With the 4-wire configuration, the instrument will pass a constant current (I) through the outer leads, 1 and 4. The voltage drop is measured across the inner leads, 2 and 3. So from V = IR we learn the resistance of the element alone, with no effect from the lead wire resistance. This offers an advantage over 3-wire configurations only if dissimilar lead wires are used, and this is rarely the case.

3 Wire RTD Sensor



4 Wire RTD sensor



Procedure:

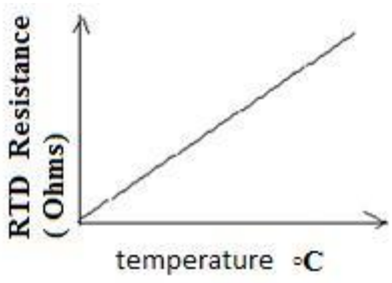
1. Connect the leads from the RTD to the respective meter.
2. The water bath heater is switched ON.
3. Immerse the RTD in water bath .when the water temperature rises note the resistance of RTD for the corresponding temparature
4. Start the stop clock and tabulate the resistance of RTD for every 5 seconds.

Graph: Draw the graph between temperature (X – axis) and RTD resistance in ohms(Y – axis).

Tabular Column:

S.No.	Temperature ◦C	RTD Resistance (Ohms)

Model Graph:



Result:

Thus the measurement of temperature using RTD with three and four leads configuration were studied.

INFERENCE

Review questions

1. What are advantages of three wire RTD?
2. What are advantages of four wire RTD ?
3. What is meant by temperature compensation?
4. What are the application of three & four wire RTD configuration
5. What is meant by pt-100?

Exp No.:7(a) **Date:**

MEASUREMENT OF MEDIUM RESISTANCE USING WHEATSTONE'S BRIDGE

Aim:

To measure the value of unknown resistance using Wheatstone's Bridge.

Apparatus Required:

S. No.	Components / Equipments	Specification	Quantity
1.	Resistors	1KΩ	2
2.	Unknown Resistors	Different value	4
3.	Decade Resistance Box	---	1
4.	Power Supply	0-30V	1
5.	Digital Multimeter	---	1
6.	Bread Board	---	1
7.	Connecting wires	---	Few

Theory:

The medium range of resistance is from 1KΩ to some mega ohms. The wheatstone bridge operates upon null indication principle. This means the indication is independent of the calibration of the null indicating instrument or any of its characteristics. For this reason, very high degree of accuracy can be achieved using Wheatstone bridge. Accuracy of 0.1% is quite common with a wheatstone bridge as opposed to accuracies of 3% to 5% with ordinary ohmmeter for measurement of medium resistances. The bridge has 4 resistance arms, consisting of resistances R_1, R_2, R_3 and R_x together with a source of emf and a null detector usually a galvanometer G or other sensitive current meter. The current through the galvanometer depends on the potential difference between the points B and D. the bridge is said to be balanced when there is no current through the galvanometer or when the potential difference across the galvanometer is zero.

For bridge balance, $I_1 R_1 = I_2 R_2$ -- (1)

For the galvanometer current to be zero, the following condition also exists:

$$I_1 = I_3 = \frac{E}{R_1 + R_2} \quad (2)$$

$$I_2 = I_4 = \frac{E}{R_x + R_2} \quad (3)$$

E = emf of the battery.

Combining equations (1), (2) and (3) and simplifying, we obtain

$$\frac{R_1}{R_1 + R_2} = \frac{R_X}{R_X + R_3} \quad (4)$$

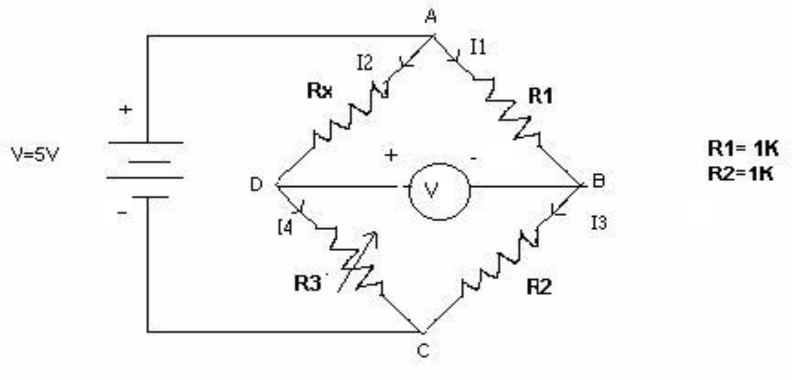
From which, $R_2 R_X = R_1 R_3$ --- (5)

Equation (5) is the well known expression for the balance of Wheatstone bridge. If three of the resistances are known, the fourth may be determined from equation (5)

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

Where Rx is the unknown resistance R_3 is called the 'standard arm' of the bridge and R_1 and R_2 are called the 'ratio arms.

Circuit Diagram:



Formulae:

$$\%Error = \frac{Measured\ Value - True\ Value}{True\ Value} \times 100$$

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

Procedure:

1. Connections are given as per the circuit diagram.
2. Supply is switched ON.
3. Check the zero balance initial condition.
4. When the unknown resistance $R_x$is connected, the bridge becomes unbalanced.
5. The bridge is balanced by varying the DRB (R_3).
6. The value of unknown resistance is calculated by the given formulae.
7. The above steps are repeated for different value of unknown resistances.
8. Calculate the % error using the given formula.

Tabular Column:

S. No	Resistance R_3 (KΩ)	Unknown Resistance R_x		% error
		True (KΩ)	Measured(KΩ)	

Result:

Thus the Wheatstone bridge was constructed and the unknown resistors were determined.

Inference:

Review Questions:

1. What are the applications of Wheatstone bridge?
2. What are standard arm and ratio arm in wheat stone bridge?
3. What are the detectors used for DC bridges?
4. What do you meant by sensitivity?
5. What is the relationship between sensitivity and accuracy of Wheatstone bridge?

Exp No.:7(b) **Date:**

KELVIN'S DOUBLE BRIDGE

Aim:

To find the unknown value of low resistance using Kelvin's DoubleBridge.

Apparatus Required:

S. No.	Components / Equipments	Specification	Quantity
1.	Resistors	1KΩ	4
2.	Unknown Resistors	Different value	4
3.	Decade Resistance Box	---	1
4.	Power Supply	---	1
5.	Digital Multimeter	---	1
6.	Bread Board	---	1
7.	Connecting wires	---	Few

Theory:

Kelvin's double bridge is a modification of Kelvin's bridge and provides more accuracy in measurement of low resistances. It incorporates two sets of ratio arms and the use of four terminal resistors for the low resistance arms, as shown in circuit diagram.

R_x is the resistance under test and S is the resistor of the same higher current rating than one under test. Two resistances R_x and S are connected in series with a short link of as low value of resistance r as possible. P, Q, p, q are four known noninductive resistances, one pair of each (P and p, Q and q) are variable. A sensitive galvanometer G is connected across dividing points PQ and pq . The ratio P/Q is kept the same as p/q , these ratios have been varied until the galvanometer reads zero.

Balance Equation:

$$Eab = \frac{P}{P+Q} Eac \text{ and } Eac = I\left[R + S + \frac{(p+q)\,r}{p+q+r}\right] \text{------------(1)}$$

$$\text{and } \; Eamd = I\left[R + \frac{p}{p+q}\left\{\frac{(p+q)r}{p+q+r}\right\}\right] = I\left[R + \frac{p\,r}{p+q+r}\right] \text{--------(2)}$$

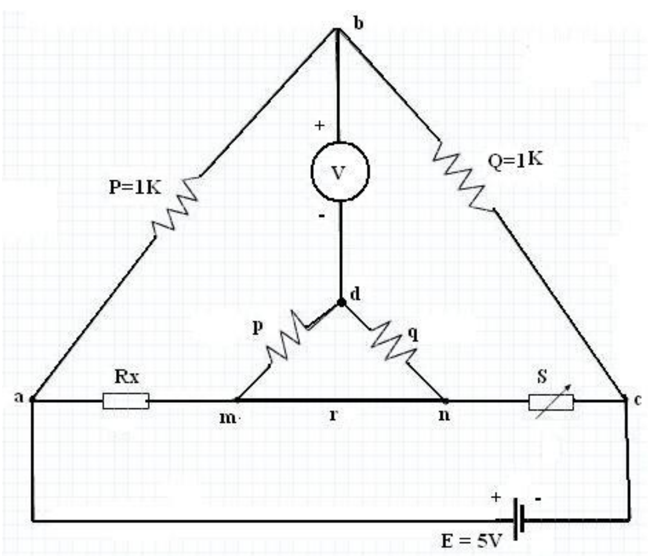
For zero galvanometer deflection, Eab = Eamd

$$\text{or } \; \frac{P}{P+Q} I\left[R+S+\frac{(p+q)r}{p+q+r}\right] = I\left[R+\frac{p\,r}{p+q+r}\right]$$

$$\text{or } \; R = \frac{P}{Q}.S + \frac{qr}{p+q+r}\left[\frac{P}{Q} - \frac{p}{q}\right] \text{--------------------(3)}$$

$$\text{Now, if } P/Q = p/q \text{ Equation (3) becomes , } R = \frac{P}{Q}.S \text{ ------------(4)}$$

Circuit Diagram:



Formulae used:

$$\%Error = \frac{Measured\ Value - True\ Value}{True\ Value} \times 100$$

$$R_x = \frac{P}{Q} . S$$

Procedure:

1. Connections are given as per the circuit diagram.
2. Switched ON the supply.
3. Check the initial zero balance candition.
4. The bridge becomes unbalanced when unknown resistance R_x is connected.
5. The bridge is balanced by varying standard resistance.
6. Unknown resistanceR_x is calculated using balance equation.
7. The above steps are repeated for various values of unknown resistanceR_x.

Tabulation:

S.No	P (Ω)	Q (Ω)	S (Ω)	Unknown Resistance R_x (Ω)		% Error
				True	Measured	

Model Calculation:

Result:

Thus the given unknown resistors were measured using Kelvin's double bridge.

Inference:

Review Questions:

1. What are the methods of measuring low resistance?
2. Why this bridge is called Kelvin's double bridge?
3. What are the advantages of kelvin's double bridge?
4. What are the limitations of kelvin's double bridge?
5. Derive the balance equation of Kelvin's double bridge.

Exp No.:8(a) **Date:**

MEASUREMENT OF SELF INDUCTANCE USING ANDERSON'S BRIDGE

Aim:

To measure the unknown self inductance of the coil using Anderson's Bridge.

Apparatus Required:

S. No.	Components / Equipments	Specification	Quantity
1.	Resistors	1KΩ,1KΩ,560Ω,5.6KΩ	Each one
2.	Unknown Resistors	Different value	4
3.	Decade Inductance Box	---	1
4.	Digital Multimeter	---	1
5.	CRO	30 MHz	1
6.	Bread Board	---	1
7.	Connecting wires	---	Few

Theory:

The unknown inductance can be measured using the Anderson's bridge trainer. To measure any other value of inductance, the resistance r & r_1 have to be correspondingly changed either by increasing or decreasing the resistance. The resistance in any of the arms of the bridge is increased by externally connecting some resistance in series or decreased by connecting in parallel for which the provision has been given in the trainer. The bridge consists of a built in power supply, 1 kHz oscillator & a detector.

Balance Equations:

Let L_1=self-inductance to be measured
R_1=resistance of self-inductor
r_1=resistance connected in series with self-inductor R, R_2, R_3, R_4 = known non-inductive resistances C=fixed standard capacitor

At balance $I_1=I_3$ and $I_2=I_c+I_4$

$$I_1 R_3 = I_c \times \frac{1}{j\omega C} \quad \therefore \; I_c = I_1 j\omega C R_3$$

Writing the other balance equations

$$I_1 (r_1 + R_1 + j\omega L_1) = I_2 R_2 + I_c . r \quad and \quad I_c \left(r + \frac{1}{j\omega C} \right) = (I_2 - I_c) R_4$$

Substituting the value of Ic in the above equations, we have

$$I_1 (r_1 + R_1 + jL\omega_1) = I_2 R_2 + I_1 j\omega C R_3 .r \; or \; I_1 (r_1 + R_1 + jL\omega_1 - j\omega C R_3) = I_2 R_2 \; ----- (1)$$

$$and \; j\omega C R_3 I_1 \left(r + \frac{1}{j\omega C} \right) = (I_2 - I_1 j\omega C R_3) R_4 \quad or \quad I_1 (j\omega C R_3 r + j\omega R_3 R_4 + R_3) = I_2 R_2 \; ----- (2)$$

From equations (1) and (2), we obtain

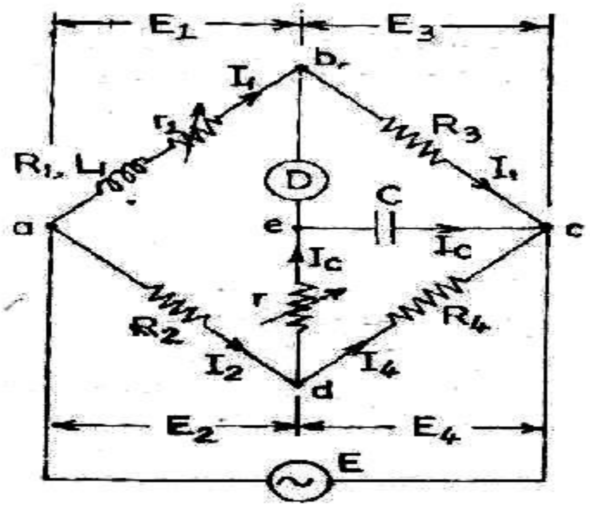
$$I_1 (r_1 + R_1 + j\omega L_1 - j\omega C R_3 r) = I_1 \left(\frac{R_2 R_3}{R_4} + \frac{j\omega C R_2 R_3 r}{R_4} + j\omega C R_3 R_2 \right)$$

Equating the real and imaginary parts

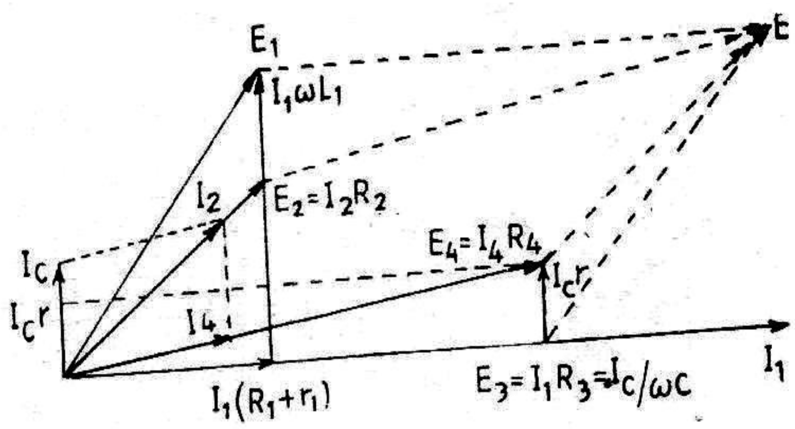
$$R_1 = \frac{R_2 R_3}{R_4} - r_1 \quad ----------------------(3)$$

$$and \quad L_1 = C \frac{R_3}{R_4} \left[r (R_4 + R_2) + R_2 R_4 \right] \; -----------(4)$$

Circuit Diagram:



Phaser Diagram:



Formula used:

$$\%Error = \frac{Measured\ Value - True\ Value}{True\ Value} \times 100$$

$1 = \frac{3}{4}[\ (\ 4 + \ 2) + \ 2\ 4]$ $\qquad 1 = \frac{2\ 3}{4} - \ 1$

Procedure:

1. Switch on the trainer & connect the unknown inductance in the arm marked R_1.
2. Connect the CRO between the ground & the output point and check for the balance condition.
3. Observe the sine wave at the secondary of the isolation transformer by using CRO.
4. Vary the resistance R from minimum position in a clockwise direction.
5. For further fine balance vary the resistance r_1 which will compensate for the resistive Componentof the inductor.
6. Remove the wiring and measure the values of R and r1 using DMM.
7. The above steps (3, 4, 5&6) are repeated for different values of unknown inductance.

Tabular Column:

S. No	R(Ω)	r1(Ω)	R2(Ω)	R3(Ω)	R4(Ω)	R1(Ω)	$Q = \frac{\omega L_1}{R_1}$	L_1(mH)		%Error
								True	Measured	

Model Calculation:

Result:

Thus the unknown inductance of the coil were measured using Anderson's Bridge.

Inference:

Review Questions:

1. What are the detectors used in AC bridges?
2. What do you mean by Q-factor?
3. What are the other bridges used to measure inductance?
4. State the merits and demerits of Anderson's bridge?
5. What will happen to the measured inductance value if frequency of the input is not maintained constant?
6. What are the limitations of Anderson Bridge?

Exp No.:8(b) **Date:**

MEASUREMENT OF CAPACITANCE USING SCHERING'S BRIDGE

Aim:

To measure the value of unknown capacitance using Schering's bridge& dissipation factor.

Apparatus required:

S. No.	Components / Equipments	Specification	Quantity
1.	Resistors	1KΩ,1KΩ,560Ω,5.6KΩ	Each one
2.	Decade Resistance Box		
3.	Decade Conductance Box	---	1
4.	Digital Multimeter	---	1
5.	CRO	---	1
6.	Bread board	---	1
7.	Connecting wires	---	Few

Theory:

In this bridge the arm BC consists of a parallel combination of resistor & a Capacitor and the arm AC contains capacitor. The arm BD consists of a set of resistors varying from 1Ω to 1 MΩ. In the arm AD the unknown capacitance is connected. The bridge consists of a built in power supply, 1 kHz oscillator and a detector.

Balance Equations:

Let C_1=Capacitor whose capacitance is to be measured.

R_1= a series resistance representing the loss in the capacitor C_1.

C_2= a standard capacitor.

R_3= a non-inductive resistance.

C_4= a variable capacitor.

R_4= a variable non-inductive resistance in parallel with variable capacitor C_4.

At balance,

$Z_1Z_4=Z_2Z_3$

$$\left(r_1 + \frac{1}{j\omega C_1}\right)\left(\frac{R_4}{1+j\omega C_4 R_4}\right) = \frac{1}{j\omega C_2}\cdot R_3$$

$$\left(r_1 + \frac{1}{j\omega C_1}\right) R_4 = \frac{R_3}{j\omega C_2}\left(1+j\omega C_4 R_4\right)$$

$$r_1 R_4 - \frac{jR_4}{\omega C_1} = -j\frac{R_3}{\omega C_2} + \frac{R_3 R_4 C_4}{C_2}$$

Equating the real and imaginary terms, we obtain

$$r_1 = R_3\frac{C_4}{C_2} \quad and$$

$$C_1 = C_2\frac{R_4}{R_3}$$

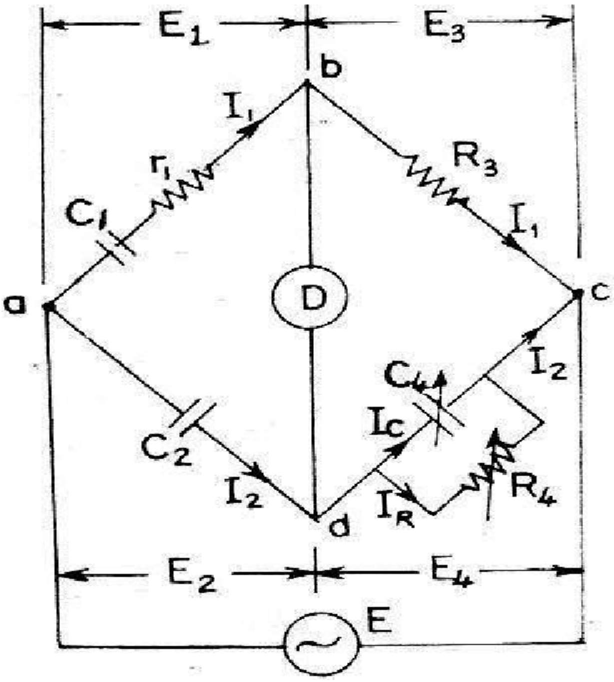
Two independent balance equations are obtained if C_4 and R_4 are chosed as the variable elements.

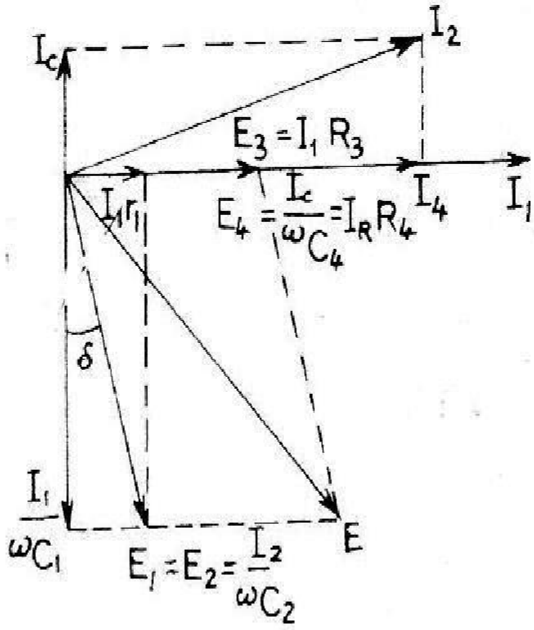
Dissipation Factor:

The dissipation factor of a series RC circuit is defined as a co-tangent of the phase angle and therefore by definition the dissipation factor is

$$D_1 = \tan\delta_1 = \omega C_1 r_1 = \omega\cdot\left(\frac{C_2 R_4}{R_3}\right)\times\left(\frac{R_3 C_4}{C_2}\right) = \omega C_4 R_4$$

Circuit Diagram: **Phaser Diagram:**





Formulae Used:

$$\%Error = \frac{Measured\ Value - True\ Value}{True\ Value} \times 100$$

$$r_1 = R_3 \frac{C_4}{C_2} \quad , C_1 = C_2 \frac{R_4}{R_3} \ \& \ D_1 = \omega C_4 R_4$$

where $C_4 = C_x$ & $R_4 = R_x$

Procedure:

1. Switch on the trainer board and connect the unknown in the arm marked Cx.
2. Observe the sine wave at the output of oscillator and patch the ckt by using the wiring diagram.
3. Observe the sine wave at secondary of isolation transformer on CRO. Select some value of R_2.
4. Connect the CRO between ground and the output point of imbalance amplifier.
5. Vary R_1(500 ohms potentiometer) from minimum position in the clockwise direction.
6. If the selection of R_2 is correct, the balance point (DC line) can be observed on CRO. (That is at balance the output waveform comes to a minimum voltage for a particular value of R_1 and then increases by varying R_1 in the same clockwise direction). If that is not the case, select another value of R_2.
7. Capacitor C_1 is also varied for fine balance adjustment. The balance of the bridge can be observed by using loud speaker.
8. Connect the loud speaker at the output of the detector. Alternatively adjust R_1 and proper selection of R_2 for a minimum sound in the loud speaker.
9. Tabulate the readings and calculate the unknown capacitance and dissipation factor.

Tabular Column:

S.No.	C_1(pF)	C_3(μF)	R_1(Ω)	R_2(Ω)	Rx(Ω)	Cx(μF)		Dissipation factor (D_1)
						True value	Measured Value	

Model Calculation:

Result:

Thus the unknown capacitance & dissipation factor were measured using Schering'sBridge.

Inference:

Review Questions:

1. State the two conditions for balancing an AC bridge?
2. State the uses of Schering's Bridge?
3. What do you mean by dissipation factor?
4. Give the relationship between Q and D.
5. Derive the balance equations.
6. What are the limitations of Schering's bridge?

Exp No.:9(a) **Date:**

CALIBRATION OF SINGLE PHASE ENERGY METER

Aim:

To calibrate the given energy meter using a standard wattmeter and to obtain percentage error.

Apparatus required:

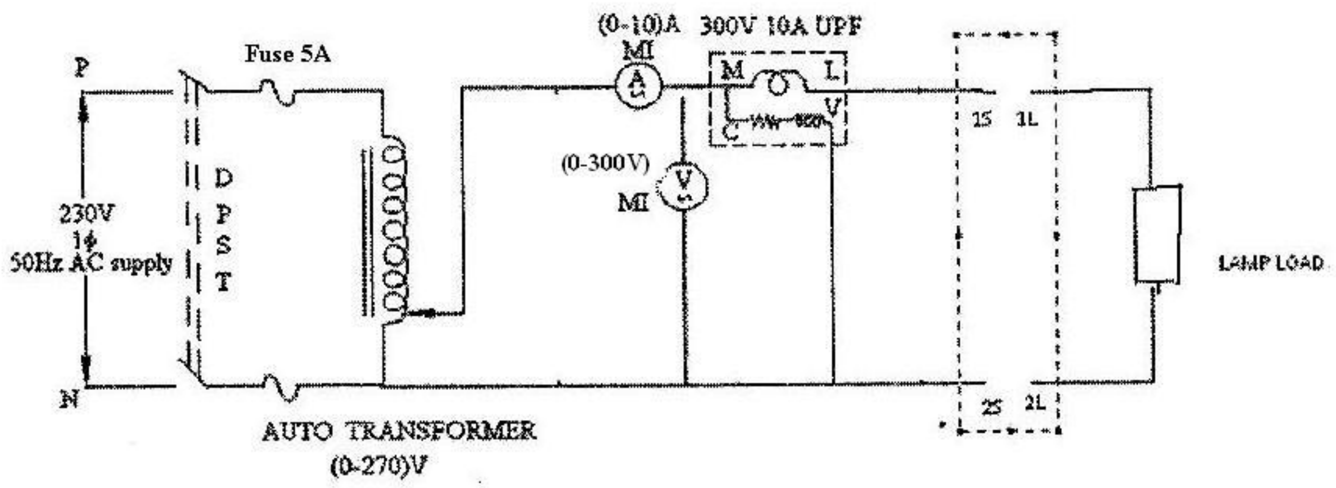
S. No.	Components / Equipments	Specification	Quantity
1.	Energy Meter	Single Phase	1
2.	Standard Wattmeter	300V, 10A, UPF	1
3.	Voltmeter	(0-300V), MI	1
4.	Ammeter	(0-10A), MI	1
5.	Lamp Load	230V, 3KW	4
6.	Connecting wires	---	Few

Theory:

The energy meter is an integrated type instrument where the speed of rotation of aluminium disc is directly proportional to the amount of power consumed by the load and the no of revs/min is proportional to the amount of energy consumed by the load. In energy meter the angular displacement offered by the driving system is connected to the gearing arrangement to provide the rotation of energy meter visually. The ratings associated with an energy meter are

1. Voltage Rating, 2. Current Rating, 3.Frequency Rating and 4. Meter Constants. Based on the amount of energy consumption, the driving system provides rotational torque for the moving system which in turn activates the energy registering system for reading the real energy consumption.The energy meter is operated based on induction principle in which the eddy current produced by the induction of eddy emf in the portion of the aluminium disc which creates the driving torque by the interaction of two eddy current fluxes.

Circuit Diagram:



Formulae used:

$$\%Error = \frac{Measured\ Value - True\ Value}{True\ Value} \times 100$$

Wattmeter Reading (P) = VI watts.

= $\frac{\emptyset}{3600}$ =(h)

Procedure:

1. Connections are given as per the circuit diagram.
2. The DPST switch is closed to give the supply to the circuit.
3. The load is switched ON.

4. Note down the ammeter, voltmeter &wattmete reading .Also note down the time taken for

5 revolutions for the initial load.

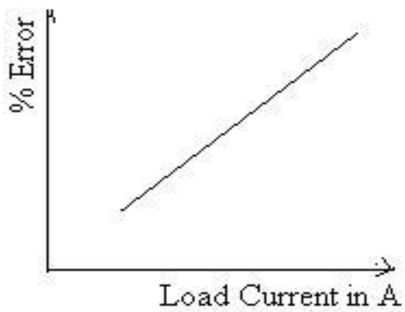
5. Note down the energy meter constant from the energy meter setup.
6. The number of revolutions can be noted down by adapting the following procedure.When the red indication mark on the aluminium disc of the meter passes, start to count the number of revolutions made by the disc by using a stop watch and note it down.
7. Repeat the above steps (4) for different load currents by varying the load for the fixed number of revolutions.
8. Calculate the % error using the given formula.

Graph: Plot the graph betweenLoad Current (X-axis) and %Error (Y-axis).

Tabulation:

Voltmeter Reading, V (Volt)	Ammeter Reading, I (Amp)	Wattmeter Reading, W(Watt)	Time Period, t(Sec)	No. of revolutions	Energy Meter Reading (kwh)		% Error
					Measured	True	

Model graph:



Model Calculation:

Result:

Thus the percentage error for the given energy meter was calculated and the same was plotted**.**

Inference:

Review Questions:

1. What do you meant by calibration?
2. What is the need for lag adjustment devices in single phase energy meter?
3. How damping is provided in energy meter?
4. What is "Creep" in energy meter? What are the causes of creeping in an energy meter?
5. How is creep effect in energy meters avoided?

Exp No.:9(b) **Date:**

CALIBRATION OF WATTMETER

Aim:

To calibrate the given Wattmeter by direct loading and obtain its percentage error.

Apparatus required:

S. No.	Components / Equipments	Specification	Quantity
1.	Wattmeter	300V, 10A, UPF	1
2.	Voltmeter	(0-300V), MI	1
3.	Ammeter	(0-10A), MI	1
4.	Lamp Load	230V, 3KW	1
5.	Connecting wires	---	Few

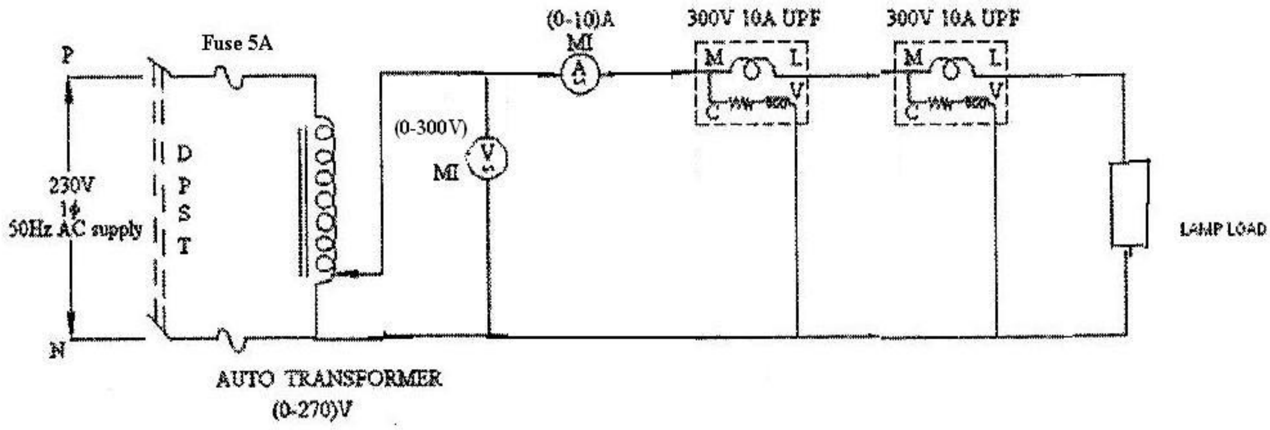
Theory:

In Electro Dynamometer wattmeter there are 2 coils connected in different circuits to measure the power. The fixed coil or held coil is connected in series with the load and so carry the current in the circuit. The moving coil is connected across the load and supply and it carries the current proportional to the voltage. The various parts of the wattmeter are

1. Fixed coil and Moving coil, 2. Controlling springs and Damping systems and 3. Pointer.

Here a spring control is used for resetting the pointer to the initial position after the deexcitation of the coil. The damping system is used to avoid the overshooting of the coil and hence the pointer. A mirror type scale and knife edge pointer is provided to remove errors due to parallax.

Circuit Diagram:



Formula Used:

$$\%Error = \frac{Measured\ Value - True\ Value}{True\ Value} \times 100$$

Procedure:

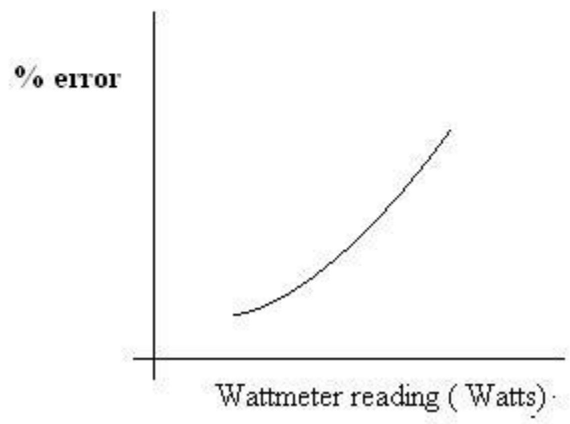
1. Connections are given as per the circuit diagram.
2. Power supply is switched ON and the load is turned ON.
3. The value of the load current is adjusted to the desired value.
4. The readings of the voltmeter, ammeter&wattmeter are noted.
5. The procedure is repeated for different values of the load current and for each value of load current all the meter readings are noted.
6. Calculate the % error using given formula.

Graph: Plot the graph between theWattmeter reading (X-axis) and Percentage error (Y-axis).

Tabulation:

S.No.	Voltmeter Reading (Volts)	Ammeter Reading (Amp)	Load (Watt)	Standard WattmeterReading (Watt)		Calibrated WattmeterReading (Watt)		% Error
				Observed	Actual	Observed	Actual	

Model graph:



Model Calculation:

Result:

Thus the percentage error was calculated for the given wattmeter and the same was plotted.

Inference:

Review Questions:

1. What do you mean by calibration.
2. State Blondel's Theorem?
3. What are the common errors in Wattmeter?
4. Can we Measure power using one Wattmeter in a 3-Phase supply?
5. How do we measure Reactive Power?How do you compensate Pressure coil in Wattmeter?

Exp No.10(a) **Date:**

CALIBRATION OF AMMETER

Aim:

To calibrate the given ammeter using standard ammeter.

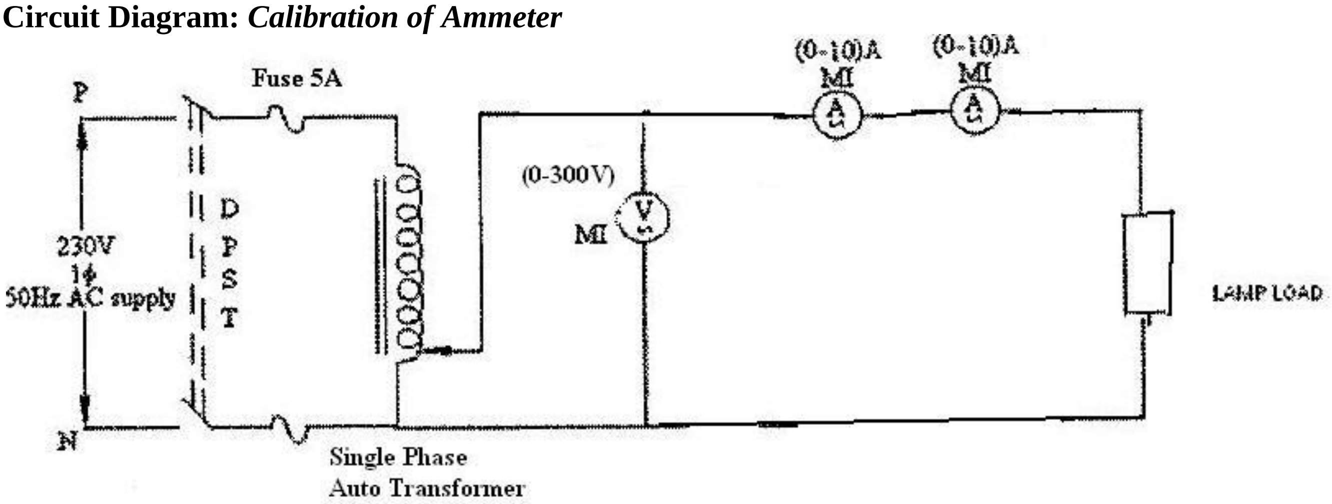
Apparatus Required:

S. No.	Components / Equipments	Specification	Quantity
1.	RPS	0-30V	1
2.	Standard Ammeter (MC)	0-500µA	1
3.	Ammeter to be calibrated (MC)	0-500µA	1
4.	Resistor	10KΩ	1
5.	Bread Board	---	1
6.	Connecting wires	---	Few

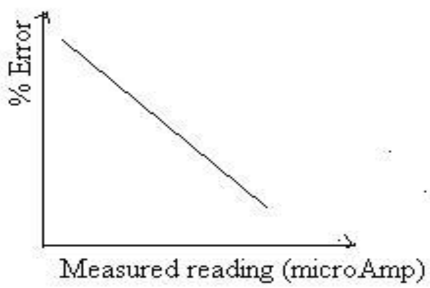
Theory:

D.C ammeters are used to measure current from one micro ampere to several hundred amperes. The D'Arsonval movement is used in most DC ammeter as a current detector. Typical lab meters of this type can withstand 1 mA of their full scale reading. Since the coil winding is small and light, it can carry very small current only. When heavy currents are to be measured the major part of the current is bypassed through a low resistance called a SHUNT.

Circuit Diagram: *Calibration of Ammeter*



Model Graph:



Procedure:

1. Connect the circuits as shown in the circuit diagram (a).
2. Switch ON the supply.
3. Adjust the voltage using RPS & compare both the values that are shown by the standard ammeter & the meter to be calibrated.
4. Find out the % error by using the formula.

Graph: Plot the error graph by taking % error along y axis & current along x axis.

Tabulation: ***Calibration of Ammeter***

S.No	**Load (Watt)**	**Voltmeter Reading (V)**	**Std. ammeter reading (A) (True reading)**	**Meter to be calibrated(A) (Measured reading)**	**% Error**

Formula used:

$$\% Error = \frac{Measured\ Value - True\ Value}{True\ Value} \times 100$$

Model Calculation:

Result:

- **(a)** Thus for the given ammeter percentage error was calculated & the same was plotted.
- **(b)** Thus the range of the given ammeter was extended.

Inference:

Review Questions:

1. What are the types of instruments used as ammeters?
2. What are the types of errors which occur in most of the ammeters?
3. What is the use shunt in ammeter?
4. What are the requirements of shunts?
5. What are the materials used for constructing shunt resistance?
6. Define multiplying power of shunt.

Exp No.10 (b) **Date:**

CALIBRATION OF VOLTMETER

Aim:

To calibrate and to extend the range of the given Voltmeter.

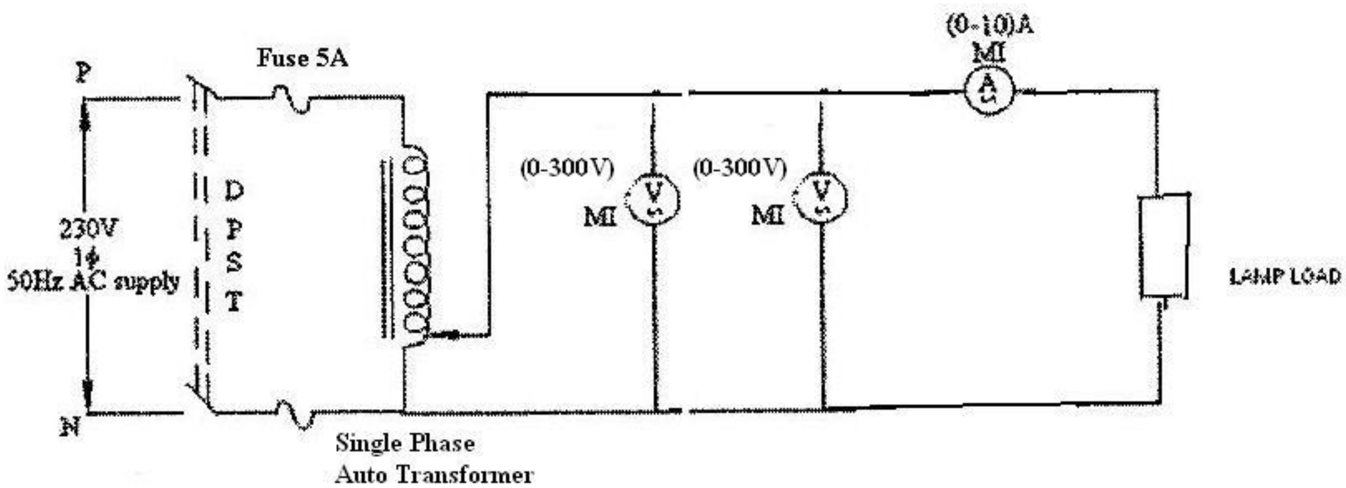
Apparatus required:

S. No.	Components / Equipments	Specification	Quantity
1.	Power Supply	0-30V	1
2.	Standard Voltmeter	(0-30V), MC	1
3.	Voltmeter to be calibrated	(0-30V), MC	1
4.	DRB	---	1
5.	Bread Board	---	1
6.	Connecting wires	---	Few

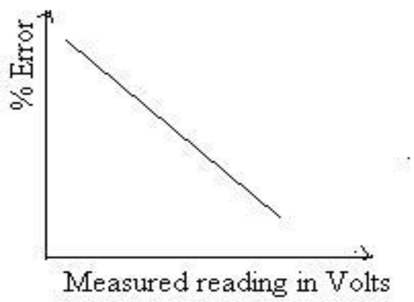
Theory:

Most DC voltmeters use D' Arsonval movements. The D' Arsonval movement itself can be considered to be a voltmeter. D' Arsonval movement causes a certain voltage drop which equals the current flowing in it multiplied by its internal resistance. The calibration can be done by comparing it with the standard meter.The error will give us an idea how much the zero & span adjustment has to be done To increase the voltage range of the meter a series resistance has to be connected with the meter to be extended. The extra resistance is called a 'MULTIPLIER' which limits the current flowing through the meter.

Circuit Diagram: ***Calibration of Voltmeter***



ModelGraph:



Procedure:

1. Connect the circuits as shown in the circuit diagram (a) and switch on the supply.
2. Adjust the voltage using RPS & compare both the values that are shown by the std. voltmeter & the meter to be calibrated.
3. Find out the % error by using the formula.

Graph: Plot the error graph by taking % error along Y axis & voltage along X axis.

Tabular Column: ***Calibration of Voltmeter***

S. No	Std. voltmeter reading (V) (True reading)	Meter to be calibrated (V) (Measured reading)	% Error

Formulae used:

$$\% Error = \frac{Measured\ Value - True\ Value}{True\ Value} \times 100$$

Model Calculation:

Result:

(a) Thus for the given voltmeter percentage error was calculated & the same was plotted.
(b) Thus the range of the given voltmeter was extended.

Inference:

Review Questions:

1. What are the types of instruments used as voltmeters?
2. What are the types of errors which occur in most of the voltmeters?
3. What is multiplier?
4. What are the essential requirements of multiplier?
5. What are the materials used for constructing multiplier?
6. Explain the effect of temperature changes in voltmeters.

Exp No.:11(a) **Date:**

ANGULAR DISPLACEMENT MEASUREMENT USING CAPACITIVE TRANSDUCER

Aim:

To study the capacitive sensor using Angular measurement Trainer.

Apparatus required:

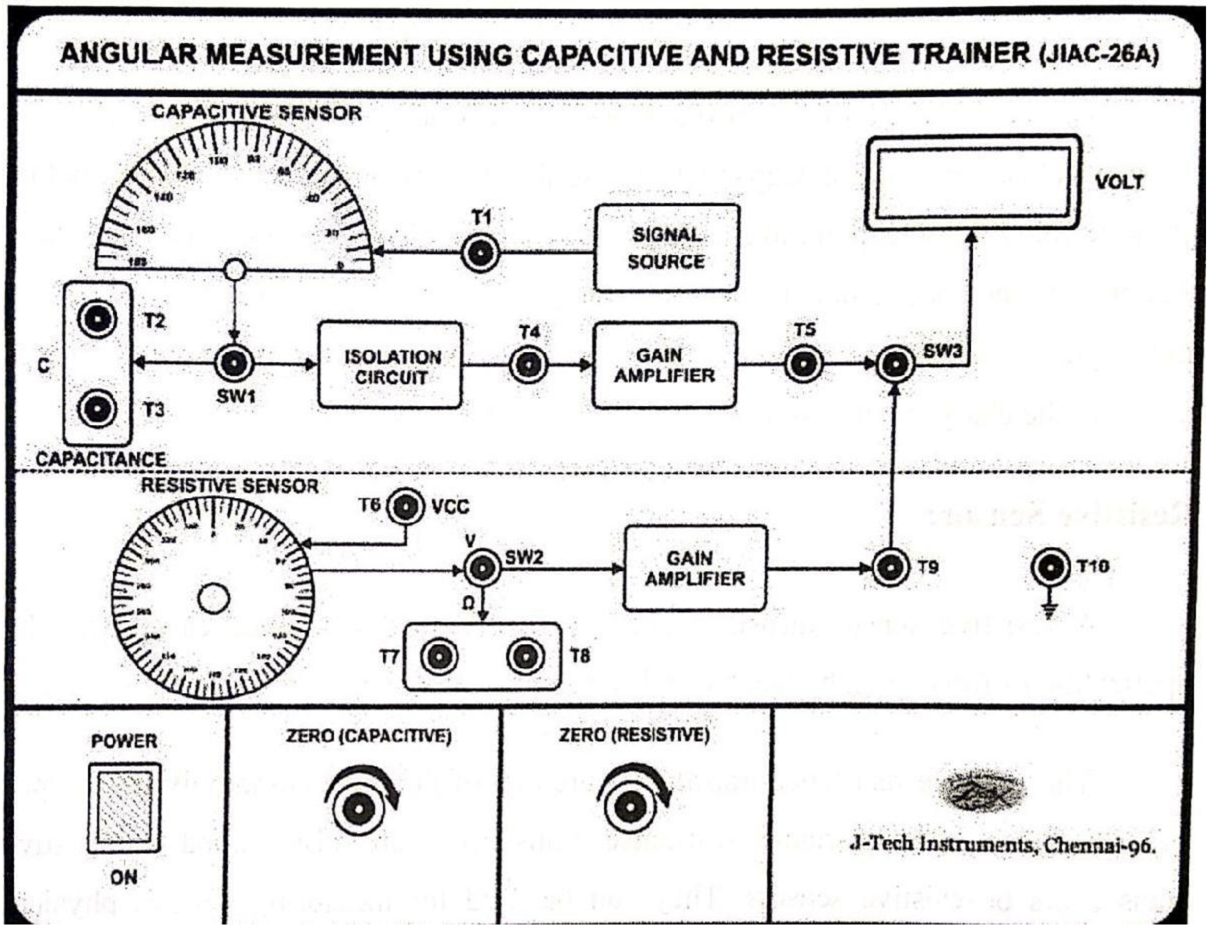
S. No.	Components / Equipments
1.	Angular measurement Trainer kit
2.	LCR meter
3.	Power card
4.	Multimeter

Theory:

The capacitive transducer is used for measuring the displacement, pressure and other physical quantities. It is a passive transducer that means it requires external power for operation. The capacitive transducer works on the principle of variable capacitances. The capacitance of the capacitive transducer changes because of many reasons like overlapping of plates, change in distance between the plates and dielectric constant.

The capacitive transducer uses the electrical quantity of capacitance for converting the mechanical movement into an electrical signal. The input quantity causes the change of the capacitance which is directly measured by the capacitive transducer.

Circuit Diagram: ***Angular displacement measurement***



Procedure:

1. Switch ON the unit.
2. Change the switch SW1 to bottom mode for capacitance measurement.
3. Connect LCR meter in T2 and T3.
4. Rotate the capacitive sensor in some degrees and measure the capacitance.
5. Tabulate the readings
6. For Volatge measurement, change the switch SW1 to top mode.
7. Connect multimeter at T5 and T10 for measuring the output voltage of capacitive sensor.
8. Rotate the capacitive sensor in some degrees and measure the Voltage output.
9. Change the switch SW3 to top mode.
10. Monitor the capacitive sensor output voltage in display and tabulate the readings.

Tabular Column:

S.No	Angle(degrees)	Capacitance(Farads)	Voltage(V)

Result:

(a) Thus for the angular measurement using capacitive sensor was studied.

Inference:

Review Questions:

1. Capacitive transducers can be used by ________________.
2. Capacitive transducers cannot be used as strain gauges. a)True b) False
3. Capacitive microphone is an application of _______________
4. Thermometers are not possible using a capacitive transducer.
a) True
b) False
5. Which of the following is correct for the capacitive transducer?
a) Capacitive strain gauges
b) Capacitive tachometers
c) Capacitive pressure transducer
d) All of the mentioned

Exp No.:11(b) **Date:**

ANGULAR DISPLACEMENT MEASUREMENT USING RESISTIVE TRANSDUCER

Aim:

To study the resistive sensor using Angular measurement Trainer.

Apparatus required:

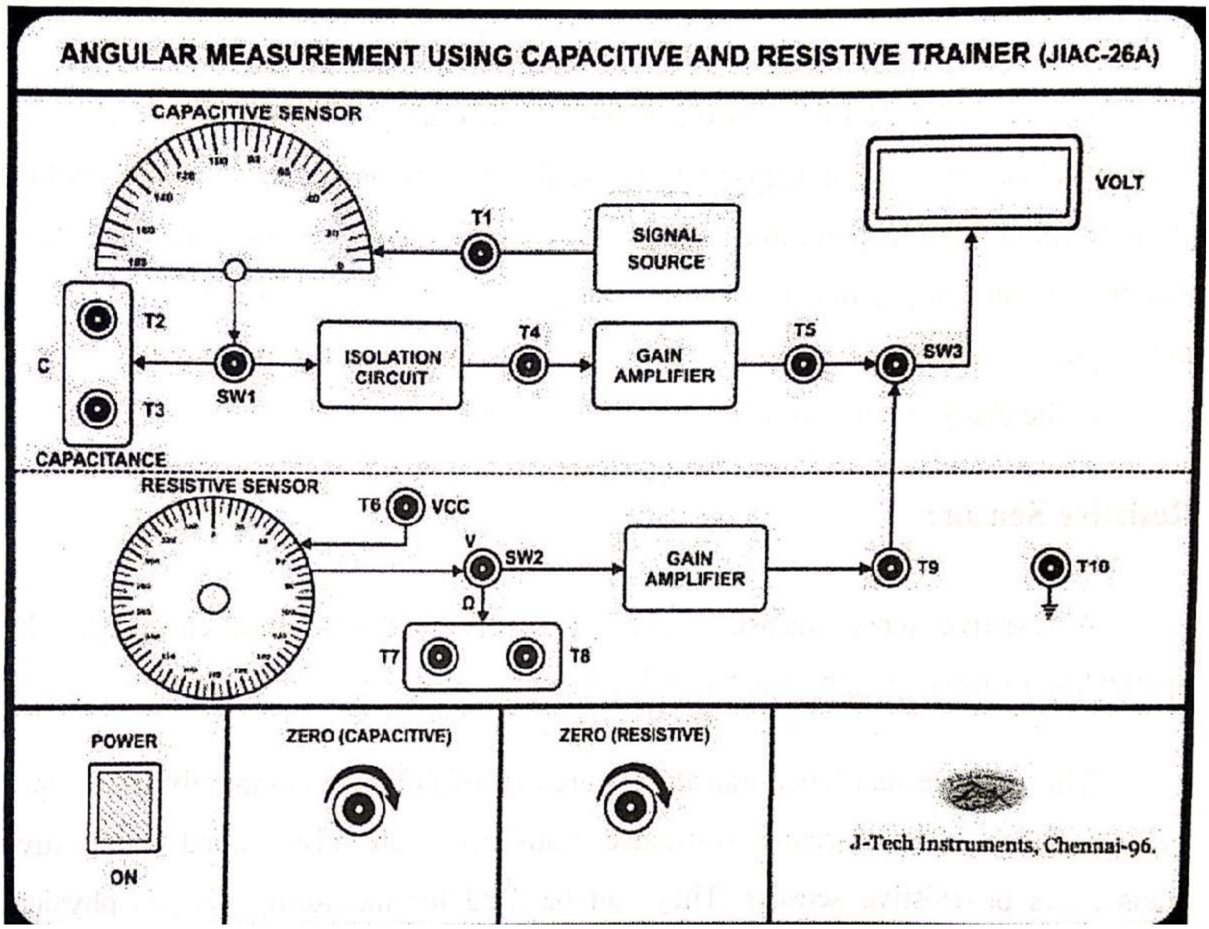
S. No.	Components / Equipments
5.	Angular measurement Trainer kit
6.	LCR meter
7.	Power card
8.	Multimeter

Theory:

The transducer whose resistance varies because of the environmental effects such type of transducer is known as the resistive transducer. The change in resistance is measured by the ac or dc measuring devices. The resistive transducer is used for measuring the physical quantities like temperature, displacement, vibration etc.

The measurement of the physical quantity is quite difficult. The resistive transducer converts the physical quantities into variableresistance which is easily measured by the meters. The process of variation in resistance is widely used in the industrial applications.The resistive transducer can work both as the primary as well as the secondary transducer. The primary transducer changes the physical quantities into a mechanical signal, and secondary transducer directly transforms it into an electrical signal.

Circuit Diagram:



Procedure:

1. Switch ON the unit.
2. Change the switch SW2 to bottom mode for resistance measurement.
3. Connect LCR meter in T7 and T8.
4. Rotate the resistive sensor in some degrees and measure the resistance.
5. Tabulate the readings
6. For Volatge measurement, change the switch SW2 to top mode.
7. Connect multimeter at T9 and T10 for measuring the output voltage of ressitive sensor.
8. Rotate the resistive sensor in some degrees and measure the Voltage output.
9. Change the switch SW3 to bottom mode.
10. Monitor the resistive sensor output voltage in display and tabulate the readings.

Tabular Column:

S.No	Angle(degrees)	Resistance(Ohms)	Voltage(V)

Result:

(a) Thus for the angular measurement using Resistive sensor was studied.

Inference:

Review Questions:

1. What will happen to resistance, if the length of the conductor is increased?
2. Which of the following can be measured using change in resistivity?
   a) Temperature
   b) Visible radiation
   c) Moisture content
   d) All of the mentioned
3. What will happen for resistivity metal and semiconductor if the temperature is increased?
4. What is the relation of temperature coefficient of resistivity on the coefficient of thermal expansion in RTD?
5. Thermistors have high stability.
   a) True
   b) False

Exp No.:12 **Date:**

TEMPERATURE MEASUREMENTS USING FILLED SYSTEM THERMOMETER

Aim:

To measure the temperature using filled system thermometer.

Theory:

The temperature is converted in to a mechanical motion caused by pressure or expansion, and this is measured. The instruments working with this principal are much simpler ones. The thermal system of a filled system thermometer comprises the thermometer bulb, an expansion element, such as a Bourdon tube, diaphragm, capsule or bellows and a capillary tube connecting the bulb and the expansion element.

Classification:

Class – I: Liquid filled thermometers

The thermal system is completely filled with a non metallic liquid and operate on the principle of liquid expansion.

Class – II: Vapour Pressure thermometers

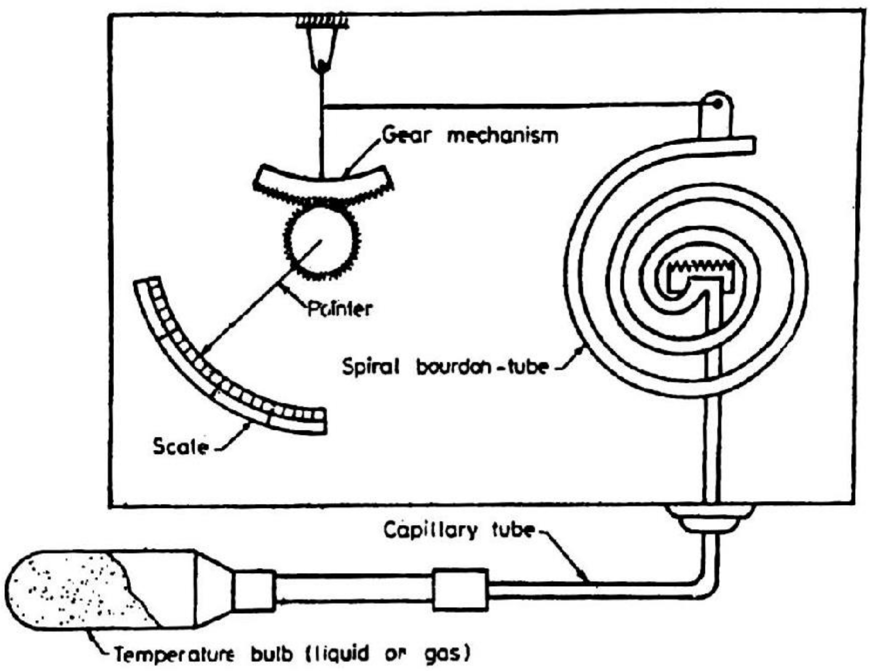
The thermal system is partially filled with a volatile liquid and operates on the principle of vapour pressure

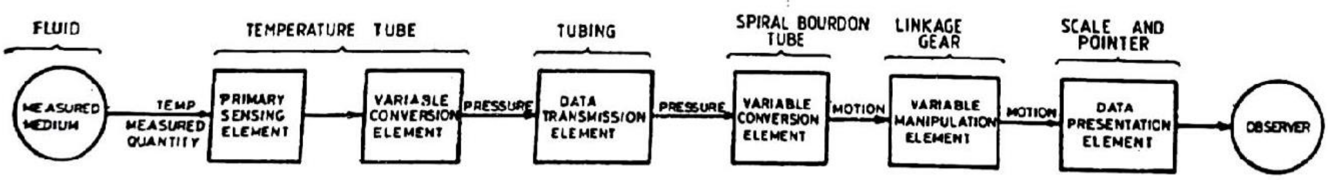
Class – III: Gas Thermometers

The thermal system is filled with gas and operates on the principle of pressure change with temperature.

Class – IV: Mercury filled thermometers

The thermal system is completely filled with mercury or mercury-thallium eutectic amalgam and operates on the principle of liquid expansion.





Filled-system thermometer

Procedure:

1. Switch ON the trainer.
2. Adjust the required set temperature in standard temperature controller.
3. Put the sensors both the filled system thermometer temperature response bulb as well as standard temperature controller thermocouple in to the furnace.
4. The digital display of temperature controller shows the furnace temperature. The corresponding temperature is also displayed in the filled system thermometer temperature dial.

Tabular Column:

S.No.	Thermocouple Voltage mV	Actual Temperature ◦C	Measured Temperature ◦C	% Error

Calculation:

$$\%Error = \frac{Measured\ Value - True\ Value}{True\ Value} \times 100$$

Model Calculation:

Result:

Thus the temperature wasmeasured using filled system thermometer.

Review questions

1. What are advantages of filled system thermometer?
2. What are disadvantages filled system thermometer?
3. What is meant by temperature compensation?
4. What are the classifications of filled system thermometer?
5. What is principle of filled system thermometer?