EC208 ELECTRONIC MEASUREMENT LAB

Exp 1. Balancing of AC bridge circuit and measurement of Inductance of medium-Q coil using Maxwell Bridge.

Exp 2. Balancing of AC bridge circuit and measurement of an unknown Capacitance using Schering Bridge.

Exp 3. Balancing of Wien's bridge circuit and measurement of Capacitance.

Exp 4. Calibration and measurement of Pressure (in Kg/cm^2) using Diaphragm and Strain Gauge.

Exp 5. Calibration and mmeasurement of Temperature (in ^{0}C) using RTD and Thermocouple.

Exp 6. Calibration and measurement of Displacement (in mm) using LVDT.

Exp 7. Calibration and measurement of level (in cm) using capacitive type level probe.

Exp 8. Measurement of rotating Speed (in RPM) using Photo Reflective and Magnetic Pick Up sensor.

Exp 9. Measurement of Vibration using Piezoelectric Accelerator Sensor.

Exp 10. Design of Bipolar DAC (Digital to Analog converter) using R-2R ladder network.

Exp 11. Measurement of the rise time of a RC circuit using Digital Storage Oscilloscope

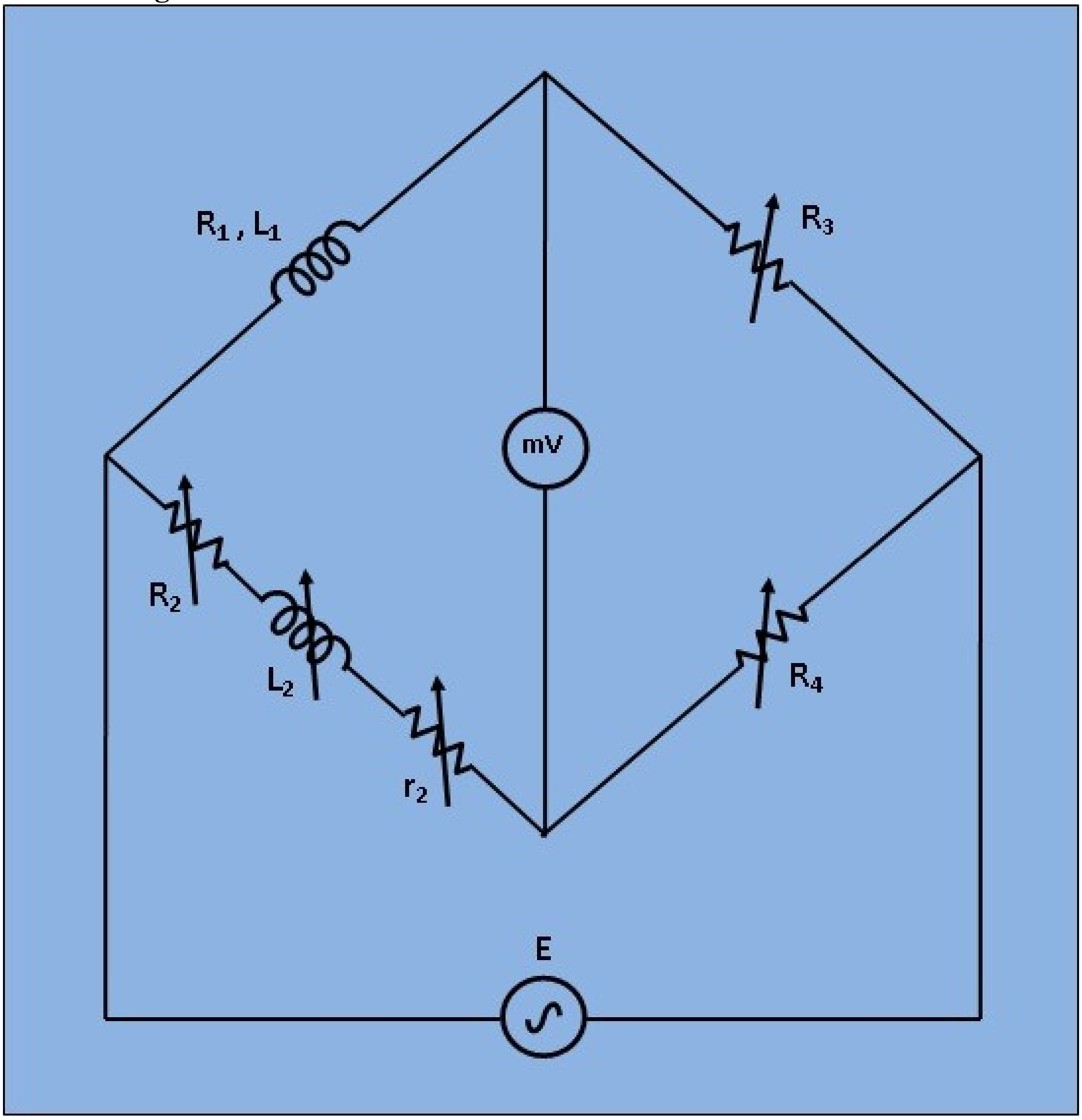
Exp 12. Design and implementation of an Instrumentation Amplifier for a variable gain.

Exp 1. Balancing of AC bridge circuit and measurement of Inductance of medium-Q coil using Maxwell Bridge.

Objective:

To determine the self-inductance of an unknown coil.
This bridge circuit measures an inductance by comparison with variable standard self-inductance. The connections for balance condition are shown in Fig. 1.

Circuit Diagram:



[Fig 1: Circuit Diagram for Measurement of Self Inductance by Maxwell Bridge]

Let,
L_1= Unknown Self-Inductance of resistance R_1,
L_2= variable inductance of fixed resistance r_2,
R_2= variable resistance connected in series with inductor L_2,
R_3, R_4= known non inductive resistances,
At balance condition,
$(R_1 + j\omega L_1) * R_4 = (R_2 + r_2 + j\omega L_2) * R_3$ ... (1)
Equating both the real and imaginary parts in eq. (1) and separating them,
$L_1 = (R_3/R_4) L_2$ ... (2)
$R_1 = (R_3/R_4) * (R_2+r_2)$ ... (3)
Resistors R_3 and R_4 are normally a selection of values from 10, 100, 1000 and 10,000 Ω. r_2 is a decade resistance box.

Procedure:

Apply Supply voltage from the signal generator with arbitrary frequency. (V =3v). Also set the unknown Inductance value from 'Set Inductor Value' tab.

2) Then switch on the supply to get millivoltmeter deflection.

3) Choose the values of L_2, r_2, R_2, R_3 and R_4 from the inductance and resistance box. Vary the values to some particular values to achieve "NULL".

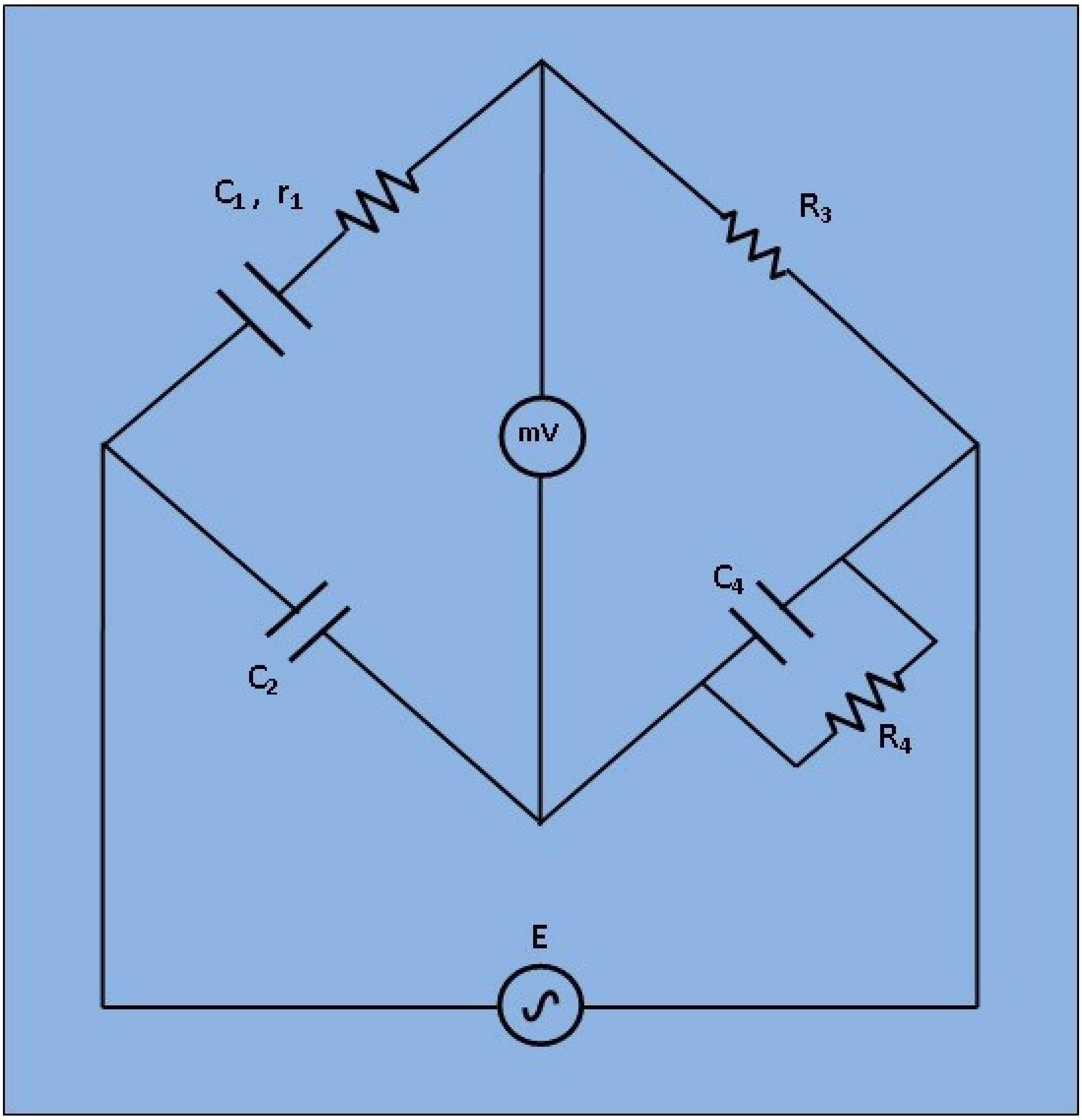
4) Observe the millivoltmeter pointer to achieve "NULL".
5) If "NULL" is achieved, switch to 'Measure Inductor Value' tab and click on 'Simulate'. Observe the calculated values of unknown inductance (L_1) and its internal resistance (R_1) of the inductor.
6) Also observe the Dissipation factor of the unknown inductor which is defined as ` (omega L)/R`.   Where, `omega=2pif`.

Experiment 2: Balancing of AC bridge circuit and measurement of an unknown Capacitance using Schering Bridge.

Objective:

To Determine the Capacitance of an unknown Capacitor.

Circuit Diagram:



[Fig 1: Circuit diagram for measurement of Capacitance by Schering Bridge]

Let, C1=capacitor whose capacitance is to be measured.
r1= a series resistance representing the loss in the capacitor C1.

$C2$= a standard capacitor.
$R3$= a non-inductive resistance.
$C4$= a variable capacitor.
$R4$= a variable non inductive resistance.

At balance,

$$(r1+(1/j\omega C1))\cdot(R4/(j\omega C4R4+1))=R3/j\omega C2 \ldots\ldots(1)$$

$$r1R4-(jR4/\omega C1)=(-jR3/\omega C2)+R3R4C4C2 \ldots\ldots(2)$$

Or Equating the real and imaginary terms in equation. (2), we obtain

$$r1=R3\cdot C4/C2 \ldots\ldots(3)$$

$$C1=R4\cdot C2/R3 \ldots\ldots(4)$$

And, two independent balance equations (3) and (4) are obtained if C4 and R4 are chosen as the variable elements.
Dissipation factor
$D=\omega C1/r1 \ldots\ldots(5)$

Procedure:

1) Apply Supply voltage from the signal generator with arbitrary frequency. (V =3v). Also set the unknown Capacitance value from 'Set Capacitor Value' tab.
2) Then switch on the supply to get millivoltmeter deflection.
3) Choose the values of C_2, C_4, R_3 and R_4 from the capacitance and resistance box. Vary the values to some particular values to achieve "NULL".
4) Observe the millivoltmeter pointer to achieve "NULL".
5) If "NULL" is achieved, switch to 'Measure Capacitor Value' tab and click on 'Simulate'. Observe the calculated values of unknown capacitance (C_1) and its internal resistance (r_1).
6) Also observe the Dissipation factor of the unknown capacitor which is defined as $\omega\cdot C/r$.

Where, $\omega=2\pi f \omega=2\pi f$.

Exp 3. Balancing of Wien's bridge circuit and measurement of Capacitance.

Objective:

To determine the capacitance of an unknown capacitor. Circuit

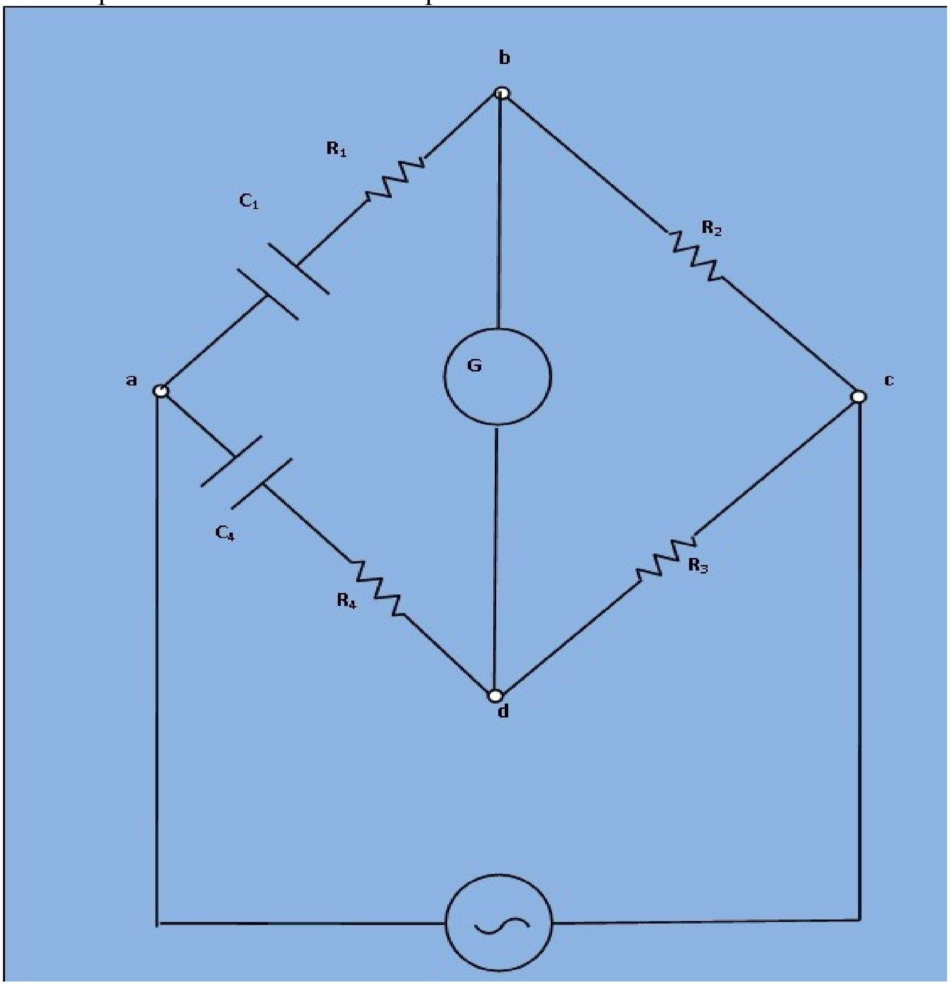


Diagram:

[Fig.1: Circuit diagram for measurement of capacitance by Wien Series Bridge]

Let,

$C1$= Capacitor whose capacitance is to be measured,

$R1$= A series resistance representing the loss in the capacitor $C1$,

$C4$ = A standard capacitance with series resistance of $R4$,

$R2$ and $R3$ = Non-inductive resistances.

At balance,

$(R1+1/j\omega C1) \cdot R3=(R4+1j\omega C4) \cdot R2$..........(1)

$R1R3+R3/j\omega C1=R2R4+R2/j\omega C4$..........(2)

Equating the real and imaginary terms,

$R1R3=R2R4$

$R1=R2R4/R3$

and, $R3j\omega C1=R2j\omega C4$

$C1=C4R2/R3$

If the bridge in Fig.1 is used to measure capacitance, it may be written as

$C1=C4R2/R3$...........(3)

$R1=R2R4/R3$...........(4)

The dissipation factor of capacitance $C1$ is defined as,

$D1=\omega C1/R1$...........(5)

While in measurement of capacitance $C1$, $R1$ is not a separate unit but represents the equivalent series resistance of the capacitor and thus can be determined in terms of the elements of the bridge.

Procedure:

1) Apply supply voltage from the signal generator V=3V at frequency 50Hz. Also set the unknown capacitance value from 'Set capacitor value' tab.
2) Then switch on the supply to get millivoltmeter deflection.
3) Choose the values of R2, R3, R4 and C4 from the resistance and capacitance box.
4) Observe the millivoltmeter pointer to achieve "Null".
5) If "NULL" is achieved, switch to 'Measure capacitance value' tab and click on 'Simulate'. Observe calculated values of unknown capacitance (C2) and unknown internal resistance (r2) of the capacitor.

6) Also observe the Dissipation factor of the unknown capacitor which is defined as ω·C/r. Where, ω=2πfω=2πf.

Exp 4: Calibration and measurement of Pressure (in Kg/cm2) using Diaphragm and Strain Gauge.

Prerequisite

What do we mean by Stress?

Stress is the force generated inside an object in response to an applied external force.
This internal force divided by the cross-sectional area of the object is called stress,
which is expressed in Pa (Pascal) or N/m^2.
If the direction of the external force is vertical to the cross-sectional area, the stress is called **vertical stress**.

What do we mean by strain?

When a bar is pulled, it causes change in its length by ΔL, making its new length = L (original length) + ΔL (change in length).
The ratio of this change in length ΔL, to the original length, L, is called **strain**.
The strain is expressed in ε (epsilon): $\varepsilon = \Delta L / L$
Strain in the same direction as the external force is called **longitudinal strain**.
Since strain is a ratio, it is an absolute number having no unit.
Strain in the direction perpendicular to the external force is called **lateral strain**.
Each material has a certain ratio of lateral strain to longitudinal strain. This ratio is called **Poisson's ratio**.

$V = -(d\varepsilon(trans) / d\varepsilon(axial))$

where

V is the resulting Poisson's ratio,
ε(trans) is transverse strain (negative for axial tension (stretching), positive for axial compression)
ε(axial) is axial strain (positive for axial tension, negative for axial compression).
The value of stress is directly proportional to the strain. Thus, we can find the stress in a material if we can find the
strain initiated by external force.

Introduction to Strain Gauge

Strain gauge transducer transforms mechanical elongation and compression into measurable value.

Types of Strain Gauges based on principle of working:

1. **Mechanical**: It is made up of two separate plastic layers. The bottom layer has a ruled scale on it and the top layer has a red arrow or pointer.
One layer is glued to one side of the crack and one layer to the other.
As the crack opens, the layers slide very slowly past one another and the pointer moves over the scale.
The red crosshairs move on the scale as the crack widens.
Some mechanical strain gauges are even more crude than this.
The piece of plastic or glass is stick across a crack and observed its nature.

2. **Electrical**: The most common electrical strain gauges are thin, rectangular-shaped strips of foil
with maze-like wiring patterns on them leading to a couple of electrical cables.
When the material is strained, the foil strip is very slightly bent out of shape and the maze-like wires are either pulled apart (so their wires are stretched slightly thinner) or pushed together (so the wires are pushed together and become slightly thicker). Changing the width of a metal wire changes its electrical resistance.
This change in resistance is proportional to the stress applied.
If the forces involved are small, the deformation is elastic and the strain gauge eventually returns to its original shape.

3. **Piezoelectric**: Some materials such as quartz crystals and various types of ceramics, are effectively "natural"

strain gauges.
When pushed and pulled, they generate tiny electrical voltages between their opposite faces.
This phenomenon is called piezoelectricity.
By measuring the voltage from a piezoelectric sensor we can easily calculate the strain.
Piezoelectric strain gauges are the most sensitive and reliable devices.

Electrical Strain Gauge: A strain gauge takes advantage of the physical property of electrical conductance. It does not depend on merely the electrical conductivity of a conductor, but also the conductor's geometry. When an electrical conductor is stretched within the limits of its elasticity such that it does not break or permanently deform, it will become narrower and longer. Similarly, when it is compressed, it will broaden and shorten. The change in the resistance is due to variation in the length and cross-sectional area of gauge wire.

Gauge Factor:
The characteristics of the strain gauges are described in terms of its sensitivity (gauge factor). Gauge factor is defined as unit change in resistance for per unit change in length of strain gauge wire given as

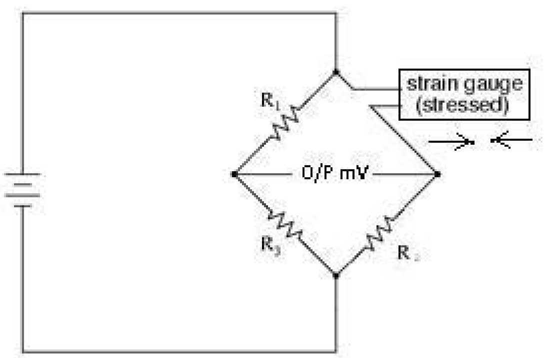
G.F. = $(\Delta R/RG) / \varepsilon$

Where,
ΔR - the change in resistance caused by strain,
RG - is the resistance of the unreformed gauge, and
ε – is strain.

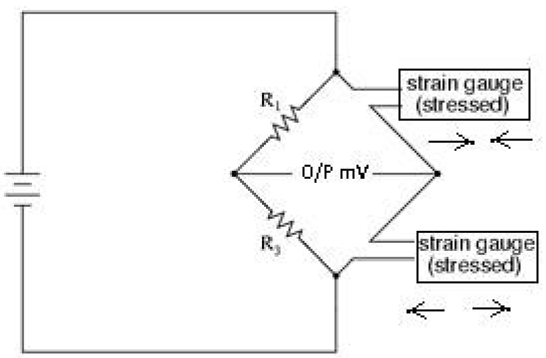
Effect of Temperature:
The resistive type strain gauges are sensitive to temperature variation; therefore, it becomes necessary to account for variations in strain gauge resistance due to temperature changes. Using dummy gauge in opposite arm of the active gauge compensates the temperature variation.

Arrangement:
In certain applications where equal and opposite strains are known to exist it is possible to attach similar gauges in way that one-gauge experiences positive strain and other negative strain. Depending on the number of gauges used the bridge, the circuit configurations are:

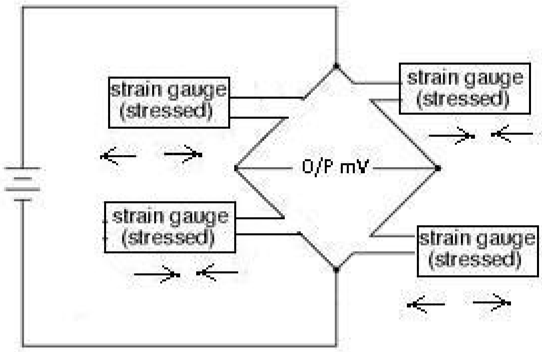
1. Quarter Bridge:



2. Half Bridge



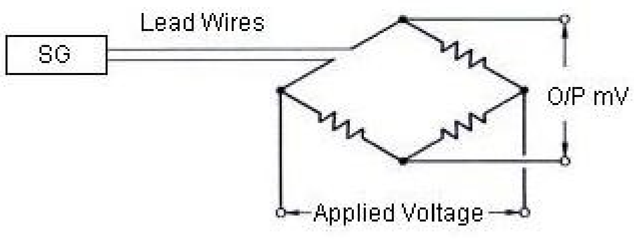
3. Full Bridge



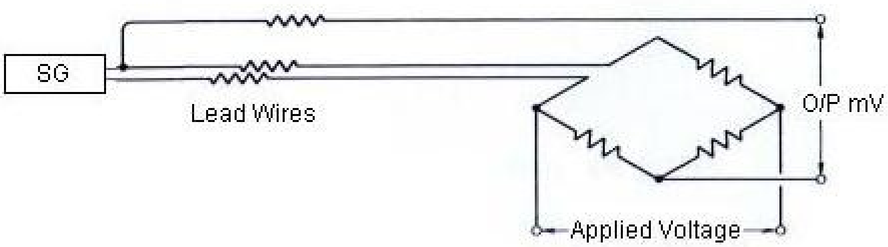
In Quarter Bridge, the strain gauge is connected in one arm as shown in the above diagram. In half bridge arrangement two active gauges are used, while in case of full bridge all the gauges are active. In this arrangement two acts in tension while other two are compression. With the help of this type of arrangement temperature compensation is also achieved. When possible, the full-bridge configuration is the best to use. This is true not only because it is more sensitive than the others, but because it is linear while the others are not. Quarter-bridge and half-bridge circuits provide an output (imbalance) signal that is only approximately proportional to applied strain gauge force. Linearity, or proportionality, of these bridge circuits is best when the amount of resistance change due to applied force is very small compared to the nominal resistance of the gauge(s). With a full-bridge, however, the output voltage is directly proportional to applied force, with no approximation.

Effect of Lead-Wire:
Strain gauges are sometimes mounted at a distance from the measuring equipment. This increases the possibility of errors due to temperature variations, lead desensitization, and lead-wire resistance changes.

Two wire:
In a **two-wire installation**, as shown in figure, the two leads are in series with the strain-gage element, and any change in the lead-wire resistance (R1) will be indistinguishable from changes in the resistance of the strain gage (Rg). In two-wire installations, the error introduced by lead-wire resistance is a function of the resistance ratio R1/Rg. The lead error is usually not significant if the lead-wire resistance (R1) is small in comparison to the gage resistance (Rg), but if the lead-wire resistance exceeds 0.1% of the nominal gage resistance, this source of error becomes significant. Therefore, in industrial applications, lead-wire lengths should be minimized or eliminated by locating the transmitter directly at the sensor.



2 Wire Configuration

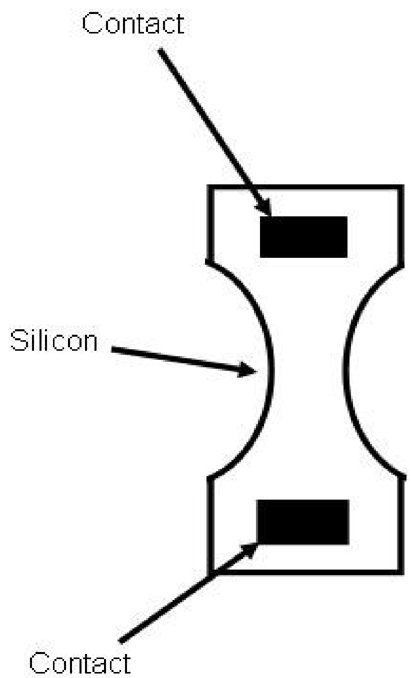


3 Wire Configuration

Three wire:
To correct for lead-wire effects, an additional, third lead can be introduced to the top arm of the bridge, **as**

shown in the above Figure. In this configuration, wire C acts as a sense lead with no current flowing in it, and wires A and B are in opposite legs of the bridge. This is the minimum acceptable method of wiring strain gages to a bridge to cancel at least part of the effect of extension wire errors. Theoretically, if the lead wires to the sensor have the same nominal resistance, the same temperature coefficient, and are maintained at the same temperature, full compensation is obtained. In reality, wires are manufactured to a tolerance of about 10%, and three-wire installation does not completely eliminate two-wire errors, but it does reduce them by an order of magnitude.
If further improvement is desired, four-wire and offset-compensated installations should be considered.

Types of strain gauge based on construction:
Optical sensors are sensitive and accurate, but are delicate and not very popular in industrial applications. They use interference fringes produced by optical flats to measure strain. Optical sensors operate best under laboratory conditions.
The photoelectric gauge uses a light beam, two fine gratings, and a photocell detector to generate an electrical current that is proportional to strain. The gage length of these devices can be as short as 1/16 inch, but they are costly and delicate.
Semiconductor strain gauges: For measurements of small strain, semiconductor strain gauges, so called piezo resistors, are often preferred over foil gauges. Semiconductor strain gauges depend on the piezoresistive effects of silicon or germanium and measure the change in resistance with stress as opposed to strain. The semiconductor bonded strain gauge is a wafer with the resistance element diffused into a substrate of silicon. The wafer element usually is not provided with a backing, and bonding it to the strained surface requires great care as only a thin layer of epoxy is used to attach it. The size is much smaller and the cost much lower than for a metallic foil sensor. The same epoxies that are used to attach foil gages are used to bond semiconductor gages. The advantages are higher unit resistance and sensitivity whereas, greater sensitivity to temperature variations and tendency to drift are disadvantages in comparison to metallic foil sensors. Another disadvantage of semiconductor strain gages is that the resistance-to-strain relationship is nonlinear. With software compensation this can be avoided.



Thin-film strain gauge: These gauges eliminate the need for adhesive bonding. The gauge is produced by first depositing an electrical insulation (typically a ceramic) onto the stressed metal surface, and then depositing the strain gauge onto this insulation layer. Vacuum deposition or sputtering techniques are used to bond the materials molecularly. Because the thin-film gauge is molecularly bonded to the specimen, the installation is much more stable and the resistance values experience less drift. Another advantage is that the stressed force detector can be a metallic diaphragm or beam with a deposited layer of ceramic insulation.
Diffused semiconductor strain gauges: This is a further improvement in strain gage technology as they

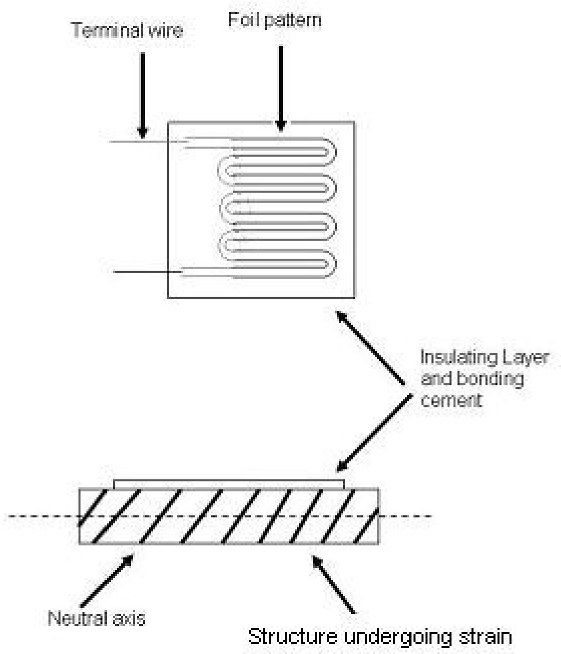
eliminate the need for bonding agents. By eliminating bonding agents, errors due to creep and hysteresis also are eliminated. The diffused semiconductor strain gage uses photolithography masking techniques and solid-state diffusion of boron to molecularly bond the resistance elements. Electrical leads are directly attached to the pattern.

The diffused gauge is limited to moderate-temperature applications and requires temperature compensation. Diffused semiconductors often are used as sensing elements in pressure transducers. They are small, inexpensive, accurate and repeatable, provide a wide pressure range, and generate a strong output signal. Their limitations include sensitivity to ambient temperature variations, which can be compensated for in intelligent transmitter designs.

Types of strain gauge based on mounting:

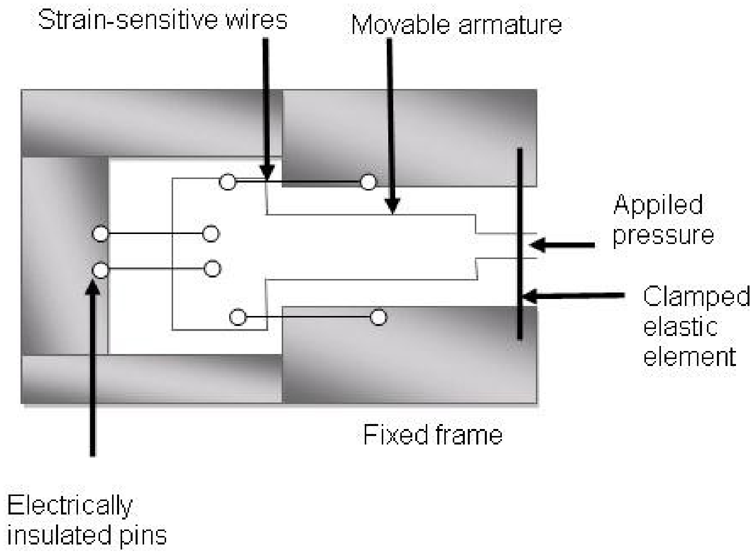
Bonded strain gauge:

A bonded strain-gage element, consisting of a metallic wire, etched foil, vacuum-deposited film, or semiconductor bar, is cemented to the strained surface.



Unbonded Strain Gauge:

The unbonded strain gage consists of a wire stretched between two points in an insulating medium such as air. One end of the wire is fixed and the other end is attached to a movable element.



Strain gauge selection criteria:
- Gauge Length
- Number of Gauges in Gauge Pattern
- Arrangement of Gauges in Gauge Pattern
- Grid Resistance
- mass
- stability
- temperature sensitivity
- Carrier Material
- Gauge Width
- Availability
- low cost
- effect of ambient conditions

exp 5: Calibration and measurement of Temperature (in 0C) using RTD and Thermocouple.

Prerequisite:

Before performing the experiments on thermocouples, students must have knowledge of:

1. Importance of temperature measurement
2. Different temperature scales
3. Various methods of temperature measurement

Theory:

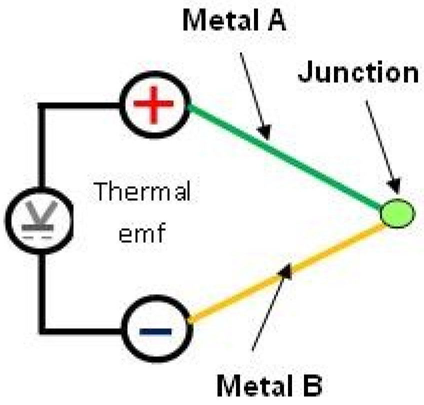
Thermoelectric effect:

The thermoelectric effect is the direct conversion of temperature differences to electric voltage and vice versa. A thermoelectric device creates a voltage when there is a difference in temperature on each side. Conversely when a voltage is applied to it, it creates a temperature difference.

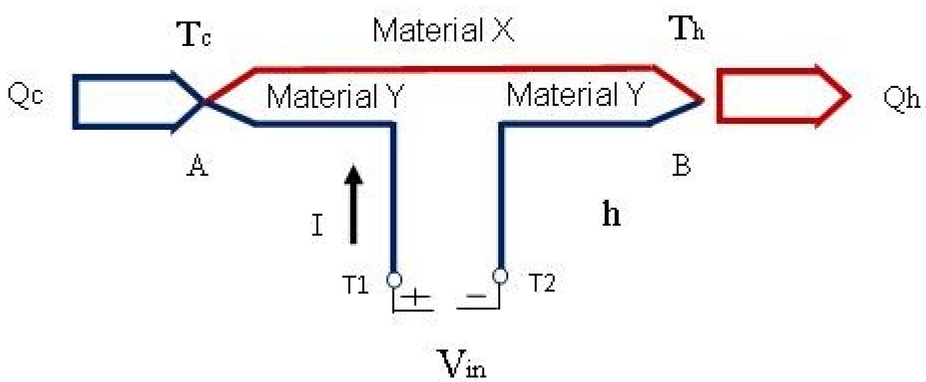
There are three basic effects that explain the working principle of a thermoelectric device.

1. Seebeck Effect: When two wires composed of dissimilar metals are joined at both ends and one of the ends is heated, there is a continuous current which flows in the thermoelectric circuit. German–Estonian physicist

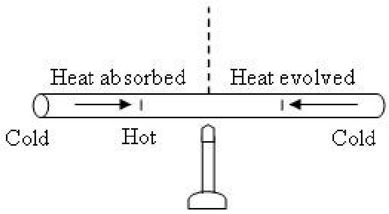
Thomas Seebeck made this discovery in 1821. This is now known as the **thermoelectric effect** or **Seebeck effect**.



2.Peltier Effect: Peltier found that the junctions of dissimilar metals get heated or cooled, depending upon the direction in which an electrical current passed through them. Heat generated by current flowing in one direction is absorbed if the current is reversed. The effect always involves pairs of junctions. The Peltier effect is found to be proportional to the first power of the current, not to its square, as is the irreversible generation of heat caused by resistance throughout the circuit. In effect it transfers the heat from one side of a device to other.



3. Thompson Effect: This describes the existence of temperature gradient while heating or cooling of a conducting material. Any current - carrying conductor (except superconductor), with a temperature difference between two points, will either absorb or emit heat, depending on the material.



Introduction to Thermocouple

What is thermocouple?

A thermocouple is a junction between two different metals that produces a voltage related to a temperature difference. When two wires composed of dissimilar metals are joined at both ends and one of the ends is heated, there is a continuous current which flows in the thermoelectric circuit (the thermoelectric effect or Seebeck effect).

Need for reference junction (cold junction):
In thermocouples, voltage is developed due to flow of electric current. This current flow depends upon the difference in temperatures at the two ends of conducting wire. That is thermocouples always measure difference in temperatures and not absolute temperature. To measure the temperature of one junction, the other junction is kept at some reference temperature. As this is done by using ice bath, it is normally called at cold junction. Using ice bath for constant temperature is useful for laboratory calibration, but is not convenient for most measurement and control applications. Instead of ice bath, an effect of cold junction is added using a thermally sensitive device such as a thermistor or diode.
This is also called as isothermal block. Special care is taken to minimize any temperature gradient between terminals. Hence, the voltage from a known cold junction can be simulated, and the appropriate correction is applied. This is known as cold junction compensation.

Software compensation is the most versatile technique used for measuring thermocouples. Many thermocouples can be connected on the same block. The technique is independent of the types of thermocouples. All of the conversions are performed by the computer. The disadvantage is that the computer requires additional time to calculate the reference junction temperature. For maximum speed we can use hardware compensation.

Hardware compensation can be viewed as inserting a battery that cancels the offset voltage produced by the reference junction. These commercially available circuits provide an electronic ice point reference. Their main advantage is speed while the disadvantage is that it is suited to compensate only a particular type of thermocouple.

Thermocouple properties:
The selection criteria for thermocouple materials:
1. Temperature Range
2. Melting point
3. Reaction to various atmospheric conditions
4. Thermoelectric output in combination
5. Electrical conductance
6. Stability
7. Interchangeability
8. Repeatability

9. accuracy
10. resolution
11. Cost
12. Availability
13. Chemical properties
14. Abrasion and vibration resistance
15. Installation requirements
16. Magnetic properties
17. Ease of handling and fabrication

Things to remember:

Wire Size of Thermocouple: Selecting the wire size used in the thermocouple sensor depends upon the application. Generally, when longer life is required for the higher temperatures, the larger size wires should be chosen. When sensitivity is the prime concern, the smaller sizes should be used.

Length of Thermocouple Probe: Since the effect of conduction of heat from the hot end of the thermocouple must be minimized, the thermocouple probe must have sufficient length. Unless there is sufficient immersion, readings will be low. It is suggested the thermocouple be immersed for a minimum distance equivalent to four times the outside diameter of a protection tube or well.

Location of Thermocouple: Thermocouples should always be in a position to have a definite temperature relationship to the work load. Usually, the thermocouple should be located between the work load and the heat source and be located approximately 1/3 the distance from the work load to the heat source.

Types of thermocouples based on metal combination:
Different types are best suited for different applications. They are usually selected based on the temperature range and sensitivity needed. Thermocouples with low sensitivities (B, R, and S types) have correspondingly lower resolutions.

Need for thermowell:
Thermowells are used in industrial temperature measurement to provide isolation between a temperature sensor (often a thermocouple) and the environment whose temperature is to be measured.
They are intrusive fittings and are subjected to static and dynamic fluid forces. These forces govern their design. Vortex shedding is the dominant concern as it is capable of forcing the thermowell into flow-induced resonance and consequent fatigue failure. The latter is particularly significant at high fluid velocities.
Thermowells are used to facilitate the repair of temperature sensing devices without interrupting the process being monitored.
Thermowells are available in three main barrel or shank design types. The barrel, or shank, is the container style apparatus, which is inserted into the process flow. Since thermowells are inserted directly into the process flow, the goal is to allow for measurement while causing as little restriction of flow as possible.

When selecting between the available types of thermowells, points considered are:
Stem length (length from bore to the end of the well) and bore diameter of the thermowell.
The temperature and viscosity of the media into which the thermowell will be seated. Lagging extensions through which the sensor will have to pass.

Exp 6: Calibration and measurement of Displacement (in mm) using LVDT.

Prerequisite

1. The basics of transformers
2. Magnetic materials and their properties
3. Concept of inductance and mutual inductance

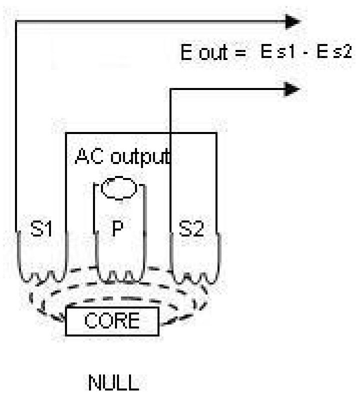
LVDT is linear Variable Differential Transformer. It is electromechanical transducer. It converts the rectilinear displacement of any object to which it is coupled mechanically in electrical signal proportional to it.

Construction:

LVDT is made of two main components: the movable armature and the outer transformer windings.
LVDT consists of 3 windings. Centre one is Primary winding while the other two are secondary windings. The secondaries are identical and placed symmetrical about the primary. The secondary coils are connected in series-opposition.
Moving element of LVDT is called core. It is a cylindrical armature made of ferromagnetic material. It is free to move along the axis of the tube. At one end, the core is coupled to an object whose displacement is to be measured, while the other end moves freely inside the coil's hollow bore.

Working:

An alternating current is connected to the primary. This current must be of appropriate amplitude and frequency. It is also called as **Primary Excitation**. The frequency is usually in the range 1 to 10 kHz. This current causes a voltage to be induced in each secondary proportional to its mutual inductance with the primary. While the frequency of induced voltage is same as that of excitation frequency, its amplitude varies with the position of the iron core.
As the core moves, the voltages induced in the secondary's changes due to change in mutual inductance.
The coils are connected in series but in opposite phase, so that the output voltage is the difference between the two secondary voltages. When the core is exactly at central position, i.e., at equal distance from the two secondary's, equal but opposite voltages are induced in these two coils, so the output voltage is zero.
When the core is displaced in one direction, the voltage in one coil increases with respect to the other, causing the output voltage to increase from zero to a maximum value. This voltage is in phase with the primary voltage.
When the core moves in the other direction, the output voltage also increases from zero to a maximum value, but the phase is opposite to that of the primary. The magnitude of the output voltage is proportional to the distance moved by the core. The phase of the voltage indicates the direction of the displacement.



Case 1:

When no displacement is applied to the core and the core remains in the null position without any movement then the voltage induced in both the secondary windings is equal which results in net output is equal to zero i.e., $E_{s1} - E_{s2} = 0$

Case 2:
When displacement is applied in such a way that the core moves in the left direction then the voltage induced in that (left) secondary coil is greater as compared to the emf induced in the other secondary coil. Therefore, the net output is $E_{s1}-E_{s2}$

Case 3:
When force is applied to core such that it moves in the right-hand side direction then the emf induced in the secondary coil 2 is greater compared to the emf voltage induced in the secondary coil 1, therefore, the net output voltage is $E_{s2}- E_{s1}$.

As seen, the voltage undergoes 180 degrees phase shift while going through null. The output E is out of phase with the excitation.
Usually, this AC output voltage is converted by suitable electronic circuitry to high level DC voltage or current that is more convenient to use.
Residual Voltage: Output voltage at the null position is ideally zero. But because of harmonics in the excitation voltage and stray capacitance coupling between primary and secondary a non-zero voltage exists at null position. This is called residual voltage. If it is less than 1 % of full-scale output voltage (which is the normal case) it is in the acceptable limits.

Eddy Currents: When alternating current is passed through the coil, a magnetic field is generated in and around the coil. When a rod is brought in close proximity to a conductive material, the rod's changing magnetic field generates current flow in the material. These are called as **eddy currents.**
The eddy currents produce their own magnetic fields that interact with the primary magnetic field of the coil. As the eddy current flows through conducting core, it creates heat. This causes power loss in the core. To reduce the eddy current losses, the core is provided with a slot. This slot cut the magnetic field created hence reducing the flux. Laminated core is also used for the same purpose.

Types of LVDT based on applications:

1. **General Purpose LVDT**: for use in many industrial and research applications.
2. **Precision LVDT**: for sensitive gauging and quality control applications
3. **Submersible LVDT**: Hermetically sealed for use in industrial and research environments involving corrosive fluids and gases, high temperature and vibrations, etc.

Types of LVDT based on range of operation:

1. **Short stroked**: full-scale linear ranges from ±0.01 inch (±0.25 mm) to ±0.5 inch (±12.7 mm)
2. **Long stroked**: full-scale linear ranges from ±0.5 inch (±12.7 mm) to ±18.5 inch (±470 mm)

Types of LVDT based on excitation used

1. **AC LVDT**: AC LVDTs are excited by an AC voltage having frequency between 50 hertz and 25 Kilohertz with 2.5 Kilohertz as a nominal value. The carrier frequency is generally selected to be at least 10 times greater than the highest expected frequency of the core motion. AC-operated LVDT's are generally smaller in size and more accurate than DC versions. They are able to tolerate the extreme variations in operating temperature than the DC LVDT.

Modern circuits often supply phase detection circuits along with the LVDT. A phase sensitive detector circuit (PSD) is useful to make the measurement direction sensitive. It is connected at the output of the LVDT and compares the phase of the secondary output with the primary signal to judge the direction of movement. The output of the phase sensitive detector after passing through low pass filter is in the dc voltage form used for steady deflection.

2. **DC LVDT**: The DC LVDT is provided with onboard oscillator, carrier amplifier, and demodulator circuitry.

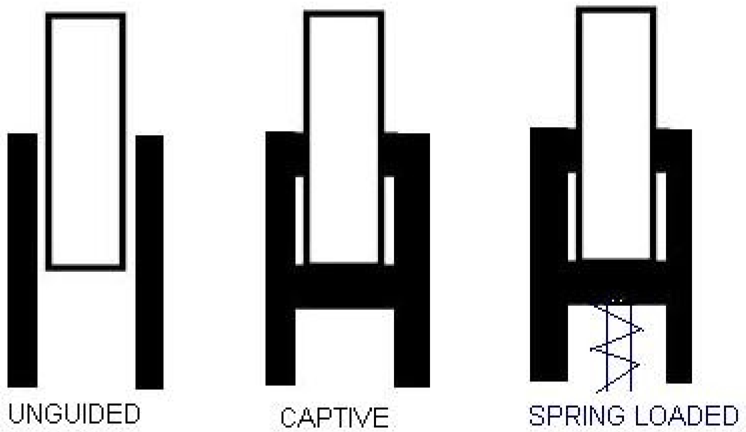
The major advantages of DC-operated ("DC-to-DC") LVDT's are ease of installation and signal conditioning, the ability to operate from dry cell batteries in remote locations, and lower system cost (especially in multipoint applications). The DC LVDT is temperature limited operating from typically - 40 deg C to +120degC

Types of LVDT based on armature:

1. **Unguided Armature**: This is simplest configuration in which armature fits loosely in the cavity of the coils bore. This requires proper installation to ensure proper movement along the axis. This allows frictionless movement with no wear. This type has unlimited fatigue life, good repeatability with infinite resolution.
   Free armature is mainly suitable for short range, high speed applications.

2. **Guided (Captive) Armature**: In this type, armature is restrained and guided by low friction bearing assembly.
   These are suitable for long working ranges. To avoid possibility of misalignment the armature is guided.

3. **Spring Extended Armature** – This armature is similar to guided armature LVDT with an addition that,
it has internal spring to push the armature continuously to its fullest possible extension. This maintains light and reliable contact with the measured object.
   Most suitable for static or slow-moving applications.



Applications:
LVDTs are commonly used for
-position feedback in servomechanisms
-automated measurement in machine tools and many other industrial and scientific applications.
-measurement of displacement ranging from fraction of mm to cm
-Acting as a secondary transducer, it can be used for force, weight and pressure measurement.

Exp 7: Calibration and measurement of level (in cm) using capacitive type level probe.

Prerequisite

Before performing this experiment, student must have knowledge about

1. Working of a typical Capacitor
2. Types of Capacitors
3. Effect of various factors that affect the output of a capacitor e.g., temperature, dielectric constant of insulator used, distance between the plates, are of the plates used, etc.

Level measurements

In industry, liquids such as water, chemicals, and solvents are used in various processes. The amount of such liquid stored can be found by measuring level of the liquid in a container or vessel. The level affects not only the quantity delivered but also pressure and rate of flow in and out of the container. Level sensors detect the level of substances like liquids, slurries, granular materials, and powders. The substance to be measured can be inside a container or can be in its natural form (e.g., a river or a lake). The level measurement can be either continuous or point values.

Continuous level sensors measure the level to determine the exact amount of substance in a continuous manner.
Point-level sensors indicate whether the substance is above or below the sensing point. This is essential to avoid overflow or emptying of tanks and to protect pumps from dry run.
The selection criteria for level sensor include:

- The physical phase (liquid, solid or slurry)
- Temperature
- Pressure or vacuum
- Chemistry
- Dielectric constant of medium
- Density (specific gravity) of medium
- Agitation (action)
- Acoustical or electrical noise
- Vibration
- Mechanical shock
- Tank or bin size and shape

From the application point of view the considerations are:

- Price
- Accuracy
- Response rate
- Ease of calibration
- Physical size and mounting of the instrument
- Monitoring or control of continuous or discrete levels

Level measurements are broadly classified in two groups:

- Direct methods
- Indirect methods

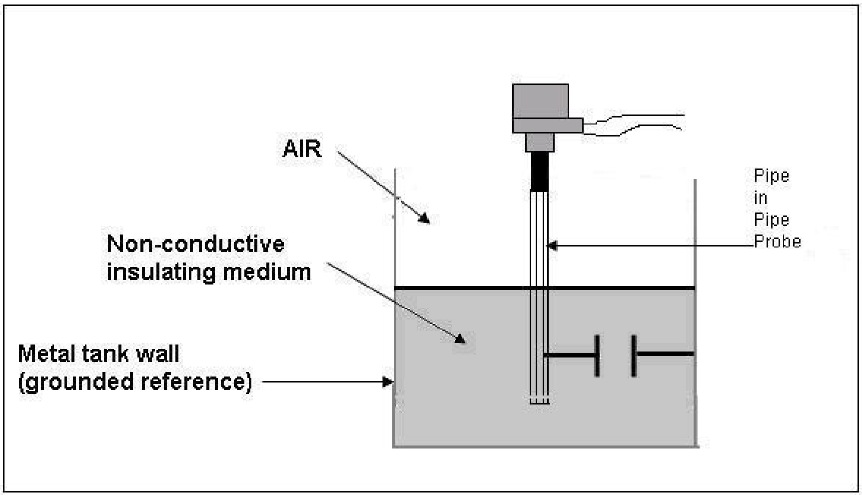
In direct methods, the level is indicated directly by means of simple mechanical devices. The measurement is not affected by changes in material density. Few examples are:

- Dip Stick
- Resistance Tapes
- Sight Glass
- Floats
- Ultrasonic
- Radar

In Indirect methods, the level is converted in a measurable signal using a suitable transducer. Change in the material affects the measurement. A corrective factor must be used in recalibrating the instrument. Few examples are:

- Hydrostatic head methods
- Load cell
- Capacitance
- Conductivity

Capacitance Level Measurement:
Capacitive level transducer is an example of indirect measurement of level



Capacitance level sensors are used for wide variety of solids, aqueous and organic liquids, and slurries. The technique is frequently referred as **RF** as radio frequency signals applied to the capacitance circuit. The sensors can be designed to sense material with dielectric constants as low as 1.1 (coke and fly ash) and as high as 88 (water) or more. Sludges and slurries such as dehydrated cake and sewage slurry (dielectric constant approx. 50) and liquid chemicals such as quicklime (dielectric constant approx. 90) can also be sensed. **Dual-probe** capacitance level sensors can also be used to sense the interface between two immiscible liquids with substantially different dielectric constants.

Since capacitance level sensors are electronic devices, phase modulation and the use of higher frequencies makes the sensor suitable for applications in which dielectric constants are similar.

Working Principle:
The principle of capacitive level measurement is based on change of capacitance. An insulated electrode acts as one plate of capacitor and the tank wall (or reference electrode in a non-metallic vessel) acts as the other plate. The capacitance depends on the fluid level. An empty tank has a lower capacitance while a filled tank has a higher capacitance.
A simple capacitor consists of two electrode plate separated by a small thickness of an insulator such as solid, liquid, gas, or vacuum. This insulator is also called as dielectric. Value of C depends on dielectric used, area of the plate and also distance between the plates.

$$C = E\,(K\,A/d)$$

Where:
C = capacitance in picofarads (pF)
E = a constant known as the absolute permittivity of free space
K = relative dielectric constant of the insulating material
A = effective area of the conductors
d = distance between the conductors
This change in capacitance can be measured using AC bridge.
Measurement:
Measurement is made by applying an RF signal between the conductive probe and the vessel wall. The RF signal results in a very low current flow through the dielectric process material in the tank from the probe to the vessel wall. When the level in the tank drops, the dielectric constant drops causing a drop in the capacitance reading and a minute drop in current flow. This change is detected by the level switch's internal circuitry and translated into a change in the relay state of the level switch in case of point level detection. In the case of continuous level detectors, the output is not a relay state, but a scaled analog signal.
Level Measurement can be divided into three categories:

- Measurement of non-conductive material
- Measurement of conductive material
- Non-contact measurement

Non-conducting material:
For measuring level of non-conducting liquids, bare probe arrangement is used as liquid resistance is sufficiently high to make it dielectric. Since the electrode and tank are fixed in place, the distance (d) is constant, capacitance is directly proportional to the level of the material acting as dielectric.

Conducting Material:
In conducting liquids, the probe plates are insulated using thin coating of glass or plastic to avoid short circuiting. The conductive material acts as the ground plate of the capacitor.

Proximity measurements (Non-contact type measurements):
In Proximity level measurement is the area of the capacitance plates is fixed, but distance between plates varies. Proximity level measurement does not produce a linear output and are used when the level varies by several inches.

Advantages of Capacitive level measurement:

1. Relatively inexpensive
2. Versatile
3. Reliable
4. Requires minimal maintenance
5. Contains no moving parts
6. Easy to install and can be adapted easily for different size of vessels
7. Good range of measurement, from few cm to about 100 m
8. Rugged
9. Simple to use
10. Easy to clean
11. Can be designed for high temperature and pressure applications.

Applications:
Capacitance Level Probes are used for measuring level of
1. Liquids
2. Powered and granular solids
3. Liquid metals at very high temperature
4. Liquefied gases at very low temperature
5. Corrosive materials like hydrofluoric acid
6. Very high-pressure industrial processes.

Disadvantages:
Light density materials under 20 lb/ft3 and materials with particle sizes exceeding 1/2 in. in diameter can be a problem due to their very low dielectric constants (caused by the large amount of air space between particles).

Exp 8. Measurement of rotating Speed (in RPM) using Photo Reflective and Magnetic Pick Up sensor.

AIM: Measurement of rotating Speed using Photo Reflective and Magnetic Pick Up

APPARATUS:
1. Power Supply
2. Oscillator
3. Signal Conditioner
4. Mixer and
5. Counter

THEORY:

PROCEDURE:

1. Before Switching ON the instrument ensure that the connections are made properly:
2. Switch ON the instrument by pushing down the toggle switch provided at the rear side of the box, LED display glows to indicate the instrument ON.
3. Allow the instrument for 10 minutes in ON position for initial warm-up.
4. Select the sensor with the help of toggle switch.
5. Switch ON the electronic regulator. The fan rotates which will rotate the tone wheels. The display will start indicating exact RPM of the motor.
6. Reading can be tabulated for both the sensors. Comparison can be made between two sensors.

OBSERVATIONS:

A **Sl.No.**	**B** **Actual Speed of Motor Photo reflective (RPM)**	**C** **Magnetic Pick-Up (RPM)**	**D** **ERROR** **B-C**

RESULT:

Exp 9. Measurement of Vibration using Piezoelectric Accelerator Sensor.

AIM: Measurement of Vibration using Piezoelectric Accelerator Sensor (USING TRAINER MODEL UITM-18)

APPARATUS:

1. Shaker
2. Control Unit
    - i) Power Oscillator
    - ii) Vibration Meter
3. Accelerometer
4. Threaded steel studs M5.

THEORY:

PROCEDURE:

1. Connect the sensor to the instrument through the BNC socket provided on the rear mentioned SENSOR.
2. Connect the Vibration generator to the instrument through the cable provided at the rear panel of the instrument marked EXCITER.
3. Connect the instrument to the 230 V 50 Hz. Supply through cable provided at the rear panel.
4. Keep the FREQ. Pot and the VOLT pot in the minimum position.
5. Switch on the instrument, the display glows to indicate the power is on.
6. Turn the VOLT pot to the max position.
7. Now turn the FREQ pot in steps of 100 Hz. And note down the readings of Acceleration, Velocity and Displacement by selecting the MODE through selector switch.
8. Tabulate the readings in the tabular column. Experiment can be repeated for different voltage levels settable through VOLT knob provided.

OBSERVATION:

Output (Measurement Parameters):

Acceleration: +/-5% of the Reading Value
Velocity: +/-5% of the Reading Value
Displacement: +/-5% of the Reading Value

CALIBRATION READINGS:

Sl No.	Frequency	Acceleration	Velocity	Displacement
	Hz	Measured (Peak) m/sec2	Measured (rms) cm/sec	Measured (p-p) mm

RESULT:

Graph can be plotted for Frequency V/s Acceleration, Velocity and displacement.

Exp 10. Design of DAC (Digital to Analog converter) using R-2R ladder network.

AIM: Convert four bits of Digital signal to an Analog equivalent signal using R-2R ladder Network

APPARATUS:

1. CRO or MULTIMETER
2. Dual Power Supply (±15V)
3. Trainer board (Microlab-II)

COMPONENTS:

1. Op-Amp. IC 741
2. Resistor 10KΩ
3. Connecting wires

PROCEDURE:

1. Connect the circuit as shown in the circuit diagram.
2. Apply the input bit combinations as per observation table and note down the output voltage.
3. Repeat step-2 for all entries mentioned in observations table.
4. At the end, compare the output voltage observed with theoretically calculated output voltage.
5. calculate the errors of conversion.

OBSERVATIONS:

Sl. No.	Decimal Equivalent of Binary I/P's	Input (V) B3	B2	B1	B0	O/P Voltage Theoretically (V)	O/P Voltage (Analog value) Practically (V)
1	0	0	0	0	0		
2	1	0	0	0	5		
3	2	0	0	5	0		
4	3	0	0	5	5		
5	4	0	5	0	0		
6	5	0	5	0	5		
7	6	0	5	5	0		
8	7	0	5	5	5		
9	8	5	0	0	0		
10	9	5	0	0	5		
11	10	5	0	5	0		
12	11	5	0	5	5		
13	12	5	5	0	0		
14	13	5	5	0	0		
15	14	5	5	5	0		
16	15	5	5	5	5		

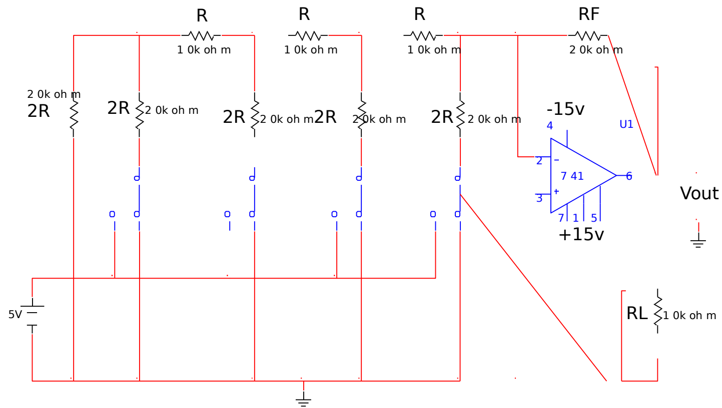


Fig. R-2R Ladder Network

RESULT:

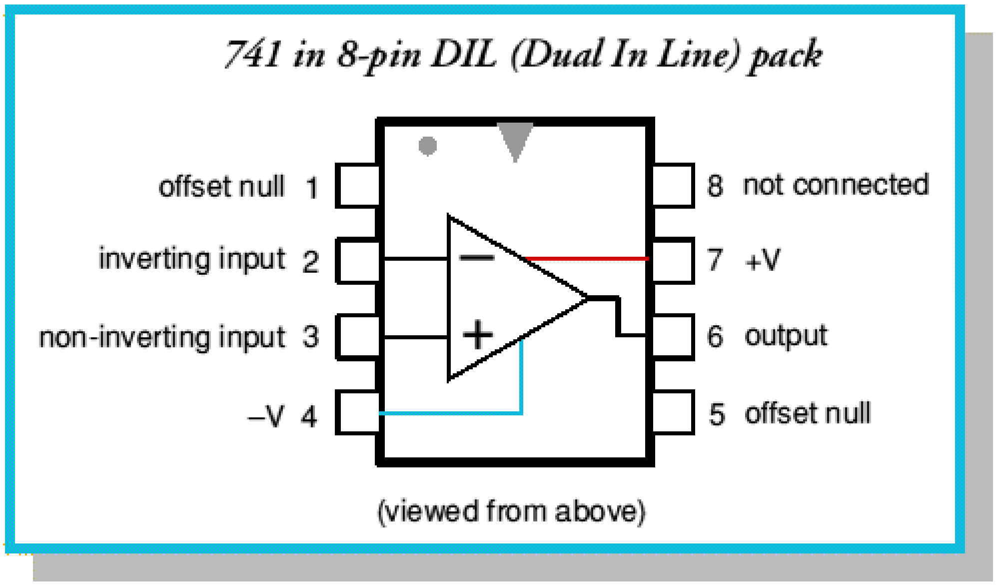
Exp 12. Design and implementation of an Instrumentation Amplifier for a variable gain. AIM: Design of an Instrumentation Amplifier using IC 741 OPAMP

APPARATUS:

1. Resistance (1K, 10K, 100K)
2. IC 741 (3 Nos)
3. AC millivoltmeter
4. Microlab Kit-II

THEORY:

The 741 is the godfather of all operational amplifiers (amplifiers on a chip). Although most up-to-date designs beat it for speed, low noise, etc, it still works well as a general-purpose device. One of its advantages is that it is compensated (its frequency response is tailored) to ensure that under most circumstances it won't produce unwanted spurious oscillations. This means it is easy to use, but the downside of this is the poor speed/gain performance compared to more modern op-amps.



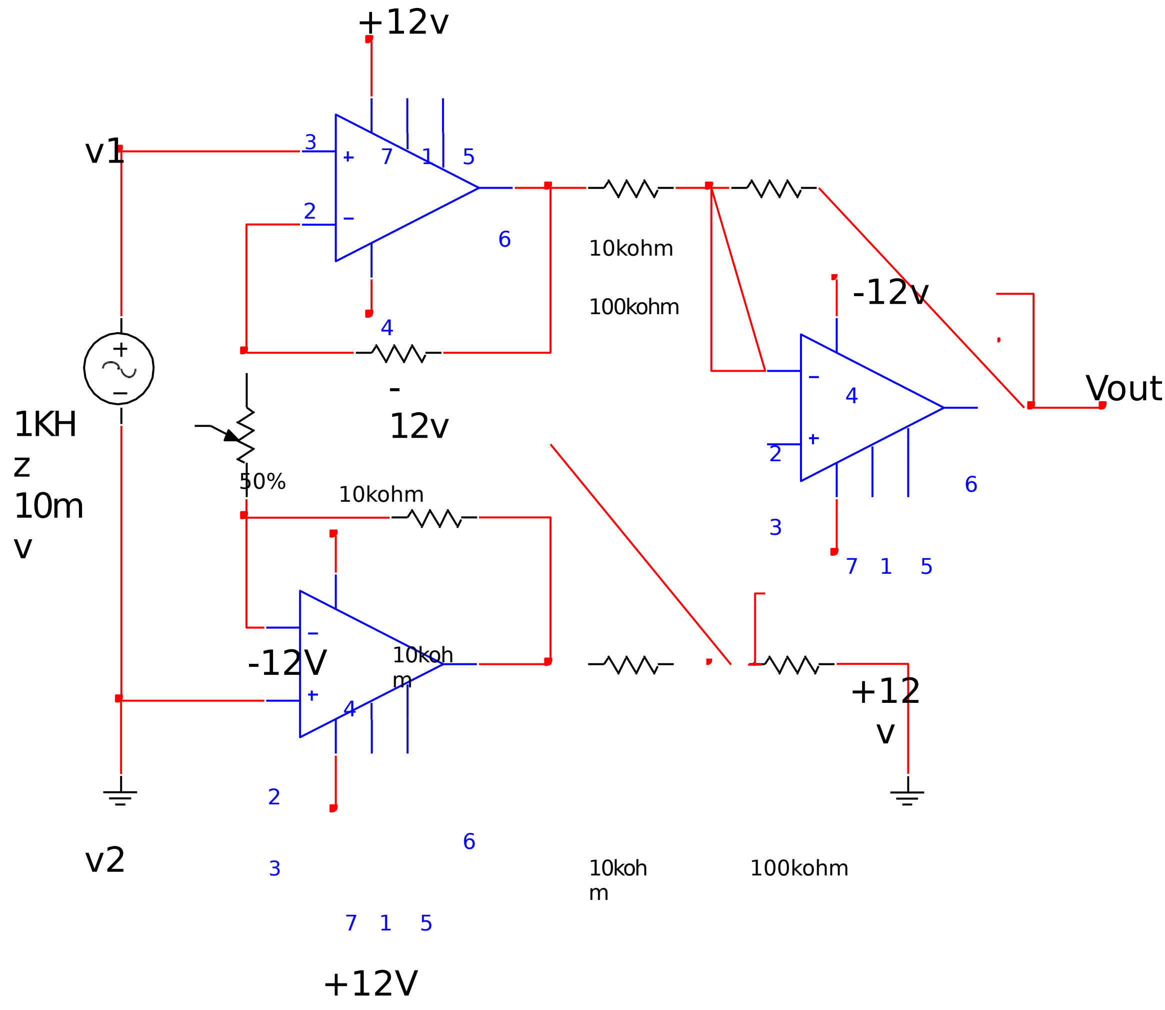
The 741 is usually supplied in an 8-pin 'DIL' (Dual In Line) or 'DIP' (Dual Inline Package, or sometimes Dual Inline Plastic) package with a pinout shown above. This has proved so popular that many other competing op-amps have adopted the same package/pinout. Hence for many applications the various op-amps are 'drop in' replacements or upgrades for one another. These days there is a large family of 741 type devices, made by various manufacturers. Sometimes one manufacturer will make different versions which work better than others in some respect. Each has a slightly different part number, but it generally has "741" in it somewhere!

The values given below are 'typical' for an ordinary 741, better versions (more expensive) may give better results...

```
Typical values of Basic Parameters:
      Rail voltages : +/- 15V dc (+/- 5V min, +/- 18V max)
      Input impedance: Around 2MegOhms
      Low Frequency voltage gain: approx 200,000
      Input bias current: 80nA
      Slew rate: 0.5V per microsecond
      Maximum output current: 20mA
      Recommended output load: not less than 2kilOhms
```

Note that, due to the frequency compensation, the 741's voltage gain falls rapidly with increasing signal frequency. Typically, down to 1000 at 1kHz, 100 at 10kHz, and unity at about 1MHz. To make this easy to remember we can say that the 741 has a gain-bandwidth product of around one million (i.e. 1 MHz as the units of frequency are Hz).

Circuit Diagram



INSTRUMENTATION AMPLIFIER

PROCEDURE:

1. Connect the circuit as shown in the circuit diagram.
2. Set the inputs V_1 and V_2 at different values but at the same frequency.
3. Adjust R_1 to a particular value.
4. Calculate the theoretical gain from the given formula and verify with the practical values.
5. Repeat the above procedure for different values of R_1.

OBSERVATIONS:

S.No	Resistance (Ω)	Input Voltage (Mv)	Gain (Theoretical)	Gain (Practical)	ERROR

RESULT:

AIM: Measurement of rise time of a RC circuit

APPARARUS REQUIRED:

1. Digital storage CRO
2. Power Supply
3. Resistance 1 Mega ohms
4. Capacitor .1 Microfarad
5. Bread board

THEORY:

Rise time of a circuit & how it is related to badwidth

PROCEDURE:

1. Arrange the experimental setup as shown in the circuit diagram.
2. Open the switch across the capacitor and observe the rise of the capacitor voltage on CRO.
3. Press the hold button just after capacitor voltage stops increasing.
4. Measure the rise time.

OBSERVATIONS:

R=

C=

Sl.No	Time/Div	No. of div.	Rise time

RESULT:

PRECAUTIONS

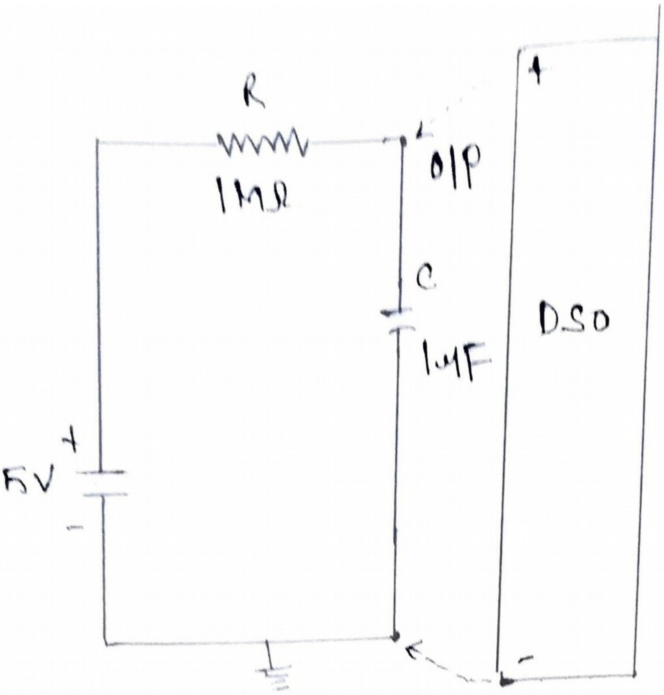
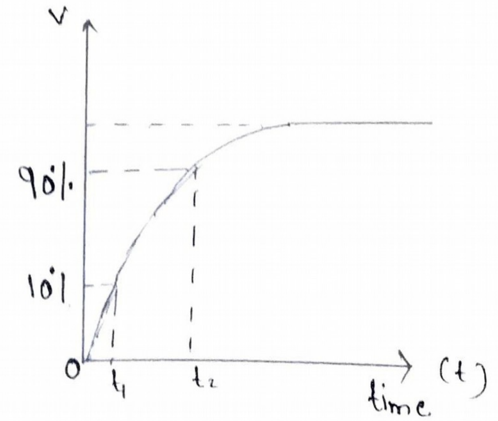


Fig: RC circuit diagram.



Graph