Experimental Engineering Laboratory

IC 211

(Common to all branches: Computer Science and Engineering, Electrical Engineering, Mechanical Engineering, Civil Engineering & MEMS Engineering)

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E.1) MEASUREMENT OF RESISTANCE USING WHEATSTONE BRIDGE (POST OFFICE BOX)

Introduction

Post Office Box Trainer is the combination of resistances which works on the principle of Wheatstone bridge. Post Office Box is helpful to determine the unknown resistance of wire like manganin, constantan, and Nichrome etc. With the help of this trainer we can determine the specific resistance of different types of wire. Post Office Box can also verify combination of resistance in series and parallel.

Post Office Box refers to a box containing a combination of ten resistors of 1 Ω, 10 Ω, 100 Ω and 1000 Ω. They are so connected that when Post Office Box is connected in series in a circuit, it is possible to introduce any resistance of integer value from 1 Ω to 10000 Ω by pulling out appropriate keys of the resistors. Post Office Box arranged in the form of a Wheatstone bridge which is used to find the value of an unknown resistance.
Post office box is a Wheatstone bridge, firstly designed to locate a short circuit in a telephone or telegraph line by measuring the resistance of the wire to the short circuit. It is called a “Post office bridge” because this design was adopted by British Post Office, which operated telegraph and telephone services as well as delivered mail.

Wheatstone was responsible for popularizing the arrangement of four resistors, a battery and a galvanometer, and gave Christie full credit in his 1843 Bakerian Lecture. Wheatstone called the circuit a "Differential Resistance Measurer." This arrangement was not invented by Sir Charles Wheatstone - although it bears his name and is commonly attributed to him, and was employed by him in some of his electrical researches - but by S. H. Christie, in 1833.

Principle of Wheatstone Bridge

The Wheatstone bridge is shown in figure 1. Resistance Rx is an unknown resistance.

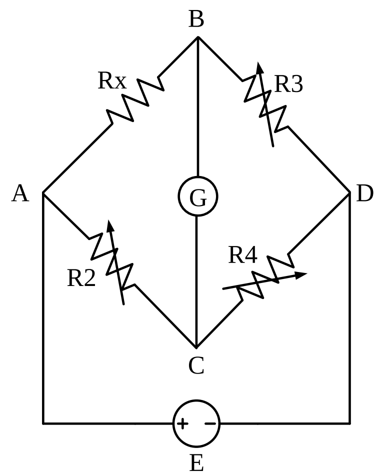


Figure 1

When the Galvanometer will indicate a current flowing between terminals B and C, it is called an unbalanced condition. By adjusting R_2, R_3 and R_4, the current flowing through galvanometer can be set to zero. This is called a balanced condition. By applying circuit laws, one can find an unknown resistance R_x as

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

Applications of Wheatstone Bridge:

One very common application in industry today is to monitor sensor devices such as strain gauges. Such devices change their internal resistance according to the specific level of strain (or pressure, temperature, etc.), and serve as the unknown resistor R. Second application is in the area of electrical power distribution to accurately locate breaks in a power line. The method is fast and accurate, and does not require a large number of field technicians. A number of resistance measuring devices have been devised on the principle of Wheatstone bridge.

There are three experiments on post office box.
1. Measurement of unknown resistance
2. Measurement of resistivity of a wire
3. Measurement of an equivalent value of a series/parallel resistance combination

Experiment 1

Objective: Determination of unknown resistance.

Procedure:

1. Connect the -ve terminal of DC Supply to I and +ve terminal to J terminal of the bridge.
2. Connect Galvanometer's +ve and -ve terminals to M and N terminals respectively.
3. Connect K & L terminals of variable resistance to E & G (R_3) terminals of bridge.
4. Connect O & P terminals of unknown resistance to H & F (Rx) terminals of bridge.
5. Set all rotaries to 0 **Ω** before starting the experiment.
6. Keep the key K1 in 'Off' position.
7. Switch 'On' the trainer.
8. Set the resistance R_x at any unknown resistance by rotating its dial knob.
9. Set resistance R_1 and R_2 at 10 **Ω**.
10. Switch 'On' the key K1 and observe the deflection on galvanometer.
11. Then adjust the valve of R_3 in step of 1**Ω**, 10 **Ω**,100 **Ω**, 1000 **Ω**, as per the requirement beginning from zero , till the null point is not obtained in the galvanometer For R_3 resistance of X1, X10, X100, X1000 **Ω** is provided. For Example, Suppose galvanometer shows deflection in left direction at 1000 **Ω** and at200 **Ω** in right direction then the null point lies between these two resistance then adjusting resistances of 100 **Ω**,10 **Ω**, and 1 **Ω**, to get the null point. Then add the value of all resistances which you have selected, this will give R_3.
12. Note the value of R_3 in the given Observation table.
13. Repeat the same procedure for 1/10 ratio by taking out R_1=**10 Ω** and R_2= 100 **Ω**, and adjust the resistance R_3 till the null point is not obtained. If the null point is not obtained then repeat the same step no. 10. Note the value of R_3 in the given Observation table.
14. Repeat the same procedure for 1\100 ratio by taking out R_1= 10 **Ω** and R_2= 1000 **Ω**.
15. Unknown resistance Rx can be determined by using Wheatstone Bridge relation **$R_1/R_2= R_3/R_x$** Where R_1 & R_2 are the resistance of arm AB and BC respectively, R_3 is Variable resistance.
16. Tabulate all the readings of R_x in the given Observation table.
17. Take the mean of R_x.

18. We get the value of unknown resistance R_x (which is the experimental value) Note : The actual value of unknown resistance can be determined with the help of dial knob. Here the dial knob can rotates 10 times corresponding to 0 to 10 numbers, it is said to be Main Scale reading and its each rotation has 50 divisions, it is said to be Circular Scale reading (least count =20 Ω). For example , If there are 5 rotations by main Scale it means the resistance on Main Scale is 5000 Ω and Circular Scale is at 30, it means no. of divisions are 15 then the actual of resistances becomes 5000 Ω +(15×20 Ω)= 5300 Ω.

S. No.	Resistance R_1 (in Ω)	Resistance R_2 (in Ω)	Resistance R_3 (in Ω)	Resistance $R_x = R_3R_2/R_1$ (in Ω)
1.	10	10		
2.	10	100		
3.	10	1000		

Experiment 2

Objective: To determine Resistivity of the material of wire.

1. Connect the -ve terminal of DC Supply to I and +ve terminal to J terminal of the bridge.
2. Connect Galvanometer's +ve and -ve terminals to M and N terminals respectively.
3. Connect K & L terminals of variable resistance to E & G (R_3) terminals of bridge.
4. Take Experimental wire and connect it between the terminals H & F (R_x) whose resistivity we have to determine (Wire material like manganin, Nichrome etc). Note: Set all rotaries all 0 **Ω** before starting the experiment.
5. Keep the key K1 in 'Off' Position.
6. Switch 'On' the trainer.
7. Then set resistance R_1 and R_2 at 10 **Ω**.
8. Switch 'On' the key K1 and observe the deflection on galvanometer
9. Switch 'On' the key K1 and observe the deflection on galvanometer
10. Note the value of R_3 in the given Observation table
11. Repeat the same procedure for 10/1 ratio by taking out R_1=**100 Ω** and R_2= 10 **Ω**, and adjust the resistance R_3 till the null point is not obtained. If the null point is not obtained then repeat the same step no. 9. Now note the value of R_3 in the given Observation table.
12. Repeat the same procedure for 100\1 ratio by taking out R_1= 1000 **Ω** and R_2= 10 **Ω**.
13. Resistance R_x can be determined by using Wheatstone Bridge relation $R_1/R_2= R_3/R_x$ Where R_1 & R_2 are the resistance of arm AB and BC respectively, R_3 is Variable resistance at which point we determined null point.
14. Tabulate all the readings of R= in the given Observation table.
15. Take the mean of R_x. We get the Value of Resistance R_x of the material of wire.
16. Specific resistance of the material of wire can be determine by using formula

$$\rho = R_X \frac{\pi r^2}{l}$$

17. The resistivity of the wire is ρ = ----- **Ω**-m

Observation Table:

S No.	Resistance R_1 (Ω)	Resistance R_2 (Ω)	Resistance R_3 (Ω)	Resistance $R_x = R_3R_2/R_1$ (Ω)
1.	10	10		
2.	10	100		
3.	10	1000		

Experiment 3

Objective: To verify law of resistance in series and parallel

Procedure:

1. Connect the -ve terminal of DC Supply to I and +ve terminal to J terminal of the bridge
2. Connect Galvanometer's +ve and -ve terminals to M and N terminals respectively.
3. Connect K & L terminals of variable resistance to E & G (R_3) terminals of bridge
4. Take two resistance of **100** Ω as r1and r2 and check with multimeter.
5. Connect K & L terminals of variable resistance to E & G (R_3) terminals of bridge
   Note: Set all rotaries all 0 **Ω** before starting the experiment.
6. Then set resistance R_1 and R_2 at 10 **Ω**
7. Keep the key K1 in 'Off' Position.
8. Switch 'On' the trainer.
9. Switch 'On' the key K1 and observe the deflection on galvanometer
10. Then adjust the valve of R_3 in step of 1**Ω**, 10 **Ω**,100 **Ω**, 1000 **Ω**, as per the requirement beginning from zero , till the null point is not obtained in the galvanometer For R_3 resistance of X1, X10, X100, X1000 **Ω** is provided. For Example, Suppose galvanometer shows deflection in left direction at 1000 **Ω** and at200 **Ω** in right direction then the null point lies between these two resistance then adjusting resistances of 100 **Ω**,10 **Ω**, and 1 **Ω**, to get the null point. Then add the value of all resistances which you have selected, this will give R_3.
11. Note the value of R3 in the given Observation table
12. Repeat the same procedure for 1/100 ratio by taking out R_1=**10 Ω** and R_2= 100 **Ω**, and adjust the resistance R_3 till the null point is not obtained. If the null point is not obtained then repeat the same step no.10. Now note the value of R_3 in the given Observation table
13. Repeat the same procedure for 1\100 ratio by taking out R_1= 10 **Ω** and R_2= 1000 **Ω**.
14. Resistance R_x of the combination of Resistances either in series or in parallel, can be determined by using Wheatstone Bridge relation:

$R_1/R_2= R_3/R_x$ Where R_1 & R_2 are the resistance of arm AB and BC respectively; R_3 is Variable resistance at which point we determined null point.

15. Tabulate all the readings of R_x in the given Observation table.
16. Take the mean of R_x.

Observation Table

S No.	Resistance R_1 (Ω)	Resistance R_2 (Ω)	Resistance R_3 (Ω)	Resistance $R_x= R_3 * R_2/R_1$ (Ω)
1.	10	10		
2.	10	100		
3.	10	1000		

E 2). MEASUREMENT OF RESISTANCE USING KELVIN'S BRIDGE

Introduction

Kelvin's bridge is useful for measuring very small values of resistance. Kelvin's double bridge or Kelvin's bridge (as it is commonly known as) is a variation of Wheatstone bridge and is based on the same principle. Consider the value of resistance is in the magnitude of contact leads. For low resistance measurement, the resistance of lead and contacts becomes significant and can introduce an error; this can be eliminated using Kelvin's bridge. This bridge is a modification over other DC bridges and provides greatly increased accuracy in measurement of low resistance. Figure 1 illustrates the basic principle of Kelvin's bridge.

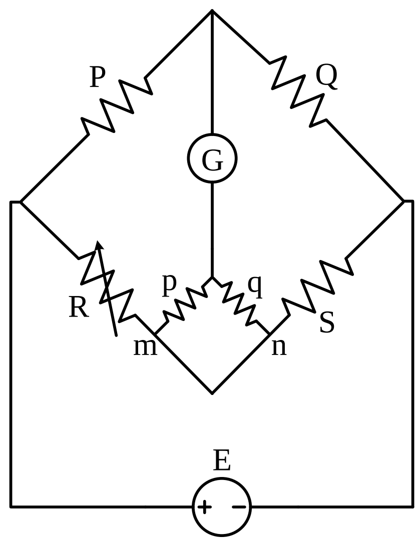


Figure 2

Kelvin's bridge consists of purely resistive elements; its first and third arms have standard resistance values, while the second arm consists of a variable resistor and the fourth arm has an unknown resistance to achieve balance condition.

P, Q, p, q = standard resistance

R = variable resistance

S = unknown resistance

The ratio p/q is made equal to ratio P/Q. Under the balance conditions there is no current through the galvanometer. By using circuit laws,

$$S = R.\ Q/P + \{(p + q + r)/\ q\ r\}.\ [Q/P - q/p]$$

Where r = resistance of the lead connecting points m and n.

Since P/Q=p/q

S=R Q/P

This is the practical balance equation for Kelvin's bridge. It indicates that the resistance of connecting lead, r has no effect on the measurement; provided that two set of ratio arms have equal ratio. However, an error will be introduced in case the ratios are not exactly same.

Experiment 1

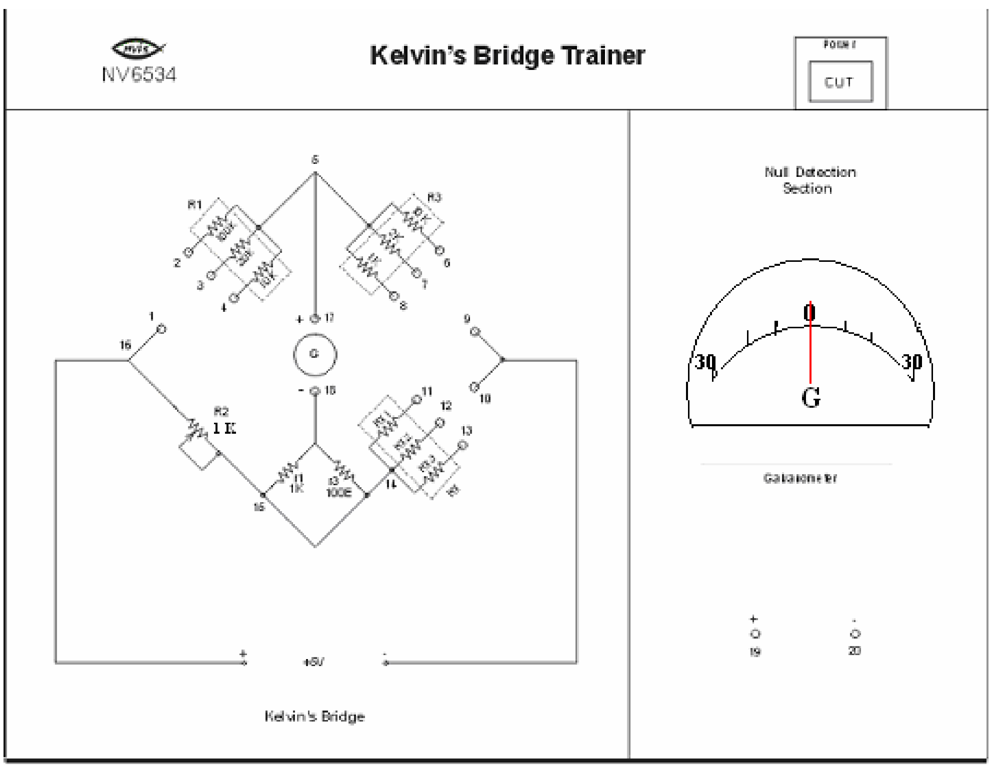
Objective: To determine unknown resistance using Kelvin's bridge method.

Equipments:

1. Kelvin's Bridge
2. 2 mm patch cords
3. Digital multimeter

Circuit diagram:

Mimic design used to illustrate the Kelvin's bridge method to measure the value of unknown resistance is shown in figure 2 below



Procedure:

1. Connect a patch cords between sockets '1' and '2' , and in between sockets '9' and '6' to maintain the 10:1 ratio of bridge.

2. Connect a patch cord between sockets '10' and '11' to measure the unknown resistance $R_{X1.}$

3. Connect positive terminal or socket '19' of galvanometer with 2mm patch cord to socket '17' of the Kelvin's bridge.

4. Connect negative terminal or socket '20' of galvanometer with 2mm patch cord to socket '18' of the Kelvin's bridge.

5. Switch 'ON' the power supply.

6. Rotate the potentiometer R_2 till the galvanometer gives the null deflection.

7. Switch 'OFF' the power supply and disconnect the patch cords between sockets '10' and '11'

8. Take reading of potentiometer R_2 between test -points '16' and '15' using digital multimeter.

9. Calculate the value of R_{x1} using the formula.

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

Where $R_x = R_{x1.}$

10. One can even verify the calculated value by measuring the value of R_{x1} in between socket '11' and test-point '14' using digital multimeter.

Observation Table

S.No.	R_1/R_3 (Ω)	r1\r3 (Ω)	R_2 (Ω)	R_{x1} (Ω)

E.3) MEASUREMENT OF INDUCTANCE USING MAXWELL'S BRIDGES

Introduction

Maxwell's bridge is useful device for measuring inductance. By setting the null point we can evaluate the unknown inductance value. For this purpose null detector with amplifier circuit is implemented on the trainer board.

Alternating current bridge methods are of outstanding importance for measurement of electrical quantities like inductance, capacitance, storage factor, loss factor etc. Besides this, these circuits find their applications in communication systems and complex electronic circuitry. Alternating current bridge circuits are commonly used for phase shifting, providing feedback paths for oscillators and amplifiers, filtering out undesirable signals ad measuring the frequency of audio signals.

Principle of AC Bridge

The AC Bridge is a Wheatstone bridge except that resistance is replaced by impedance Z and DC source is replaced by AC source as shown in figure 1.

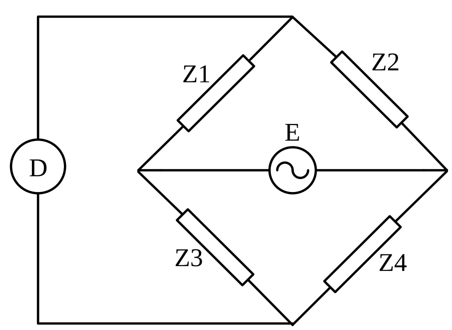


Figure 3

When the Detector detects a current between terminals B and C, the bridge is in an unbalanced condition. By adjusting Z1, Z2, Z3 and Z4 the owing through galvanometer can be set to zero. This is called a balanced condition. By applying circuit laws, one can derive that

$$\overline{Z}_1\overline{Z}_4 = \overline{Z}_2\overline{Z}_3$$

There are two conditions that should get satisfy for balanced bridge that both magnitude as well as phase should be equal on both right and left sides.

The detector D is of three types

1) Headphone detector 2) Vibration galvanometers 3) Tunable amplifier detectors

In this lab, the tunable amplifier detector is used.

Maxwell's Inductance Bridge:

This bridge is the simplest method of comparing two inductance values and to determine the values of unknown inductance. Figure 2 shows the basic circuit for Maxwell’s inductance bridge circuit configuration.

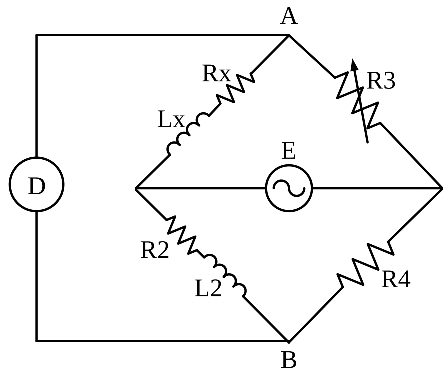


Figure 4

By applying the AC bridge balance equations one gets

$$L_1 = \frac{R_3}{R_4} L_2$$

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

Maxwell's Inductance-Capacitance Bridge:

In this bridge, an inductance is measured by comparison with a standard or variable capacitance. Figure 3 shows basic circuit for Maxwell's inductance capacitance bridge.

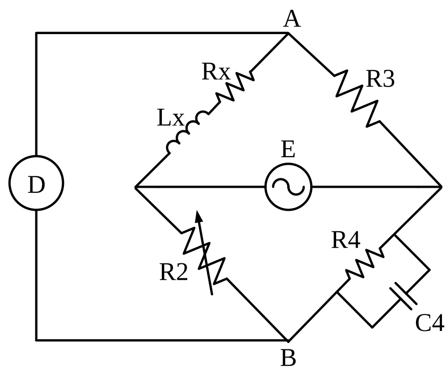


Figure 5

By applying the AC bridge balance equation one gets

$$L_1 = R_2 R_3 C_4 \text{ and } R_1 = \frac{R_3}{R_4} R_2$$

The expression for Q factor is

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

Advantages:

1. Frequency does not appear in any of the two equations.

2. Useful for measurement of wide range of inductance at power and audio frequencies.

The limitation of this bridge is that it can measure inductance of only medium Q coils (1<Q<10).

Experiment 1

Objective: To determine unknown inductance using Maxwell's inductance bridge method

Equipments:

1. Maxwell's inductance bridge
2. Digital Multimeter
3. 2mm patch chords

Circuit diagram:

Mimic illustrate with connections for Maxwell's inductance bridge method for measurement of unknown inductance is shown in the figure 4 below

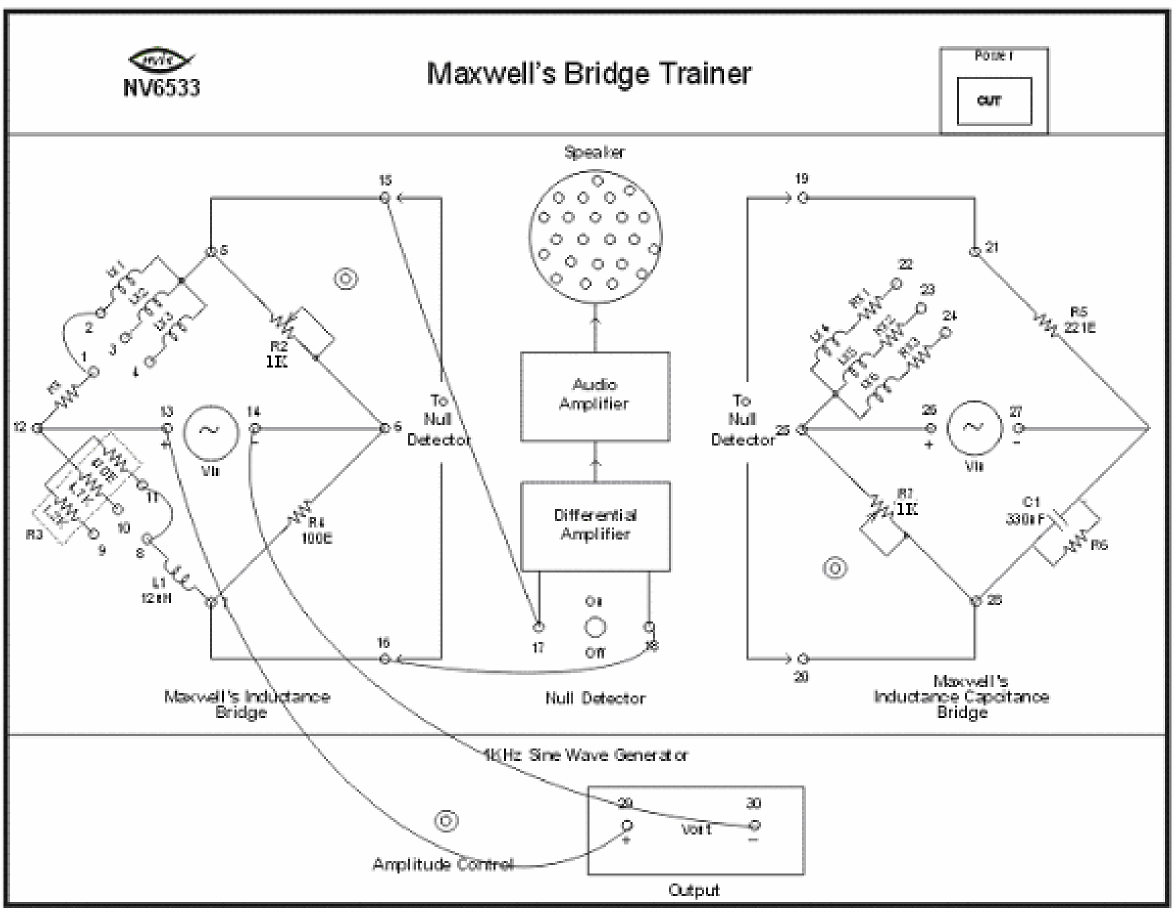


Figure 6

Procedure:

1. Connect a patch cord between socket '13' of vin terminals of Maxwell's inductance bridge and socket '29' of Vout terminals of the 1 KHz sine wave generator.
2. Connect a patch cord between socket '14' of vin terminals of Maxwell's inductance bridge and socket '30' of Vout terminals of the 1 KHz sine wave generator.
3. Connect a patch cord between socket '1' and '2' and connect another patch cord between Sockets '8' and '11' to determine the value of Lx1 and Rx1.
4. Connect a patch cord between socket '15' and '17' and sockets '16' and '18' for the purpose of null detection.
5. Switch 'ON' the power supply and the Null Detector.
6. Set the amplitude or loudness of the audio detector as per your requirement by rotating amplitude control knob of 1 KHz sine wave generator.
7. Adjust the pot in the minimum position so that the resistance R_2 between the arms is minimum by measuring it with help of multimeter. Rotate the potentiometer R2 to find a condition where null (or a minimum sound) is generated.
8. Switch 'Off' the power supply and the Null Detector
9. Remove the patch cords between sockets '1' and '2'.
10. Take the reading of resistance R2 between test-points '5' and '6' using a digital multimeter.
11. Calculate the value of inductance Lx1 and resistance Rx using the formula Lx = L1.R2/R4 where Lx = Lx1.

    Note: Value of R4 and L1 are indicated on the front of the board.
12. Calculate the value of unknown resistance using the formula.

    Rx = R2.R3/R4.

    Note: value of R3 and R4 are indicated on the front of the board.
13. Connect a patch cord between socket '1' and '3' and connect another patch cord between Sockets '10' and '8
14. Repeat the above steps from 5 to 12 and calculate the value of inductors Lx2 and resistor Rx.
15. Now Connect a patch cord between socket '1' and '4' and connect another patch cord between Sockets '9' and '8'

16. Repeat the above steps from 5 to 12 and calculate the value of inductors L_{x3} and resistor R_x.

Observation Table

S. No	R_2 Ω	R_4 Ω	R_3 Ω	L_1 µH	$L_x = L_1.R_2/R_4$ µH	$R_x = R_3/R_4$ Ω

Calculation:

Measured value of R_2 is..................................... **Ω**

Now measure the value of L_x by the formula

$$L_x = L_1.R_2/R_4$$

Measured value of resistance R_x by multimeter between sockets...................... **Ω**

Now measure the value of Rx by the formula

$$R_x = R_2.R_3/R_4.$$

Note: value of R_3, R_4 and L_1 are indicated on the front of the board.

Result:

The unknown value of inductance L_{x1} =................................ μH.

The unknown value of inductance L_{x2} =................................ μH.

The unknown value of inductance L_{x3} =................................ μH.

The unknown value of resistance R_x=................................ ... Ω

Experiment 2

Objective: To determine unknown inductance and Q-factor using Maxwell's inductance-capacitance bridge method.

Equipment:

1. Maxwell's Inductance-Capacitance Bridge
2. Multimeter.
3. 2mm patch chords

Circuit diagram:

Mimic illustrate with connections for Maxwell's inductance capacitance bridge method for measurement of unknown inductance is shown in the figure 5 below.

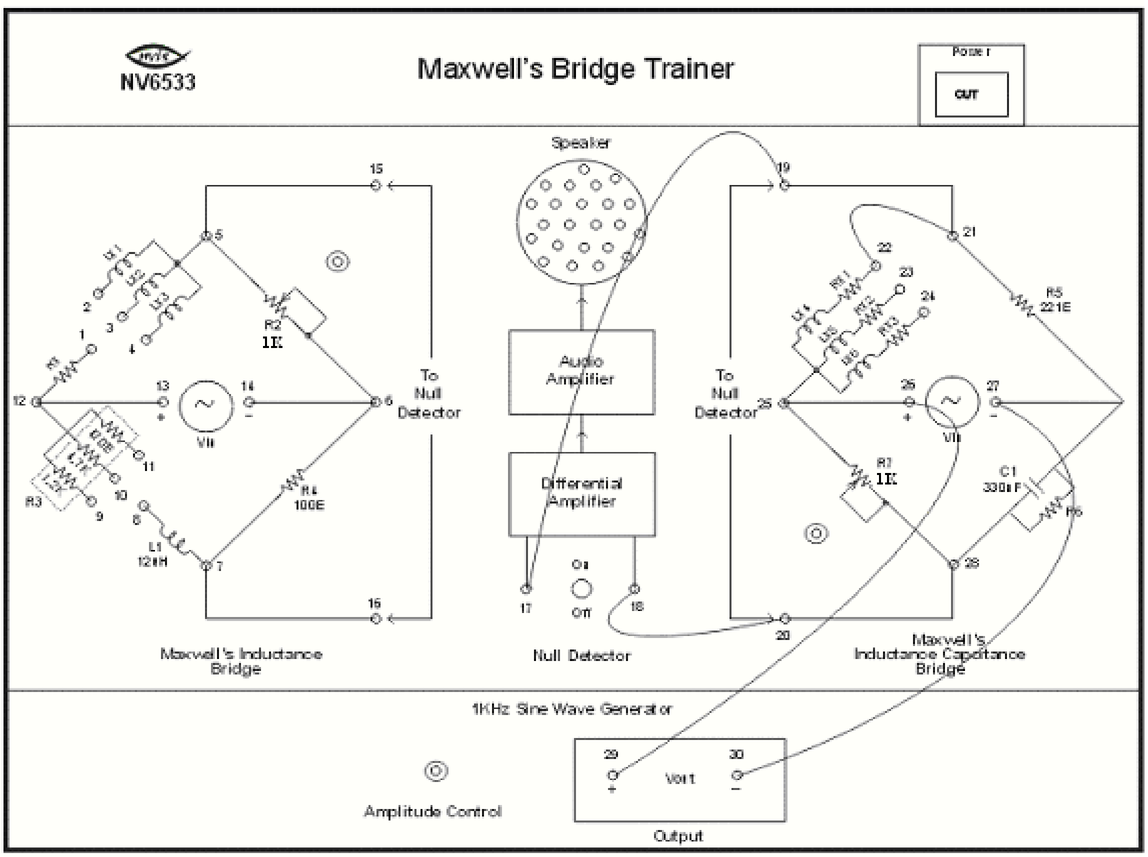


Figure 7

Procedure:

1. Adjust the pot in the minimum position so that the resistance R2 between the arms is minimum by measuring it with help of multimeter
2. Connect a patch cord between socket '26' of vin terminals of Maxwell's inductance bridge and socket '29' of Vout terminals of the 1 KHz sine wave generator.
3. Connect a patch cord between socket '27' of vin terminals of Maxwell's inductance bridge and socket '30' of Vout terminals of the 1 KHz sine wave generator output.
4. Connect a patch cord between socket '19' and '17' and sockets '20' and '18' for the purpose of null detection.
5. Connect the unknown inductor Lx4 with internal resistance Rx1 from socket '22' to arm consisting resistance R5 at socket '21'.
6. Switch 'ON' the power supply and the Null Detector
7. Now vary the resistance R7 with the help of pot till the null position (or the first minimum sound position) is achieved.
8. Now Switch 'Off' the power supply and remove the patch cord from socket; 22; and measure the resistance R7 with the help of multimeter.
9. Calculate the value of unknown inductor using the following equation
   Where, Lx = Lx4.
   Note: Value of R5 and C1 are indicated on the front of the board.
10. Calculate unknown value of internal resistance by using the following equation
    Rx = R5.R7/R6   where Rx= Rx1.
    Note: Value of R5 is indicated on the front of the board and the value of R6 is 1.122 kΩ.
11. Calculate the value for Q factor by using the following equation.
    $Q = \omega Lx/Rx = \omega.C1.R6$
    Note: $\omega = 2\pi$ f, where f = frequency = 1 KHz and π= 3.14
12. Verify the result for calculation of Q factor using both the formulae in the above step.
13. Connect the unknown inductor Lx5 from socket '23' to arm consisting resistance R5 at socket '21'.
14. Repeat steps from 6 to 12 and calculate the values of Lx5, Rx2, and their corresponding Q factor.
15. Connect the unknown inductor Lx6 from socket '24' to arm consisting resistance R5 at socket '21'.
16. Repeat steps from 6 to 12 and calculate the values of Lx6, Rx3, and their corresponding Q factor.

Observation Table

S.No	R7 Ω	R5 Ω	R6 Ω	C1 nF	Lx = R5.R7.C1 mH	Rx = R5.R7/R6 Ω	Q = ωLx/Rx = ωC1.R6
1							
2							
3							

Calculation:

Measured value of R7 is... Ω

Now measure the value of Lx by the formula:

Lx = R5.R7.C1

Now measure the value of Rx by the formula:

Q = ωLx/Rx = ω.C1.R6 Note: ω = 2π f, where f = frequency = 1 KHz and π= 3.14

Note: Value of R5 is indicated on the front of the board and the value of R6 is 1.122 K Ω.

Result:

The unknown value of Inductor Lx4 Resistance Rx1 an Q factor are............................

The unknown value of Inductor Lx4 Resistance Rx1 an Q factor are............................

The unknown value of Inductor Lx4 Resistance Rx1 an Q factor are............................

E.4) MEASUREMENT OF CAPACITANCE USING DESAUTY'S AND SCHERING BRIDGE

Introduction

Desauty`s and Schering Bridge is useful for measuring very small value of capacitances. These are based on the principle of Wheatstone bridge.

DeSauty's Bridge

The Desauty's bridge is a direct carry over of the Wheatstone bridge with the DC source replaced by an AC source. The null detector we will be using also has an amplifier where the gain can be adjusted. This is connected to Null detector which is used for getting the null point. The bridge is as shown in the figure 1.

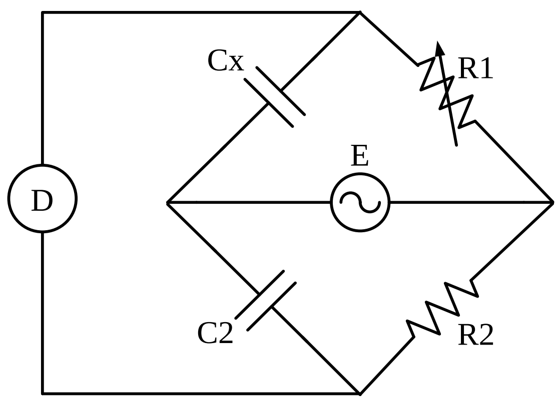


Figure 8

At balanced condition, unknown capacitance Cx can be calculated as

$$C_X = C_2 \frac{R_2}{R_1} \mu F$$

Schering Bridge

A Schering bridge is a bridge circuit used for measuring an unknown electrical capacitance and its dissipation factor. The dissipation factor of a capacitor is the ratio of its resistance to its capacitive reactance. The Schering Bridge is shown in figure 2.

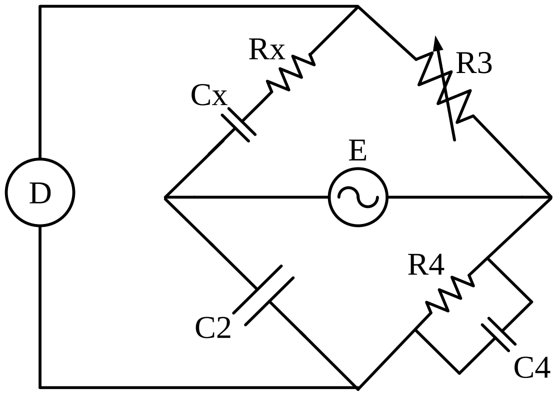


Figure 9

At balanced condition, unknown capacitance Cx can be calculated as

$$C_X = C_2 \frac{R_4}{R_3} \mu F$$

Experiment 1

Objective: Determination of unknown capacitance using Desauty's bridge method

Equipments:

1. Deasuty's bridge
2. 2 mm patch cords

Procedure:

1. Connect mains cord to the trainer.
2. Connect terminal 1 to 4 (for evaluating unknown capacitance Cx1)
3. Turn variable resistance R1 towards anticlockwise direction
4. Connect null detector (i.e. terminal 5 to 10 and 9 to 11)
5. Keep toggle of null detector towards 'off' condition
6. Select Frequency Selector for any desired range of frequency.
   - 500 Hz to 1 kHz
   - 1 kHz to 10 kHz
   - 10 Hz to 60 kHz
7. For example 8 kHz frequency, select frequency sector between the range 1 Hz to -10 kHz
8. Chose any ambient frequency (let it be 10 kHz)
9. use frequency variable knob to set 10 kHz frequency on display screen
10. connect terminal 20 to 6 and 21 to 7
11. Now "on" the mains and trainer switch
12. set toggle of null detector towards 'on' condition
13. Vary amplitude variable for enough sound of speaker.
14. Vary resistance R1 towards clockwise direction slowly. (sound diminishes)
15. Keep varying R1 until you get very low sound or null sound (Null Condition) further varying R1 in same direction speaker starts sounding
16. finally adjust the value of R1 to get null point.(where sound completely diminishes)
17. Take multimeter and record the value of R1 in the observation table.

18. Report above procedure for different value of frequency and different value of unknown capacitors (i.e. Cx2 and Cx3)
19. Tabulate all the retried data in observation table below.

Observation Table

S.No	Unknown capacitor	Frequency Frequency		Resistance R1 ohm	Resistance R2 ohm	Capacitor C2 μF
1.	Cx1	f_1				
		f_2				
		f_3				
2.	Cx2	f_1				
		f_2				
		f_3				
3.	Cx3	f_1				
		f_2				
		f_3				

Calculation:

For DeSauty's bridge, the unknown capacitance can be calculated as

$$C_X = C_1 \frac{R_2}{R_1} \mu F$$

Experiment 2

Objective: Determination of unknown capacitance using Schering bridge method.

Equipments Needed:

1 Schering bridge
2 2 mm patch cords

Procedure:

1. Connect mains cord to the mains and trainer.
2. Connect terminal 13 to 16 (for evaluating unknown capacitance Cx4)
3. Turn variable resistance R_3 towards anticlockwise direction
4. Connect null detector (i.e. terminal 10 to 12 and 11 to 19)
5. Keep toggle of null detector towards 'off' condition
6. Select Frequency Selector for any desired range of frequency.
    - 500 Hz to 1 kHz
    - 1 kHz to 10 kHz
    - 10 Hz to 60 kHz
7. For example 8 kHz frequency, select frequency selector between the range 1 Hz to -10 kHz
8. Chose any ambient frequency (let it be 10 kHz)
9. use frequency variable knob to set 10 kHz frequency on display screen
10. connect terminal 20 to 17 and 21 to 18
11. Now "on" the mains and trainer switch
12. set toggle of null detector towards 'on' condition
13. Vary amplitude variable for enough sound of speaker.
14. Vary resistance R_3 towards clockwise direction slowly. (sound diminishes)
15. Keep varying R_3 until you get very low sound or null sound (Null Condition further varying R_3 in same direction speaker starts sounding
16. finally adjust the value of R_3 to get null point.(where sound completely diminishes)
17. Take multimeter and record the value of R_3 in the observation table.

18. Report above procedure for different value of frequency and different value of unknown capacitors (i.e. Cx5 and Cx6).

Tabulate all the retried data in observation table below

Observation Table

S.No	For Unknown capacitor	Frequency		Resistance R_3 ohm	Resistance R_4ohm	Capacitor C_3μF
1.	Cx4	f_1				
		f_2				
		f_3				
2.	Cx5	f_1				
		f_2				
		f_3				
3.	Cx6	f_1				
		f_2				
		f_3				

Calculation:

For DeSauty's bridge, the unknown capacitance can be calculated as

$$C_X = C_3 \frac{R_4}{R_3} \mu F$$

E.5) STUDY OF LVDT CHARACTERISTICS

Linear variable differential transformers (LVDT) are used to measure displacement. LVDTs operate on the principle of a transformer. As shown in figure 4, an LVDT consists of a coil assembly and a core. The coil assembly is typically mounted to a stationary form, while the core is secured to the object whose position is being measured. The coil assembly consists of three coils of wire wound on the hollow form. A core of permeable material can slide freely through the center of the form. The inner coil is the primary, which is excited by an AC source as shown. Magnetic flux produced by the primary is coupled to the two secondary coils, inducing an AC voltage in each coil.

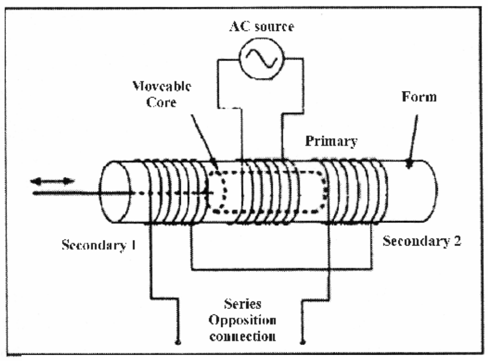


Figure 10

The main advantage of the LVDT transducer over other types of displacement transducer is the high degree of robustness. Because there is no physical contact across the sensing element, there is no wear and tear in the sensing element. Because the device relies on the coupling of magnetic flux, an LVDT can have infinite resolution. Therefore the smallest fraction of movement can be detected by suitable signal conditioning hardware, and the resolution of the transducer is solely determined by the resolution of the data acquisition system.

LVDT Measurement:

LVDT measures displacement by associating a specific signal value for any given position of the core. This association of a signal value to a position occurs through electromagnetic coupling of an AC excitation signal on the primary winding to the core and back to the secondary windings. The position of the core determines how tightly the signal of the primary coil is coupled to each of the secondary coils. The two secondary coils are series-opposed, which means wound in series but in opposite directions. This results in the two signals on each secondary being 180 deg out of phase. Therefore phase of the output signal determines direction and its amplitude, distance.

Figure 2 depicts a cross-sectional view of an LVDT. The core causes the magnetic field generated by the primary winding to be coupled to the secondary. When the core is centered perfectly between both secondary and the primary, as shown, the voltage induced in each secondary is equal in amplitude and 180 deg out of phase. Thus the LVDT output (for the series-opposed connection shown in his case) is zero because the voltages cancel each other.

Displacing the core to the left (figure 3) causes the first secondary to be more strongly coupled to the primary than the second secondary. The resulting higher voltage of the first secondary in relation to the second secondary causes an output voltage that is in phase with the primary voltage.

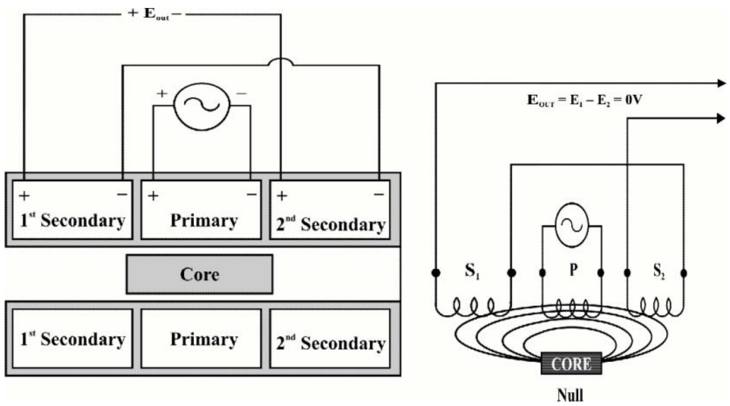


Figure 2

Likewise, displacing the core to the right causes the second secondary to be more strongly coupled to the primary than the first secondary as shown in figure below. The greater voltage of the second secondary causes an output voltage to be out of phase with the primary voltage.

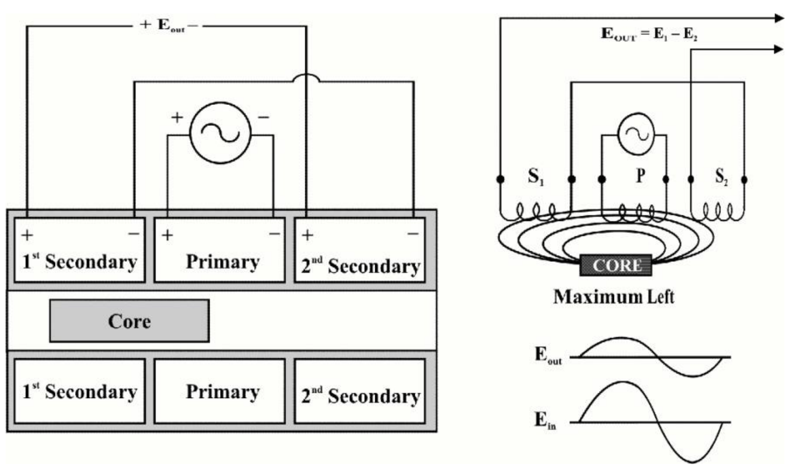


Figure 11

Likewise, displacing the core to the right causes the second secondary to be more strongly coupled to the primary than the first secondary as shown in figure below. The greater voltage of the second secondary causes an output voltage to be out of phase with the primary voltage.

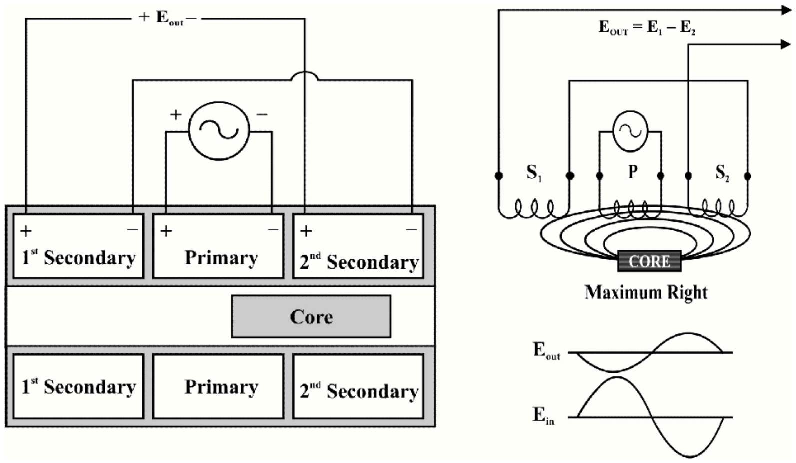


Figure 12

To summarize, "The LVDT closely models an ideal zero-order displacement sensor structure at low frequency, where the output is a direct and linear function of the input. It is a variable-reluctance device, where a primary center coil establishes a magnetic flux that is coupled through a center core (mobile armature) to a symmetrically wound secondary coil on either side of the primary. Thus, by measurement of the voltage amplitude and phase, one can determine the extent of the core motion and the direction, that is, the displacement." Figure below shows the linearity of the device within a range of core displacement. Note that the output is not linear as the core travels near the boundaries of its range. This is because less magnetic flux is coupled to the core from the primary. However, because LVDTs have excellent repeatability, nonlinearity near the boundaries of the range of the device can be predicted by a table or polynomial curve-fitting function, thus extending the range of the device.

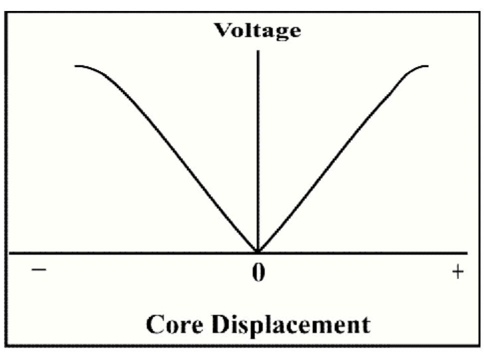


Figure 13

Construction:

The physical construction of a typical LVDT consists of a movable core of magnetic material and three coils comprising the static transformer. One of the three coils is the primary coil and the other two are secondary coils.

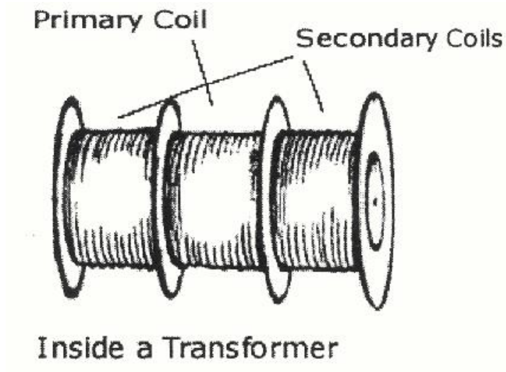


Figure 14

Features and applications:

LVDTs have certain significant features and benefits, most of which derive from its fundamental physical principles of operation or from the materials and techniques used in its construction.

1. **Friction-Free Operation :**

   One of the most important features of an LVDT is its friction-free operation. In normal use, there is no mechanical contact between the LVDT's core and coil assembly, so there is no rubbing, dragging or other source of friction. This feature is particularly useful in materials testing, vibration displacement measurements, and high resolution dimensional gauging systems.

2. **Infinite Resolution :**

   Since an LVDT operates on electromagnetic coupling principles in a friction- free structure, it can measure infinitesimally small changes in core position. This infinite resolution capability is limited only by the noise in an LVDT signal conditioner and the output display's resolution. These same factors also give an LVDT its outstanding repeatability.

3. **Unlimited Mechanical Life :**

   Because there is normally no contact between the LVDTs core and coil structure, no parts can rub together or wear out. This means that an LVDT features unlimited mechanical life. This factor is especially important in high reliability applications such as aircraft, satellites and space vehicles, and nuclear installations. It is also highly desirable in. many industrial process control and factory automation systems.

4. **Over travel Damage Resistant :**

   The internal bore of most LVDTs is open at both ends. In the event of unanticipated over travel, the core is able to pass completely through the sensor coil assembly without causing damage. This invulnerability to position input overload makes an LVDT the ideal sensor for applications like extensometers that are attached to tensile test samples in destructive materials testing apparatus.

5. **Single Axis Sensitivity :**

   An LVDT responds to motion of the core along the coil's axis, but is generally insensitive to cross-axis motion of the core or to its radial position. Thus, an LVDT can usually function without adverse effect in applications involving misaligned or floating moving members, and in cases where the core doesn't travel in a precisely straight line.

6. **Separable Coil and Core :**

   Because the only interaction between an LVDT's core and coil is magnetic coupling, the coil assembly can be isolated from the core by inserting a non- magnetic tube between the core and the bore. By doing so, a pressurized fluid can be contained within the tube, in which the core is free to move, while the coil assembly is unpressurized. This feature is often utilized in LVDTs used for spool position feedback in hydraulic proportional and/or servo valves.

7. **Environmentally Robust :**

   The materials and construction techniques used in assembling an LVDT result in a rugged, durable sensor that is robust to a variety of environmental conditions. Bonding of the windings is followed by epoxy encapsulation into the case, resulting in superior moisture and humidity resistance, as well as the capability to take substantial shock loads and high vibration levels in all axes. And the internal high-permeability magnetic shield minimizes the effects of external AC fields. Both the case and core are made of corrosion resistant metals, with the case also acting as a supplemental magnetic shield. And for those applications where the sensor must withstand exposure to flammable or corrosive vapors and liquids, or operate in pressurized fluid, the case and coil assembly can be hermetically sealed using a variety of welding processes. Ordinary LVDTs can operate over a very wide temperature range, but, if required, they can be produced to operate down to cryogenic temperatures, or, using special materials, operate at the elevated temperatures and radiation levels found in many nuclear reactors.

8. **Null Point Repeatability :**

The location of an LVDT's intrinsic null point is extremely stable and repeatable, even over its very wide operating temperature range. This makes an LVDT perform well as a null position sensor in closed-loop control systems and high performance servo balance instruments.

9. **Fast Dynamic Response :**

The absence of friction during ordinary operation permits an LVDT to respond very fast to changes in core position. The dynamic response of an LVDT sensor itself is limited only by the inertial effects of the core's slight mass. More often, the response of an LVDT sensing system is determined by characteristics of the signal conditioner.

10. **Absolute Output :**

An LVDT is an absolute output device, as opposed to an incremental output device. This means that in the event of loss of power, the position data being sent from the LVDT will not be lost. When the measuring system is restarted, the LVDT's output value will be the same as it was before the power failure occurred.

Experiment 1

Objective: Study of input output characteristics of LVDT

Procedure:

1. Switch ON the trainer.
2. Make micrometer to read 10 mm i.e. rotate thimble till 0 of the circular scale coincides with 10 of main scale.
3. Display will indicate 00.0. This is the position when core is at centre i.e. equal flux linking to both the secondary.
4. If display is not 00.0 then adjust display reading to 00.0 with the help of hexagonal nut arrangement given with the LVDT.
5. Rotate thimble clockwise so that micrometer read 9.9 mm. It will move core 0.1 mm inside the LVDT and simultaneously observe reading on display. It will indicate displacement from 10 mm position in positive direction. The reading will be positive. It indicates that secondary I is at higher voltage than secondary II. User can see resulting Waveforms on real time software window or Oscilloscope.
6. Repeat above step by rotating thimble again clockwise by 0.1mm. Reading will be taken after each 0.1 mm rotation until micrometer read 0 mm. This is positive. At this point secondary I have highest voltage and secondary II has lowest voltage (not Zero).
7. Rotate thimble anticlockwise so that micrometer read 10 mm. The display will be 00.0 (Centre or null position).
8. Rotate thimble anti clockwise so that micrometer read 10.1 mm. It will move core 0.1 mm outside the LVDT and simultaneously observe reading on display. It will indicate displacement from 10 mm position in negative direction. The reading will be negative. It indicates that secondary II is at higher voltage than secondary I.
9. Repeat above step by rotating thimble again anticlockwise by 0.l mm. Reading will be taken after each 0.1 mm rotation until micrometer read 20 mm. This is negative end. At this point secondary II has highest voltage and secondary I have lowest voltage (not Zero).

Sensitivity of real time software is 0.5mm (i.e. on real time software window, readings will change after every 0.5mm displacement).

10. Compare above results with the observation table.
11. Plot the graph between displacement (mm) indicated by micrometer and Display reading (mm).The graph will be linear as shown in figure 7.

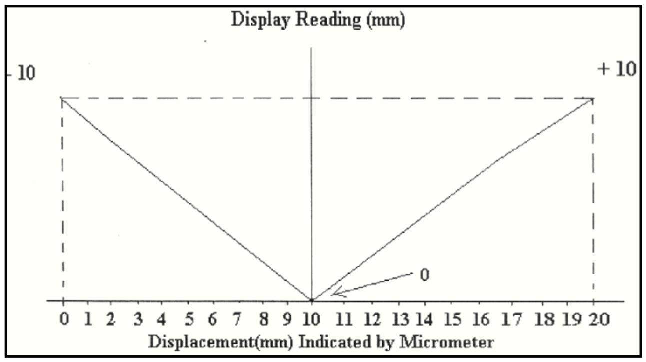


Figure 7

Observation Table

Displacement (mm)	Display Reading (mm)
0 mm + 10	
1 mm +9	
2 mm +8	
3 mm +7	
4 mm +6	
5 mm +5	
6 mm +4	
7 mm +3	
8 mm +2	
9 mm +1	
10 mm +0	
11 mm -1	
12 mm -2	
13 mm -3	
14 mm -4	
15 mm -5	
16 mm -6	
17 mm -7	
18 mm -8	
19 mm -9	
20 mm -10	

Experiment 2

Objective: Determination of Linear range of operation of LVDT

Procedure:

1. Repeat the procedure of Experiment 1.
2. Plot the graph for the display reading with the proportional change with the displacement (as done in the previous Experiment). Find the point from which it disobeys the linear relation.
3. Note the displacement reading of micrometer for the above point and subtract 10 mm from it. The difference is the linear range of LVDT.
4. The trainer is linear over full scale that is 10 mm, so linear range is 10 mm.

Experiment 3

Objective: Determination of Sensitivity of LVDT

Theory: Sensitivity S = AC output / Displacement: Vpp/mm or

DC output/Displacement: Vdc/mm

Procedure:

1. Switch ON the trainer.
2. Make micrometer to read 10 mm.
3. Note the reading of micrometer.
4. Measure the differential voltage between Test Point TP6 and TP7 with multi-meter in mV range.
5. Make micrometer to read 9 mm.
6. Repeat step 4.
7. Calculate S

Experiment 4

Objective: Measurement of phase difference between LVDT secondaries.

Procedure:

1. Switch ON the trainer.
2. Make micrometer to read 10 mm.
3. Observe output at Test Point TP4 by connecting it to CH 1 of oscilloscope.
4. Change attenuator position of CH 1 so that signal displayed cover 3 vertical divisions.
5. Make oscilloscope to work in dual mode.
6. Observe output at Test Point TP5 by connecting it to CH 2 of oscilloscope.
7. Change attenuator position of CH 2 so that signal displayed cover 3 vertical divisions.
8. Observe output of CH 1 and CH 2.
9. Adjust vertical position of signals displayed so as negative peak of one touches positive peak of other as shown in figure below

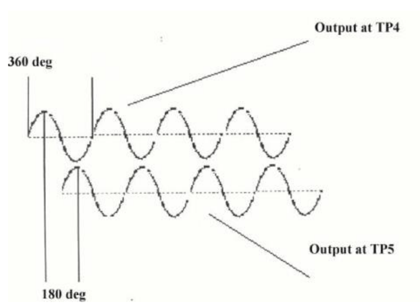


Figure 8

10. Phase difference between two wave forms is 180 degrees.
11. Make micrometer to read 5 mm and observe waveforms at Test Point TP4, TP5.
12. Note the phase difference.
13. Make micrometer to read 15 mm. observe waveforms at Test Point TP4, TP5.
14. Note the phase difference

M.1) Study of Pressure Measurement

Aim: To study the measurement of pressure using U-tube manometer and inclined tube manometer.

1. Introduction

Pressure is usually expressed with reference to either absolute zero pressure (a complete vacuum) or local atmospheric pressure. The absolute pressure is the difference between the value of pressure and absolute zero pressure. Gauge pressure is the difference between the value of the absolute pressure and the local atmospheric pressure. When the gauge pressure becomes negative is called as Vacuum Pressure. The schematic is shown in Fig.1

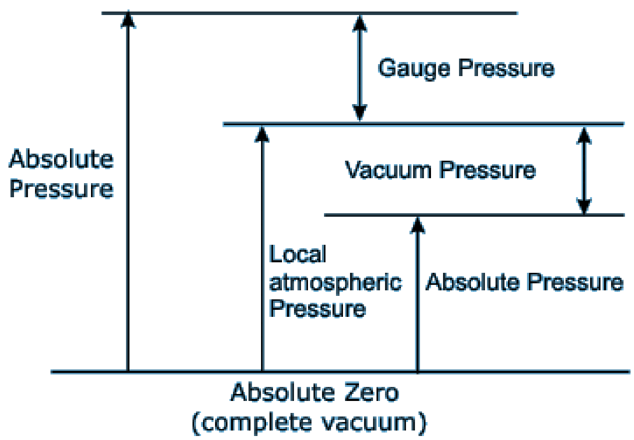


Fig.1: The Scale of Pressure

2. Measurement of Pressure

The principle pressure measurement by using different device is elaborated below

2.1 Piezometer Tube

The direct proportional relation between gauge pressure and the differential height "h" for a fluid of constant density enables the pressure to be simply visualized in terms of the vertical height, ***h = P/ρg***. The height "*h*" is termed as pressure head corresponding to pressure "P". For a liquid without a free surface in a closed pipe, the pressure head *P/ρg* at a point corresponds to the vertical height above the point to which a free surface would rise, if a small tube of sufficient length and open to atmosphere is connected to the pipe. Such a tube is called a piezometer tube, and the height h is the measure of the gauge pressure of the fluid in the pipe. If such a piezometer tube of sufficient length were closed at the top and the space above the liquid surface were a perfect vacuum, the height of the column would then correspond to the absolute pressure of the liquid at the base. This principle is used in the well-known mercury barometer to determine the local atmospheric pressure.

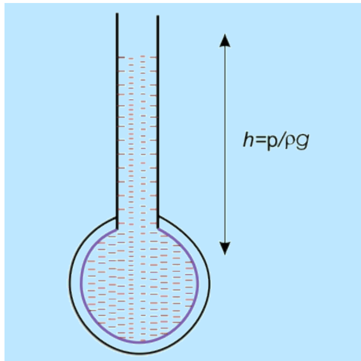


Fig. 2: **A piezometer Tube**

2.2. The Barometer

Barometer is used to determine the local atmospheric pressure. Mercury is employed in the barometer because its density is sufficiently high for a relative short column to be obtained. and also because it has very small vapour pressure at normal temperature. High density scales down the pressure head (h) to represent same magnitude of pressure in a tube of smaller height.

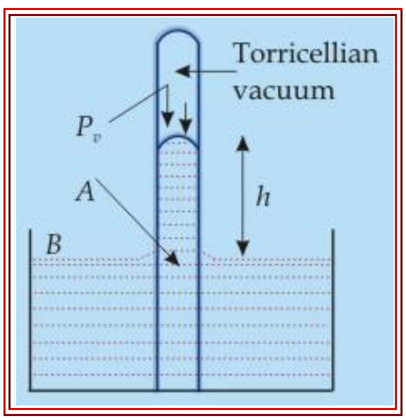


Fig. 3: A simple barometer

Even if the air is completely absent, a perfect vacuum at the top of the tube is never possible. The space would be occupied by the mercury vapour and the pressure would equal to the vapour pressure of mercury at its existing temperature. This almost vacuum condition above the mercury in the barometer is known as Torricellian vacuum. The pressure at A equal to that at B (Fig. 3) which is the atmospheric pressure p_{atm} since A and B lie on the same horizontal plane. Therefore, we can write

$$P_B = P_{atm} = P_v + \rho g h \qquad (1)$$

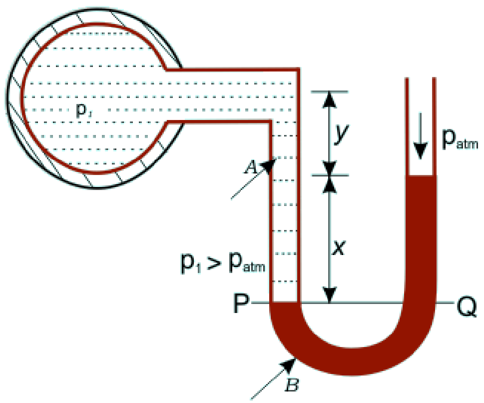
The vapour pressure of mercury P_v, can normally be neglected in comparison to P_{atm}. At 20^0C, P_v is only 0.16 P_{atm}, where $P_{atm} = 1.0132 \text{ X}10^5$ Pa at sea level. Then we get from Eq. (1)

$$h = P_{atm}/\rho g = (1.0132\times10^5)/(13560\times9.81) = 0.752 \text{ m of Hg.}$$

For accuracy, small corrections are necessary to allow for the variation of density with temperature, the thermal expansion of the scale (usually made of brass), and surface tension effects. If water was used instead of mercury, the corresponding height of the column would be about 10.4 m provided that a perfect vacuum could be achieved above the water. However, the vapour pressure of water at ordinary temperature is appreciable and so the actual height at say, 15°C would be about 180 mm less than this value. Moreover with a tube smaller in diameter than about 15 mm, surface tension effects become significant.

2.3 Manometers for measuring Gauge and Vacuum Pressure

Manometers are devices in which columns of a suitable liquid are used to measure the difference in pressure between two points or between a certain point and the atmosphere. Manometers are generally used for measuring large gauge pressures. They are basically the modified form of the piezometric tube. A common type manometer is like a transparent "U-tube" as shown in Figs. 4.



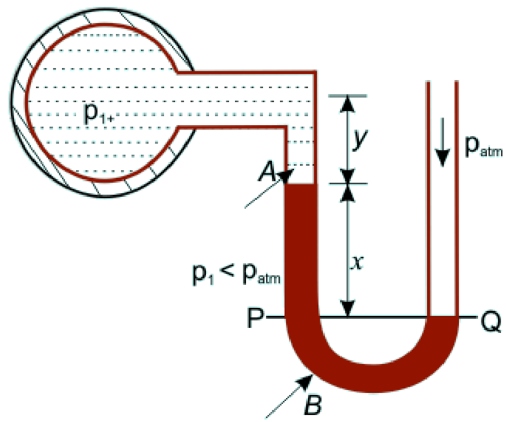


Fig. 4: A simple manometer to measure gauge pressure

Fig.5:A simple manometer to measure vacuum pressure

One of the ends is connected to a pipe or a container having a fluid (A) whose pressure is to be measured while the other end is open to atmosphere. The lower part of the U-tube contains a liquid immiscible with the fluid A and is of greater density than that of A. This fluid is called the manometric fluid. The pressures at two points *P* and *Q* (Fig. 4) in a horizontal plane within the continuous expanse of same fluid (the liquid B in this case) must be equal. Then equating the pressures at *P* and *Q* in terms of the heights of the fluids above those points, with the aid of the fundamental equation of hydrostatics, we have:

$$P_1 + \rho_A g(y+x) = P_{atm} + \rho_B gx \qquad (2)$$

Hence, $$P_1 - P_{atm} = (\rho_B - \rho_A)gx - \rho_A gy \qquad (3)$$

where p_1 is the absolute pressure of the fluid A in the pipe or container at its centre line, and p_{atm} is the local atmospheric pressure. When the pressure of the fluid in the container is lower than the atmospheric pressure, the liquid levels in the manometer would be adjusted as shown in Fig.5. Hence it becomes,

$$P_1 + \rho_A gy + \rho_B gy = P_{atm} \qquad (4)$$

Hence, $$P_{atm} - P_1 = (\rho_A y + \rho_B y)g \qquad (5)$$

2.4 Manometer for measuring differential pressure

Manometers are also frequently used to measure the pressure difference, in course of flow, across a restriction in a horizontal pipe. The axis of each connecting tube at A and B should be perpendicular to the direction of flow and also for the edges of the connections to be smooth. Applying the principle of hydrostatics at P and Q we have:

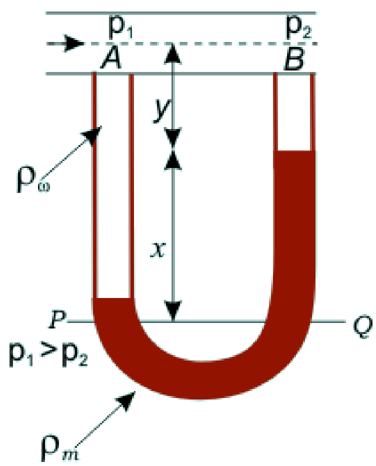


Fig. 6: Manometer measuring pressure difference

From the fig. 6, one can write:

$$P_1 + (y+x)\rho_w g = P_2 + y\rho_w g + \rho_m g x \qquad (6)$$

$$P_1 - P_2 = (\rho_m - \rho_w) g x \qquad (7)$$

Where, ρ_m is the density of manometric fluid and ρ_w is the density of the working fluid flowing through the pipe. We can express the difference of pressure in terms of the difference of heads (height of the working fluid at equilibrium).

$$(h_1 - h_2) = (P_1 - P_2)/\rho_w g = [(\rho_m/\rho_w) - 1]x \qquad (8)$$

2.8 Inclined Tube Manometer

As the pressure difference {P_1-P_2} reduces, the corresponding value of 'X' {Eq. 6} (Difference of differential height of u-tube manometer) reduces and it becomes difficult to read it. This situation can be solved by two methods.

1) By using mano-metric fluid of less density in order to reduce (ρ_m-ρ_w) (No constraint is there on use of manometric fluid.)

2) For few working fluids i.e. air, the difference of (ρ_m-ρ_w) is always very high even if we change the manometric fluid from mercury to water. In such cases, it is better to utilize inclined manometer, which increases the value of Δx by inclined one of the limb of manometer. If the transparent tube of a manometer, instead of being vertical, is set at an angle θ to the horizontal (Fig.7), then a pressure difference corresponding to a vertical difference of levels x gives a movement of the meniscus s = x/sin along the slope.

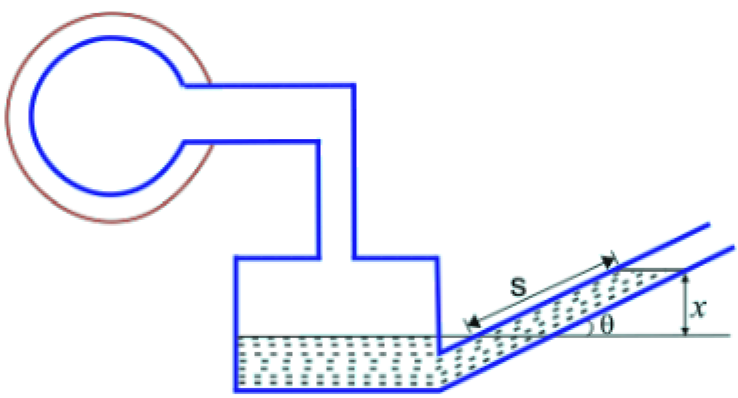
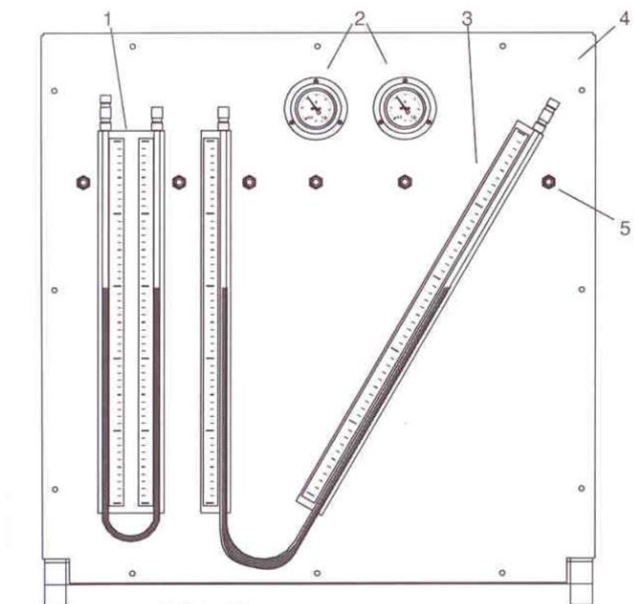


Fig .7 An Inclined Tube Manometer

If θ is small, a considerable magnification of the movement of the meniscus may be achieved. Angles less than 5^0 are not usually satisfactory, because it becomes difficult to determine the exact position of the meniscus. One limb is usually made very much greater in cross-section than the other. When a pressure difference is applied across the manometer, the movement of the liquid surface in the wider limb is practically negligible compared to that occurring in the narrower limb. If the level of the surface in the wider limb is assumed constant, the displacement of the meniscus in the narrower limb needs only to be measured, and therefore only this limb is required to be transparent.

3. Pressure measurement tutor

The present experimental unit consists of U-tube manometer, inclined manometer, manometer panel and pneumatic quick action and dial gauges shown in the Fig. 8. The tubes are filled with water to which ink is added as a dye to improve readability. The panel has two dial gauges for measurement of gauge and vacuum pressure. Both the inclined and U tube manometer can be connected and combined with each other by using connecting hoses.



1 U-Tube Manometer
2 Dial Manometer
3 Slanted Tube Manometer
4 Manometer Panel
5 Pneumatic Quick Action

Fig. 2

3.1 Experimental Procedure

A.U-Tube manometer

1. Check the levels in the manometer and be sure that water is properly filled in the manometer.
2. Make the required connection to measure pressure through U- tube manometer.
3. Plunge the syringe in the inlet port of the U-tube manometer (be sure that it contains sufficient amount of air in it).
4. Push the syringe plunger until it reaches to the next small mark (3mm) into the u –tube.

5. Take the difference in water column between the left and right limbs of the manometer.

6. Repeat the procedure 4 and 5 and take at least eight readings.

7. Calculate the pressure from the manometer readings.

8. Plot a curve between the pressure (calculated) and the distance travelled by the syringe plunger.

B. Inclined manometer

1. Check the levels in the manometer and be sure that water is properly filled in the manometer.

2. Make the required connection to measure pressure through inclined manometer.

3. Plunge the syringe in the inlet port of the inclined manometer (be sure that it contains sufficient amount of air in it).

4. Repeat the procedure from A.4- A.8 for inclined manometer.

C. U- tube manometer and inclined manometer in series

1. Connect the right limb of the U tube manometer with the left limb of inclined manometer by using a hose pipe.

2. Check the levels in the manometer and be sure that water is properly filled in the manometer.

2. Make the required connection with the pipe to connect the u tube manometer and inclined manometer

3. Plunge the syringe in the inlet port of the inclined manometer (be sure that it contains sufficient amount of air in it).

4. Repeat the procedure from A.4- A.8 for the above test set up.

D. Dial gauge (positive pressure)

1. Plunge the syringe in the inlet of positive pressure gauge.

2. Push the syringe plunger until next mark (3mm).

3. Note three reading of pressure for the particular displacement of plunger.

E. Dial Gauge (vacuum pressure)

1. Plunge the syringe in the inlet of vacuum pressure gauge.

2. Push the syringe plunger until next mark (3mm).

3. Note three reading of pressure for the particular displacement of plunger.

3.2 Observation Table

One column of plunger = 3mm of scale

Table 1: U-Tube manometer

Sr. No.	Displacement of Plunger (mm)	Difference in U tube manometer reading (mm)	Pressure (m bar)

Table 2: Inclined manometer

Sr. No.	Displacement of Plunger (mm)	Difference in manometer reading (mm)	Pressure (m bar)

Table 3: U tube manometer and inclined manometer connected in series

Sr. No.	Displacement of Plunger(mm)	Difference in manometer reading U tube (mm)	Difference in manometer reading inclined tube (mm)	Pressure (U-Tube) (m bar)	Pressure (Inclined tube) (m bar)

3.3 Sample Calculations

3.3.1. U-tube manometer

A water manometer connects the upstream and downstream located in an air flow. The difference height of the water column is 10 mm. The pressure difference head can then be expressed as:

$$P_d = (9.8\ kN/m^3)\ (10^3\ N/kN)\ (10\ mm)\ (10^{-3}\ m/mm)$$

$$= 98\ N/m^2\ (Pa)$$

Where,

9.8 (kN/m^3) is the specific weight of water.

3.3.2. Inclined manometer

Using the same data as above and considering the angle of inclination as *30^o*, we obtain the pressure difference as:

$P_d = (9.8\ kN/m^3)\ (10^3\ N/kN)\ (10\ mm)\ (10^{-3}\ m/mm)\ \sin(30) =$ ………. N/m^2(Pa)

M.2) Study of Different types of Temperature Measurement Methods

Qualitatively, the temperature of an object determines the sensation of warmth or coldness felt by touching it. More specifically, temperature is a measure of the average kinetic energy of the particles in a sample of matter, expressed in units of degrees on a standard scale. In many engineering applications measurement of the temperature is required to access the temperature of the system.

Different temperature measurement methods can be classified in to two categories.

1. Temperature measurement by mechanical effect.

These Devices operate on the basis of a change in mechanical dimension with a change in property. Different temperature measuring techniques based on mechanical effect are elaborated below.

1.1Gas Pressure Thermometer

A gas thermometer measures temperature variation by measuring the corresponding variation in volume or pressure of a gas. One common apparatus is a constant volume thermometer. For the gas thermometer a fixed volume container is filled with gas and exposed for the measurement of temperature. The outlet of this container is attached to the pressure gauge. As the temperature varies, corresponding change in the pressure of the fixed volume system is calibrated for unknown temperature through following equations.

$$T = T_{ref}\left(\frac{P}{P_{ref}}\right)_{const\ vol}$$

Figure 1 Gas pressure thermometer

Gas thermometers are often used to calibrate other thermometers

1.2 Mercury Thermometer

Mercury Thermometer is one of the most common types of temperature measurement devices. It has a large bulb at the lower portion to hold Mercury, which rises or falls in the capillary tube due to temperature fluctuations. The capillary tube is having appropriate scale markings to measure the temperature of the surrounding space.

At the top of the capillary tube another bulb is placed to provide a safety feature in case the temperature range of the thermometer is inadvertently exceeded.

During operation the bulb of the mercury in thermometer is exposed to the environment whose temperature is to be measured. An increase in temperature causes the liquid to expand in the bulb and rise in the capillary thereby indicating the temperature and vice versa.

Alcohol and mercury are the most commonly liquids used for measurement of temperature. Alcohol has the advantage that it has a higher coefficient of expansion than mercury, but it is limited to low temperature measurements because it tends to boil away at higher temperatures. Mercury cannot be used below its freezing point -38.78°F (-37.8°C). The size of the capillary depends on the size of the sensing bulb, the liquid, and the desired temperature range for the thermometer.

Figure 2 Mercury thermometer

Mercury-in-glass thermometers are generally applicable up to 600°F (315°C), but their range may be extended to 1000°F (538°C) by filling the space above the mercury with a gas like nitrogen, this increases the pressure on the mercury, raises its boiling point and thereby permits the use of thermometers at higher temperatures.

1.3 Bimetallic Thermometer

In Bimetallic Thermometer two pieces of metal with different coefficients of thermal expansion are bonded together to form the device. When the strip is subjected to a temperature higher than the bonding temperature, it will bend in one direction when it is subjected to lower temperature it will bend in the other direction. This motion is exploited to sense the temperature variation.

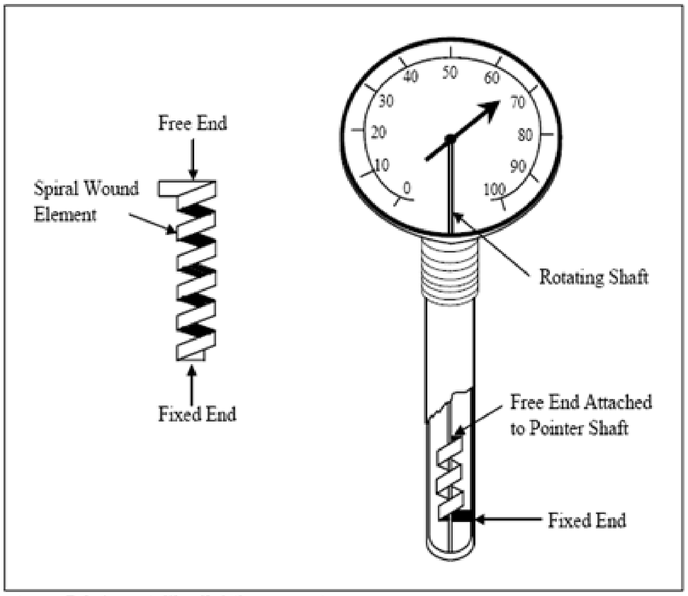


Figure 3 Bimetallic thermometer

Bimetallic strips are frequently used in simple on-off temperature-control devices (thermostats).Movement of the strip has sufficient force to trip control switches for various devices .The bimetallic strip has the advantages of low-cost, negligible maintenance expenses and stable operation over extended periods of time. Alternate methods of construction can use a coiled strip to drive a dial indicator (similar to bourdon gauge) for temperatures.

2. Temperature measurement by electrical effect.

Electrical methods of temperature measurement are very convenient because they furnish a electrical signal that can be easily detected, amplified. These types of temperature measurement methods are very useful in online monitoring as well as automatic control of temperature. In addition, they are usually quite accurate when properly calibrated and compensated.

2.1 Resistance Thermometer

Resistance thermometers, also called resistance temperature detectors or resistive thermal devices (**RTD**s), are temperature sensors that exploit the predictable change in electrical resistance of some materials with given change in its temperature. Several types of materials may be used as resistive elements, characteristics of few typical resistive elements used in RTD are reported in Table 1.which is exposed to the temperature to be measured. The Temperature is indicated through a measurement of the change in resistance of the element.

Table 1: Resistance-temperature coefficients and resistivity at 20°C

Substance	α(°C ⁻¹)	ρ (μΩ . cm)
Nickel	0.0067	6.85
Iron(Alloy)	0.002 to 0.006	10
Tungsten	0.0048	5.65
Aluminum	0.0045	2.65
Copper	0.0043	1.67
Platinum	0.00392	10.5
Mercury	0.00099	98.4
Manganin	±0.00002	44
Electrolytes	-0.02 to -0.09	Variable
Semiconductor(thermistors)	-0.068 to +0.14	10^9

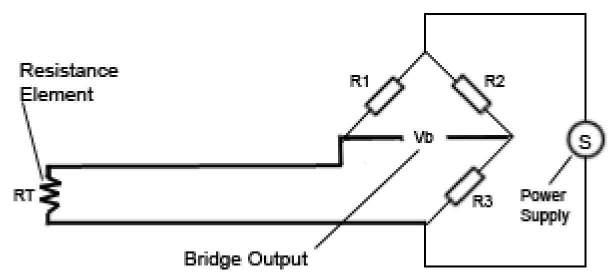


Figure4. Resistance temperature detector

Various methods are employed for construction of resistance thermometers, depending on the application. In all cases care must be taken to ensure that the resistance wire is free of mechanical stresses and so mounted that the moisture cannot come in contact with the wire and influence the measurement.

one construction technique involves winding the platinum on a glass or ceramic bobbin followed by sealing with molten glass . This technique protects the platinum RTD element but is subject to stress variations over wide temperature ranges. Stress relief techniques can alleviate the problem so that the element may be used for temperature measurements within ±0.1°

Practical problems which are encountered with RTDs involve lead error and relatively bulky size which sometimes gives rise to poor transient response and conduction error. These can be used either as 2 core wire configuration or 4 core wire configuration.

2.2 Thermistor

Thermistor is a semiconductor device that has a negative temperature coefficient of resistance in contrast to the positive coefficient displayed by most metals. Furthermore, the resistance follows an exponential variation with temperature instead of a polynomial relation.

$$R = R_0 exp\left[\beta\left(\frac{1}{T} - \frac{1}{T_0}\right)\right]$$

Thermistors are semiconducting ceramics composed of mixtures of several metal oxides. Metal electrodes or wires are attached to the ceramic material so that the thermistor resistance can be measured conveniently. The resistance does not change linearly with temperature.

The thermistor is a very sensitive device, and consistent performance 0.01°C may be anticipated with proper calibration. A rather nice feature of the thermistor is that it may be used for temperature compensation of electric circuits. This is possible because of the negative temperature characteristic that it exhibits so that it can be used to counteract the increase in resistance of a circuit with a temperature increase.

The thermistor is an extremely sensitive device because its resistance changes so rapidly with temperature. However, it has the disadvantage of highly non-linear behavior. This is not a particularly severe problem because data acquisition systems can employ computing programs to provide direct temperature readout from the resistance measurement.

Thermistors can be classified into two types, depending on the change in Resistance with the Temperature. If the resistance increases with increasing temperature, the device is called as positive temperature coefficient (**PTC**) thermistor. If the resistance decreases with increasing temperature, the device is called as negative temperature coefficient (**NTC**) thermistor.

Because the resistance of the thermistor is so high the error due to lead resistance is small compared to that for the RTD.

The Thermistor is a semiconductor device and therefore is subjected to deterioration at high temperatures; for this reason they are limited to temperature measurements below about 300°C.The RTDs are useful over larger temperature ranges, while Thermistors typically achieve a higher precision within a limited temperature range [usually −90 °C to 130 °C].

2.3 Thermocouple

The most common electrical method of temperature measurement uses the thermocouple. when two dissimilar metals are joined together and the junction is kept at any temperature. An emf will exist between two free ends which is primarily a function of the junction temperature. This phenomena is called the **Seebeck effect**. If the two materials are connected to an external circuit in such a way that a current is drawn, the emf may be altered slightly owing to phenomena called **Peltier effect**. Further if a temperature gradient exists along either or both of the materials, the junction emf may undergo an additional slight alteration .This is called the **Thomson effect**. The Seebeck emf is of prime concern since it is dependent on junction temperature. If the emf generated at the junction of two dissimilar metals is carefully measured as a function of temperature, then such a junction may be utilized for the measurement of temperature. The main problem arises when one attempts to measure the potential. When the two dissimilar materials are connected to a measuring device, there will be another thermal emf generated at the junction of the materials and the connecting wires to the voltage measuring instrument. This emf will be dependent on the temperature of the connection, and provision must be made to take account of this additional potential.

It may be observed that all thermocouple circuits must involve at least two junctions. If the temperature of one junction is known, then the temperature of the other junction may be easily calculated using the thermoelectric properties of the materials. The known temperature is called the reference temperature.

Thermocouples are used in applications ranging from measurement of room air temperature to that of a liquid metal bath.

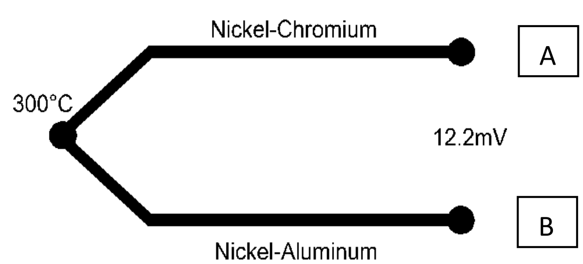


Figure 5: Thermocouple

Experiment 1

Comparison of the response of the RTD, thermocouple sensor, Gas pressure Thermometer, Bimetallic Thermometer and Mercury thermometer with the phase transition temperatures of water.

Aim:

Studying the response of the different temperature measurement instruments with the phase transition of water at 0° C with ice water and at 100° C with boiling water

Preparation:

Turn on the WL202 at the master switch.

Fill the insulated tank with very small crushed pieces of ice cubes and sufficient amount of water to form ice water.

Turn on the relevant switch above the socket.

Connect the laboratory heater at the socket.

Connect the Pt100 and Thermocouple temperature sensors and multimeters to the displays on the WL202 base unit.

Place a container of water on the laboratory heater. Bring the water (purified RO water) to the boil and record the measured values.

Procedure:

1) Turn on the WL202 at the master switch.

2) Fill the stainless steel tank with very small crushed pieces of ice cubes and sufficient amount of water (purified RO water) to form ice water.

3) Using the five instruments record the measured temperature values for 0° C with ice water. Then measure for the Pt100 (RTD) and Thermocouple the generated voltage through multimeter (by connecting the multimeter to relevant port and setting it for voltage measurement).

4) Connect the laboratory heater at the socket.

5) Place the container of water on the laboratory heater.

6) Dip the Temperature sensors into the water bath at the same height.

7) Turn on the heater.

8) Bring the water gradually to the boiling stage and at this stage record the measured values of boiling point temperature, through sensors display and multimeter simultaneously.

(Similar procedure adopted for ice point temperature measurement through different sensors.

Observation table 1:

0° C ice water					
Temperature sensor	Quantity	Unit	Measured	Set point	Variation
Pt100	Temperature	°C			
	Voltage	mV			
Thermocouple	Temperature	°C			
	Voltage	mV			
Gas Pressure Thermometer	Temperature	°C			
Bimetallic Thermometer	Temperature	°C			
Mercury Thermometer	Temperature	°C			
100° C Boiling Water					
Temperature sensor	Quantity	Unit	Measured	Setpoint	Variation
Pt100	Temperature	°C			
	Voltage	mV			
Thermocouple	Temperature	°C			
	Voltage	mV			
Gas Pressure Thermometer	Temperature	°C			
Bimetallic Thermometer	Temperature	°C			
Mercury Thermometer	Temperature	°C			

Graph: Draw the graph comparing the response of all five temperature measuring instrument.

Conclusion: Comments on the experimental results.

Experiment 2

Calibration of NTC temperature measuring instrument with Pt100 temperature measuring instrument.

Aim:

Thermistor or any other electrical temperature measuring method, gives the electrical output. These electrical outputs should be calibrated either through first principle or some other instrument more accurate than thermocouple.

Assuming RTD to be more accurate, perform the calibration of NTC temperature measuring instrument.

Preparation:

Turn on the WL202 at the master switch.

Connect the Pt100 and NTC temperature sensors and multimeters to the displays on the WL202 base unit.

Ice water and boiling water are required to perform the experiment. The water is added to the stainless steel tank.

Procedure:

1) Turn on the WL202 at the master switch.

2) Fill the stainless steel tank with suitable amount of water mixed with proper ice to bring down temperature of water till 10^0 C.

3) Dip the RTD and NTC both inside the stainless steel tank (tip of both sensors should be dipped inside the water level at equal height) and start with very slow rate of heating of the stainless steel tank. Connect multimeter across the thermocouple port to note down generated voltage.

4) Note down the reading of RTD (^{0}C) and corresponding reading of multimeter (voltage; connected across NTC) at interval of 5^0C (refer table 3). Control the heating rate accordingly to achieve higher temperature.

5) Repeat the experiment for few of the readings in cooling mode by switching of the heater and allowing the water to cool down.

Observation table 2:

Measurement					
Pt100	**Pt100**	**NTC**	**NTC**	**Variation**	**Variation**
Temp. In °C	**Voltage In mV**	**Temp. In** °C	**Voltage In mV**	**In** °C	**In mV**
10					
15					
20					
25					
30					
35					
40					
45					
50					
55					
60					
65					
70					
75					
80					
85					
90					
95					

Graph:

1. Study the responses of NTC with temperature variation by drawing the graph between temperature and corresponding voltage generated.

2. Study the responses of RTD with temperature variation by drawing the graph between temperature and corresponding voltage generated.

Conclusion:

Experiment 3

Aim: Calibration of thermocouple using RTD.

Thermocouple or any other electrical temperature measuring method, gives the electrical output. These electrical outputs should be calibrated either through first principle or some other instrument more accurate than thermocouple.

Assuming RTD to be more accurate, perform the calibration of thermocouple.

Preparation:

Turn on the WL202 at the master switch.

Connect the Pt100 and Thermocouple temperature sensors and multimeters to the displays on the WL202 base unit.

Procedure:

1) Turn on the WL202 at the master switch.

2) Fill the stainless steel tank with suitable amount of water mixed with proper ice to bring down temperature of water till 10^0 C.

3) Dip the RTD and thermocouple both inside the stainless steel tank (tip of both sensors should be dipped inside the water level at equal height) and start with very slow rate of heating of the stainless steel tank. Connect multimeter across the thermocouple port to note down generated voltage.

4) Note down the reading of RDT (^{0}C) and corresponding reading of multimeter (voltage; connected across thermocouple) at interval of 5^0C (refer table 3). Control the heating rate accordingly to achieve higher temperature.

5) Repeat the experiment for few of the readings in cooling mode by switching of the heater and allowing the water to cool down.

Observation table 3:

Pt100 Temp. In °C	**Thermocouple Voltage In mV (Heating mode)**	**Pt100 Temp. In** °C	**Thermocouple Voltage In mV (Cooling mode)**
10			
15			
20			
25			
30			
35			
40			
45			
50			
55			
60			
65		**65**	
70		**70**	
75		**75**	
80		**80**	
85		**85**	
90		**90**	
95			

Graph: Draw the calibration graph of thermocouple in heating mode.

Conclusion: Comments on the experimental results.

Experiment No.4

Comparison of the response time for Pt100 and Thermocouple.

Aim: Comparing the response time of two different methods measuring same parameter.

What is response time of the measuring instrument?

Response time of the instrument shows, how early the instrument catches up the steady state value of the parameter. Scientifically the response time of the instrument is stated as the time for the system to settle to within ±10% of the steady state value.

Procedure:

This will be open ended experiment. In order to check students understanding, their ability to perform experiment etc, the procedure of this experiment is kept open ended. Students are supposed to decide procedure, perform experiment and comment on their experimental result.

Conclusion:

M.3) Mechatronics sensors

1. Piezo Film

The piezo is a flexible component that includes a piezoelectric polymer film that is laminated to a polyester substrate. The laminated strip contains an added mass at the end weighing 0.078 kg

Piezo film sensor

Piezo Film produces voltage in proportion to compressive or tensile mechanical stress or strain, making it an ideal dynamic strain gage. It gives them capability to work as highly reliable low-cost vibration sensor. Piezo Film is also ideally suited for high fidelity (The degree to which an electronic system accurately reproduces the sound or image of its input signal.) transducers

Pressure Sensor		
Pressure range	0-30	PSI
Sensitivity	0.133	V/PSI
Output range	0.5-4.5	V
Quantization step	3.0	mV
Accuracy	+/-2	%Vs

operating throughout the high audio (>1kHz) and ultrasonic (up to 100MHz) ranges.

Piezo film is a flexible, lightweight, tough engineering plastic available in a wide variety of thicknesses and large areas. Piezo film has low density and excellent sensitivity, and is mechanically tough. When extruded into thin film, piezoelectric polymers can be directly attached to a structure without disturbing its mechanical motion.
Piezo film is well suited to strain sensing applications requiring very wide bandwidth and high sensitivity. As an actuator, the polymer's low acoustic impedance permits the efficient transfer of a broadband of energy into air and other gases.

2. Pressure

The pressure transducer on the Mechatronics sensor trainer has a range of 0-30 PSI, a sensitivity of 0.133 V/PSI, and outputs a voltage between 0.5-4.5 V. thus it has a zero pressure offset of 0.5 V and a full scale span of 4.5 V.

Pressure Sensor

A pressure transducer is a transducer that converts pressure into an analog electrical signal.

A pressure sensor usually acts as a transducer, it generates a signal as a function of the pressure

Piezo Film		
Ring mass on film	0.72	g
Location of mass from edge	1.40	cm
For 0.78 g added mass:		
Sensitivity at resonance	16.0	V/g
Resonant frequency	40.0	Hz
3 dB frequency	20.0	Hz

imposed, and such a signal is electrical.

Although there are various types of pressure transducers, one of the most common is the strain gauge base transducer. Pressure applied to the pressure transducer produces a deflection of the diaphragm which introduces strain to the gages. The strain will produce an electrical resistance change proportional to the pressure.

Pressure sensors can also be used to indirectly measure other variables such as fluid/gas flow, speed, water level, and altitude. Pressure sensors can alternatively be called pressure transducers, pressure transmitters, pressure senders, pressure indicators and piezometers, manometers, among other names. These sensors are commonly manufactured out of piezoelectric materials such as quartz.

3. Sonar

The sonar range finder device on the trainer has a operation measuring range of 6-254 inches.

Sonar Sensor

The term *sonar* is also used for the equipment used to generate and receive the sound. Sonar sensors are commonly used in mobile robotics and variety of other applications for distance measurement. The working of sonar sensor is based on sound propagation. In sonar sensor, a speaker (Transducer) is used to emit a short burst of sound (Ping). The sound wave travels through the air and reflects off a target back to the Transducer (Echo). By measuring the Time of Flight between Ping and Echo detection, one can calculate the distance between the target and transducer. The sonar sensors are also used in submarines in order to detect the location of other vessels.

Sonar		
Object detection	0-254	in
Sonar range	6-254	in
Resolution	1.0	in
Reading frequency	20.0	Hz

The acoustic frequencies used in sonar systems vary from very low (infrasonic) to extremely high (ultrasonic).

Active sonar uses a sound transmitter and a receiver. When the two are in the same place it is mono-static operation. When the transmitter and receiver are separated it is bi-static operation. When more transmitters (or more receivers) are used, again spatially separated, it is multi-static operation. Most sonar sensors are used mono-statically with the same array often being used for transmission and reception.

This pulse of sound is generally created electronically using a sonar Projector consisting of a signal generator, power amplifier and electro-acoustic transducer/array. A beam former is usually employed to concentrate the acoustic power into a beam, which may be swept to cover the required search angles.

4. Infrared

The infrared distance measuring unit uses a triangulation method to detect the distance of an object and has a distance measuring range of 20-150 cm. it outputs a voltage that correlates to the distance of the target.

Infrared Sensor		
Distance measuring range	20 to 150	cm

Infra-Red (IR) Triangulation Sensor

Optical triangulation position sensors use reflected waves to pinpoint position and displacement. The source of these waves may be a light emitting diode (LED), infrared (IR) light, or laser. Most optical triangulation position sensors house the sensor itself with the emitter. The sensor detects the beam that is reflected from the surface or objects and provides an output that varies with the distance. Outputs for optical triangulation position sensors include analog current, analog voltage, and frequency. Digital, serial, and parallel outputs are also available, along with alarms and changes in state of switches.

Typically, the sensing component for optical triangulation position sensors is either a charged coupled device (CCD) or a photodiode (PSD). The sampling rate is important, as this specification may determine the suitability of optical triangulation position sensors for specific applications. Beam patterns are designated as point, line, or area. To achieve a line pattern, many point-style sensors are used together in a line. To create an area scan, several optical triangulation position sensors are used together in a matrix or other shape.

Optical triangulation position sensors have a working range and a reference or standoff distance. This standoff distance is the mid-point in the working range. By definition, the working range is either more or less the reference-distance and usually given as a value. For example, a sensor with a reference of 9” and a working range of 4” will have an effective total range of 8” over which it can measure. Since the midpoint of that range is 9” from the sensor, the distance to measure must be between 5” and 13” from the sensor. Optical triangulation position sensors may use either visible or invisible light beams. Sometimes, a visible beam can make the sensors easy to mount and aim at a target. Occasionally, a visible beam can be undesirable. For instance, in a factory or processing centre personnel are working, a visible beam may be distracting and potentially lead to accidents. Additional considerations when selecting optical triangulation position sensors are resolution and accuracy. Resolution is the smallest unit of distinction that optical triangulation position sensors can detect. Accuracy is a percentage of full scale.

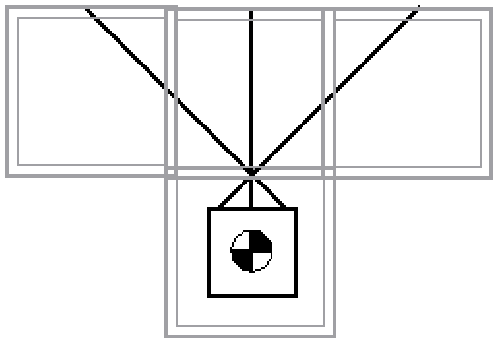


Figure : Configuration of IR range finding sensors

5. Optical Position

The optical position sensor on the trainer consists of an infrared emitting disilicon photo-transistor, both mounted side by side. the range of the optical position sensor is 0.25 inches.

Optical Position		
Range	0.25	in

Optical Sensor

Position sensing is used to electronically monitor the position or movement of a mechanical component. The position sensor produces an electrical signal that varies as the position of the component in question varies.

Electrical position sensors are an important part of innumerable products. Determining a linear position of a moveable member has a variety of applications. For example, in order to know the position of a work tool of a work machine, such as a blade of a motor grader or a bucket of a wheel loader or excavator, the extension of a hydraulic cylinder that controls the position of the blade/bucket is often measured.

These hydraulic cylinders are often quite long, ranging up to several meters in length. Many scientific, industrial, military and aerospace applications require precise and accurate knowledge of the angular orientation of a shaft or other rotating object or the linear position of a reciprocating object. Angular and linear position sensors are widely used in automatic control systems as feedback-sensing devices in one or more control loops of the system.

Various linear sensor assemblies are known, which utilize the eddy current principle to produce an output signal in accordance with movement of a core element with respect to a coil. Linear position sensing is generally performed using a variety of electrically based sensor devices. Present linear position sensors include linear voltage differential transducers (LDVT), variable inductance, variable capacitance and eddy current killed oscillators. LDVT and variable inductance sensors determine linear position by means of a rod inserted in a coil or coils of wire. In contrast, eddy current and capacitance based position sensors measure frequency. The frequency of the signal depends on the position of the target.

A common method for sensing linear position involves using a magnet connected to a displaceable member such as a rod or piston and measuring the magnetic field from the magnet. A contacting position sensor requires physical contact between a signal generator and a sensing element to produce the electrical signal. Contacting position sensors typically consist of a potentiometer to produce electrical signals that vary as a function of the component's position. Contacting position sensors are generally accurate and precise.

A non-contacting position sensor (NPS) does not require physical contact between the signal generator and the sensing element. For example, a non-contacting position sensor may utilize magnets to generate magnetic fields that vary as a function of position and devices to detect varying magnetic fields to measure the position of the component to be monitored.

6. Push button

The push button analog line goes to +5 V when the button is pressed down, i.e. when the switch is closed as shown in figure. Optical switches and generate A and B signals. the index pulse is generated by a pickup sensor

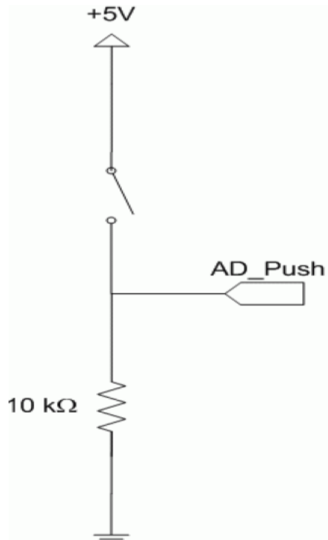


Figure : Push button circuit.

7. Micro Switch

the analog input line connected to the miniature snap action switch is pulled high to +5V, when switch is in open position and goes down to low when pressed down. the micro switch circuit depicted in figure

A miniature snap-action switch, also trademarked and frequently known as a **micro switch**, is an electric switch that is actuated by very little physical force, through the use of a tipping-point mechanism, sometimes called an "over-center" mechanism. Switching happens reliably at specific and repeatable positions of the actuator, which is not necessarily true of other mechanisms. They are very common due to their low cost and durability, greater than 1 million cycles and up to 10 million cycles for heavy duty models. This durability is a natural consequence of the design.

Internally a flat metal spring must be bent to activate the switch. Inside is a small curved spring (at the top, just right of center in the photo). Before assembly, it is more nearly straight. After assembly, it presses against a stationary part of the mechanism at one end. At its other end, its force is in a direction to stretch the flat spring (although far too small a force to cause any practical change of shape at all). Acting at an angle, it presses the contact end of the flat spring against one or the other fixed contacts. With the mechanism not actuated, the curved spring's force aids that from the flat spring, to ensure that the normally-closed contacts have sufficient force. (When the actuator is released, the flat spring's tension overcomes that from the curved spring.)

When actuated, the flat spring is displaced to close the normally-open contact. As the "pivoting" ends of the curved spring move into line with the flat spring, the curved spring's effect decreases. Continuing movement of the actuator causes "over-center" action, in which the curved spring now aids motion of the flat spring. As the curved spring straightens out slightly, it progressively exerts more force on the flat spring. When the normally-open contacts close, the curved spring again ensures sufficient contact force. This action produces a very distinctive clicking sound and a very crisp feel. When actuator force is removed the flat spring goes back to its original state.

Common applications of micro switches include the door interlock on a microwave oven, leveling and safety switches in elevators, vending machines, and to detect paper jams or other faults in photocopiers. Micro switches are commonly used in tamper switches on gate valves on fire sprinkler systems and other water pipe systems, where it is necessary to know if a valve has been opened or shut.

The defining feature of micro switches is that a relatively small movement at the actuator button produces a relatively large movement at the electrical contacts, which occurs at high speed (regardless of the speed of actuation). Most successful designs also exhibit hysteresis, meaning that a small reversal of the actuator is insufficient to reverse the contacts; there must be a significant movement in the opposite direction. Both of these characteristics help to achieve a clean and reliable interruption to the switched circuit.

The first micro switch was invented by Peter McGall in 1932 in Freeport, Illinois. McGall was an employee of the Burgess Battery Company at the time. In 1937 he started the company MICRO SWITCH, which still exists as of 2009. The company and the *Micro Switch* trademark have been owned by Honeywell Sensing and Control since 1950. The trademark has become a widely used description for snap-action switches. Companies other than Honeywell now manufacture miniature snap-action switches.

Micro switches are very widely used; among their applications are appliances, machinery, industrial controls, vehicles, and many other places for control of electrical circuits. They are usually rated to carry current in control circuits only, although some switches can be directly used to control small motors, solenoids, lamps, or other devices. Special low-force versions can sense coins in vending machines, or with a vane attached, air flow. Micro switches may be directly operated by a mechanism, or may be packaged as part of a pressure, flow, or temperature switch, operated by a sensing mechanism such as a Bourdon tube. In these latter applications, the repeatability of the actuator position when switching happens is essential for long-term accuracy. A motor driven cam (usually relatively slow-speed) and one or more micro switches form a timer mechanism. The snap-switch mechanism can be enclosed in a metal housing including actuating levers, plungers or rollers, forming a limit switch useful for control of machine tools or electrically-driven machinery.

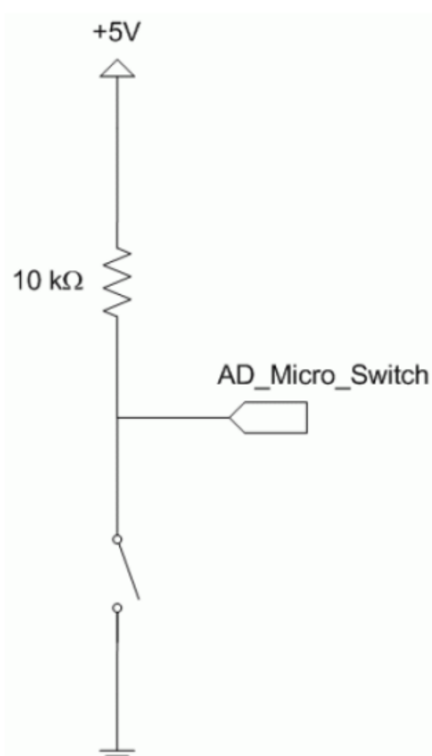


Figure : Micro switch circuit.

08. LED

***L**ight **e**mitting **d**iode*, an electronic device that lights up when electricity is passed through it. LEDs are usually red. They are good for displaying images because they can be relatively small, and they do not burn out. However, they require more power than LCDs.

We see LEDs every day. A light-emitting diode (LED) is a semiconductor diode that radiates light (electroluminescence) when current passes through it in the forward direction. Electrons move though semiconductor medium and "fall into" other energy levels during their transit of the *p-n* junction. When these electrons make a transition to a lower energy level, they give off a photon of light. This photon may be in the infrared region or just about anywhere across the visible spectrum up to and into ultraviolet - but we have to pick a color when we make them. That means we can get an infrared LED to work in our remote controls, and get other ones of different colors to make indicators or, in large arrays, displays - even color ones.

LEDs usually are made to emit one color of light, though bicolor ones and more can be fabricated. Intensity is being improved as well. That broadens the applications considerably (think vehicular tail lights). The device has a pair of leads, and a (usually) plastic body molded around the leads and the semiconductor crystal itself. That way the light can get out through the plastic. There is frequently a "round dome" at the top of the LED which serves to focus the light headed out through it. Remember that it is the material of the semiconductor crystal that determines the light given off by the device. A normal LED isn't really voltage dependent. When obtaining the LEDs, a manufacturer or hobbiest specifies the color. Red, green and blue are most popular, and, though there are other colors, it might be tough(er) to find them. Note that the big LED color displays use a three-LED pixel, and by driving it (the 3-LED assembly) appropriately, a wide range of colors can be obtained.

A **diode** is the simplest sort of semiconductor device. Broadly speaking, a semiconductor is a material with a varying ability to conduct electrical current. Most semiconductors are made of a poor conductor that has had **impurities** (atoms of another material) added to it. The process of adding impurities is called **doping**.

In the case of LEDs, the conductor material is typically **aluminum-gallium-arsenide** (AlGaAs). In pure aluminum-gallium-arsenide, all of the atoms bond perfectly to their neighbors, leaving no free **electrons** (negatively-charged particles) to conduct electric current. In doped material, additional atoms change the balance, either adding free electrons or creating **holes** where electrons can go. Either of these additions makes the material more conductive.

A semiconductor with extra electrons is called **N-type material**, since it has extra **n**egatively-charged particles. In N-type material, free electrons move from a negatively-charged area to a positively charged area.

A semiconductor with extra holes is called **P-type material**, since it effectively has extra **p**ositively-charged particles. Electrons can jump from hole to hole, moving from a negatively-charged area to a positively-charged area. As a result, the holes themselves appear to move from a positively-charged area to a negatively-charged area.

A diode comprises a section of N-type material bonded to a section of P-type material, with electrodes on each end. This arrangement conducts electricity in only one direction. When no voltage is applied to the diode, electrons from the N-type material fill holes from the P-type material along the **junction** between the layers, forming a **depletion zone**. In a depletion zone, the semiconductor material is returned to its original **insulating state** -- all of the holes are filled, so there are no free electrons or empty spaces for electrons, and charge can't flow.

The interaction between electrons and holes in this has an interesting side effect -- it generates **light**!

09. Optical Switch

The optical switch is photo-microsensor that consists of a transmissive and a reflective component. if an object is placed between the component and the reflective sensor does not sense any light, the goes high to +5 V. the switch outputs 0V when no object is detected.

In telecommunication, an **optical switch** is a switch that enables signals in optical fibers or integrated optical circuits (IOCs) to be selectively switched from one circuit to another.

The word is used on several levels. In commercial terms (such as "the telecom optical switch market size") it refers to any piece of circuit switching equipment between fibers. The majority of installed systems in this category actually use electronic switching between fiber transponders. Systems that perform this function by physically switching light are often referred to as "photonic" switches, independent of how the light itself is switched. Away from the world of telecom systems, an optical switch is the unit that actually switches light between fibers, and a photonic switch is one that does this by exploiting nonlinear material properties to steer light (i.e., to switch wavelengths or signals within a given fiber).

An optical switch may operate by mechanical means, such as physically shifting an optical fiber to drive one or more alternative fibers, or by electro-optic effects, magneto-optic effects, or other methods. Slow optical switches, such as those using moving fibers, may be used for alternate routing of an optical transmission path, such as routing around a fault. Fast optical switches, such as those using electro-optic or magneto-optic effects, may be used to perform logic operations; also included in this category are the semiconductor optical amplifiers, which are optoelectronic devices that can be used as optical switches and be integrated with discrete or integrated microelectronic circuits.

10. Encoder

A **rotary encoder**, also called a **shaft encoder**, is an electro-mechanical device that converts the angular position of a shaft or axle to an analog or digital code, making it an angle transducer. Rotary encoders are used in many applications that require precise shaft unlimited rotation—including industrial controls, robotics, special purpose photographic lenses, computer input devices (such as optomechanical mice and trackballs), and rotating radar platforms. There are two main types: absolute and incremental (relative).

1. MEASURING SYSTEMS

To solve positioning problems in automation, it is often necessary to measure lengths and angles as exactly as possible. In general there are two different measuring systems:

Incremental Measuring Systems

The principle of the incremental measuring system is the scanning of a line pattern on a glass or plastic disc (see Image 1).

The states of the line pattern transparent or not transparent are converted into electronic pulses by an opto-electronic unit (e.g. transparent = 5V, not transparent = 0V).

The analysis of the signals is performed in an evaluation unit by counting up or down with each pulse. The current count is stored in digital form and is instantly available for evaluation.

Image 1: Incremental Disc

However, this method has some serious disadvantages. It is possible that the result is continuously invalid due to signal glitches, unmeasured impulses or similar problems. Furthermore, after a loss of the supply voltage it is often necessary to return to a reference point which can cure complications.

For these reasons applications with a high emphasis on precision or applications where it is complicated or not possible to return to the reference point often use the absolute measuring system.

An incremental rotary encoder, also known as a quadrature encoder or a relative rotary encoder, has two outputs called quadrature outputs. They can be either mechanical or optical. In the optical type there are two gray coded tracks, while the mechanical type has two contacts that are actuated by cams on the rotating shaft. The mechanical type requires debouncing and is typically used as digital potentiometers on equipment including consumer devices. Most modern home and car stereos use mechanical rotary encoders for volume. Due to the fact the mechanical switches require debouncing, the mechanical type are limited in the rotational speeds they can handle. The incremental rotary encoder is the most widely used of all rotary encoders due to its low cost: only two sensors are required.

The fact that incremental encoders use only two sensors does not compromise their accuracy. One can find in the market incremental encoders with up to 10,000 counts per revolution, or more.

There can be an optional third output: reference, which happens once every turn. This is used when there is the need of an absolute reference, such as positioning systems.

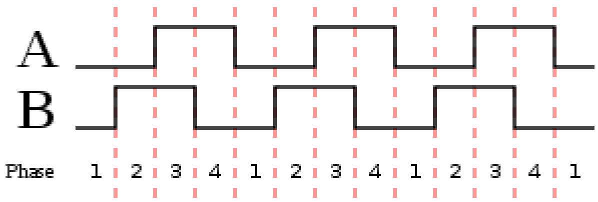
The optical type is used when higher RPMs are encountered or a higher degree of precision is required.

Incremental encoders are used to track motion and can be used to determine position and velocity. This can be either linear or rotary motion. Because the direction can be determined, very accurate measurements can be made.

They employ two outputs called A & B which are called quadrature outputs as they are 90 degrees out of phase.

The state diagram:

Gray coding for clockwise rotation			Gray coding for counter-clockwise rotation		
Phase	**A**	**B**	**Phase**	**A**	**B**
1	0	0	1	1	0
2	0	1	2	1	1
3	1	1	3	0	1
4	1	0	4	0	0



Two square waves in quadrature (clockwise rotation).

The two output wave forms are 90 degrees out of phase, which is all that the quadrature term means. These signals are decoded to produce a count up pulse or a countdown pulse. For decoding in software, the A & B outputs are read by software, either via an interrupt on any edge or polling, and the above table is used to decode the direction. For example if the last value was 00 and the current value is 01, the device has moved one half step in the clockwise direction. The mechanical types would be debounced first by requiring that the same (valid) value be read a certain number of times before recognizing a state change.

If the encoder is turning too fast, an invalid transition may occur, such as 00->11. There is no way to know which way the encoder turned; if it was 00->01->11, or 00->10->11.

If the encoder is turning even faster, a backward count may occur. Example: consider the 00->01->11-> 10 transitions (3 steps forward). If the encoder is turning too fast, the system might read only the 00 and then the 10, which yields a 00-> 10 transitions (1 step backward).

This same principle is used in ball mice to track whether the mouse is moving to the right/left or forward/backward.

Rotary sensors with a single output are not encoders and cannot sense direction, but can sense RPM. They are thus called tachometer sensors.

Absolute Measuring Systems

Using this measuring system, every position of the measurement range/angle is identified by a definite code on a glass or plastic disc. This code is represented on the disc in the form of light and dark regions within different tracks. This combination relates to an absolute numerical value. Thus, the position value is always directly available, counters are not necessary. In addition it is not possible to get continuously invalid values caused by interferences or loss of the supply voltage. Movements which are done while the system is turned off are immediately measured after the system is Powered up.

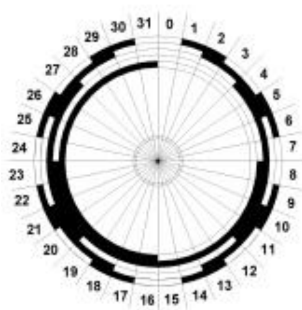


Image 2: Code disc with Gray-Code

2. STRUCTURE OF AN ABSOLUTE ENCODER

The measuring system consists of a light source, a code disc pivoted in a precision ball bearing and an opto-electronic scanning device (see Image 3). A LED is used as a light source which shines through the code disc and onto the screen behind. The tracks on the code disk are evaluated by an opto-array behind the reticle. With every position another combination of slashes in the reticle is covered by the dark spots on the code disk and the light beam on the photo transistor is interrupted. That way the code on the disc is transformed into electronic signals. Fluctuations in the intensity of the light source are measured by an additional photo transistor and another electronic circuit compensates for these. After the electronic signals are amplified and converted they are then available for evaluation.

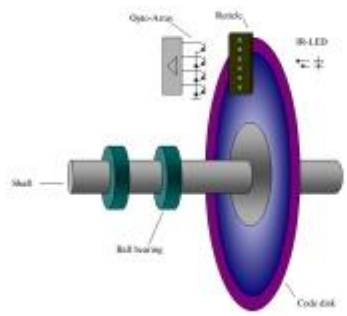


Image 3: Construction Absolute Encoder

Single-Turn

Single turn encoders are encoders that specify the absolute position for one turn of the shaft i.e. for 360°. After one turn the measuring range is completed and starts again from the beginning.

Multi-Turn

Linear systems normally need more than one turn of a shaft. A single turn encoder is unsuitable for this type of application because of the additional requirement of the number of turns. The principle is relatively simple: Several single turn encoders are connected using a reduction gear (see Image 4). The first stage supplies the resolution per turn, the stages behind supply the number of turns.

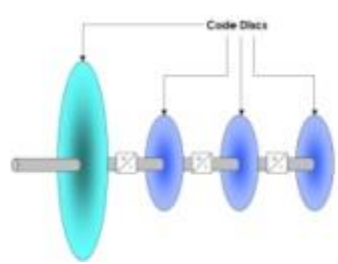


Image 4: Principle of the Multi Turn

The total number of steps in this example is 16 x 16 x 16 x 8192 steps = 33,554,432 steps

Binary 111,1111,1111,1111111111111)

9. Rotary potentiometer

The rotary potentiometer outputs a voltage that varies linearly with the angle being measured. the potentiometer has a mechanical limit of 300 degree.

The potentiometer (or pot, as it is more commonly known) is a simple electro-mechanical transducer. It converts rotary or linear motion from the operator into a change of resistance, and this change is (or can be) used to control anything from the volume of a hi-fi system to the direction of a huge container ship.

The pot as we know it was originally known as a rheostat - essentially a variable wire wound resistor. The array of different types is now quite astonishing, and it can be very difficult for the beginner (in particular) to work out which type is suitable for a given task. The fact that quite a few different pot types can all be used for the same task makes the job that much harder - freedom of choice is at best confusing when you don't know what the choices actually are, or why you should make them. This article is not about to cover every aspect of pots, but is an introduction to the subject. For anyone wanting to know more, visit manufacturers' web sites, and have a look at the specifications and available types.

The very first variable resistors were either a block of carbon (or some other resistive material) with a sliding contact, or a box full of carbon granules, with a threaded screw to compress the granules. More compression leads to lower resistance, and vice versa. These are rare in modern equipment, so we shall limit ourselves to the more common types.

10. Magnetic field sensor

The linear magnetic fields transducer on the sensor trainer outputs a voltage that is proportional to the magnetic field that is applied perpendicularly to the object being measured. The relationship however, between the output voltage and the target distance is exponential.

A magnetic field transducer outputs a voltage proportional to the magnetic field that is applied to the target. The magnetic field sensor is the chip located on the bottom of the trainer. It applies a magnetic field perpendicular to the flat screw head. the position of the screw head is changed by rotating the knob. This magnetic field transducer has a similar range to the optical position sensor.

Description	***Value***	***Unit***
Potentiometer		
Mechanical angle range	300.000	deg
Independent linearity	+/-5	%
Infrared Sensor		
Distance measuring range	20 to 150	cm
Pressure Sensor		
Pressure range	0-30	PSI
Sensitivity	0.133	V/PSI
Output range	0.5-4.5	V
Quantization step	3.0	mV
Accuracy	+/-2	%Vs
Sonar		
Object detection	0-254	in
Sonar range	6-254	in
Resolution	1.0	in
Reading frequency	20.0	Hz
Piezo Film		
Ring mass on film	0.72	g
Location of mass from edge	1.40	cm
For 0.78 g added mass:		
Sensitivity at resonance	16.0	V/g
Resonant frequency	40.0	Hz
3 dB frequency	20.0	Hz
Optical Position		
Range	0.25	in

Table : MECHKIT Specifications

Experiment 1

1. Aim - Study of Strain Gage with Flexible Link

1. Ensure J7 is set to Strain Gage.
2. Open the QNET_MECHKIT_Flexgage.vi.
3. Ensure the correct Device is chosen.

1.1. Collect Data

1. Run the QNET_MECHKIT_Flexgage.vi.
2. Move the flexible link to -1 cm.
3. Enter the strain gage voltage reading in the Sensor Measurement (V) array
4. Repeat for -0.5 cm, 0 cm, 0.5 cm, and 1.0cm. A linear curve is automatically fitted to the data being entered and its slope and intercept are generated.
5. Exercise 1: Enter the measured voltages in Table and capture the Sensor Reading scope.
6. Click on Stop button to stop the VI.

1.2. Calibrate Sensor

1. Run the QNET _MECHKIT_Flexgage.vi.
2. Select the Calibrate Sensor tab and enter the slope and intercept obtained into the Calibration Gain and Offset controls. When the link is moved, the slider indicator in the VI should match up with the actual location of the flexible link on the QNET module.
3. Exercise 2: Enter the gain and offset obtained in Table.
4. Click on Stop button to stop the VI.

1.3 Natural Frequency

1. Run the QNET_MECHKIT_Flexgage.vi.
2. Select the Natural Frequency tab.
3. Manually perturb the flexible link and stop the VI when it stops resonating (after about 5 seconds). The spectrum should then load in the chart.
4. Exercise 3: Enter natural frequency found and capture the resulting power spectrum response.

Hint: You can use the cursor to take measurements off the graph.

Exercise 1: Collected Data

Parameter	Value	Units	Notes
Sensor Measurement: at -1.0 cm		V	
Sensor Measurement: at -1.0 cm		V	
Sensor Measurement: at -1.0 cm		V	
Sensor Measurement: at -1.0 cm		V	
Sensor Measurement: at -1.0 cm		V	

Exercise 2: Sensor Calibration

Parameter	Value	Units	Notes
Gain		Cm/V	
Offset		cm	

Exercise 3: Natural Frequency

Conclusion -

Experiment 2

2. **Aim-** Study of Pressure Sensor

Pressure Sensor

This VI can be used to view the pressure sensor measurements as the plunger is moved at different locations within the syringe on the QNET mechatronic sensors trainer.

1. Ensure J9 is set to pressure.
2. Run the QNET_MECHKIT_Pressure_Sensor.vi.
3. Important: Completely remove the plunger from the tube and re-insert it this will ensure the chamber is pressurized enough.

2.1 Collect Data

1. Push the plunger up to the 6 cm marked on the MECHKIT board and measure the resulting voltage using the Pressure (v) scope (or the digital display).
2. Enter the result in the Sensor Measurement (V) array
3. Repeat for when the plunger is at 5.0 cm, 4.0cm, 3.0cm, 2.0cm,1.0cm, and 0 cm. The Pressure sensor is quadratic. The coefficients for the second-order polynomial are generated and the fitted curve is automatically plotted

Exercise 1: Enter collected results in Table and capture the Sensor Readings scope.

Exercise 1: collect Data

Parameter	Value	Units	Notes
Sensor Measurement: 6.0 cm		V	
Sensor Measurement: 5.0 cm		V	
Sensor Measurement: 4.0 cm		V	
Sensor Measurement: 3.0 cm		V	
Sensor Measurement: 2.0 cm		V	
Sensor Measurement: 1.0 cm		V	
Sensor Measurement:0.0 cm		V	

2.2. Calibrate Sensor

1. Run the QNET_MECHKIT_Pressure_Sensor.vi.
2. In the Calibrate Sensor tab, enter the polynomial coefficients, to measure correct position of the plunger. Verify that the sensor is reading properly, e.g. display should read 0.5 cm when plunger is placed at 0.5 cm.
3. Exercise 2: Enter the a, b and c, parameters used in table.

Exercise 2: Sensor calibration

Parameter	Value	Units	Notes
a		cm/V2	
b		cm/V	
c		cm	

Conclusion -

Experiment 3

3. Aim- Study of Piezo Sensor

1. Ensure J8 is set to Piezo.

2. Run the the QNET_MECHKIT_Piezo.vi.

3.1. Data Analysis

1. Manually perturb the plastic band that is attached to the piezo sensor by flicking it and examine the response in the piezo (V) Scope.

2 Grab the end of the plastic band and move it slowly up and down. Examine the response.

3. Exercise 1: From these two tests, what does the Piezo sensor measure? How is this different then a strain gage measurement? Capture a sample Piezo (V) scope response after it has been perturbed (by flicking it).

3.2. Natural Frequency

1. Manually perturb the piezo sensor.
2. Once it stopped resonating, stop running the VI (after about 3 seconds). The spectrum should be displayed in the Power Spectrum graph.
3. Exercise 2: Capture the resulting power spectrum response and give the measured natural frequency.

Hint: You can use the cursor to take measurements off the graph.

3.3. Exercise

Exercise 1: strain Gage versus Piezo

Exercise2: Measured Natural Frequency

Conclusion -

Experiment 4

4. Aim - Study of Rotary Potentiometer

1. Ensure J10 is set to POT.

2. Run the QNET_MECHKIT_Potentiometer VI.

4.1. Collect Data

1. Rotate the arrowhead of the potentiometer to a certain position, e. g. 45 degrees,

2. Enter the position in the *pot angel (degree)* array,

3. Enter corresponding measured sensor voltage in sensor measurement (V) array

4. Fill out table with appropriate amount of data points. Notice that as the measured potentiometer readings are entered, a curve is automatically generated to fit the data the slope and intercept of this line is generated as well.

5. Exercise 1: Enter the collected data in Table and capture the Sensor Reading chart.

Exercise 1: To collect data

Pot Angle (deg)	Sensor Measurement (V)

4.2 Calibrate Sensor

1. Run the QNET_ MECHKIT_ Potentiometer VI,
2. In the Calibrate Sensor tab, set the Gain and Offset controls, to values such that the potentiometer measures the correct angle. Verify that the sensor is reading properly e.g. when pot arrow is turned to 45.0 deg, the Display: Potentiometer (deg) knob indicator should read 45.0 deg.
3. Exercise 2: Enter Gain and Offset values used.

Exercise 2: Calibration Data

Parameter	Value	Units	Notes
Gain		Deg/v	
Offset		deg	

.

Conclusion -

Experiment 5

5. Aim - Study of Infrared Sensor

1. Ensure J10 is set to Infrared.
2. Run the QNET_ MECHKIT_Infrared VI.
3. Turn ON the IR switch to enable the Infrared sensor. The IR ON LED should be lit bright red.
4. Important: Make sure you turn OFF the IR switch when the experiment is over. When active the infrared sensor tends to generate noise in other sensor measurements.

5.1. Collect Data

i. Get a target, such as a sturdy piece of cardboard, that is at least 10 by 10 cm2 with a reflective color like white or yellow.
ii. Begin with the target close to the Ir sensor and slowly move it away.
iii. Once its range of operation is found, enter the distance between the target and the IR sensor in the Target Range (cm) array.
iv. Repeat for different target positions. The IR sensor is quadratic. As the Measurement are entered, the coefficients for the second-order polynomial are generated and the fitted curve is automatically plotted.

v. Exercise 1: Record your distance and voltage observation in Table and capture the corresponding Sensor Reading scope

vi. Exercise 2: What did you notice when the target is close to the IR sensor? That is did the behavior of the sensor change when the target was in close proximity as opposed to being further way?

Exercise 1: Collect data

Target Range (cm)	Sensor Measurement (V)

Exercise 2: Infrared Sensor Range

5.2. Calibrate Sensor

i. Run the QNET_ MECHKIT_Infrared VI.
ii. In the Calibrate sensor tab, enter the polynomial coefficients to correctly measure the distance of the target. Make it is measuring correctly, e.g. when target is 25.0 cm away then display should read 25.0 cm

Exercise 3: Calibration Parameters

Parameter	Value	Units	Notes
a		cm/V^2	
b		cm/V	
c		cm	

Conclusion -

Experiment 6

6. Aim - Study of Sonar Sensor

1. Ensure J9 is set to Sonar

2. Run the QNET_ MECHKIT_Sonar VI.

Sonar Sensor

Use this VI to view the sonar Measurement as a target is moved at different distances away from the sensor.

6.1. Collect data

1. Get a target such as a sturdy piece of cardboard that is at least 10 by 10 cm^2 with a reflective color like white or yellow.

2. Begin with the target close to the Ir sensor and slowly move it upwards.

3. Once its range of operation is found, enter the distance between the target and the Sonar sensor in the Target Range (cm) array

4. Enter the corresponding measured voltage from the sonar sensor in the Sensor Measurement (V) array,

5. Repeat for different target positions. The Sonar sensor is Linear. The slope and intercept are generated and the fitted curve is automatically plotted.
6. Exercise 1: Enter your collected target distances and voltages in the Table. Capture the Sensor reading scope as well.
7. Exercise 2: What is the resolution and operating range of the sonar senor? enter them in table, below How does the resolution and range compare with the IR sensor?

Exercise 1: Collected Data

Target Range (cm)	Sensor Measurement (V)

Exercise 2: Range and Resolution

Parameter	Value	Units	Notes
Range		Inch	
Resolution		inch	

6.2. Calibrate Sensor

1. Run the QNET_ MECHKIT_Sonar vi.
2. Select the Calibrate sensor tab and enter Gain and Offset coefficients to correctly measure the distance of the target. Make sure the coefficients are correct, e.g., when the target is 10.0 inches away then the sonar (inch) display should read 10.0 inches.
3. Exercise 3: enter Gain and offset values used in Table.

Exercise 3: Calibration Parameters

Parameter	Value	Units	Notes
Gain		inch/v	
Offset		inch	

Conclusion -

Experiment 7

7. **Aim** - Study of Optical Position sensor

1. Ensure J7 is set to Optical Position.
2. Run the QNET_ MECHKIT_Optical VI.

Optical Position

The QNET_ MECHKIT optical VI is used to view the measurements of the optical position sensors the target is moved at different locations using the knob.

7.1 Collect Data

1. Gently turn the knob of the optical position sensor clockwise until the flat metal surface gently rests on top of the tube. Then, rotate the knob slightly counter-clockwise so the 0 mark on the knob faces up. At this point, the reflective target is very close to the optical sensor and will be array.
2. Enter the voltage measured by the optical position sensor, when the target is 0 cm away, in the sensor measurements (V) array.
3. Turn the knob counter-clockwise one rotation to move the target further from the sensor. The target move 1-inch for every 20 turns. Enter the position the target has moved from the reference in the Target Range (cm) array.
4. Record the measured sensor voltage in the Sensor Measurement (v) array.
5. Take samples for the entire range of the target (i.e. until the knob cannot be rotated CCW anymore) Remark that the optical position sensor is exponential as data is being entered, the exponential parameters are generated and the fitted curve is automatically plotted.
6. Exercise 1: Enter the measured sensor data in table and capture the sensor readings response.

Exercise 1: Collected Data

Target Range (in)	Sensor Measurement (V)

7.2. Calibrate Sensor

1. Run the QNET_ MECHKIT_Optical VI.
2. In the Calibrate Sensor tab, enter values for the gain and Damping exponential function parameters, to correctly measure the distance of the target , e.g. when target is 0.10-inch away them display should 0.10-inch.
3. Exercise 2: Enter the Gain and Damping parameters used in Table.

Exercise 2: Calibration Data

Parameter	Value	Units	Notes
Gain		In	
Damping			

Conclusion -

Experiment 8

8. Aim - Study of Magnetic Field Sensor.

1. Ensure J8 is set to Magnetic Field.
2. Run the QNET_MECHKIT_Magnetic_Field VI

Magnetic Field sensor

Using this VI, the magnetic Field measurements can be read as the target is moved at different locations using this knob on the QNET Mechatronic sensors trainer.

8.1. Collect Data

1. Gently turn the knob of the magnetic field sensor clockwise until it is st its limit. Then, rotate the knob slightly counter-clockwise so the 0 mark on the knob faces up this will be reference0cm target position. Enter this in the Target Range (cm) array.
2. Enter the voltage measured from the magnetic field position sensor for the reference 0cm position in the Sensor Measurements (V) array. The array.
3. Turn the knob counter-clockwise one rotation to move the target further from the sensor. The target moves 1-inch for every 20 turns. Enter the position the target has moved from the reference in the Target Range (cm) array.
4. Record the measured sensor voltage in the Sensor Measurements (V) array.
5. Take samples for the entire range of the target (i.e. until the knob cannot be rotated CCW anymore) the magnetic field sensor is exponential. The parameters of the exponential function are outputted and the fitted curve is automatically plotted as data is entered.
6. Exercise 1: Enter the range and measured sensor voltage in table below, and capture the Sensor Readings scope.

Exercise 1: Collected Data

Target Range (in)	Sensor Measurement (V)

8.2. Calibrate Sensor

1. Run the QNET_MECHKIT_Magnetic_Field VI.
2. Enter Gain and Damping exponential function parameters to correctly measure the distance of the target. For instance, when target is at 0.10 –inch from the reference then display should read 0.10 –inch.
3. Exercise 2: Record Gain and Damping parameters used for correct Measurement in Table.

Exercise 2: Calibration Data

Parameter	Value	Units	Notes
Gain		In/V	
Damping			

Conclusion -

Experiment 9

9. Aim - Study of Encoder

1. Ensure jumpers J7 is set to Enc A, J8 to Enc B, and J10 to Enc I.
2. Run the QNET_MECHKIT_ Encoder VI.

Encoder

This VI shows the A, B and Index signals generated by the rotary optical encoder on the QNET mechatronic sensors trainer as the knob is rotated.

9.1. Analysis of A, B and I Signals

1. Exercise 1: Turn the encoder knob clockwise and examine the response of the A and B signals Note that the signals are offset by 2.5 V for display purposes. Enter your observation in Table. Similarly, turn the encoder knob counter-clockwise and enter your observation.
2. Exercise 2: When is the index pulse triggered? What can this be used for?

Exercise 1: synchronization of Encoder A and B signals

Encoder Knob rotation	A or B signal Leads ?
Clockwise	
Counter-clockwise	

Exercise 2: Index Pulse

9.2. Encoder Calibration

1. Using the 16-bit Position (counts) indicator on the VI, rotate the knob and determine how many counts there are per revolution. Enter your result in the counts per rev box in the VI Rotate the knob and confirm that the Angle (deg) indicator is displaying an accurate angle.
2. Turn the knob such that the 0 is in the upward position and reset the counter by clicking on the Reset button.
3. Enable the index by clicking on the Enable index button.
4. Rotate the knob a full CW turn until the index is triggered. Keep turning the knob until the 0 mark on the knob is pointing upwards. What do you notice about the 16-bit Position (counts) and the Angle (deg) indicator values?

5. Adjust the Reload Value such that Angle (deg) measures 0 degrees when the 0 mark of the knob is pointing up. Confirm this by moving the knob CW.
6. Exercise 3: Enter the count per rev and the Reload Value values used for a calibrated measurement in Table 30.
7. Exercise 4: Position the knob such that its 0 label is pointing upwards again. The counts per rev and Angle (deg) should both be reading 0. Rotate the knob in the CCW fashion one full rotation Is Angle (deg) reading 0 degrees? Discuss why or why not.

Exercise 3: Encoder Specifications

Parameter	Value	Units	Notes
Counts per rev		Counts/rev	
Reload Value		counts	

Conclusion -