UNIT – I INTRODUCTION

Functional elements of an instrument – Static and dynamic characteristics – Errors in measurement – Statistical evaluation of measurement data – Standards and calibration. Principle and types of analog and digital voltmeters, ammeters.

PART-A

1. What is standard? What are the different types of standards? (MAY 2008/MAY 2009/MAY 2011)

a. A standard is a physical representation of a unit of measurement. A known accurate measure of physical quantity is termed as standard. Types are International standard, primary standard, secondary standard and working standard.

2. Define calibration. (NOV/DEC 2010)

a. Calibration is the process of checking the accuracy of instrument comparing the instrument reading with a standard against a similar meter of known accuracy.

3. Define static error and how is it classified? (NOV 2009)

a. The static error of a measuring system is the numerical difference between the true value of a quantity and its value as obtained by measurement. The various types are gross error, systematic error and random error.

4. What are the various important functional elements of a typical measurement system? (Apr / May 13)

a. Primary sensing element ,Variable conversion element, Variable manipulation element, Data transmission element, Data presentation element

5. Illustrate the difference between precision and accuracy. (Apr / May 15, Apr/May19, Nov/Dec19)

Accuracy	Precision
Accuracy refers to the degree of closeness or conformity to the true value of quantity under measurement where the true value is the ideal value	Precision refers to the degree of agreement within a group of measurements and instruments or reproducibility of the value
Accuracy gives the maximum error which is maximum departure of the final result from its true value	Precision of a measuring system gives its capability to reproduce a certain reading with a given accuracy

6. Give the international standards of instruments. (Apr / May 14)

a. International Ohms

b. International Amperes

7. What is drift? (Nov/Dec 2011)

a. It is the variation of the measured value with time. Perfect reproducibility means that the instrument has no drift.

8. The expected value of the voltage across a resistor is 40 volt, however the measurement gives a value of 39 volt. Calculate the absolute error. (May/June 2013)

a. Absolute error e= At-Am=40-39=1volt

9. Define limiting errors. (Dec 2007)

a. Instruments having analog meters are usually guaranteed to be accurate within certain percentage limits called limiting errors or Guarantee errors.

10. Define dynamic characteristics of instrument. (Dec 2008)

a. The behavior of instrument when inputs vary with time and do the output.

11. Define fidelity (Nov 2009)

a. It is determined by the fact that how closely the instrument reading follows the measured variable. i.e. It is the degree to which an instrument indicates the changes in measured variable without dynamic error.

12. What are the static characteristics of instrument? (May 2008)

a. Static characteristics of instrument are used to measure unvarying processes of the instrument. The main static characteristics are accuracy, resolution, precision, drift, static error, dead zone etc.

13. What are the Functional elements of an Instrument? Illustrate with a suitable example.(Nov/Dec2019)

a. Primary sensing element (In Ammeter current carrying coil is a Primary Sensing element)

b. Variable conversion element (In Ammeter to get deflection Magnet act as Variable Conversion element)

c. Variable manipulation element (Transformer)

d. Data transmission element (optical fibers, copper wires)

e. Data presentation element (In case of our Ammeter Example, it is the Pointer and the scale arrangement that acts as the Data presentation element)

14. Distinguish between Gravity control and Spring Control. (Apr/May2019)

1. In gravity control, adjustable small weight is used which produces the controlling torque. In spring control, two hair springs are used which exert controlling torque.

2. Controlling torque can be varied in gravity control whereas controlling torque is fixed in spring.

3. In gravity, the performance is not temperature dependent while in the spring the performance is temperature dependent.

4. The scale is non-uniform in gravity. The scale is uniform in spring control.

5. The controlling torque is proportional to sin(angle) in the first whereas in the second, the controlling torque is proportional to the angle.

6. The readings can not be taken accurately in the gravity. The readings can be taken very accurately in the spring.

7. The system must be used in vertical position only in gravity control. The system need not be necessarily in vertical position in spring control.

8. Proper leveling is required as gravity control. The leveling is not required

PART-B

1. Explain the static and dynamic characteristics of an instrumentation system. (APR/MAY 2019)

The set of criteria defined for the instruments, which are used to measure the quantities which are slowly varying with time or mostly constant, i.e., do not vary with time, is called ‘static characteristics.

The various static characteristics are: i) Accuracy ii) Precision iii) Sensitivity iv) Linearity v) Reproducibility vi) Repeatability vii) Resolution viii) Threshold ix) Drift x) Stability xi) Tolerance xii) Range or span

Accuracy: It is the degree of closeness with which the reading approaches the true value of the quantity to be measured.

Precision: It is the measure of reproducibility i.e., given a fixed value of a quantity, precision is a measure of the degree of agreement within a group of measurements. The precision is composed of two characteristics

a) Conformity: Consider a resistor having true value as 2385692, which is being measured by an ohmmeter. But the reader can read consistently, a value as 2.4 M due to the non availability of proper scale. The error created due to the limitation of the scale reading is a precision error.

b) Number of significant figures: The precision of the measurement is obtained from the number of significant figures, in which the reading is expressed. The significant figures convey the actual information about the magnitude & the measurement precision of the quantity. Sensitivity:

The sensitivity denotes the smallest change in the measured variable to which the instrument responds. It is defined as the ratio of the changes in the output of an instrument to a change in the value of the quantity to be measured.

Linearity: The linearity is defined as the ability to reproduce the input characteristics symmetrically & linearly.

Reproducibility:

It is the degree of closeness with which a given value may be repeatedly measured. It is specified in terms of scale readings over a given period of time.

Repeatability: It is defined as the variation of scale reading & random in nature.

Drift: Drift may be classified into three categories:

a) Zero drift: If the whole calibration gradually shifts due to slippage, permanent set, or due to undue warming up of electronic tube circuits, zero drift sets in.

b) Span drift or sensitivity drift: If there is proportional change in the indication all along the upward scale, the drifts is called span drift or sensitivity drift.

c) Zonal drift: In case the drift occurs only a portion of span of an instrument, it is called zonal drift. **Resolution:** If the input is slowly increased from some arbitrary input value, it will again be found that output does not change at all until a certain increment is exceeded. This increment is called resolution. **Threshold:** If the instrument input is increased very gradually from zero there will be some minimum value below which no output change can be detected. This minimum value defines the threshold of the instrument.

Stability: It is the ability of an instrument to retain its performance throughout is specified operating life. **Tolerance:** The maximum allowable error in the measurement is specified in terms of some value which is called tolerance.

Range or span: The minimum & maximum value of a quantity for which an instrument is designed to measure is called its range or span.

Dynamic characteristics: The set of criteria defined for the instruments, which are changes rapidly with time, is called ‘dynamic characteristics. The various static characteristics are: i) Speed of response ii) Measuring lag iii) Fidelity iv) Dynamic error

Speed of response: It is defined as the rapidity with which a measurement system responds to changes in the measured quantity.

Measuring lag: It is the retardation or delay in the response of a measurement system to changes in the measured quantity. The measuring lags are of two types:

a) Retardation type: In this case the response of the measurement system begins immediately after the change in measured quantity has occurred.

b) Time delay lag: In this case the response of the measurement system begins after a dead time after the application of the input.

Fidelity: It is defined as the degree to which a measurement system indicates changes in the measurand quantity without dynamic error.

Dynamic error: It is the difference between the true value of the quantity changing with time & the value indicated by the measurement system if no static error is assumed. It is also called measurement error.

2. With a suitable illustration elaborate the significance of calibrations. (APR/MAY14)

Calibration is the process of making an adjustment or marking a scale so that the readings of an instrument agree with the accepted & the certified standard.

• In other words, it is the procedure for determining the correct values of measurand by comparison with the measured or standard ones.

• The calibration offers a guarantee to the device or instrument that it is operating with required accuracy, under stipulated environmental conditions.

• The calibration procedure involves the steps like visual inspection for various defects, installation according to the specifications, zero adjustment etc.,

• The calibration is the procedure for determining the correct values of measurand by comparison with standard ones.

• The standard of device with which comparison is made is called a standard instrument. The instrument which is unknown & is to be calibrated is called test instrument.

•Thus, in calibration, test instrument is compared with standard instrument.

Types of calibration methodologies: There are two methodologies for obtaining the comparison between test instrument & standard instrument. These methodologies are

i) Direct comparisons and ii) Indirect comparisons

Direct comparisons: In a direct comparison, a source or generator applies a known input to the meter under test. The ratio of what meter is indicating & the known generator values gives the meters error. In such case the meter is the test instrument while the generator is the standard instrument. The deviation of meter from the standard value is compared with the allowable performance limit. With the help of direct comparison, a generator or source also can be calibrated.

Indirect comparisons:

In the indirect comparison, the test instrument is compared with the response standard instrument of same type i.e., if test instrument is meter, standard instrument is also meter, if test instrument is generator; the standard instrument is also generator &so on. If the test instrument is a meter then the same input is applied to the test meter as well a standard meter. In case of generator calibration, the output of the generator tester as well as standard, or set to same nominal levels. Then the transfer meter is used which measures the outputs of both standard and test generator.

3. Discuss the different types of standards of measurements (Apr/May 15)

Standard All the instruments are calibrated at the time of manufacturer against measurement standards. A standard of measurement is a physical representation of a unit of measurement. A standard means known accurate measure of physical quantity.

The different size of standards of measurement are classified as

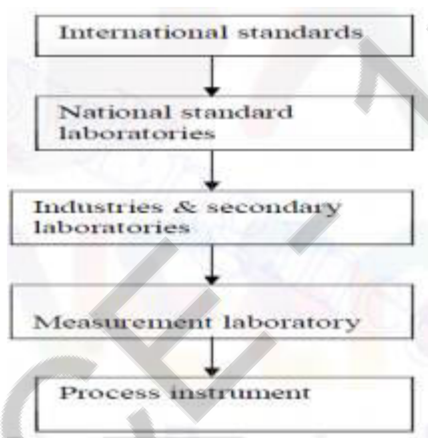
• International standards • Primary standards • Secondary standards • Working standards

International standards: International standards are defined as the international agreement. These standards, as mentioned above are maintained at the international bureau of weights and measures and are periodically evaluated and checked by absolute measurements in terms of fundamental units of physics. These international standards are not available to the ordinary users for the calibration purpose. For the improvements in the accuracy of absolute measurements the international units are replaced by the absolute units in 1948. Absolute units are more accurate than the international units.

Primary standards: These are highly accurate absolute standards, which can be used as ultimate reference standards. These primary standards are maintained at national standard laboratories in different countries. These standards representing fundamental units as well as some electrical and mechanical derived units are calibrated independently by absolute measurements at each of the national laboratories. These are not available for use, outside the national laboratories. The main function of the primary standards is the calibration and verification of secondary standards.

Secondary standards: As mentioned above, the primary standards are not available for use outside the national laboratories. The various industries need some reference standards. So, to protect highly accurate primary standards the secondary standards are maintained, which are designed and constructed from the absolute standards. These are used by the measurement and calibration laboratories in industries and are maintained by the particular industry to which they belong. Each industry has its own standards.

Working standards: These are the basic tools of a measurement laboratory and are used to check and calibrate the instruments used in laboratory for accuracy and the performance.



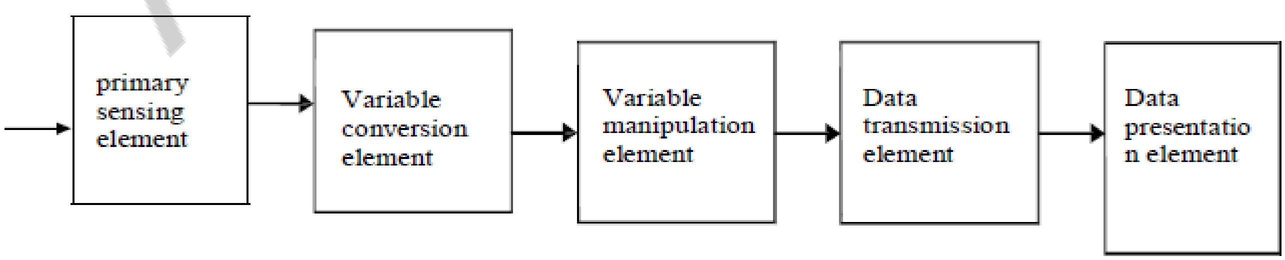
4. Explain the functional elements of Measurement system with neat block diagram. (Dec2014)

Most of the measurement systems contain three main functional elements. They are:

i) Primary sensing element

ii) Variable conversion element &

iii) Data presentationelement.



(i). Primary sensingelement:

The quantity under measurement makes its first contact with the primary sensing element of a measurement system. i.e., the measurand- (the unknown quantity which is to be measured) is first detected by primary sensor which gives the output in a different analogous form This output is then converted into an e electrical signal by a transducer - (which converts energy from one form to another). The first stage of a measurement system is known as a detector transducer stage.

(ii). Variable conversion element:

The output of the primary sensing element may be electrical signal of any form it may be voltage, a frequency or some other electrical parameter
For the instrument to perform the desired function, it may be necessary to convert this output to some other suitable form.

Variable manipulation element:

The function of this element is to manipulate the signal presented to it preserving the original nature of the signal. It is not necessary that a variable manipulation element should follow the variable conversion element. Some non -linear processes like modulation, detection, sampling, filtering, chopping etc, are performed on the signal to bring it to the desired form to be accepted by the next stage of measurement system This process of conversion is called signal conditioning.

The term signal conditioning includes many other functions in addition to Variable conversion & Variable manipulation In fact the element that follows the primary sensing element in any instrument or measurement system is called conditioning element.

Note: When the elements of an instrument are actually physically separated, it becomes necessary to transmit data from one to another. The element that performs this function i s called a data transmission element.

(iii). Data presentationelement:

The information about the quantity under measurement has to be conveyed to the personnel handling the instrument or the system for monitoring, control, or analysis purposes. This function is done by data presentation element

In case data is to be monitored, visual display devices are needed These devices may be analog or digital indicating instruments like ammeters, voltmeters etc. In case data is to be recorded, recorders like magnetic tapes, high speed camera & TV equipment, CRT, printers may be used. For control & analysis purpose microprocessor or computers may be used. The final stage in a measurement system is known as terminating stage.

5. Along with a diagram showing constructional features and derivation for the deflection torque developed, explain the working principle of a Permanent Magnet Moving Coil Type ammeter. What is the type of damping used in the meter? Given

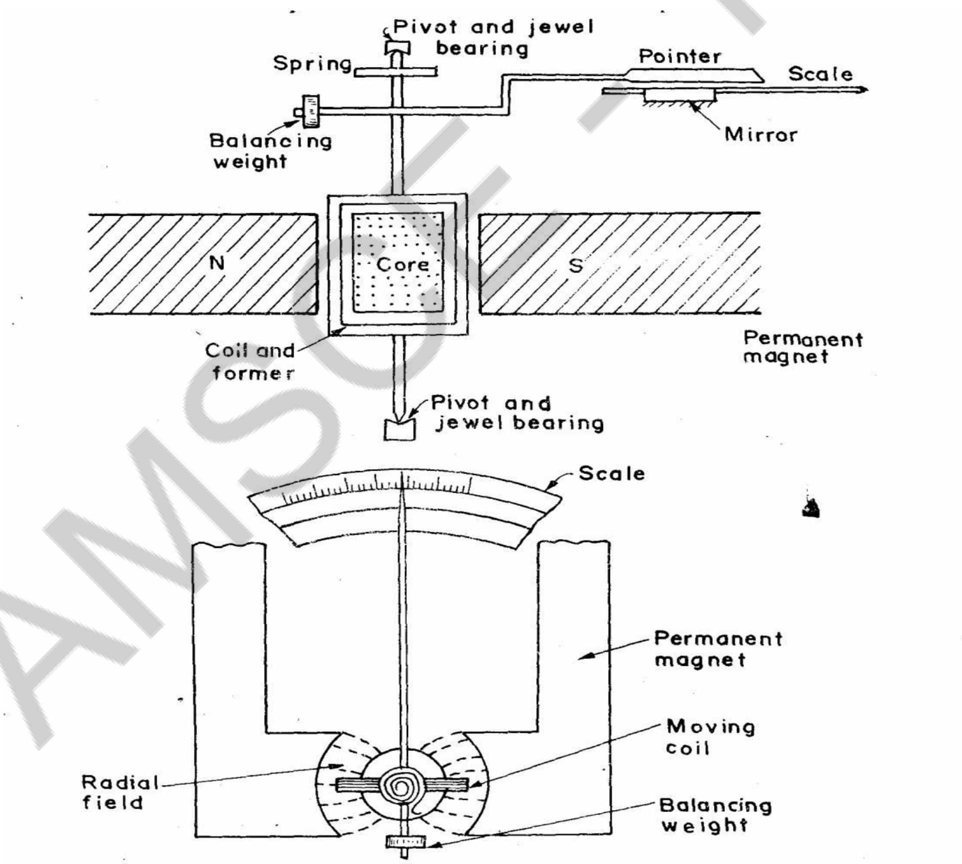
(0-0.1) A d.c ammeter, how would you obtain a multi-range d.c. voltmeter for ranges:(0-10)V,(0-30)V and (0-600)V? (Nov/Dec 2019)

The permanent magnet moving coil instrument is the most accurate type for d.c. measurements. The working principle of these instruments i s the same as that of the d' Arsonval type of galvanometers, the difference being that a direct reading instrument is provided with a pointer and a scale.

Construction of PMMC Instruments

The constructional features of this instrument are shown in Fig.

- The moving coil is wound with m any turns of enameled or silk covered copper wire.
- The coil is mounted on a rectangular aluminum former which is pivoted on jewelled bearings.
- The coils move freely in the field of a permanent magnet.
- Most voltmeter coils are wound on metal frames to provide the required electro-magnetic damping.
- Most ammeter coils, however, are wound on non –magnetic formers, because coil turns are effectively shorted by the ammeter shunt.
- The coil itself, therefore, provides electromagnetic damping.



Magnet Systems

- Old style magnet system consisted of relatively long U shaped permanent magnets having soft iron pole pieces.
- Owing to development of materials liken Alcomax and Alnico, which have a high co-ercive force, it is possible to use smaller magnet lengths and high field intensities.
- The flux densities used in PMIMC instruments vary from 0.1W b/m to 1Wb/m.

Control

- When the coil is supported between two jewel bearings the control torque is provided by two phosphor bronze hair springs.

- These springs also serve to lead current in and out of the coil. The control torque is provided by the ribbon suspension as shown.
- This method is comparatively new and is claimed to be advantageous as it eliminates bearing friction.

Damping

- Damping torque is produced by movement of the aluminium former moving in the magnetic field of the permanent magnet.

Pointer and Scale

- The pointer is carried by the spindle and moves over a graduated scale.
- The pointer is of light-weight construction and, apart from those used in some inexpensive instruments has the section over the scale twisted to form a fine blade.
- This helps to reduce parallax errors in the reading of the scale.
- When the coil is supported between two jewel bearings the control torque is provided by two phosphor bronze hair springs.
- These springs also serve to lead current in and out of the coil.

Torque Equation.

The torque equation of a moving coil instrument is given by

Deflecting torque $T_d = NB\ l\ dI = GI$

where G = a constant = $NB\ ld$

The spring control provides a restoring (controlling) torque $T_c = K\theta$

where K = spring constant.

For final steady deflection $T_c = T_d$ or $GI = K\theta$

$\therefore$ Final steady deflection $\theta = (G/K)\ I$

or current $I = (K/G)\ \theta$

As the deflection is directly proportional to the current passing through the meter (K and G being constants) we get a uniform (linear) scale for the instrument.

Multirange Voltmeter

ADC Voltmeter can be converted into a multirange voltmeter by connecting a number of resistors (multipliers) along with a range switch to provide a greater number of workable ranges.

Figure (1) shows a multirange voltmeter using a three-position switch and three multipliers R1, R2, and R3 for voltage values V1, V2, and V3.

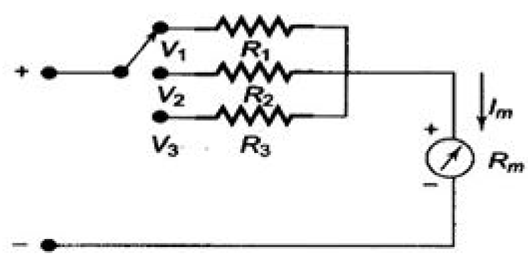
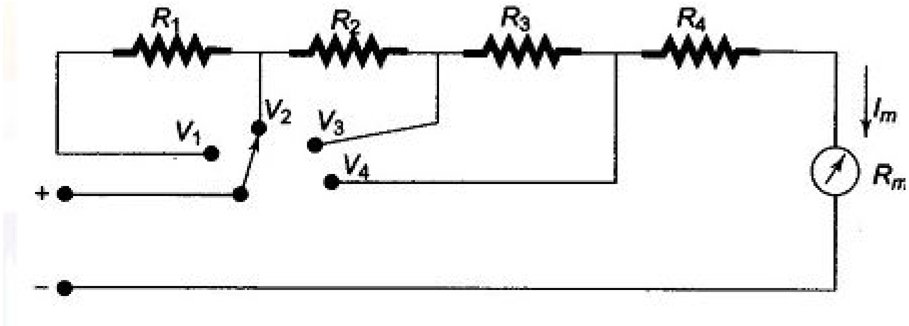


Figure (1) can be further modified to Fig(2) which is a more practical arrangement of the multiplier resistors of a multirange voltmeter.

In this arrangement, the multipliers are connected in a series string, and the range selector selects the appropriate amount of resistance required in series with the movement.

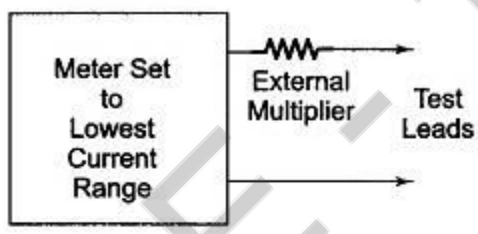


This arrangement is advantageous compared to the previous one, because all multiplier resistances except the first have the standard resistance value and are also easily available in precision tolerances:

The first resistor or low range multiplier, R4, is the only special resistor which has to be specially manufactured to meet the circuit requirements.

Extending Voltmeter Ranges

The range of a voltmeter can be extended to measure high voltages, by using a high voltage probe or by using an external multiplier resistor, as shown in Fig. 4.4. In most meters the basic movement is used on the lowest current range..



Extending Voltage Range

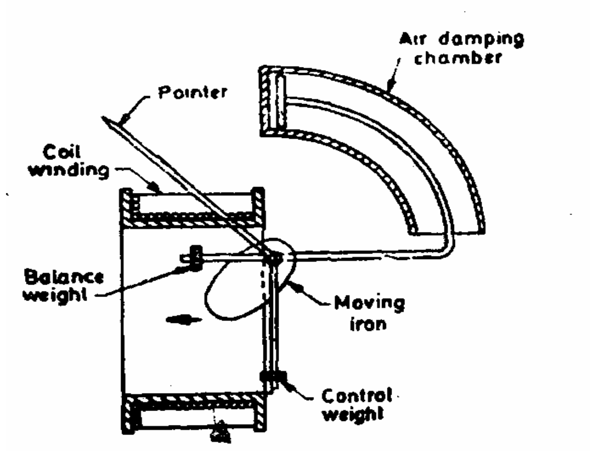
6. Elaborate the working of Moving iron instrument and derive the torque equation of the Moving iron instrument. (Apr/May2019)

Classification of Moving Iron Instruments
Moving iron instruments are of two types(i)Attraction type and (ii)Repulsion

Attraction Type

- The coil is flat and has a narrow slot like opening.
- The moving iron is a flat disc or a sector eccentrically mounted.
- When the current flows through the coil, a magnetic field is produced and the moving iron moves from the weaker field outside the coil to the
- Stronger field inside it or in other words the moving iron is attracted in.
- The controlling torque is providing by springs hut gravity control can be used for panel type of instruments which are vertically mounted.

Damping is provided by air friction with the help of a light aluminium piston (attached to the moving system) which move in a fixed chamber closed at one end as shown in Fig. or with the help of a vane (attached to the moving system) which moves in a fixed sector shaped chamber a shown



Repulsion Type

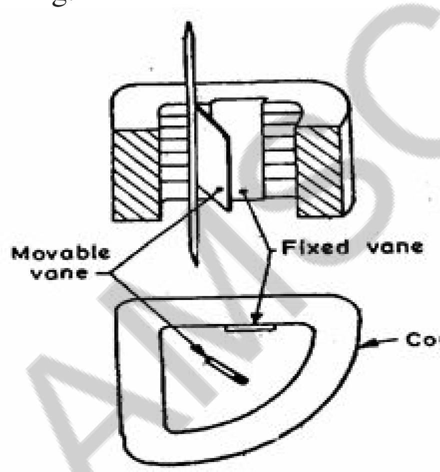
- In the repulsion type, there are two vanes inside the coil one fixed and other movable. These are similarly magnetized when the current flows through the coil and there is a force of repulsion between the two vane s resulting in the movement of the moving vane.
- Two different designs are in common use
  Radial vane type. (b) Co-axial vane type

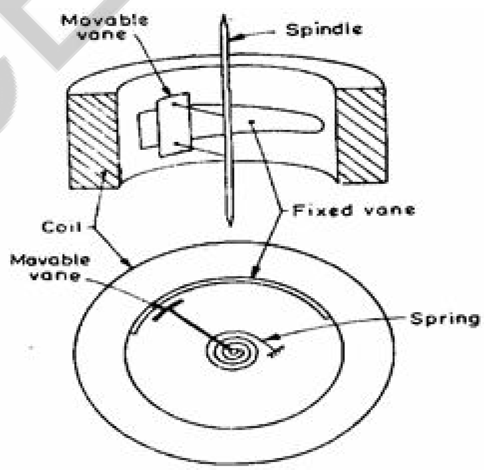
(i). Radial Vane Type

In this type, the vanes are radial strips of iron.
The strips are placed within the coil as shown in Fig.
The fixed vane is attached to the coil and the movable one to the spindle of the instrument.

(ii) Co-axial Vane Type

In this type of instrument, the fixed and moving vanes are sections of co axial cylinders as shown in Fig.





- The controlling torque is provided by springs. Gravity control can also he used in vertically mounted instruments. The damping torque is produced by air friction as in attraction type instruments.
- The operating magnetic field in moving iron instruments is very weak and therefore eddy current damping is not used in them as introduction of a permanent magnet required for eddy current damping would destroy the operating magnetic field.
- It is clear that whatever may be the direction of the current in the coil of the instrument, the iron vanes are so magnetized that there is always a force of attraction in the attraction type and repulsion in the repulsion type of instruments.
- Thus moving iron instruments are unpolarized instruments i.e., they are independent of the direction in which the current passes.
- Therefore, these instruments can be used on both ac. and d.c.

Torque Equation of Moving Iron Instrument:

An expression for the torque moving iron instrument may be derived by considering the energy relations when there is a small increment in current supplied to the instrument. When this happens there will be a small deflection dș a mechanical work will be done. Let Td be the deflecting torque.

Mechanical work done = Td. dș

Alongside there will be a change in the energy stored in the magnetic field owing to change in inductance.

Suppose the initial current is I, the instrument inductance L and the deflection ș. If the current is increased by di then the deflection changes by dș and the inductance by dL. In order to affect an increment the current there must be an increase in the applied voltage given by

$$e = \frac{d}{dt}(LI) = I\frac{dL}{dt} + L\frac{dI}{dt}.$$

The electrical energy supplied $eIdt = I^2dL + ILdI$

The stored energy changes from $= \frac{1}{2}I^2 L$ to $\frac{1}{2}(I + dI)^2(L + dL)$.

Hence the change in stored energy $\frac{1}{2}(I^2 + 2IdI + dI^2)(L + dL) - \frac{1}{2}I^2L$.

Neglecting second and higher order terms in small quantities this becomes $ILdI + \frac{1}{2}I^2dL$

From the principle of the conservation of energy,

Electrical energy supplied = increase in stored energy + mechanical work done

$$I^2dL + ILdI = ILdI = \frac{1}{2}I^2dL + T_d d\theta$$

Thus $$T_d\, d\theta = \frac{1}{2}I^2dL$$

or Deflecting torque $$T_d = \frac{1}{2}I^2\frac{dL}{d\theta}$$

T is in newton-metre, I in ampere, L in henry, and θ in radian.

The moving system is provided with control springs and it turns the deflecting torque T_d is balanced by the controlling torque $T_c = K\theta$

where K = control spring constant ; Nm/rad, θ = deflection ; rad.

At equilibrium (or final steady) position, $T_c = T_d$ or $K\theta = \frac{1}{2}I^2\frac{dL}{d\theta}$

Hence the deflection is proportional to square of the rms value of the operating current. The deflecting torque is, therefore, unidirectional (acts in the same direction) whatever may be the polarity of the current.

7. Distinguish between Attraction and Repulsion Types moving iron meters.For an attraction type moving iron meter, derive an expression for the deflection torque.(Nov/Dec2019)

- In general, it may be said that attraction-type instruments possess the same advantages, and are subject to the limitations, described for the repulsion type.
- An attraction type instrument will usually have a lower inductance than the corresponding repulsion type instrument, and voltmeters will therefore be accurate over a wider range of frequency and there is a greater possibility of using shunts with ammeters.
- On the other hand, repulsion instruments are more suitable for economical production in manufacture, and a nearly uniform scale is more easily obtained; they are, therefore, much more common than the attraction type.

Note: For derivation Please refer the previous derivation

PART-C

1. Classify and explain the different errors of measurements. (Nov/Dec 14)

The types of errors are follows i) Gross errors ii) Systematic errors iii) Random errors

Gross Errors: The gross errors mainly occur due to carelessness or lack of experience of a human being. These errors also occur due to incorrect adjustments of instruments. These errors cannot be treated mathematically. These errors are also called personal errors.

Ways to minimize gross errors:

The complete elimination of gross errors is not possible but one can minimize them by the following ways:

• Taking great care while taking the reading, recording the reading & calculating the result.

• Without depending on only one reading, at least three or more readings must be taken preferably by different persons.

Systematic errors: A constant uniform deviation of the operation of an instrument is known as a Systematic error. The Systematic errors are mainly due to the short comings of the instrument & thecharacteristics of the material used in the instrument, such as defective or worn parts, ageing effects, environmental effects, etc.

Types of Systematic errors: There are three types of Systematic errors as:

i) Instrumental errors ii) Environmental errors iii) Observational errors

Instrumental errors: These errors can be mainly due to the following three reasons:
a) Short comings of instruments: These are because of the mechanical structure of the instruments. For example friction in the bearings of various moving parts; irregular spring tensions, reductions in due to improper handling, hysteresis, gear backlash, stretching of spring, variations in air gap, etc.

Ways to minimize this error:

These errors can be avoided by the following methods:

a) Selecting a proper instrument and planning the proper procedure for the measurement recognizing the effect of such errors and applying the proper correction factors calibrating the instrument carefully against a standard

b) Misuse of instruments: A good instrument if used in abnormal way gives misleading results. Poor initial adjustment, Improper zero setting, using leads of high resistance etc., are the examples of misusing a good instrument. Such things do not cause the permanent damage to the instruments but definitely cause the serious errors.

c) Loading effects Loading effects due to improper way of using the instrument cause the serious errors. The best example of such loading effect error is connecting a well calibrated volt meter across the two points of high resistance circuit. The same volt meter connected in a low resistance circuit gives accurate reading.

Ways to minimize this error: Thus the errors due to the loading effect can be avoided by using an instrument intelligently and correctly.

Environmental errors: These errors are due to the conditions external to the measuring instrument. The various factors resulting these environmental errors are temperature changes, pressure changes, thermal emf, ageing of equipment and frequency sensitivity of an instrument. **Ways to minimize this error**:

The various methods which can be used to reduce these errors are:

i) Using the proper correction factors and using the information supplied by the manufacturer of the instrument

ii) Using the arrangement which will keep the surrounding conditions Constant

iii) Reducing the effect of dust, humidity on the components by hermetically sealing the components in the instruments

iv)The effects of external fields can be minimized by using the magnetic or electrostatic shields or screens

v) Using the equipment which is immune to such environmental effects.

Observational errors: These are the errors introduced by the observer. These are many sources of observational errors such as parallax error while reading a meter, wrong scale selection, etc. **Ways to minimize this error** To eliminate such errors one should use the instruments with mirrors, knife edged pointers, etc.,

The systematic errors can be subdivided as static and dynamic errors. The static errors are caused by the limitations of the measuring device while the dynamic errors are caused by the instrument not responding fast enough to follow the changes in the variable to be measured. **Random errors**: Some errors still result, though the systematic and instrumental errors are reduced or atleast accounted for. The causes of such errors are unknown and hence the errors are called random errors. Ways to minimize this error The only way to reduce these errors is by increasing the number of observations and using the statistical methods to obtain the best approximation of the reading.

2. Explain the concept of static evaluation of measurement data? (April/may 2011)

(OR)

How is the statistical analysis of measurement data form performed? (May/June 2013)

Statistical Evaluation Of Measurement Data

Out of the various possible errors, the random errors cannot be determined in the ordinary process of measurements. Such errors are treated mathematically the mathematical analysis of the various measurements is called statistical analysis of the data'. For such statistical analysis, the same reading is taken number of times, generally u sing different observers, different instruments & by different ways of measurement. The statistical anlysis helps to determine analytically the uncertainty of the final test results.

Arithmetic mean& median: When the n umber of readings of the same measurement are taken, the most likely value from the set of measured value is the arithmetic mean of the number of readings taken. The arithmetic mean value can be mathematically obtained as,

$$\overline{X} = \frac{X_1 \quad X_2 \quad .... \quad Xn}{n}$$

This mean is very close to true value, if number of readings is very large. But when the number of readings is large, calculation of mean value is complicated. In such a case, a median value is obtained which is obtained which is a close approximation to the arithmetic mean value. For a set of Qmeasurements X1, X2, X3. Xn written down in the ascending order of magnitudes, the median value is given by,

Xmedian=X (n+1)/2

Average deviation: The deviation tells us about the departure of a given reading from the arithmetic mean of the data set di=xi- ¯X Where di = deviation of ith reading Xi= value of ith reading ¯X = arithmetic mean The average deviation is defined as the sum of the absolute values of deviations divided by the number of readings. This is also called mean deviation **Standard Deviation:** The standard deviation, or root mean square deviation of a sample is both mathematically more convenient and statistically more meaningful for analyzing grouped data than is the average deviation. By definition, the standard deviation of a sample is given by **Variance:** It is the mean square deviation, which is the same as standard deviation, except that square root is not extracted. V=(standard deviation)2 =d1 2+ d1 2+ d1 2+……. d1 2 /n =∑d2 /n When the number of observations is less than 20, Variance V=∑d2

n – 1

Unit-2

ELECTRICAL AND ELECTRONIC INSTRUMENTS

Principle and types of multi meters – Single and three phase watt meters and energy meters – Magnetic measurements – Determination of B-H curve and measurements of iron loss – Instrument transformers – Instruments for measurement of frequency and phase.

PART-A

1. What is creeping in energy meter? How it is prevented? (MAY/JUN 2012)

Or

What is creeping in an induction type energy meter? How is it avoided? (Nov/Dec2019)

A slow but continuous rotation of the energy meter disc system even when there is no current flowing though the coil but only the pressure coil is energized is called as creeping. It can be prevented by drilling two diametrically opposite holes in the disc which makes the disc comes to rest with one of the holes under the edge of a pole of the shunt magnet.

2. 2.Why the PMMC instruments are not used for AC measurements? (NOV/DEC 14)

When the PMMC instruments are connected to AAC, the torque reverses as the current reverses and the pointer cannot follow the rapid reversals. Hence the deflection corresponding to mean torque is zero thus making the PMMC instrument not suitable for AC measurements.

3. Which torque is absent in energy meter? Why? (NOV 2009)

In energy meter, there is no controlling torque, as the driving torques is enough to cause continuous revolution of the disc.

4. State the purpose of shunts in the voltmeter (APR/MAY 11)

When an ammeter is needed to measure currents of having large magnitudes a proportion of the current is diverted through a low value resistance connected in parallel with the meter. Such a diverting type of resistor is referred to as shunt. The milli ammeter is converted into voltmeter by connecting a resister series with the meter called multiplier.

5. Classify different types of iron loss. (APR/MAY 11)

• Eddy current • Hysteresis losses

6. Explain with example the term hysteresis. (Nov/Dec 12)

Hysteresis is the phenomenon which depicts different output effects when loading and unloading in any system, whether it is a electrical system or a mechanical system.

7. How does one extend the range of ammeter and voltmeter? (Nov/Dec 2011)

Voltmeter is extended by adding resistance in series with it whereas ammeter is extended by connecting resistance in parallel with it.

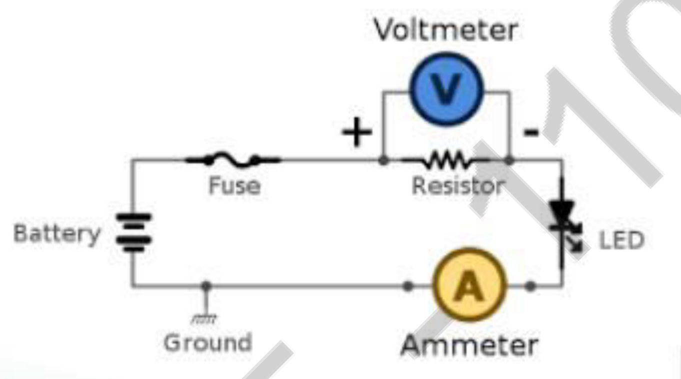
8. How we do the ballistic test? (Nov/Dec 2011)

Or

How the flux density is measured? (Apr/May 2019)

These tests are generally employed for the determination of B- H curves and hysteresis loops of Ferro-magnetic materials.

9. Draw the circuit of a basic dc voltmeter. (May/June 2013)



10. What are the different types of torque produced in PMMC instrument?(Dec 2009)

• Deflection torque • Controlling Torque • Damping Torque

11. What are the advantages of digital multimeter?

• Highly accurate • Loading effect is Nil • Easily portable • Very Cheap • Easy to interface

12. Why ordinary watt meters are not suitable in places of LPF circuits? (Dec 2010)

• The deflecting torque is very small due to low power factor • Errors due to induction coil is large due to low power factor

13. What are the components of 'Iron loss'?(Nov/Dec2019)

Iron losses consist of three components namely eddy currents loss, hysteresis loss, and anomalous loss.

14. Specify the use of copper shading bands. Where it is placed in the energy meter? (Apr/May2019)

Copper shading rings are provided on the central limb of the shunt magnet to make the phase angle displacement between magnetic field set up by shunt magnet and supply voltage is approximately 90^o . The copper shading bands are also called the power factor compensator or compensating loop.

PART-B

1. Along with constructional diagram and derivation for the torque developed discuss the working principle of an induction disc type single-phase energy meter.Also explain how braking torque is obtained in it.(Nov/Dec2019)

Or

Describe the functional operation of energy meter.(Apr/May2011)

The construction and principle of operation of Single Phase Energy Meters is explained below

Construction of Induction Type Energy Meters

There are four main parts of the operating mechanism

(i) Driving system

(ii) Moving system

(iii) Braking system

(iv) Registering system

Driving system

- The driving system of the meter consists of two electro-magnets.
- The core of these electromagnets is made up of silicon steel laminations. The coil of one of the electromagnets is excited by the load current. This coil is called the current coil.
- The coil of second electromagnet is connected across the supply and, therefore, carries a current proportional to the supply voltage. This coil is called the pressure coil.
- Consequently the two electromagnets are known as series and shunt magnets respectively.
- Copper shading bands are provided on the central limb. The position of these bands is adjustable.
- The function of these bands is to bring the flux produced by the shunt magnet exactly in quadrature with the applied voltage.

Moving System

- This consists of an aluminum disc mounted on a light alloy shaft.
- This disc is positioned in the air gap between series and shunt magnets. The upper bearing of the rotor (moving system) is a

steel pin located in a hole in the bearing cap fixed to the top of the shaft.

- The rotor runs on a hardened steel pivot, screwed to the foot of the shaft. The pivot is supported by a jewel bearing.
- A pinion engages the shaft with the counting or registering mechanism.

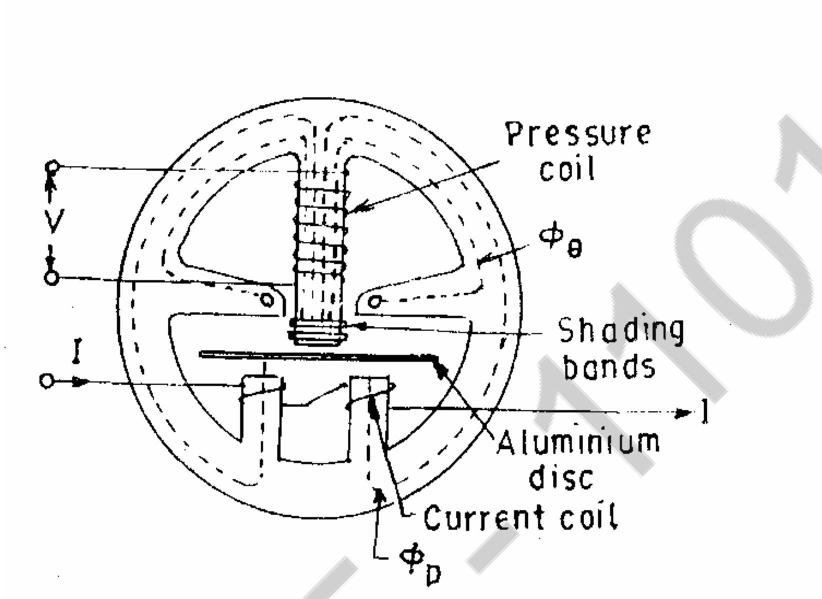
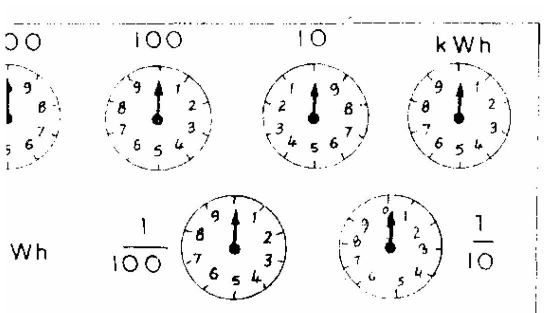
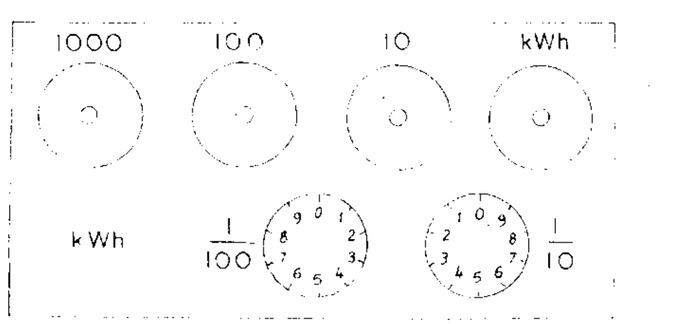


Fig 1.Single phase energy meter

Braking System

- A permanent magnet positioned near the edge of the aluminium disc forms the braking system. The aluminium disc moves in the field of this magnet and thus provides a braking torque.
- The position of the permanent magnet is adjustable, and therefore braking torque can be adjusted by shifting the permanent magnet to different
- radial positions as explained earlier.





(fig) Pointer type (fig) cyclometer register

Registering (counting) Mechanism

- The function of a registering or counting mechanism is to record continuously a number which is proportional to the revolutions made by the moving system. By a suitable system, a train of reduction gears the pinion on the rotor shaft drives a series of five or six pointers.
- These rotate on round dials which are marked with ten equal divisions.
- The pointer type of register is shown in Fig. Cyclo-meter register as shown in Fig can also be used.

Working Principle:

The basic working of Single phase induction type Energy Meter is only focused on two mechanisms:

1. Mechanism of rotation of an aluminum disc which is made to rotate at a speed proportional to the power.
2. Mechanism of counting and displaying the amount of energy transferred.

Torque equation

Let us study theory behind the working.

Let V = Supply voltage

I_2 = Current through pressure coil proportional to V

ϕ_2 = Flux produced by I_2

I_1 = Current through current coil i.e. load

ϕ_1 = Flux produced by I_1

Now I_2 lags V by 90° as pressure coil is highly inductive and copper shading bands. And ϕ_2 and I_2 are in phase. While I_1 lags V by ϕ where ϕ is decided by the load connected. The flux ϕ_1 and I_1 are in phase.

The phasor diagram is shown in the Fig 3.6.2.

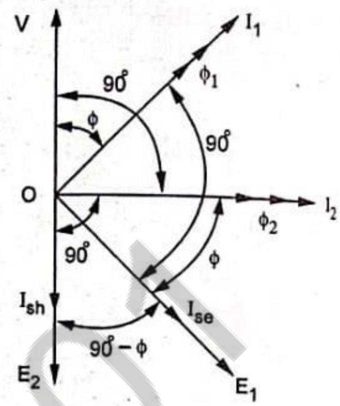


Fig. 3.6.2

E_1 = Induced e.m.f. in disc due to ϕ_1

E_2 = Induced e.m.f. in disc due to ϕ_2

I_{sh} = Eddy current due to E_1

I_{se} = Eddy current due to E_2

The induced e.m.f. lags the respective flux producing it by 90°. The eddy currents are in phase with the induced e.m.f. producing them.

Now there is interaction between ϕ_1 and I_{sh} which produces torque T_1 and the interaction between ϕ_2 and I_{se} which produces torque T_2 .T_2 is in opposite direction to T_1. Hence net deflecting torque is,

$$T_d \propto T_2 - T_1$$

$$\propto \phi_2 I_{se} \cos\left(\phi_2 \wedge I_{se}\right) - \phi_1 I_{sh} \cos\left(\phi_2 \wedge I_{sh}\right)$$

Now $\phi_2 \wedge I_{se} = \phi$ and $\phi_1 \wedge I_{sh} = \phi$ from Fig 2.18.2

$$\therefore \quad T_d \propto \phi_2 I_{se} \cos\phi - \phi_1 I_{sh} \cos(180-\phi)$$

$$\therefore \quad T_d \propto \phi_2 I_{se} \cos\phi + \phi_1 I_{sh} \cos\phi$$

As $\cos(180-\phi_1) = -\cos\phi$

But $\phi_2 \propto I_2 \propto V$, $I_{se} \propto E_1 \propto I_1$, $\phi_1 \propto I_1$, $I_{sh} \propto E_2 \propto I_2 \propto V$

$$\therefore \quad T_d \propto K_1 V I_1 \cos\phi + K_2 I_1 V \cos\phi$$

$$\therefore \quad T_d \propto (K_1+K_2) V I_1 \cos\phi$$

$$\therefore \quad \boxed{T_d \propto V I_1 \cos\phi \quad \text{i.e. power consumed by load.}}$$

Now braking torque is proportional to speed N with which disc rotates.

$$\therefore \quad \boxed{T_b \propto N}$$

2. Describe the step by process involved in determination of B-H curve and hysteresis loop.(Apr/May2019),(Apr/May2014)

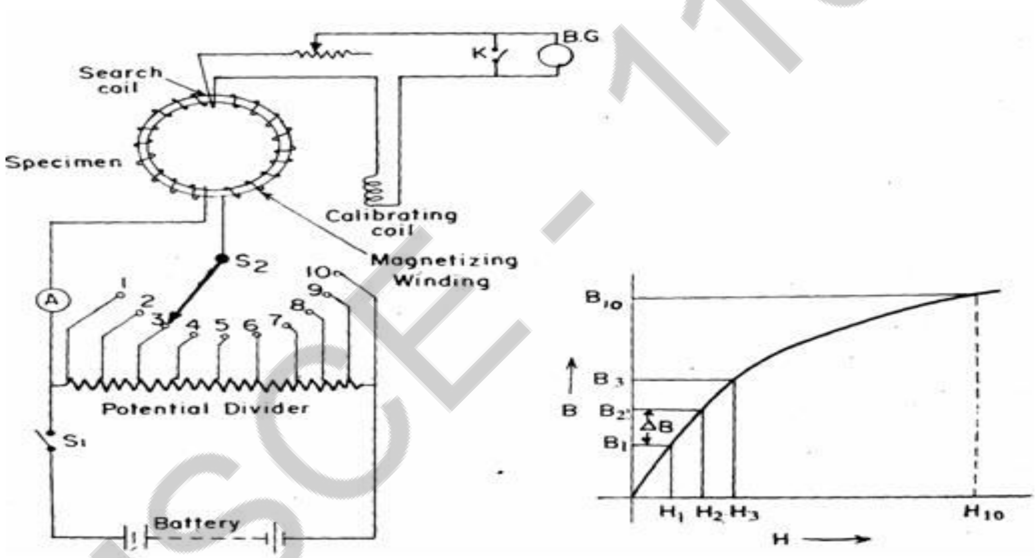
Method of reversals

- A ring shaped specimen whose dimensions are known is used for the purpose
- After demagnetizing the test is started by setting the magnetising current to its lowest test value.
- With galvanometer key K closed, the iron specimen is brought into a ‘reproducible cyclic magnetic state’ by throwing the reversing switch S backward and forward about twenty times. Key K is now opened and the value of flux corresponding to this value of H is measured by reversing the switch S and noting the throw of galvanometer.
- The value of flux density corresponding to this H can be calculated by dividing the flux by the area of the specimen.

- The above procedure is repeated for various values of H up to the maximum testing point.
- The B-H curve may be plotted from the measured values of B corresponding to the various values of H.

Step by step method

- The circuit for this test is shown in Fig below.
- The magnetizing winding is supplied through a potential divider having a large number of tapping. The tappings are arranged so that the magnetizing force H may be increased, in a number of suitable steps, up to the desired maximum value. The specimen before being tested is demagnetized.
- The tapping switch S is set on tapping I and the switch S is closed. The throw of the galvanometer corresponding to this increase in flux density in the specimen, from zero to some value B, is observed.
- After reaching the point of maximum H i.e... when switch S is at tapping 10, the magnetizing current is next reduced, in steps to zero by moving switch 2 down through the tapping points 9, 8, 7 3, 2, 1. After reduction of magnetizing force to zero, negative values of H are obtained by reversing the supply to potential divider and then moving the switch S up again in order 1, 2, 3 7, 8. 9, 10.



Method of reversals

This test is done by means of a number of steps, but the change in flux density measured at each step is the change from the maximum value + Bm down to some lower value.

But before the next step is commenced the iron specimen is passed through the remainder of the cycle of magnetization back to the flux density + Bm. Thus the cyclic state of magnetization is preserved.

The connections for the method of reversals are shown in Fig.

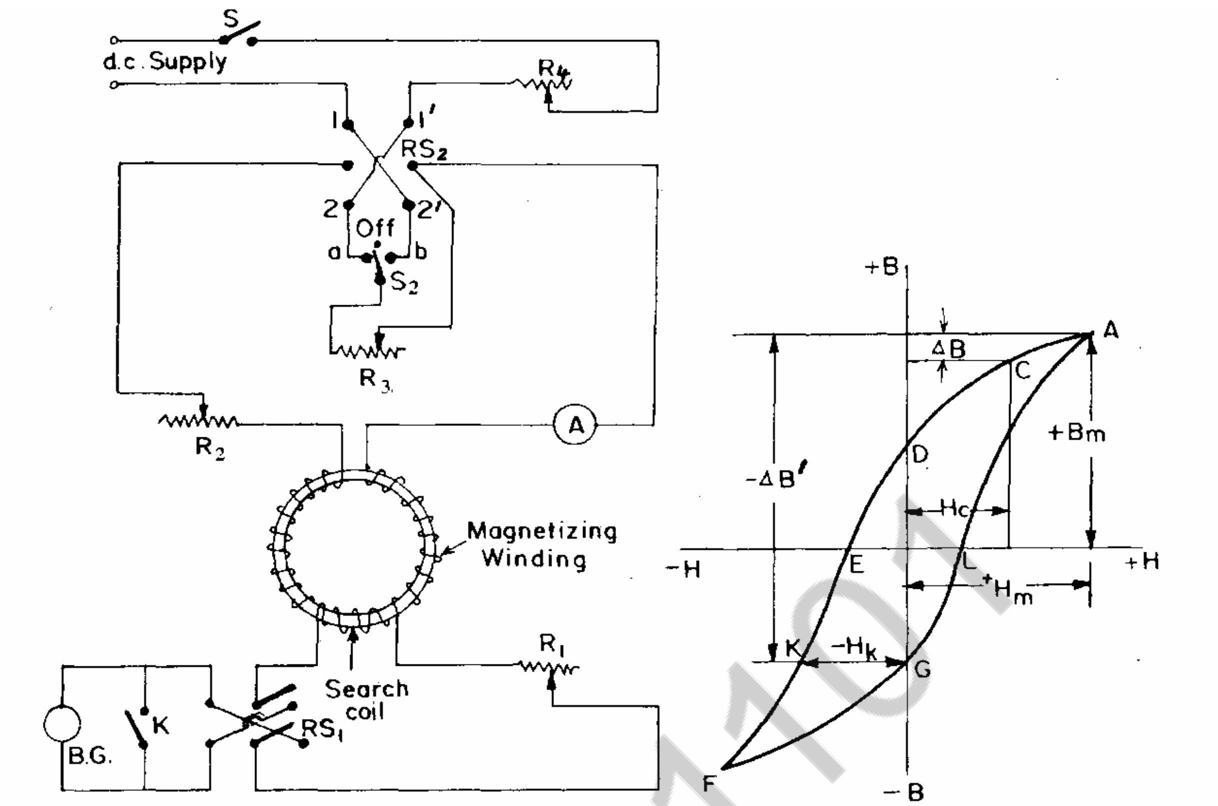


Fig Method of reversal

3. State Blondel's theorem and explain how the power measurement using two wattmeter method.(Apr/May2019)

   The theorem states that the power provided to a system of N conductors is equal to the algebraic sum of the power measured by N watt-meters. The N watt-meters are separately connected such that each one measures the current level in one of the N conductors and the potential level between that conductor and a common point. In a further simplification, if that common point is located on one of the conductors, that conductor's meter can be removed and only N-1 meters are required.

   Two Wattmetermethod:

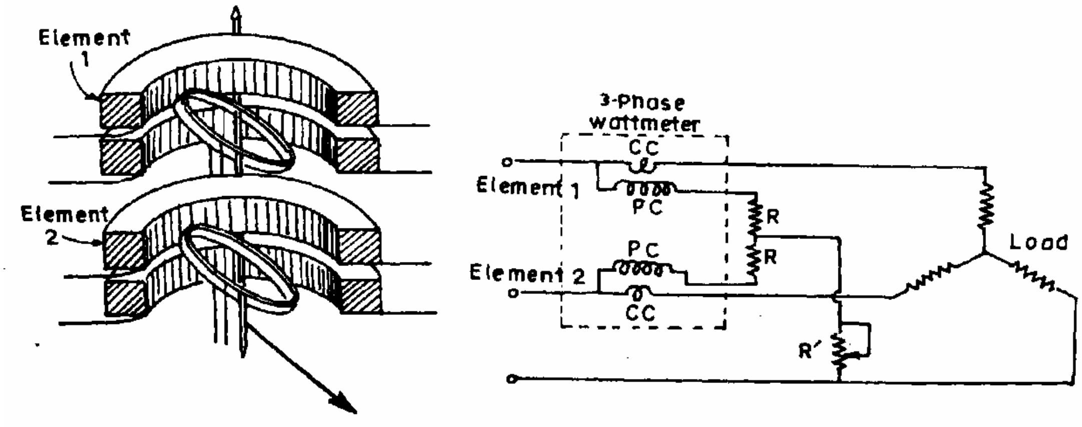
   A dynamometer type three-phase wattmeter consists of two separate wattmeter movements mounted together in one case with the two moving coils mounted on the same spindle.

   The arrangement is shown in Fig.

   - There are two current coils and two pressure coils.
   - A current coil together with its pressure coil is known as an element.

- Therefore, a three phase wattmeter has two elements.
- The connections of two elements of a 3 phase wattmeter are the same as that for two wattmeter method using two single phase wattmeter.
- The torque on each element is proportional to the power being measured by it. The total torque deflecting the moving system is the sum of the deflecting torque of' the two elements.
- Hence the total deflecting torque on the moving system is proportional to the total Power.
- In order that a 3 phase wattmeter read correctly, there should not be any mutual interference between the two elements.

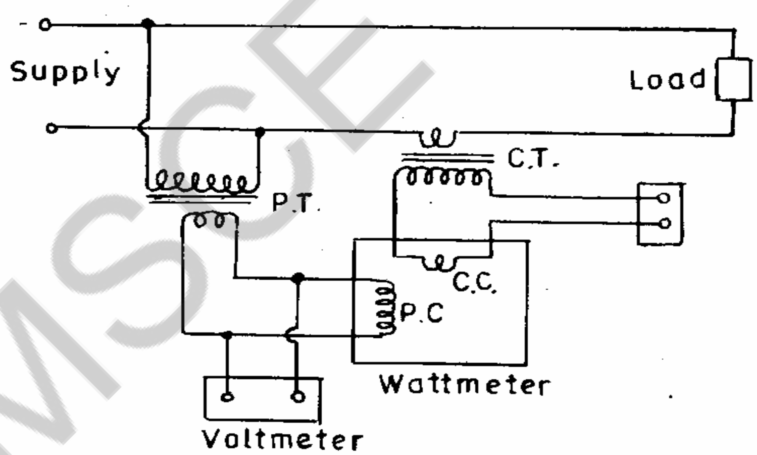
- A laminated iron shield may be placed between the two elements to eliminate the mutual



effects.

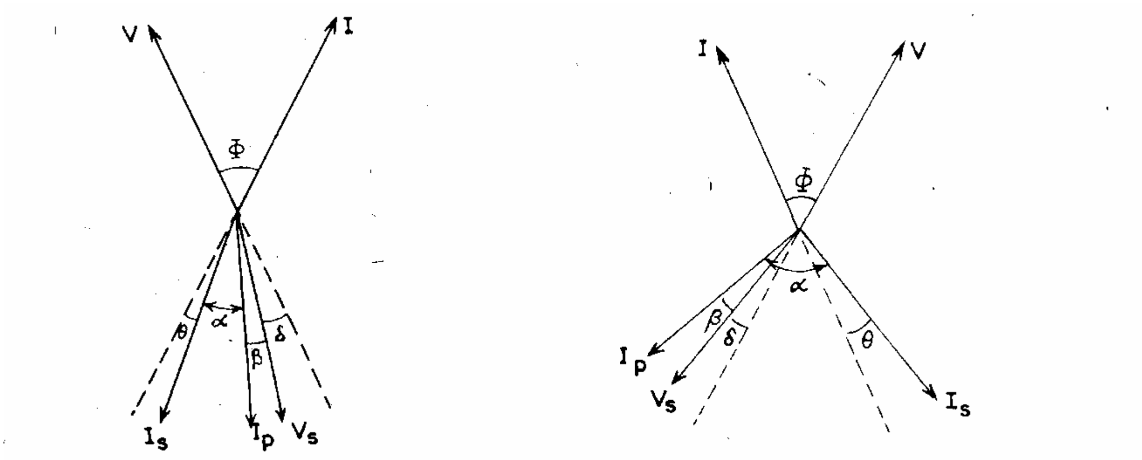
4. Explain in detail the Instrument Transformer with a neat sketch.(Apr/May 2014)

- Power measurements are made in high voltage circuits connecting the wattmeter to the circuit through current and potential transformers as shown.
- The primary winding of the C.T. is connected in series with the load and the secondary winding is connected in series with an ammeter and the current coil of a wattmeter.
- The primary winding of the potential transformer is connected across the supply lines and a voltmeter and the potential coil circuit of the wattmeter are connected in parallel with the secondary winding of the transformer. One secondary terminal of each transformer and the casings are earthed.



- The errors in good modem instrument transformers are small and may be ignored for many purposes. However, they must be considered in precision work. Also in some power measurements these errors, if not taken into account, may lead to very inaccurate results.
- Voltmeters and ammeters are affected by only ratio errors while wattmeters are influenced in addition by phase angle errors. Corrections can be made for these errors if test information is available about the instrument transformers and their burdens.

Phasor diagrams for the current and voltages of load, and in the wattmeter coils.



(a) (b)

PART-C

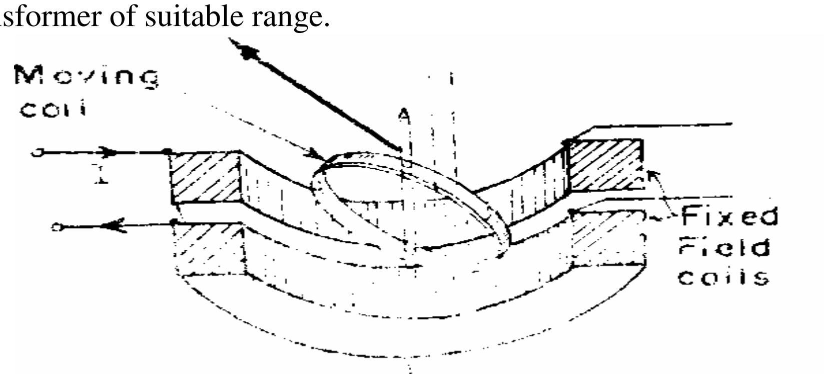
1. Explain about the working principle of electrodynamometer type instrument.(Nov/Dec2013)

Electrodynamometer Wattmeters

- These instruments are similar in design and construction to electrodynamometer type ammeters and voltmeters.
- The two coils are connected in different circuits for measurement of power.
- The fixed coils or " field coils" arc connected in series with the load and so carry the current in the circuit.
- The fixed coils, therefore, form the current coil or simply C.C. of the wattmeter.
- The moving coil is connected across the voltage and, therefore, carries a current proportional to the voltage.
- A high non-inductive resistance is connected in series with the moving coil to limit the current to a small value.
- Since the moving coil carries a current proportional to the voltage, it is called the ''pressure coil'' or "voltage coil" or simply called P.C. of the wattmeter.

Construction of Electrodynamometer Wattmeter Fixed coils

- The fixed coils carry the current of the circuit. They are divided into two halves.
- The reason for using fixed coils as current coils is that they can be made more massive and can be easily constructed to carry considerable current since they present no problem of leading the current in or out.
- The fixed coils are wound with heavy wire. This wire is stranded or laminated especially when carrying heavy currents in order to avoid eddy current losses in conductors. The fixed coils of earlier wattmeters were designed to carry a current of 100 A but modem designs usually limit the maximum current ranges of wattmeters to about 20 A. For power measurements involving large load currents, it is usually better to use a 5 A wattmeter in conjunction with a current transformer of suitable range.



(Fig) Dynamometer wattmeter

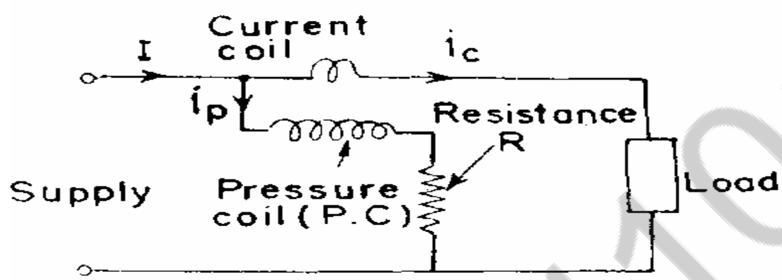
Damping

- Air friction damping is used.
- The moving system carries a light aluminium vane which moves in a sector shaped box. Electromagnetic or eddy current damping is not used as introduction of a permanent magnet (for damping purposes) will greatly distort the weak operating magnetic field.

Scales and Pointers

- They are equipped with mirror type scales and knife edge pointers to remove reading errors due to parallax.

Theory of Electrodynamometer Watt-meters



(Fig) circuit of electrodynamometer

It is clear from above that there is a component of power which varies as twice the frequency of current and voltage (mark the term containing 2Ȧt).

Average deflecting torque

$$T_d = \frac{1}{T}\int_0^T T_i \; d\,(\omega t) = \frac{1}{T}\int_0^T I_p \, I \, [\cos\phi - \cos(2\omega t - \phi)] \, \frac{dM}{d\theta} \, . \, d\,(\omega t)$$
$$= I_p \, I \cos\phi \, . \, dM/d\theta$$
$$= (VI/R_p)\cos\phi \, . \, dM/d\theta$$

Controlling torque exerted by springs Tc= KșWhere, K = spring constant; ș= final steady deflection.

Unit-3

COMPARATIVE METHODS OF MEASUREMENTS

D.C potentiometers, D.C (Wheat stone, Kelvin and Kelvin Double bridge) & A.C bridges (Maxwell, Anderson and Schering bridges), transformer ratio bridges, self-balancing bridges. Interference & screening–Multiple earth and earth loops-Electrostatic and electromagnetic Interference–Grounding techniques.

PART-A

1. Write the necessary balance conditions for a Schering bridge. (Nov/Dec 12)
 Rx = R3 *R4 2C4 R4 2 C2 RX = R3C4 R3 CX = R4 C2 R3
2. Define transformer Ratio Bridge.
 The transformer ratio bridges are replacing the conventional AC bridges which consist of voltage transformer whose performance approaches that of an ideal transformer.
3. Define interference.
 The instruments used for electrical measurements are in an environment which contains many sources of electrical and magnetic energy. These sources can produce undesirable signals called interference.
4. What is the need for screening? (Apr/May15)
 Screening is a process of preventing EM radiation from coupling into or leaking out of defined areas, or regions.
5. What are the applications of potentiometers? (Nov/Dec13)
 a) Calibration of voltmeter
 b) Calibration of ammeter
 c) Calibration of wattmeter
 d) Measurement of resistance
 e) Measurement of power
6. How does Hay's bridge differ from Maxwell's bridge? What is its uniqueness? (May/Jun13) The difference in Maxwell's bridge and Hay's bridge is that the Hay's bridgeconsists of resistance R1 in series with standard capacitor C1 in one of the ratio arms. Hence for larger phase angle, R1 needed is very low, which is practicable. Hence bridge can be used for the coils with high values
7. Which instrument is used for measuring very high resistance found in cable insulations? (May/Jun13)
 Kelvin Bridgewas used for measuring very high resistance found in cable insulations.
8. List the applications of ac bridge.(April/May 2011)
 Measurement of inductance, capacitance, storage factor, loss factor may be made conveniently and accurately by employing ac bridge network
9. Enumerate the principle of grounding. .(April/may 2011)
 The Shielding and grounding of bridge is one way of reducing the effect of stray capacitances. But this technique does not eliminate the stray capacitances but makes them constant in value and hence they can be compensated.
10. Which bridge is used to measure incremental inductance? (Nov/Dec 2011)
 Hay's bridge is used to measure incremental inductance.
11. Define the term standardization of potentiometer.(Nov/Dec 2009)
 Before putting the potentiometer in in use it is standardized by the adjustment of current from the supply battery by direct reading.
12. What are the advantages of Kelvin's double Bridge?
 The effect of lead and contact resistance is completely eliminated and it is mainly designed for measurement of very low resistance.

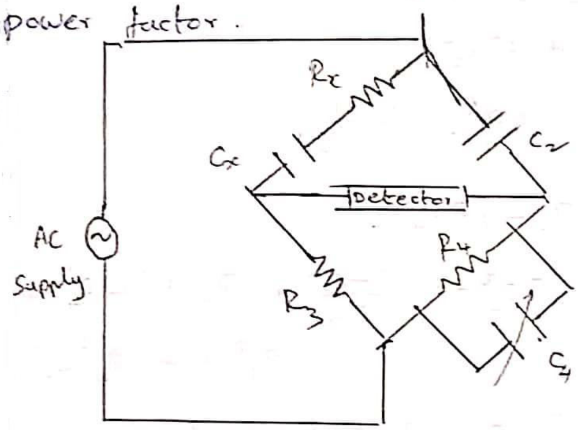
13. How does ‘Loading effect’ cause error in a D.C potentiometer based measurements?(Nov/Dec2019).
    When we measure the output voltage of potentiometer by a voltmeter and every voltmeter has its resistance which produces erroneous readings and hence loading effect occurs in the potentiometer.
14. How are the measuring instruments protected from electrostatic and electromagnetic interference?(Nov/Dec2019)
    By providing proper shielding and grounding electrostatic and electromagnetic interference are reduced and instruments are protected.
15. Specify the purpose of Wagner earthing device.(Apr/May2019)
    The Wagner earthing device is used for removing the earth capacitance from the bridges. It is a type of voltage divider circuit used to reduce the error which occurs because of stray capacitance. The Wagner Earth device provides high accuracy to the bridge.
16. How Maxwell’s bridge differ from Anderson bridge, although both are used for measuring inductance?(Apr/May2019).
    The lower the Q-factor of the coil the more accurate the Anderson Bridge will operate. Anderson Bridge is a modification of Maxwell-inductance Capacitance Bridge and is known to be the most accurate bridge for the measurement of self – inductance over a wide range of values, from a few micro-Henries to several Henries

PART-B

1. Derive the expression for measurement of unknown capacitance with a neat bridge circuit.(Apr/May2019)

Schering Bridge:-

It is one of the most widely used a.c. bridges for the measurement of unknown capacitors, dielectric loss and power factor.



$$Z_1 Z_4 = Z_2 Z_3$$

$$Z_1 = R_x - j\frac{1}{\omega C_x} \quad ; \quad Z_2 = \frac{-j}{\omega C_2}$$

$$Z_3 = R_3 \quad ; \quad Z_4 = R_4 \parallel \frac{-j}{\omega C_4}$$

$$= \frac{R_4\left(\frac{-j}{\omega C_4}\right)}{\left(R_4 - j\frac{1}{\omega C_4}\right)}$$

$$= \frac{-jR_4}{\omega R_4 C_4 - j} \times \frac{(\omega R_4 C_4 + j)}{\omega R_4 C_4 + j}$$

$$\therefore Z_4 = \frac{R_4 - j\omega R_4^2 C_4}{\omega^2 R_4^2 C_4^2 + 1}$$

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

$$= \frac{\left(\frac{-j}{\omega C_2}\right) R_3}{\left(\frac{R_4 - j\omega R_4^2 C_4}{1+\omega^2 R_4^2 C_4^2}\right)}$$

$$= \frac{(1+\omega^2 R_4^2 C_4^2) R_3 \left(\frac{-j}{\omega C_2}\right)}{(R_4 - j\omega R_4^2 C_4)}$$

$$= (1+\omega^2 R_4^2 C_4^2)\left(\frac{-j}{\omega C_2}\right) \times \frac{R_4 + j\omega R_4^2 C_4}{R_4^2 + \omega^2 R_4^4 C_4^2}$$

$$R_x - j\frac{1}{\omega C_x} = \frac{R_3(1+\cancel{\omega^2 R_4^2 C_4^2})}{R_4^2(1+\cancel{\omega^2 R_4^2 C_4^2})} \cdot \left(\frac{R_4^2 C_4}{C_2} - \frac{jR_4}{\omega C_2}\right)$$

Equating real & imaginary parts

$$R_x = \frac{R_3}{R_4^2} \times \frac{R_4^2 C_4}{C_2} = \frac{R_3 C_4}{C_2}$$

$$-j\frac{1}{\omega C_x} = -j\frac{R_3}{R_4^2} \times \frac{R_4}{\omega C_2} = -j\frac{R_3}{\omega R_4 C_2}$$

$$\omega C_x = \frac{\omega R_4 C_2}{R_3}$$

$$\boxed{\therefore C_x = \frac{R_4 C_2}{R_3}}$$

Power factor & Loss angle :-

i) Power factor :-

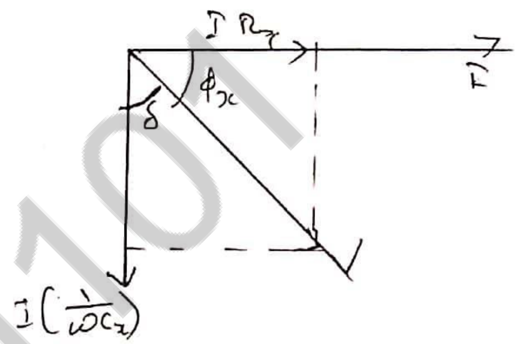
The power factor of the series RC combination is defined as the cosine of the phase angle of the circuit. Thus,

$$p.f = \cos\phi_x = \frac{R_x}{Z_x}$$

For phase angles very close to 90°,

$$p.f = \frac{R_x}{X_x} = \frac{R_x}{\left(\frac{1}{\omega C_x}\right)}$$

$$\boxed{\therefore p.f = \omega R_x C_x}$$



(ii). Loss angle :-

For a series combination of R_x & C_x, the angle b/w the voltage across the series combination & voltage across the capacitor C_x is called loss angle (δ).

$$\tan\delta = \frac{IR_x}{I\left(\frac{1}{\omega C_x}\right)} = \omega R_x C_x$$

$$\tan\delta = \omega\left(\frac{R_3 C_4}{C_2}\right)\left(\frac{R_4}{R_3} C_2\right) = R_4 C_4 \omega$$

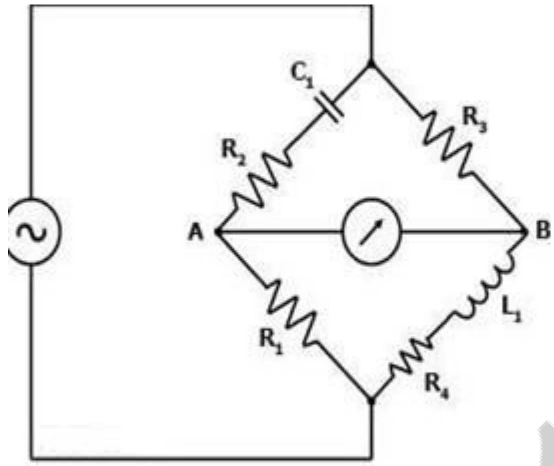
iii). Dissipation factor :-

$$D = \cot\phi_x = \frac{1}{\tan\phi_x} = \omega R_4 C_4$$

The Quality factor $Q = \frac{X}{R} = \frac{1}{\omega R_4 C_4}$

2. Derive the expression for measurement of unknown inductance using Hays bridge.(Apr/May2019)

A Hay Bridge is an AC bridge circuit used for measuring an unknown inductance by balancing the loads of its four arms, one of which contains the unknown inductance. One of the arms of a Hay Bridge has a capacitor of known characteristics, which is the principal component used for determining the unknown inductance value. Figure 1 below shows a diagram of the Hay Bridge.



Explanation

- One arm of the Hay Bridge consists of a capacitor in series with a resistor (C1 and R2) and another arm consists of an inductor L1 in series with a resistor (L1 andR4).
- The other two arms simply contain a resistor each (R1 and R3). The values of R1and R3 are known, and R2 and C1 are both adjustable.
- The unknown values are those of L1 and R4.
- Like other bridge circuits, the measuring ability of a Hay Bridge depends on 'balancing'the Circuit.
- Balancing the circuit in Figure 1 means adjusting R2 and C1 until the current through the ammeter between points A and B becomes zero. This happens when the voltages at points A and B areequal.
- When the Hay Bridge is balanced, it follows that Z1/R1 = R3/Z2 wherein Z1 is the impedance of the arm containing C1 and R2 while Z2 is the impedance of the arm containing L1 andR4

  Thus, $Z1 = R2 + 1/(2\pi fC)$ while $Z2 = R4 + 2\pi fL1$. $[R2 + 1/(2\pi fC1)] / R1 = R3 / [R4 + 2\pi fL1]$;

  Or

  $[R4 + 2\pi fL1] = R3R1 / [R2 + 1/(2\pi fC1)]$;

  Or

  $R3R1 = R2R4 + 2\pi fL1R2 + R4/2\pi fC1 + L1/C1$

- When the bridge is balanced, the reactive components are equal, so

  $2\pi fL1R2 = R4/2\pi fC1$,

  Or

  $R4 = (2\pi f)\, 2L1R2C1$.

- Substituting R4, one comes up with the following equation:

  $R3R1 = (R2+1/2\pi fC1)\, ((2\pi f)\, 2L1R2C1) + 2\pi fL1R2 + L1/C1$;

  Or

  $L1 = R3R1C1 / (2\pi f)\, 2R22C12 + 4\pi fC1R2 + 1)$;

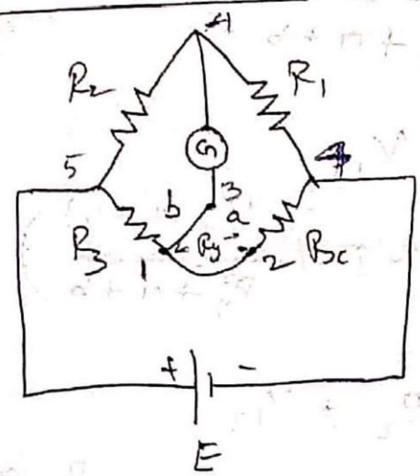
  $L1 = R3R1C1 / [1 + (2\pi fR2C1)2]$

  :

- $L1 = R3R1C1 / [1 + (2\pi fR2C1)2]$; and
- $R4 = (2\pi fC1)2R2R3R1 / [1 + (2\pi fR2C1)2]$

3. For a Kelvin's double bridge, obtain expressions for the bridge balance conditions.(Nov/Dec2019)

Kelvin's Double Bridge :-



This bridge consists of another set of ratio arms hence called double bridge.

The second set of ratio arms is the resistance a and b.

$E_{45} = E_{513}$

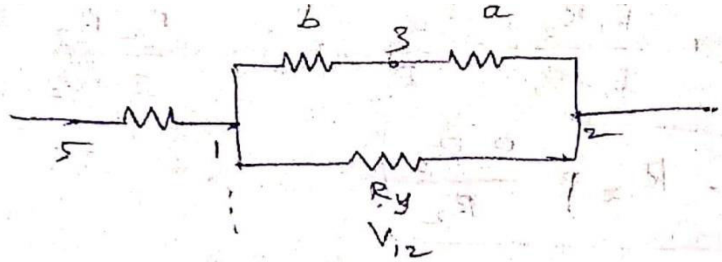
$E_{45} \Rightarrow$ potential across R_2

$E_{513} \Rightarrow$ Potential across R_3 & b.

The ratio of the resistances a & b is same as the ratio of R_1 & R_2.

$$\therefore \frac{a}{b} = \frac{R_1}{R_2}$$

$$E_{45} = R_2 \frac{E}{R_1 + R_2}$$



$$V_{12} = I \cdot \left(\frac{R_y (a+b)}{R_y + a + b} \right)$$

$$\& \quad V_{13} = \frac{b}{a+b} V_{12}$$

$$V_{13} = \frac{b}{a+b} \times I \cdot \left(\frac{R_y (a+b)}{R_y + a + b} \right)$$

$$\therefore E_{513} = I R_3 + V_{13}$$

$$= I R_3 + \frac{b}{a+b} \times I \times \frac{R_y (a+b)}{R_y + a + b}$$

$$E_{45} = E_{513}$$

$$\frac{I R_2}{R_1 + R_2} \left[R_3 + R_x + \frac{(a+b) R_y}{a+b+R_y} \right] = I \left[R_3 + \frac{b}{a+b} \left[\frac{R_y (a+b)}{R_y + a + b} \right] \right]$$

$$\therefore R_x = \frac{R_1 R_3}{R_2} + \frac{b R_y}{R_y + a + b} \left(\frac{R_1}{R_2} - \frac{a}{b} \right)$$

$$\frac{a}{b} = \frac{R_1}{R_2} \quad \therefore \frac{R_1}{R_2} - \frac{a}{b} = 0$$

$$\therefore R_x = \frac{R_1 R_3}{R_2}$$

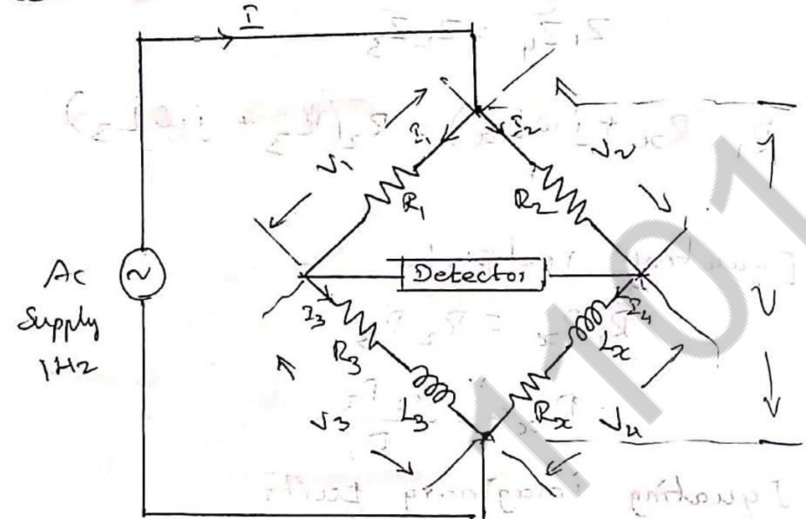
This is the std equation of the bridge balance, a, b, R_y → not present. This the effect of lead & contact resistances is completely eliminated.

4. Along with relevant phasor diagram under balance conditions and derivation of expression for balance condition, explain how Maxwell's bridge is useful for measurement of an unknown inductance? (Nov/Dec2019)

Maxwell's Bridge :-

Maxwell's bridge can be used to measure inductance by comparison either with a variable std self inductance or with a std variable capacitance.

Maxwell's Inductance Bridge :-



At balance,

$$\frac{R_1}{(R_3+r)+j\omega L_3} = \frac{R_2}{R_x+j\omega L_x}$$

$$R_1(R_x+j\omega L_x) = R_2((R_3+r)+j\omega L_3)$$

$$R_1R_x+j\omega R_1L_x = R_2(R_3+r)+j\omega R_2L_3$$

Equating imaginary terms,

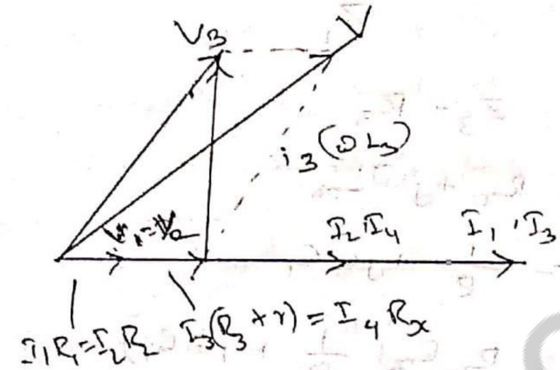
$$R_x L_x = R_2 L_3$$

$$\boxed{\therefore L_x = \frac{R_2 L_3}{R_1}}$$

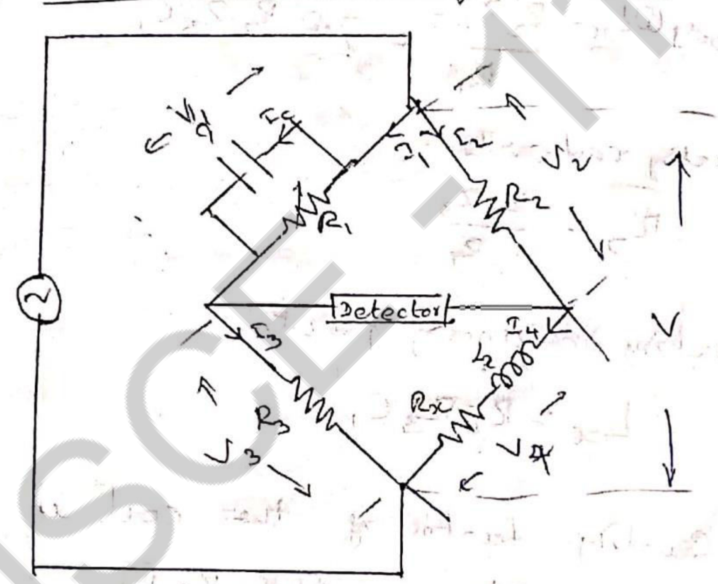
Equating real terms,

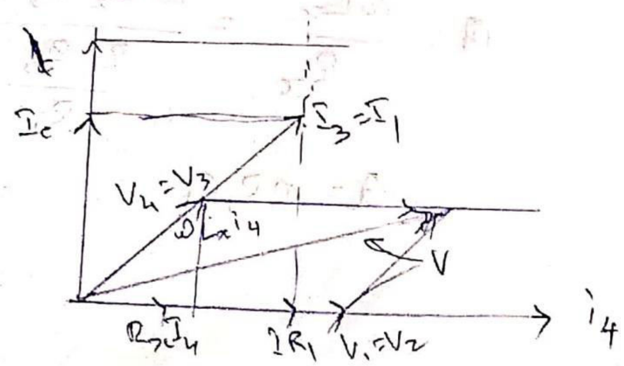
$$R_1 R_x = R_2 (R_3 + r)$$

$$\therefore R_x = \frac{R_2}{R_1}(R_3 + r)$$



Maxwell's Inductance Capacitance Bridge :-





The general balance equation is

$$\bar{Z_1 Z_x} = \bar{Z_2 Z_3}$$

$$Z_x = \frac{\bar{Z_2}\bar{Z_3}}{\bar{Z_1}} = \bar{Z_2 Z_3 Y_1}$$

$\bar{Z_2} = R_2$; $\bar{Z_3} = R_3$

$$Z_x = R_x + j\omega L_x$$

$$Y_1 = \frac{1}{R_1} + j\omega C_1$$

$$R_x + j\omega L_x = R_2 R_3 \left(\frac{1}{R_1} + j\omega C_1\right)$$

$$R_x + j\omega L_x = \frac{R_2 R_3}{R_1} + j\omega R_2 R_3 C_1$$

Equating real parts

$$\boxed{R_x = \frac{R_2 R_3}{R_1}}$$

Equating imaginary part

$$\boxed{L_x = R_2 R_3 C_1}$$

The Quality factor of the coil is

$$Q = \frac{\omega L_x}{R_x} = \frac{\omega R_2 R_3 C_1}{\frac{R_2 R_3}{R_1}}$$

$$\boxed{\therefore Q = \omega R_1 C_1}$$

5. Write a detail note on ‘transformer ratio bridges’.(Nov/Dec2019)
The transformer Ratio Bridges are becoming increasingly popular and are being used

for a wide range of applications. This is on account of versatility and accuracy of Ratio Transformers, which are used in the transformer ratio bridges. In fact, transformer ratio bridges are replacing the conventional ac bridges at a rapid rate. In this, we will discuss transformer Ratio Bridge working principle.A transformer ratio bridge consists of voltage transformer whose performance approaches that of an transformer. An ideal transformer is one that has no resistance, no core loss and no leakage flux (i.e., there is perfect coupling between the windings).The ratio transformer is provided with a number of tappings in order to obtain voltage division.

Transformer Ratio Bridges Working Principle:

The below figure shows an autotransformer provided with tappings. Suppose an alternating voltage E is applied across the winding. Assuming that the autotransformer is ideal type, the division of applied voltage E into output voltages E1 and E2 is :

$$E1 = E.\ N1/N \quad \text{and} \quad E2 = E.\ N2/N$$

Voltage appearing across the windings of a transformer is :

$E = 4\ Kf\ N\ \varphi m\ f$ volt where N = number of turns

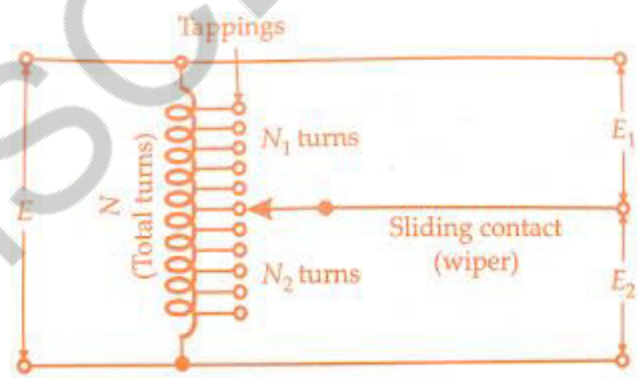
φm = maximum value of flux ; Wb,

f = frequency ; Hz,

Kf = form sector ,(Its value is 1.11 for sinusoidal flux).

For a given value of K flux φm and frequency f,

$$E = K1N$$

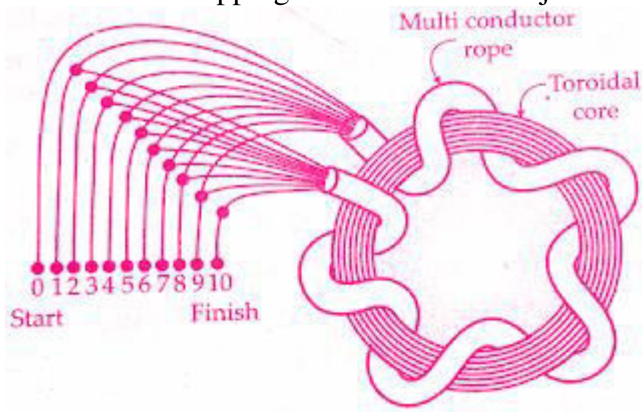


ifferent values of E1 and E2 may be had by changing the position of the wiper on the tappings.

However, in practice, it is impossible to construct an ideal transformer. But the ideals of zero winding resistance, zero core loss and perfect coupling can be closely achieved if the design features similar to those for instrument transformers am used. The material used for the construction of core should be such that it gives the smallest core losses at the desired operating frequency.

The magnetizing current is reduced by using a Toroidal Core.The added advantage of a toroidal core is that winding put on it has minimum leakage reactance giving an almost perfect coupling. The leakage reactance can be reduced further by using a special type of construction for the windings as shown in the below figure of transformer ratio bridges.

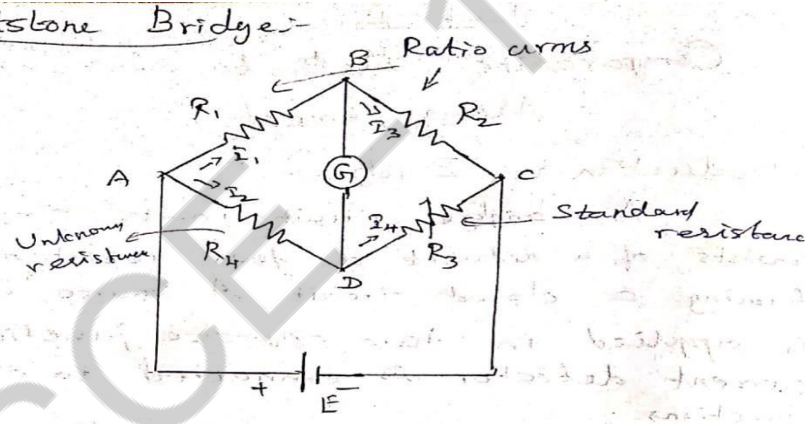
This winding takes the form of a Multiconductor Rope. In order to obtain a decade of voltage division, the multiconductor rope has ten wires with successive sets of turns connected in series and a tapping is taken from each joint.



The resistance of the windings can be reduced by using copper wire of heavy cross-section. A 4-decade ratio transformer is shown. The successive decades are obtained by using an arrangement similar to that in a Kelvin Varley slide.This transformer arrangement gives a ratio error of less than 1 part in 10^4.

6. Derive the expression for measurement of unknown resistance with Wheatstone bridge.

Wheatstone Bridge:-



The bridge consists of four resistive arms together with a source of emf & a null detector. The galvanometer is used as a null detector.

$R_1, R_2 \rightarrow$ Ratio arms

$R_3 \rightarrow$ std arm

$R_4 \rightarrow$ unknown resistance

Balance Condition:

When the bridge is balanced, the galvanometer carries zero current & it does not show any deflection.

$I_G = 0$; $I_1 = I_3$ & $I_2 = I_4$

$\Rightarrow I_1 R_1 = I_2 R_4$

$$I_1 = I_3 = \frac{E}{R_1 + R_2}$$

$$I_2 = I_4 = \frac{E}{R_3 + R_4}$$

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

$$R_1(R_3 + R_4) = R_4(R_1 + R_2)$$

$$R_1R_3 + \cancel{R_1R_4} = \cancel{R_4R_1} + R_4R_2$$

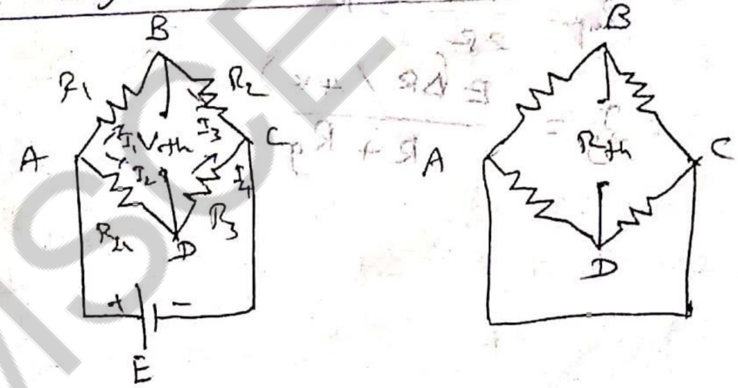
$$\boxed{\therefore R_4 = \frac{R_1 R_3}{R_2}}$$

Sensitivity of Wheatstone Bridge:

$$S = \frac{\text{Deflection}}{\text{Current}} = \frac{D}{I}$$

$$S_v = \frac{\theta}{e} = \frac{\text{Voltage across galvanometer}}{\text{Deflection}}$$

Wheatstone Bridge under Small Unbalance :-



$$E_{AB} = I_1 R_1 \quad ; \quad E_{AD} = I_2 (R_4 + \Delta R)$$

$$I_1 = \frac{E}{R_1 + R_2} \quad ; \quad I_2 = \frac{E}{R_3 + R_4 + \Delta R}$$

$$V_{BD} = V_{TH} = E_{AD} - E_{AB}$$

7. Explain Interference and Screening of Cables.
Interference is one of the most serious as well as most common problems in audio electronics. We encounter interference when it produces effects like noise, hiss, hum or cross-talk. If a radio engineer faces such problems, good theoretical knowledge as well as experience is required to overcome them.

However, it should be considered, that interference is always present. All technical remedies only aim at reducing the effect of interference to such a degree, that it is neither audible nor disturbing. This is mainly achieved by different ways of screening. This paper will explain the technical background of interference and provides some common rules and hints which may help you to reduce the problems.

TYPES OF INTERFERENCE.

Theoretically, the effects and mechanism of a single interference can well be calculated. But in practice, the complex coupling systems between pieces of equipment prevent precise prediction of interference. The following picture shows the different types of interference coupling. The different types of interference between the components of an electric system. If we consider all possible coupling paths in the diagram above we will find 10 different paths. This means a variety of 1024 different combinations. It should be noted, that not only the number of paths, but also their intensity is important.

SYMMETRICAL AND ASYMMETRICAL INTERFERENCE.

Having a closer look at the interference of cable, we find that hf-interference currents cause measurable levels on signal (audio) lines and on supply lines. A ground-free interference source would produce signals on a cable which spread along the line. These voltages and currents can be called symmetrical interference. In practice this rarely occurs.

Through interference, asymmetrical signals are produced in respect to the ground. The asymmetrical interference current flows along the two wires of the symmetrical line to the sink and via the ground back to the source. These interference signals are cancelled at the symmetrical input.

GALVANIC COUPLING OF INTERFERENCE.

Galvanic coupling of interference occurs if the source and the sink of interference are coupled by a conductive path.As can be seen from the equivalent circuit diagram, the source impedance of the interference consists of the resistance RC and the inductance LC of the conductor, which are common to the two parts of the circuit. From these elements the interference source voltage can be calculated.

CAPACITIVE COUPLING OF INTERFERENCE.

The capacitive coupling of interference occurs due to any capacitance between the source and sink of interference.

PRINCIPLE OF CAPACITIVE COUPLING OF INTERFERENCE.

The interference voltage in the sink is proportional to its impedance. Systems of high impedance are therefore more sensitive to interference than those of low impedance. The coupled interference current depends on the rate of change of the interference and on the coupling capacitance CC.

INDUCTIVE COUPLING OF INTERFERENCE.

Inductive coupling of interference occurs if the interference sink is in the magnetic field of the interference source (e.g. coils, cables, etc.)

Principle of the inductive coupling of interference.

The interference voltage induced by inductive coupling is

- increasing the distance between conductors
- mounting conductors close to conductive surfaces
- using short conductors
- avoiding parallel conductors
- screening
- using twisted cable

Note that by the same means the capacitive as well as the inductive coupling of interference will be reduced.

INTERFERENCE BY RADIATION.

Interference by electromagnetic radiation becomes important at cable lengths greater than 1/7 of the wavelength of the signals. At frequencies beyond 30Mhz, most of the interference occurs by e.m. radiation

INTERFERENCE BY ELECTROSTATIC CHARGE.

Charged persons and objects can store electrical charges of up to several micro- Coulombs, which means voltages of some 10kV in respect to ground. Dry air, artificial fabrics and friction favour these conditions.When touching grounded equipment, an instantaneous discharge produces arcing with short, high current pulses and associated strong changes of the e.m. field.

REDUCTION OF INTERFERENCE

There are a number of methods to prevent interference. But all of them only **reduce**

the interference and never fully prevent it. This means there will never be a system which is 100% safe from interference. Because the efforts and the cost will rise with the degree of reduction of interference, a compromise has to be found between the effort and the result.

The requirement for the reduction of interference will depend on:

- The strength of the interference source
- The sensitivity of the interference sink
- The problems caused by interference

We will discuss ways of preventing interference, their effect, and the main aspects for the optimum efficiency of each method.

SCREENING.

When considering the effect of electrical and magnetic fields, we have to distinguish between low and high frequencies. At high frequencies the skin effect plays an important roll for the screening. The penetration describes the depth from the surface of the conductor, where the current density has decayed to 37% compared to the surface of the conductor.

SCREENING OF CABLES.

When signal lines run close to interference sources or when the signal circuit is very sensitive to interference, screening of signal lines will give an improvement. There are different ways of connecting the cable screen:

Three different ways of connecting the cable screen. Cable screen not connected. This screen will not prevent any interference, because the charge on the screen, produced by interference, will remain and will affect the central signal line. Also, the current induced by interference in the line will flow through the sink, effecting the signal. Cable screen grounded on one side only. This screen will only prevent interference at low frequency signals. For electromagnetic interference, where the wavelength is short compared to the length of the cable, the screening efficiency is poor. Cable screen grounded on either sidet is effective for all kinds of interference. Any current induced in the screen by magnetic interference will flow to ground. The inner of the cable is not affected. Only the voltage drop on the screen will affect the signal in the screen. type of grounding is

- Ensure proper and careful connection of the screens.
- Use suitable plugs in connection with the cable screen.

UNIT-4

STORAGE AND DISPLAY DEVICES

Magnetic disk and tape–Recorders, digital plotters and printers, CRT display, digital CRO, LED, LCD & Dot matrix display–Data Loggers

PART-A

1. What are data loggers? (NOV/DEC 13)

The data loggers are used to automatically make a record of the readings of instruments located at different parts of the plant.

2.Define the deflection sensitivity of CRT.

The deflection sensitivity of a CRT is defined as the deflection of the screen per unit deflection voltage.

3. What are the different materials used in LED? Also name the colors emitted.

Gallium Arsenide phosphate, Gallium Arsenide and Gallium phosphide. It emits red, yellow and green colors.

4. Distinguish between LED & LCD.(Nov/Dec 13)

Parameter	**LED**	**Dynamic Scattering LCD**	**Field Effect LCD**
Power/Digit	10-140 mw depending on color	100μw	1 to 10 μw
Voltage	5V	18V	3 to 7V
Switching Speed	1 μs	300 ms	100 to 300ms
Colors	Red, orange, Yellow and Green	Depends on illumination	Depends on illumination

5. What are the various components of a recording instrument? (May/Jun13,Nov/Dec2019)
   - Recording head
   - Magnetic tape
   - Reproducing head
   - Tape transport mechanism
   - Conditioning devices.
6. Reason out why today's commercial LED monitor have become more popular than their LCD counterparts.(May/Jun 13)
   - Less power consumption
   - Low cost
   - Uniform brightness with good contrast
7. List any two storage devices.(April/may 2011)
   1) Bitable storage oscilloscopes
   2) fast storage oscilloscopes
   3) Digital storage oscilloscopes
8. Differentiate the functions of printer and plotter. (April/ May 2011)
   Printers are the most commonly used output devices today for producing hard copy output. Analog X-Y recorders are replaced by digital x-y recorders it is known as digital plotters .To measure the performance of the digital plotters are used.
9. How does dynamic scattering type LCD work? (Nov/Dec 2011)
   When not activated the transmittive type cell simply transmits the light through the cell in the straight lines. In this condition the cell will not appear bright .When the cell is activated, the

incident light is scattered forward and the cell appears quite bright even under high intensity light conditions

10. What are the advantage of magnetic tape recorder? (Nov/Dec 2011)
 i) Magnetic tape can be recorded over and reused repeatedly.
 ii) Large amounts of information is stored.
 iii) Magnetic tape is inexpensive and budget friendly.
11. What are the merits of digital storage oscilloscope?(May 2010)
    - Infinite storage time
    - Easy to operate
    - Signal processing is possible
    - Cursor measurement is possible
    - A number of traces depending on memory size can be stored& Recalled
12. What are the types of printers? (Dec 2009)
    - Drum& Chain printer
    - Dot matrix printer
    - Inkjet Printer
    - Laser Printer
13. List the Parts of Cathode Ray Tube(CRT).(Nov/Dec2019)
 The main parts of the CRT are
    - Electron gun
    - Deflection system
    - Fluorescent screen
    - Glass tube or envelope
    - Base
14. Specify the applications of data loggers.(Apr/May2019)
 Temperature sensor,Pressure sensor and unattended soil moisture level recording.
15. Mention the use of Lissajous patterns.(Apr/May2019)
 Lissajous patterns can be used to graphically illustrate the relationship between two waveforms. One waveform is entered along the X axis the other along the Y axis.

PART-B

1. Explain the Principle of working of Magnetic Tape Recorder. What are the basic components and their functions? (Apr/May2015)

Recorders

A recorder is a measuring instrument which records time varying quantity, even after the quantity or variable to be measured has stopped. The electrical quantities such as voltage & current are measured directly. The non- electrical quantities are recorded using indirect methods. The non- electrical quantities are first converted to their equivalent voltages or currents, using various transducers.

Electronic recorders may be classified as:

1. Analog recorders
2. Digital recorders

Analog recorders dealing with analog systems can be classified as

1. Graphic recorders
2. Oscillographicrecorders
3. Magnetic Tape recorders

Digital recorders dealing with digital output can be classified as

1. Incremental digital recorders and 2. Synchronous digital recorders

<u>Magnetic Disk AndTape</u>

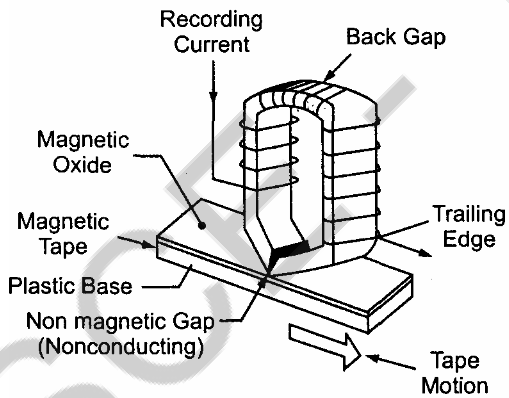
MagneticTapeRecorder

- The magnetic tape recorders are used for high frequency signal recording.
- In these recorders, the data is recorded in a way that it can be reproduced in electrical form any time.
- Also main advantage of these recorders is that the recorded data can be replayed for almost infinite times.
- Because of good higher frequency response, these are used in Instrumentation systems extensively.

- Basic Components of Tape Recorder
    1. Recording Head
    2. Magnetic Tape
    3. Reproducing Head
    4. Tape Transport Mechanism
    5. Conditioning Devices

Recording Head

The construction of the magnetic recording head is very much similar to the construction of a Transformer having a toroidal core with coil. There is a uniform fine air gap of 5µ m to 15µ m between the head and the magnetic tape.



- When the current used for recording is passed through coil wound around magnetic core, it produces magnetic flux.
- The magnetic tape is having iron oxide particles.
- When the tape is passing the head, the flux produced due to recording current gets linked with iron oxide particles onthemagnetictapeand theseparticlesgetmagnetized.
- This magnetization particle remains as it is, event Hough the magnetic tape leaves the gap. The actual recording takes placeat the trailing edgeof the air gap.
- Any signal is recorded in the form of thepatterns.
- These magnetic patterns are dispersed anywhere along the length of magnetic tape in accordancewith the variation in recording current with respect to time.

Magnetic Tape

- The magnetic tape is made of thin sheet of tough and dimensionally stable plastic ribbon. Ø One side of this plastic ribbon is coated by powdered iron oxide particles (Fe2O3) thick. Ø The magnetic tape is wound around areel.
- This tape is transferred from one reel to another.

- When the tape passes across air gap magnetic pattern is created in accordance with variation of recordingcurrent.
- To reproduce this pattern, the same tape with some recorded pattern is passed across another magnetic head in which voltage isinduced.
- This voltage induced is in accordance with the magnetic pattern.

Reproducing Head

- The use of the reproducing head is to get the recorded data played back.
- The working of the reproducing head is exactly opposite to that of the recording head.
- The reproducing head detects the magnetic pattern recorded on the tape.
- The head converts the magnetic pattern back to the original electrical signal. Ø In appearance, both recording and reproducing heads are very much similar.

Tape Transport Mechanism

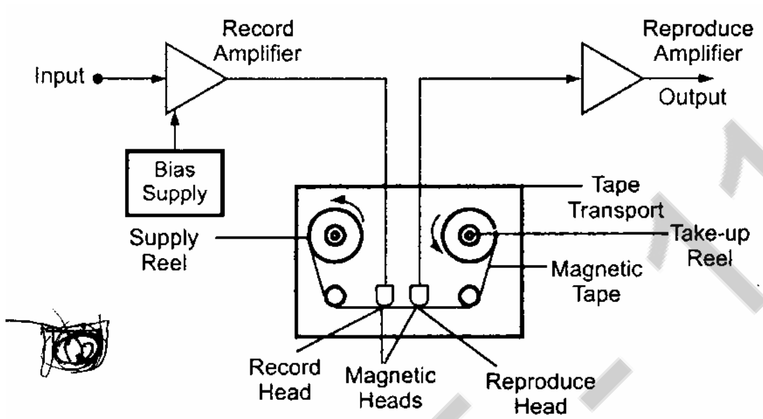


Fig Basic Tape Recorder Mechanism.

- The tape transport mechanism moves the magnetic tape along the recording head or reproducing head with a constant speed
- The tape transport mechanism must perform following tasks. It must handle the tape without straining and wearing it.
- It must guide the tape across magnetic heads with great precision. It must maintain proper tension of magnetic tape.
- It must maintain uniform and sufficient gap between the tape and heads.
- The magnetic tape is wound on reel.
- There are two reels; one is called as supply & other is called as take-upreel. Ø Both the reels rotate in samedirection.
- The transportation of the tape is done by using supply reel and take-up reel.
- The fast winding of the tape or the reversing of the tape is done by using special arrangements.
- The rollers are used to drive and guide the tape.

Conditioning Devices

- These devices consist of amplifiers and fitters to modify signal to be recorded.
- The conditioning devices allow the signals to be recorded on the magnetic tape with proper format.
- Amplifiers allow amplification of signal to be recorded and filters removes unwanted ripple quantities.

Principle of Tape Recorders

- When a magnetic tape is passed through a recording head, the signal to be recorded appears as some magnetic pattern on the tape.
- This magnetic pattern is in accordance with the variations of original recording current.

- The recorded signal can be reproduced back by passing the same tape through a reproducing head where the voltage is induced corresponding to the magnetic pattern on the tape.
- When the tape is passed through the reproducing head, the head detects the changes in the magnetic pattern i.e. magnetization.
- The change in magnetization of particles produces change in the reluctance of the magnetic circuit of the reproducing head, inducing a voltage in itswinding.
- The induced voltage depends on the direction of magnetization and its magnitude on the tape.
- Theemf,thusinducedisproportionaltotherateofchangeof magnitudeofmagnetization

i.e.e =N(dĭ/ dt)

Where N = number of turns of the winding on reproducing head Ǽ = magnetic flux produced.

Supposethe signal to be recorded is Vm sin Ǔt. Thus, the current in the recording head and flux induced will be proportional to this voltage.

It is given by e= k 1. Vm sin wt, where k1 = constant.

Above pattern of flux is recorded on the tape. Now, when this tape is passed through the reproducing head, above pattern is regenerated by inducing voltage in the reproducing head winding.

It is given by e= k2 ǓVm cos wt

Thus, the reproducing signal is equal to derivative of input signal& it is proportional to flux recorded & frequency of recorded signal.

2. Explain in detail about LED and LCD displays. (Apr/May2019)

LED (Light Emitting Diode)

LED's are special diodes that emit lightwhenconnected in a circuit. They are frequentlyused as "pilot" lights in electronic appliances to indicate whether the circuitis closed or not. A a clear (or often colored) epoxy case enclosed the heart of an LED, the semi-conductorchip.

The two wires extending below the LED epoxy enclosure, or the "bulb" indicate how the LED should be connected into a circuit. The*negative*sideof an LED lead is indicated in two ways: 1) by the *flat side* of the bulb, and 2) by the *shorter* of thetwowiresextending from theLED. The negative lead should be connected to the negative terminal of a battery. LED's operate at relative low voltages between about 1 and 4 volts, and draw currents between about 10 and 40 *milli*amperes. Voltages and currents substantially above these values can melt a LEDchip.

The most important part of a *light emitting diode (LED)* is the semi-conductor chiplocated in the center of the bulb as shown at the right. The chiphas two regions separated by a *junction.*

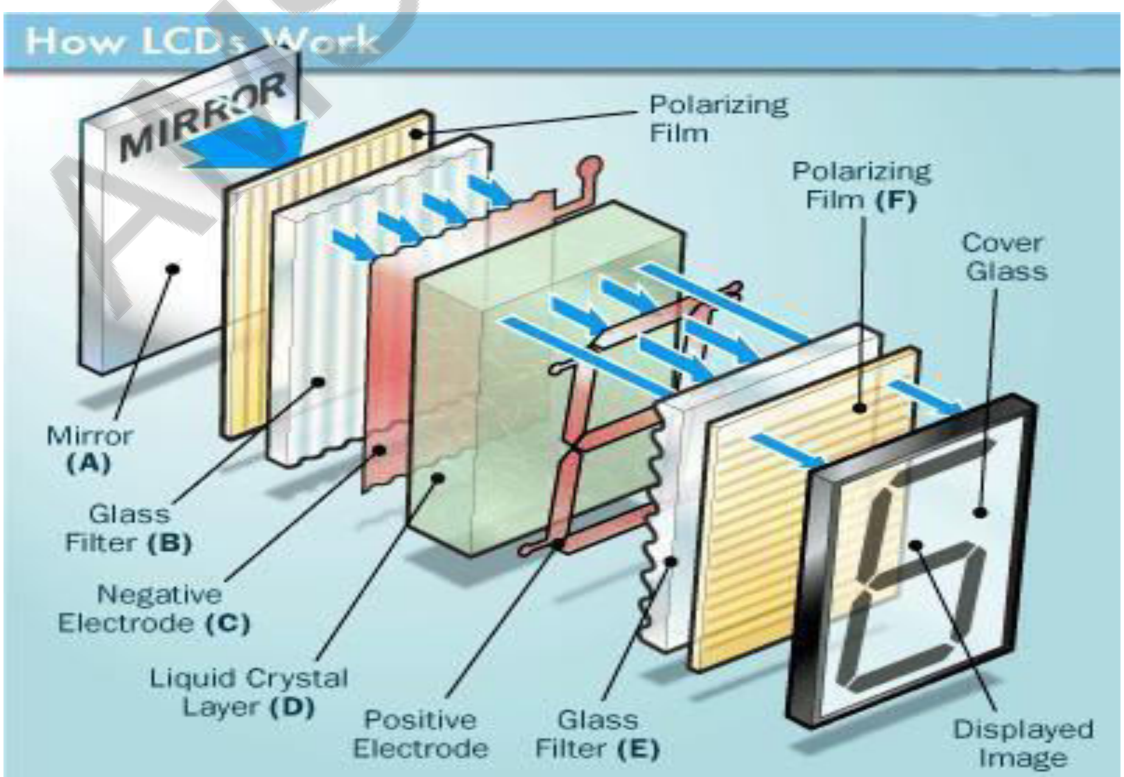
The *p region* is dominated by positiveelectric charges, and the *n region* is dominated by negativeelectric charges. The *junction* acts as a barrier to the flow of electrons between the *p* and the *n regions.* Only when sufficient voltage is applied to the semi-conductor chip, can thecurrent flow, and the electrons cross the junction into the *pregion.*

In the absence of a large enough electric potential difference (voltage) across the LED leads, the *junction* presents an electric potential barrier to the flow ofelectrons.

When sufficient voltage is applied to the chipacross the leadsof the LED, electrons can move easily in only one direction across the *junction* between the *p* and *n* regions. In the *p region* there are many more positive than negative charges. Inthe*nregion*theelectronsaremorenumerous than the positive electric charges. When a voltage is applied and the current starts to flow, electrons in the *n region* have sufficient energy to move across the junction into the *p region*. Once in the *p region* the electrons are immediately attracted to the positive charges due to the mutual Coulomb forces of attraction between opposite electric charges. When an electron moves sufficiently close to a positive charge in the *p region*, the two charges"re-combine".

Each time an electron *recombines* with a positive charge, electric potential energy is converted into electromagnetic energy. For each recombination of a negative and a positive charge, a quantum of electromagnetic energy is emitted in the form of a photon of light with a frequency characteristic of the semi-conductor material (usually a combination of the chemical elements gallium, arsenic and phosphorus). Only photons in a very narrow frequency range can be emitted by any material. LED's that emit different colors are made of differentsemi-conductor materials, and require different energies to lightthem.

Liquid Crystal Display

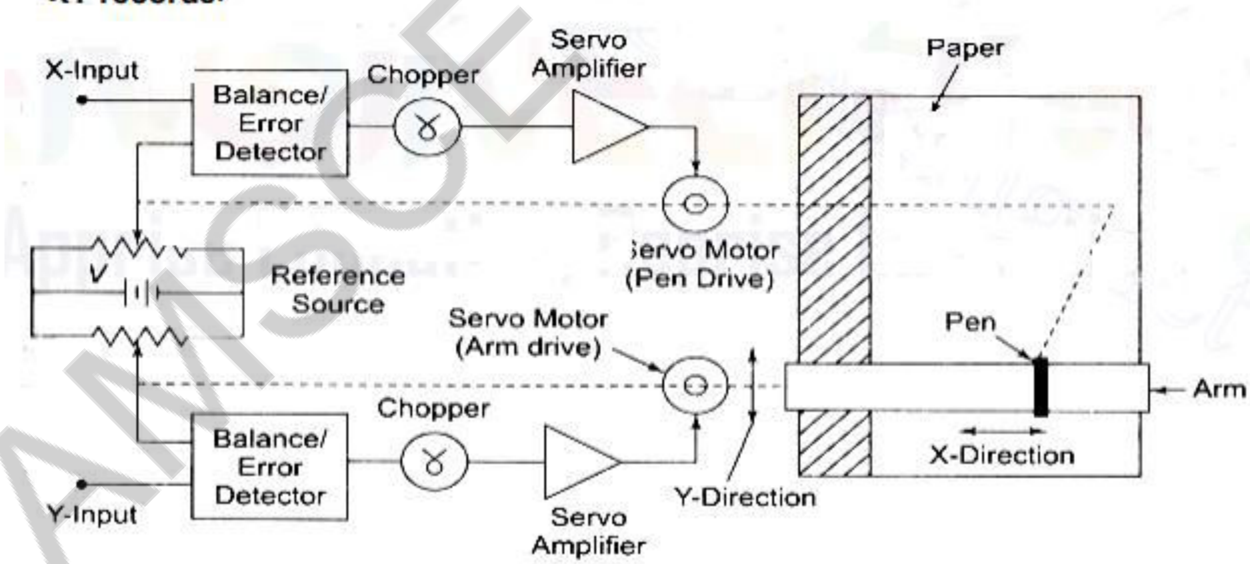


The liquid crystal display has the distinct advantages of having a lower power requirement than the LED. it is typically of the order of micro watts of the display in comparison to the same order of mill watts for LEDs. Low power requirement has made it compatible with MOS integrated logiccircuit.

A liquid crystal display consist of a film of liquid crystal, about 15 micro meter of thickness sandwich between it does not generate light. Its brightness depends upon the intensity of light source shining through reflectedfromthe crystal. The response time of LCD typically range between 10 and 100 ms. the main drawbacks of LCD are additional requirement of light source a limited temperaturerange of operation, low reliability, and short operating life. Basically LCD operates from a low voltage, low frequency ac signal and draw very light current. They are often arranged as 7 segment display fornumericaldisplayfornumericalreadoutasshown infig.The AC voltage required to turn on a segment is applied between the segment and thebackplane from a capacitor thatdraws v e r y light currentforlow frequency ac voltage. The voltage frequency is usually notkeptlowerthan25 Hz as thiswouldproducevisibleflicker.LCDs widely used in battery powered devices such as calculators andwatches.

3. Along with a neat sketch the block diagram, describe the working of X-Y plotter.(Nov/Dec2019,Nov/Dec2011)

XY recorder



- Each of the input signals is attenuated in the range of 0-5mV, so that it can work in the dynamic range of the recorder
- In X-Y recorder one variable is plotted against another variable. In this recorder,Pen is moved in either X or Y direction on a fixed graph paper.
- The writing assembly movement is controlled by using either servo feedback system or self balancing potentiometer. The writing assembly consists of one or two pens depending on this application.
- In practice, X-Y recorder plots one voltage as a function of other voltage.

- Many times X-Y recorder is used to record non electrical physical such as displacement, pressure, strain etc as a function of another non electrical physical quantity.

Construction:

It consists of attenuator which attenuates the input circuit. The balancing signal and error detector gives error signal. This error signal is DC signal. The chopper circuit converts error signal to AC signal The servo amplifier drives servomotor which drives writing assembly on a fixedgraph paper. There are two such circuits for two different inputs X and Y. The error signal of X input is amplified by servo amplifier of X channel driving corresponding servomotor and pen in X-direction. Similar section is performed for Y channel.

4. Along with a functional block diagram, explain the operation of Cathode Ray Oscilloscope.(Nov/Dec2019,Nov/Dec2014)

The device which allows, the amplitude of such signals, to be displayed primarily as a function of time, is called cathode ray oscilloscope. The cathode ray tube (CRT) is the heart of the C.R.O. The CRT generates the electron beam, accelerates the beam, deflects the beam and also has a screen where beam becomes visible as a spot.

The main parts of the CRT are i) Electron gun ii) Deflection system iii) Fluorescent screen iv) Glass tube or envelope v) Base

Electron gun

The electron gun section of the cathode ray tube provides a sharply focused, electron beam directed towards the fluorescent-coated screen. This section starts from thermally heated cathode, emitting the electrons. The control grid is given negative potential with respect to cathode. This grid controls the number of electrons in t beam, going to the screen. The momentum of the electrons (their number x their speed) determines the intensity, or brightness, of the light emitted from the fluorescent screen due to the electron bombardment. The light emitted is usually of the green color

Deflection System

When the electron beam is accelerated it passes through the deflection system, with which beam can be positioned anywhere on the screen.

Fluorescent Screen

The light produced by the screen does not disappear immediately when¬ bombardment by electrons ceases, i.e., when the signal becomes zero. The time period for which the trace remains on the screen after the signal becomes¬ zero is known as "persistence or fluorescence". The persistence may be as short as a few micro second, or as long as tens of seconds or even minutes. Medium persistence traces are mostly used for general purpose applications. Long¬ persistence traces are used in the study of transients. Long persistence helps in the study of transients since the trace is still seen on the screen after the transient has disappeared.

Glass Tube

All the components of a CRT are enclosed in an evacuated glass tube called envelope. This allows the emitted electrons to move about freely from one end of the tube to the other end.

Base

The base is provided to the CRT through which the connections are made to the various parts

5. Explain the theory of 'Seven Segment display'. You may consider common anode type connection for your explanation. (Nov/Dec2019)

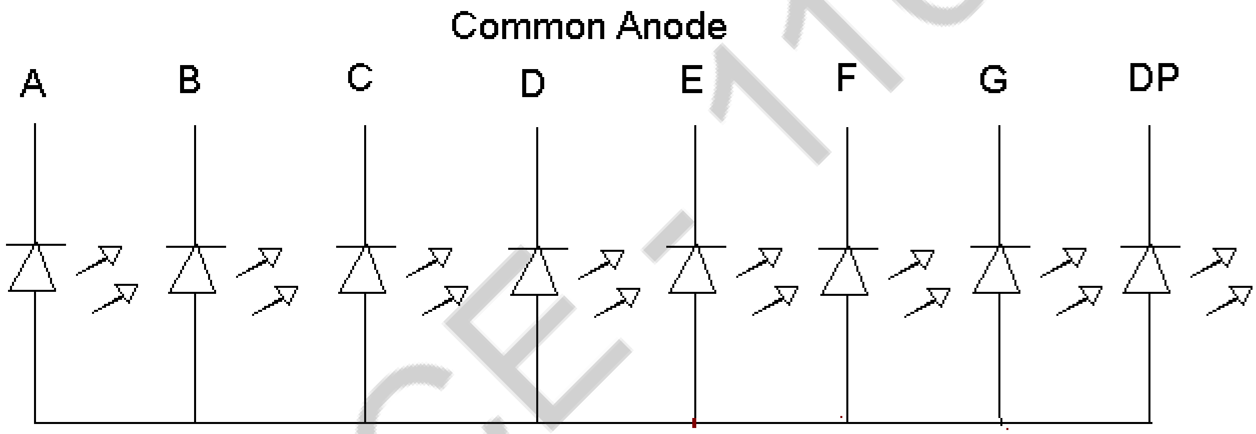
   "Seven segment display", consists of seven LEDs arranged in a rectangular fashion as shown. Each of the seven LEDs is called a segment because when illuminated the segment forms part of a numerical digit (both Decimal and Hex) to be displayed. An additional 8th LED is sometimes used within the same package thus allowing the indication of a decimal point, (DP) when two or more 7-segment displays are connected together to display numbers greater than ten.

Each one of the seven LEDs in the display is given a positional segment with one of its connection pins being brought straight out of the rectangular plastic package. These individually LED pins are labelled from a through to g representing each individual LED. The other LED pins are connected together and wired to form a common pin.

So by forward biasing the appropriate pins of the LED segments in a particular order, some segments will be light and others will be dark allowing the desired character pattern of the number to be generated on the display. This then allows us to display each of the ten decimal digits 0 through to 9 on the same 7-segment display.

The displays common pin is generally used to identify which type of 7-segment display it is. As each LED has two connecting pins, one called the "Anode" and the other called the "Cathode", there are therefore two types of LED 7-segment display called: Common Cathode (CC) and Common Anode (CA).

The difference between the two displays, as their name suggests, is that the common cathode has all the cathodes of the 7-segments connected directly together and the common anode has all the anodes of the 7-segments connected together and is illuminated as follows.



As shown above all the anode segments are connected together. When working with a CA seven segment display, power must be applied externally to the the anode connection that is common to all the segments. Then by applying a ground to a particular segment connection (a-g), the appropriate segment will light up. An additional resistor must be added to the circuit to limit the amount of current flowing thru each LED segment.

6. What is a 'data logger'? What are its components? What are the functions of a data logger? (Nov/Dec2019,Nov/Dec2011)

Data logger is an electronic device that records data over time or in relation to location either with a built-in instrument or sensor.

Components

- Pulse inputs
- Counts circuit closing
- Control ports
- Digital in and out
- Most commonly used to turn things on and off can be programmed as a digital input

Excitation outputs

- Though they can be deployed while connected to a host PC over an Ethernet or serial port a data logger is more typically deployed as standalone devices. The term data logger (also sometimes referred to as a data recorder) is commonly used to describe a self-contained, standalone data acquisition system or device. These products are comprised of a number of analog and digital inputs that are monitored, and the results or conditions of these inputs is then stored on some type of local memory (e.g. SD Card, Hard Drive).
- Examples of where these devices are used abound. A few of these examples are shown below:
- monitoring temperature, pressure, strain and other physical phenomena in aircraft flight tests (even including logging info from Arinc 429 or other serial communications buses)
- Monitoring temperature, pressure, strain and other physical phenomena in automotive and in-vehicle tests including monitoring traffic and data transmitted on the vehicles CAN bus.
- Environmental monitoring for quality control in food processing, food storage, pharmaceutical manufacturing, and even monitoring the environment during various stages of contract assembly or semiconductor fabrication
- Monitoring stress and strain in large mechanical structures such as bridges, steel framed buildings, towers, launch pads etc.
- Monitoring environmental parameters in temperature and environmental chambers and test facilities. A data logger is a self-contained unit that does not require a host to operate.
- It can be installed in almost any location, and left to operate unattended.
- This data can be immediately analyzed for trends, or stored for historical archive purposes.
- Data loggers can also monitor for alarm conditions, while recording a minimum number of samples, for economy.
- If the recording is of a steady-state nature, without rapid changes, the user may go through rolls of paper, without seeing a single change in the input.
- A data logger can record at very long intervals, saving paper, and can note when an alarm condition is occurring. When this happens, the event will be recorded and any outputs will be activated, even if the event occurs in between sample times.
- A record of all significant conditions and events is generated using a minimum of recording hardcopy
- The differences between various data loggers are based on the way that data is recorded and stored.Ø The basic difference between the two data logger types is that one type allows the data to be stored in a memory, to be retrieved at a later time, while the other type automatically records the dataon paper, for immediate viewing and analysis.
- Many data loggers combine these two functions, usually unequally, with the emphasis on either the ability to transfer the data or to provide a printout of it

Advantages

- A data logger is an attractive alternative to either a recorder or data acquisition system in many applications. When compared to a recorder, data loggers have the ability to accept a greater number of input channels, with better resolution and accuracy.
- Also, data loggers usually have some form of on-board intelligence, which provides the user with diverse capabilities.
- For example, raw data can be analyzed to give flow rates, differential temperatures, and other interpreted data that otherwise would require manual analysis by the operator the operator has a permanent recording on paper,
- No other external or peripheral equipment is required for operation, and
- Many data loggers of this type also have the ability to record data trends, in addition to simple digital data recording

Applications

Temperature sensor and Pressure sensor

7. Explain in detail about the various types of Recorders. (Apr/May2012, Apr/May2019)
    - The recording procedure performed in magnetic tape recorder can be done by 3 methods. They are 1. Direct recording 2. FM (frequency Modulation) Recording 3. PDM (Pulse Duration Modulation) recording

Direct recording :

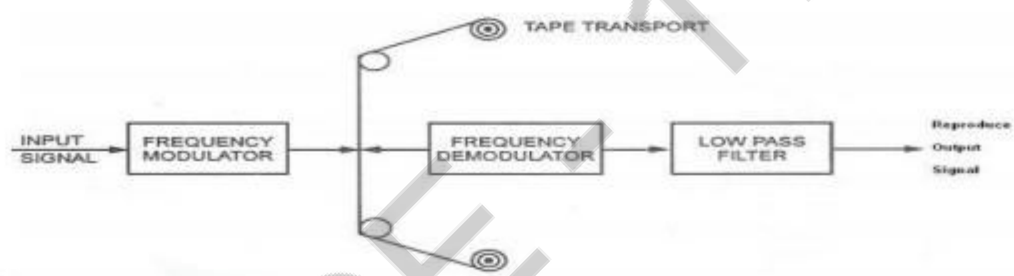
- The signal to be recorded modulates the current in the recording head. Because of current modulation, magnetic flux in the recording gap is linearly modulated. When the tape is moved under the recording head, the magnetic particles retain a state of permanent magnetization proportional to the flux in the gap.
- The input signal is thus converted to a spatial variation of the magnetization of the particles on the tape. The reproduce head detects these changes as changes in the reluctance of its magnetic circuit which will induce a voltage in its winding.
- This voltage is proportional to the rate of change of flux. The signal on the exposed tape can be retrieved and played out at any time.

Disadvantages:

(i) .This method cannot be used in DC because reproduce head geneth& a signal which is proportional to the rate of change of flux.

(ii) Lower limit is around 100 Hz and upper limit is around 2 Mhz.

FM Recording:



- In this FM system, the input signal is used to frequency modulate a carrier which is then recorded on the tape in the usual way. The central frequency is selected with respect to the tape speed and frequency deviation selected for the tape recorders is ±40% about the carrier frequency.
- The reproduce head reads the tape in the usual way and sends a signal to the FM demodulator and low pass filter and the original signal is reconstructed.
- The signal to noise ratio (S/N) of an FM recorder is of the order of 40-50 db, with an accuracy of less than ±1%. This ±1 db flat frequency response of FM recorder can go as high as 80 kHz at 120 in/s tape speed, when using very high carrier frequencies above 400 kHz.
- When high frequency (HF) is not needed and with a View to conserving tape, a tape speed range selector is generally provided. When the tape speed is changed, the carrier frequency also changes in the same proportion. Input to the tape recorders is generally at 1 V level and so most transducers require amplification before recording.
- A FM recording system is illustrated in figure. In this system, a carrier oscillator frequency f6, called the centre frequency, is modulated by the level of the input signal. When there is no input signal, the modulation is at centre frequency fc.
- If a positive input signal is applied, the frequency deviates from the centre frequency by some amount in a certain direction, the application of 8 negative input voltage deviates the carrier frequency in the opposite direction
- The output of the modulation, which is fed to the tape, is a signal of Constant frequency for DC inputs and varying frequency for AC inputs. The Variation of frequency is directly proportional to the amplitude of the input signal. On playback, the output of the reproduce head is demodulated and

fed through a low pass filter which removes the carrier and other unwanted (frequencies produced due to the modulation process.

- The operation of FM modulation can be easily checked by applying a known input voltage and measuring the output frequency with an electronic counter. This signal is applied to the tape with no further conditioning. as the signal is independent of the amplitude.
- The FM demodulator converts the difference between the centre frequency and the frequency on the tape, to a voltage proportional to the difference in the frequencies. This system can thus record frequencies from DC to several thousand Hertz. Residual carrier signals and out of band noise are removed by a low pass filter.

Advantages:

- DC component of the input signal is preserved.
- Wide frequency range.
- No drop out effect due to in homogeneities of the tape material.
- Accurately reproduces the wave form of the input signal.

Disadvantages:

(i) Extremely sensitive to tape speed fluctuations.
(ii) Limited frequency response.
(iii) Requires a high tape speed.
(iv) Requires a high quality of tape transport and speed control.

Pulse Duration Modulation:

- Pulse duration modulation allows simultaneous recording of a large number of slowly changing variables by using Time Division Multiplexing (TDM).
- The PDM recording process requires the input signal at the instant of sampling be converted to a pulse, the duration of which is proportional to amplitude of the signal at that instant.
- As an example, for recording sine wave, it is sampled and recorded at uniformly spaced discrete intervals instead of continuously recording instantaneous values. The original sine wave can be reconstructed on playback by passing the discrete readings through an appropriate filter.

UNIT-V
TRANSDUCERS AND DATA ACQUISITION SYSTEMS

Classification of transducers – Selection of transducers – Resistive, capacitive & inductive Transducers – Piezoelectric, Hall effect, optical and digital transducers – Elements of data acquisition system – Smart Sensors-Thermal Imagers

PART-A

1. Give any two applications of smart sensors. (April/May 2011)
   Measuring exposures in cameras, optical angle encoder and optical arrays
2. Mention the need of ADC and DAC in Digital data Acquisition system. (Nov/Dec 2011)

ADCs are used to convert analog signals like the output from a temperature transducer, a radio receiver or a video camera into digital signals for processing. Conversely, DACs are used to convert digital signals back to analog signals

3. Give the factors to be considered in selecting a transducer.
   Operating range, sensitivity, electrical output characteristics, errors, accuracy, environmental conditions .
4. Define inverse transducer.
   An inverse transducer is defined as a device which converts an electrical quantity into a non – electrical quantity.
5. Define gauge factor.
   The gauge factor is defined as the ratio of per unit change in resistance to per unit change in length. Gauge factor $Gf = (\Delta R/R) / (\Delta L/L)$
6. What is piezo-electric effect? How is this concept used as a transducer? (Nov/Dec2019)
   A piezo electric material is one in which an electric potential appears across certain surfaces of a crystal if the dimensions of he crystal are changed by the application of a mechanical force.
7. List any four force summing devices. (Nov/Dec 11)
   - Bourdon tube
   - Bellows
   - Capsule
   - Diaphragm
8. When do you call an instrument to be intelligent? (May/Jun 13)
   The system can able to process and gives their output its own calibration by sensing. Automatic operation done by all the system by using various sensors. These systems are called intelligent.
9. What is known as thermocouple effect & how do you use it in a transducer? (May/Jun13)
   It is a thermoelectric transducer which converts the thermal energy into an electrical energy. It is mostly used as primary transducer for temperature measurement where thermocouple directly converts changes in temperature into an electrical signal. Thermocouple comes under class of active transducer.
10. What is Transducer? (Dec 2010)
    A transducer is a device which converts physical energy in to electrical energy. Eg. LVDT , Strain guage, thermistor etc.
11. What are the materials used for piezoelectric transducers? (Dec 2009)
    Some of the piezoelectric materials are
    - Rochelle salt
    - Ammonium Dihydrogen Phosphate (ADP)
    - Quartz

12. What is an active transducer? (May 2010)
An active transducer generates an electrical signal directly in response to the physical parameter and does not require external power source for its operation. Eg. Tachogenerators, piezoelectric crystals
13. List the elements of data acquisition system. (Nov/Dec2019, Apr/May2019)
All data acquisition systems consist of three essential elements – Sensor, Signal Conditioning, and Analog-to-Digital Converter (ADC).
14. Mention the electrical phenomena used in transducers. (Apr/May2019)
Some of the most commonly electrical quantities in a transducer are resistance, capacitance, voltage, current or inductance. During transduction, there may be changes in resistance, capacitance and induction, which in turn change the output voltage or current.

PART-B

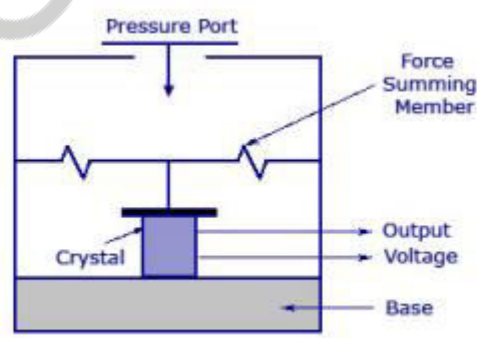
1. Explain the principle of operation a) Piezoelectric transducer. (April/May 2011) (May/June 2013)

Piezoelectric Transducers

Piezoelectric transducers produce an output voltage when a force is applied to them. They are frequently used as ultrasonic receivers and also as displacement transducers, particularly as part of devices measuring acceleration, force and pressure. In ultra- sonic receivers, the sinusoidal amplitude variations in the ultrasound wave received are translated into sinusoidal changes in the amplitude of the force applied to the piezoelectric transducer. In a similar way, the translational movement in a displacement transducer is caused by mechanical means to apply a force to the piezoelectric transducer. Piezoelectric transducers are made from piezoelectric materials. These have an asymmetrical lattice of molecules that distorts when a mechanical force is applied to it. This distortion causes a reorientation of electric charges within the material, resulting in a relative displacement of positive and negative charges. The charge displacement induces surface charges on the material of opposite polarity between the two sides. By implanting electrodes into the surface of the material, these surface charges can be measured as an output voltage.

For a rectangular block of material, the induced voltage is given by

$$V = kFd/A$$



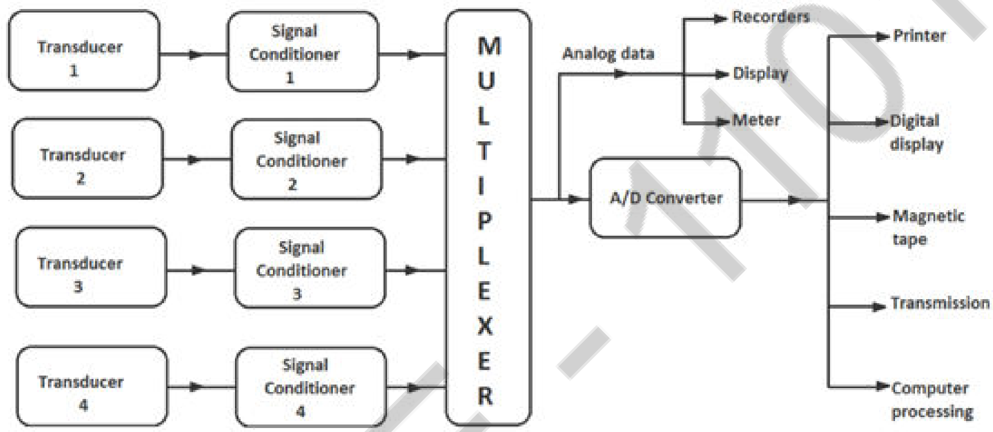
Piezo-Electric Transducer

- Where F is the applied force in g, A is the area of the material in mm, d is the thickness of the material and k is the piezoelectric constant.
- The polarity of the induced voltage depends on whether the material is compressed or stretched.
- Where F is the applied force in g, A is the area of the material in mm, d is the thickness of the material and k is the piezoelectric constant. The polarity of the induced voltage depends on whether the material is compressed or stretched.

- Materials exhibiting piezoelectric behaviour include natural ones such as quartz, synthetic ones such as lithium sulphate and ferroelectric ceramics such as barium titanate. The piezoelectric constant varies widely between different materials.
- Typical values of k are 2.3 for quartz and 140 for barium titanate. Applying equation (13.1) for a force of 1 g applied to a crystal of area 100 mm2 and thickness 1 mm gives an output of 23 μV for quartz and 1 .4 mV for barium titanate. The piezoelectric principle is invertible, and therefore distortion in a piezoelectric material can be caused by applying a voltage to it.
- This is commonly used in ultrasonic transmitters, where the application of a sinusoidal voltage at a frequency in the ultra- sound range causes a sinusoidal variation in the thickness of the material and results in a sound wave being emitted at the chosen frequency

2. Elucidate the elements of data acquisition system. (Apr/May2019)

A generalized data acquisition system block diagram is shown in Figure.



The function of each block is explained below:

Transducers: They are converting physical quantities (such as temperature, pressure, etc.) into electrical quantities, or measuring electrical quantities directly. They collect data from the physical world.

The most commonly used transducers are:

- RTDs, thermocouples, and thermistors for temperature measurements.
- Photosensors for light measurements.
- Strain gages, piezoelectric transducers for force and pressure measurements.
- Microphone for sound measurements.
- Potentiometer, LVDT, optical encoder for position and displacement measurements.

Signal Conditioning Unit: The signal produced by the transducers may or may not be very suitable for our system to work properly. It may be very weak, very strong or may have some noise.
To convert this signal into the most suitable form, amplification, and filtration is done respectively by signal conditioning unit. So, the signal conditioning unit converts electrical signals in the most suitable form.

Multiplexer: The multiplexer receives multiple analog inputs and provides a single output signal according to the requirements. If a separate channel is used for each quantity, the cost of installation, maintenance, and periodic replacement becomes high. Therefore, a single channel is used which is shared by various quantities.

Analog to Digital (A/D) Converters: The data is converted into digital form by A/D converters.

After the conversion of data into digital form, it is displayed with the help of oscilloscopes, numerical displays, panel meters to monitor the complete system.

Also, the data can be either permanently or temporarily stored or recorded according to the requirement. The data is recorded on optical, ultraviolet, stylus or ink recorders for future use.

Objectives of Data Acquisition System

- It must collect the necessary data at the correct speed.
- It must use all the data efficiently to inform the operator about the state of the system.
- It must monitor the complete system operation to maintain on-line optimum and safe operations.
- It must be able to summarize and store data for the diagnosis of operation and record purpose.
- It must be flexible for future requirements.
- It must be reliable and not have a downtime of more than 0.1%.
- It must provide an effective communication system.

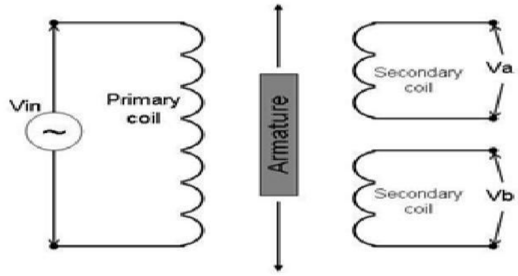
Applications of Data Acquisition System

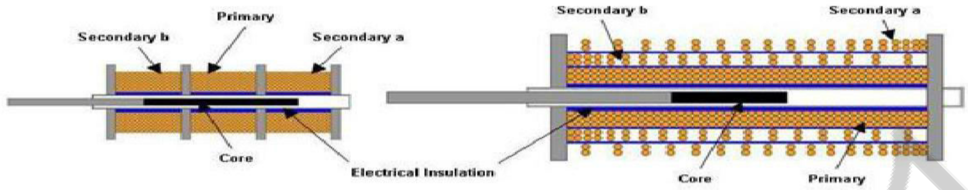
The data acquisition system is used in industrial and scientific fields like aerospace, biomedical and telemetry industries.

3. Elaborate the types of resistive and inductive transducers used for measuring pressure. (Apr/May2019)

Inductive Transducers

- An LVDT, or Linear Variable Differential Transformer, is a transducer that converts a linear displacement or position from a mechanical reference (or zero) into a proportional electrical signal containing phase (for direction) and amplitude information (for distance).
- The LVDT operation does not require electrical contact between the moving part (probe or core rod assembly) and the transformer, but rather relies on electromagnetic coupling; this and the fact that they operate without any built-in electronic circuitry are the primary reasons why LVDTs have been widely used in applications where long life and high reliability under severe environments are a required, such Military/Aerospace applications.
- The LVDT consists of a primary coil (of magnet wire) wound over the whole length of a non-ferromagnetic bore liner (or spool tube) or a cylindrical coil form.
- Two secondary coils are wound on top of the primary coil for “long stroke” LVDTs (i.e. for actuator main RAM) or each side of the primary coil for “Short stroke” LVDTs (i.e. for electro-hydraulic servo-valve or EHSV).
- The two secondary windings are typically connected in “opposite series” (or wound in opposite rotational directions). A ferromagnetic core, which length is a fraction of the bore liner length, magnetically couples the primary to the secondary winding turns that are located above the length of the core.





- When the primary coil is excited with a sine wave voltage (Vin), it generates a variable magnetic field which, concentrated by the core, induces the secondary voltages (also sine waves).
- While the secondary windings are designed so that the differential output voltage (Va-Vb) is proportional to the core position from null, the phase angle (close to 0 degree or close to 180 degrees depending of direction) determines the direction away from the mechanical zero.
- The zero is defined as the core position where the phase angle of the (Va-Vb) differential output is 90 degrees.
- The differential output between the two secondary outputs (Va-Vb) when the core is at the mechanical zero (or "Null Position") is called the Null Voltage; as the phase angle at null position is 90 degrees, the Null Voltage is a "quadrature" voltage.
- This residual voltage is due to the complex nature of the LVDT electrical model, which includes the parasitic capacitances of the windings.

Note: For resistance transducers refer question number 4

4. Give two examples for resistive transducers. Also explain in detail, any one of these two. (Nov/Dec2019)

Resistance Transducers

Temperature Sensors

Temperature is one of the fundamental parameters indicating the physical condition of matter, i.e. expressing its degree of hotness or coldness. Whenever a body is heat' various effects areobserved. They include

- Change in the physical or chemical state, (freezing, melting, boiling etc.)
- Change in physical dimensions,
- Changes in electrical properties, mainly the change in resistance,
- Generation of an emf at the junction of two dissimilar metals.

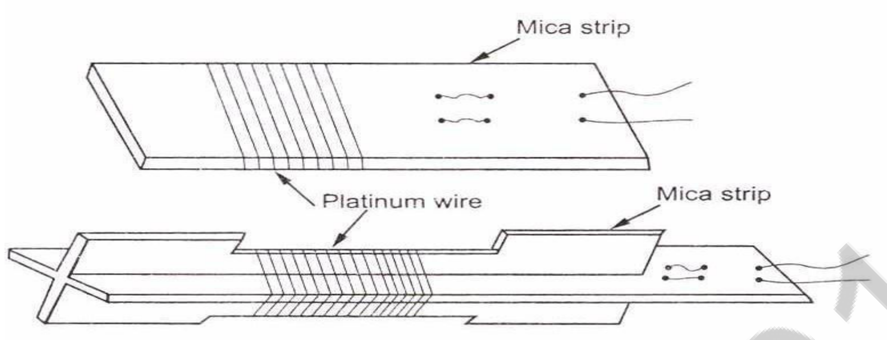
One of these effects can be employed for temperature measurement purposes. Electrical methods are the most convenient and accurate methods of temperature measurement. These methods are based on change in resistance with temperature and generation of thermal e.m.f. The change in resistance with temperature may be positive or negative. According to that there are two types

Resistance Thermometers —Positive temperature coefficient

Thermistors —Negative temperature coefficient

Construction of Resistance Thermometers

- The wire resistance thermometer usually consists of a coil wound on a mica or ceramic former,as shown in the Fig.
- The coil is wound in bifilar form so as to make it no inductive. Such coils are available in different sizes and with different resistance values ranging from 10 ohms to 25,000 ohms.



(Fig) Resistance Thermometer Advantages of Resistance Thermometers

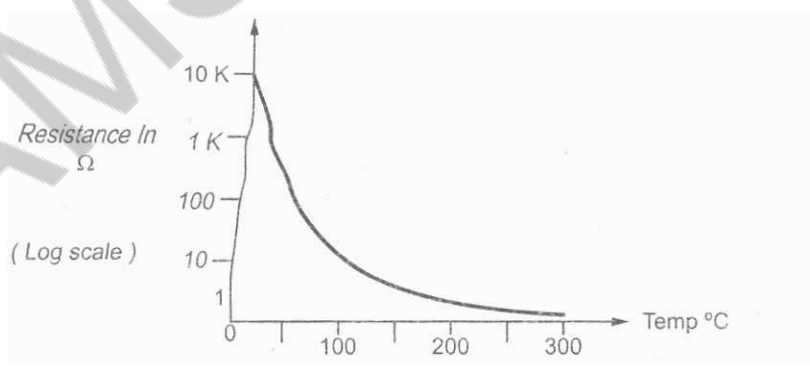
- The measurement is accurate.
- Indicators, recorders can be directly operated.
- The temperature sensor can be easily installed and replaced.
- Measurement of differential temperature is possible.
- Resistance thermometers can work over a wide range of temperature from-20' C to + 650° C.
- They are suitable for remote indication.
- They are smaller in size
- They have stability over long periods of time.

Limitations of Resistance Thermometers

bridge circuit with external power source is necessary for their operation.
They are comparatively costly.

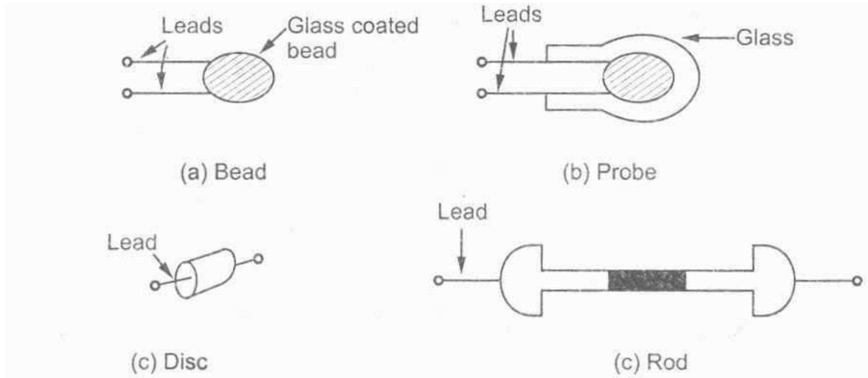
Thermistors

Thermistor is a contraction of a term ' thermal-resistors'.
Thermistors are semiconductor device which behave as thermal resistors having negative temperature coefficient [i.e. their resistance decreases as temperature increases.
The below Fig. shows this characteristic.



Construction of Thermistor

- Thermistors are composed of a sintered mixture of metallic oxides, manganese, nickel, cobalt, copper, iron, and uranium.
- Their resistances at temperature may range from 100 to 100k .
- Thermistors are available in variety of shapes and sizes as shown in the Fig.



- Smallest in size are the beads with a diameter of 0.15 mm to 1.25 mm.
- Beads may be sealed in the tips of solid glass rods to form probes.
- Disks and washers are made by pressing thermistor material under high pressure into flat cylindrical shapes.
- Washers can be placed in series or in parallel to increase power dissipation rating.
- Thermistors are well suited for precision temperature measurement, temperature control, and temperature compensation, because of their very large change in resistance with temperature. They are widely used for measurements in the temperature range -100 C to+100 C
- **Advantages of Thermistor**

1. Small size and low cost.
2. Comparatively large change in resistance for a given change in temperature
3. Fast response over a narrow temperature range.

Limitations of Thermistor

- The resistance versus temperature characteristic is highly non-linear.
- Not suitable over a wide temperature range.
- Because of high resistance of thermistor, shielded cables have to be used to minimize interference.

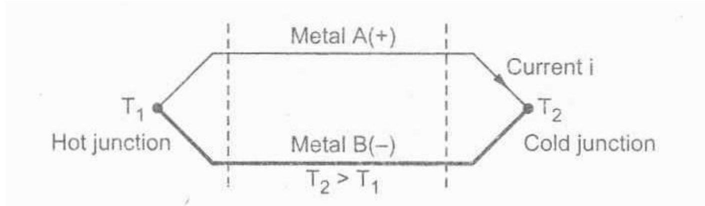
Applications of Thermistor

- The thermistors relatively large resistance change per degree change in temperature [known as sensitivity] makes it useful as temperature transducer.
- The high sensitivity, together with the relatively high thermistor resistance that
- may be selected [e.g. 100k .], makes the thermistor ideal for remote measurement or control. Thermistor control systems are inherently sensitive, stable, and fast acting, and they require relatively simple circuitry.
- Because thermistors have a negative temperature coefficient of resistance,
- thermistors are widely used to compensate for the effects of temperature on circuit performance.
- Measurement of conductivity.

Temperature Transducers

They are also called thermo-electric transducers. Two commonly used temperature transducers are Resistance Temperature Detectors or Thermocouples.

Thermocouples



(Fig) Basic circuit

The thermocouple is one of the simplest and most commonly used methods of measuring process temperatures.

5. Explain the classification and characteristics of transducers.

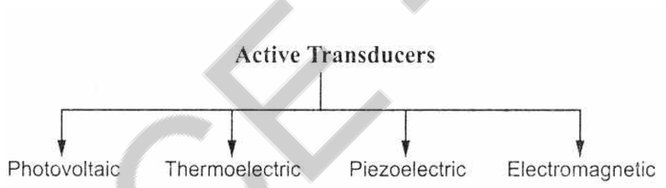
Transducers may be classified according to their structure, method of energy conversion and application. Thus, we can say that transducers are classified

- As active and passivetransducer
- According to transductionprinciple
- As analog and digitaltransducer
- As primary and secondarytransducer
- As transducer and inversetransducer

Active and Passive Transducer Active Transducers

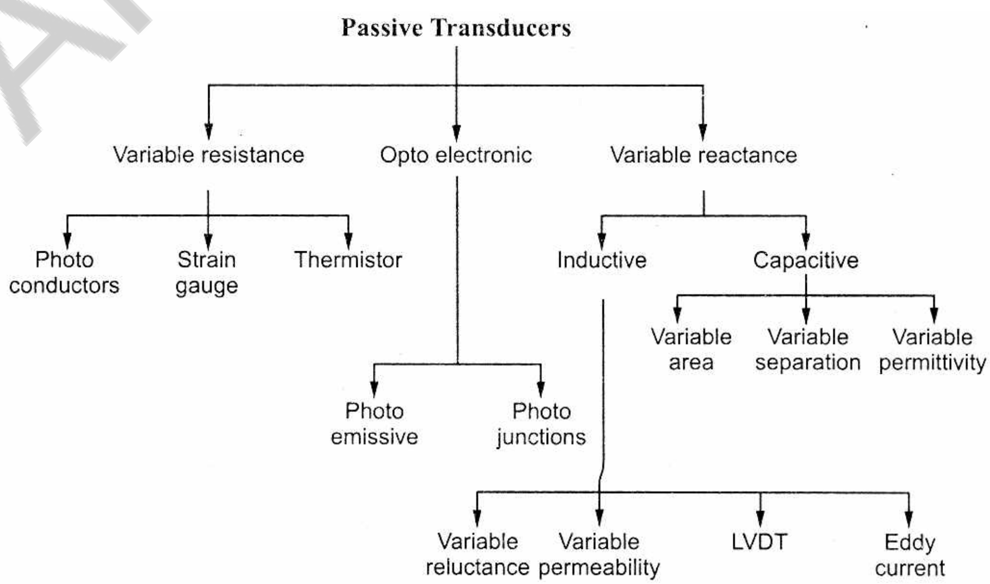
- Active transducers are self-generating type of transducers.
- These transducers develop an electrical parameter (i.e. voltage or current) which is proportional to the quantity under measurement.
- These transducers do not require any external source or power for their operation.

They can be subdivided into the following commonly used types



Passive Transducers

- Passive transducers do not generate any electrical signal by themselves.
- To obtain an electrical signal from such transducers, an external source of power is essential.
- Passive transducers depend upon the change in an electrical parameter (R, L, or C).
- They are also known as externally power-driven transducers.
- They can be subdivided into the following commonly used types.



According to Transduction Principle

The transducers can be classified according to principle used in transduction.

- Capacitive transduction
- Electromagnetic transduction
- Inductivetransduction
- Piezoelectrictransduction
- Photovoltaictransduction
- Photoconductive transduction
- Analog and Digital Transducers

The transducers can be classified on the basis of the output which may be a continuous function of time or the output may be in discrete steps.

Analog Transducers

These transducers convert the input quantity into an analog output which is acontinuousfunction of time. A strain gauge, LVDT, thermocouples or thermistors are called analog transducers as they produce an output which is a continuous function of time.

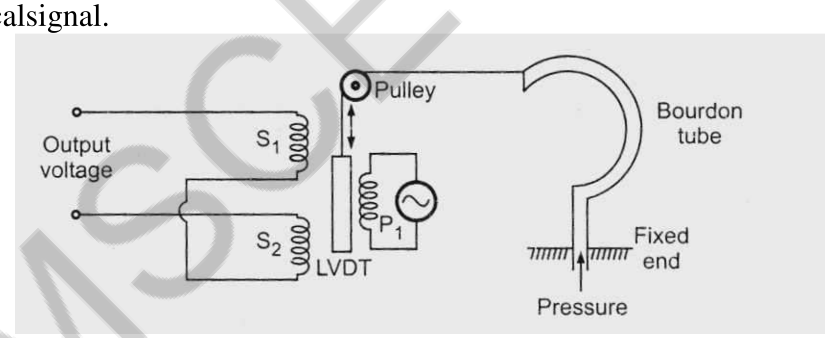
Digital Transducers

Digital transducers produce an electrical output in the form of pulses which forms an unique code. Unique code is generated for each discrete value sensed.

Primary or Secondary Transducers

- Some transducers consist of mechanical device along with the electrical device.
- In such transducer's mechanical device acts as a primary transducer and converts physical quantity into mechanical signal.
- The electrical device then converts mechanical signal produced by primary transducer into an electrical signal.
- Therefore, electrical device acts as a secondary transducer.

For an example, in pressure measurement Bourdons tube acts as a primary transducer which converts a pressure into displacement and LVDT acts as a secondary transducer which converts this displacement into an equivalent electricalsignal.



(Fig) pressureMeasurement

Transducer and Inverse Transducer

- Transducers convert non-electrical quantity into electrical quantity whereas inverse transducer converts electrical quantity into non-electrical quantity.
- For example, microphone is a transducer which converts sound signal into anelectrical signal whereas loudspeaker is an inverse transducer which converts electrical signal into sound signal.

Advantages of Electrical Transducers

- Electrical signal obtained from electrical transducer can be easily processed (mainly amplified) and brought to a level suitable for output device which may be an indicator orrecorder.
- The electrical systems can be controlled with a very small level ofpower
- The electrical output can be easily used, transmitted, and processed for the purpose ofmeasurement.
- With the advent of IC technology, the electronic systems have become extremely small in size, requiring small space for theiroperation.

- No moving mechanical parts are involved in the electrical systems. Therefore there is no question of mechanical wear and tear and no possibility of mechanicalfailure.
- Electrical transducer is almost a must in this modem world.

Disadvantages of Electrical Transducers

- The electrical transducer is sometimes less reliable than mechanical type because of the ageing and drift of the active components.
- Also, the sensing elements and the associated signal processingcircuitryarecomparatively expensive.
- With the use of better materials, improved technology and circuitry, the range of accuracy and stability have been increased for electrical transducers.
- Using negative feedback technique, the accuracy of measurement and the stability of the system are improved, but all at the expense of increased circuit complexity, more space, and obviously, more cost.

Characteristics of Transducer

Accuracy: It is defined as the closeness with which the reading approaches an accepted standard value or ideal value or true value, of the variable beingmeasured.

Ruggedness: The transducer should be mechanically rugged to withstand overloads. Itshould have overload protection.

Linearity: The output of the transducer should be linearly proportional to the input quantityunder measurement. It should have linear input - output characteristic.-

Repeatability: The output of the transducer must be exactly the same, under same environmental conditions, when the same quantity is applied at the inputrepeatedly.

High output: The transducer should give reasonably high output signal so that it can be easily processed and measured. The output must be much larger than noise. Now-a-days, digital output is preferred in manyapplications;

High Stability and Reliability: The output of the transducer should be highly stable and reliable so that there will be minimum error in measurement.Theoutput must remain unaffected by environmental conditions such as change in temperature, pressure,etc.

Sensitivity: The sensitivity of the electrical transducer is defined as the electrical output obtained per unit change in the physical parameter of the input quantity. For example, for a transducer used for temperature measurement, sensitivity will be expressed in mV/’ C. A high sensitivity is always desirable for a given transducer.

Dynamic Range: For a transducer, the operating range should be wide, so that it can be used over a wide range of measurementconditions.

Size: The transducer should have smallest possible size and shape with minimal weight and volume. This will make the measurement system verycompact.

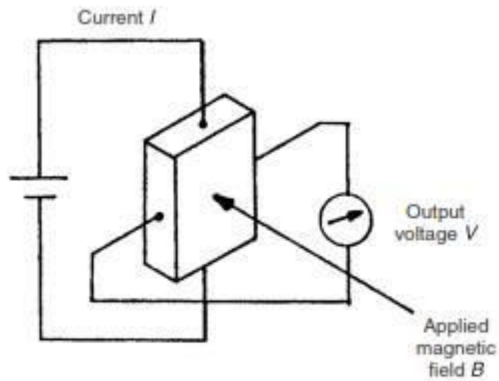
Speed of Response: It is the rapidity with which the transducer responds to changes in the measuredquantity.Thespeedofresponseofthetransducer shouldbeashighaspracticable.

Transducer Selection Factors

- Nature ofmeasurement
- Loadingeffect
- Environmentalconsiderations
- Measuringsystem
- Cost &Availability

6. Explain Hall-effect transducers in detail

- Hall-effect sensor is a device that is used to measure the magnitude of a magnetic field. It consists of a conductor carrying a current that is aligned orthogonally with the magnetic field, as shown in Figure 13.4. This produces a transverse voltage difference across the device that is directly proportional to the magnetic field strength. For an excitation current I and magnetic field strength B, the output voltage is given by V D KIB, where K is known as the Hall constant



The conductor in Hall-effect sensors is usually made from a semiconductor material as opposed to a metal, because a larger voltage output is produced for a magnetic field of a given size. In one common use of the device as a proximity sensor, the magnetic field is provided by a permanent magnet that is built into the device. The magnitude of this field changes when the device becomes close to any ferrous metal object or boundary. The Hall Effect is also commonly used in keyboard pushbuttons, in which a magnet is attached underneath the button. When the button is depressed, the magnet moves past a Hall-effect sensor. The induced voltage is then converted by a trigger circuit into a digital output. Such pushbutton switches can operate at high frequencies without contact bounce.

7. With block diagram, explain DAS in detail.

- Data acquisition is the process of real world physical conditions and conversion of the resulting samples into digital numeric values that can be manipulated by a computer.
- Data acquisition and data acquisition systems (abbreviated with the acronym DAS) typically involves the conversion of analog waveforms into digital values for processing.
- The components of data acquisition systems include: i) Sensors that convert physical parameters to electrical signals.
- ii) Signal conditioning circuitry to convert sensor signals into a form that can be converted to digital values
- iii) Analog-to-digital converters, which convert conditioned sensor signals to digital values.

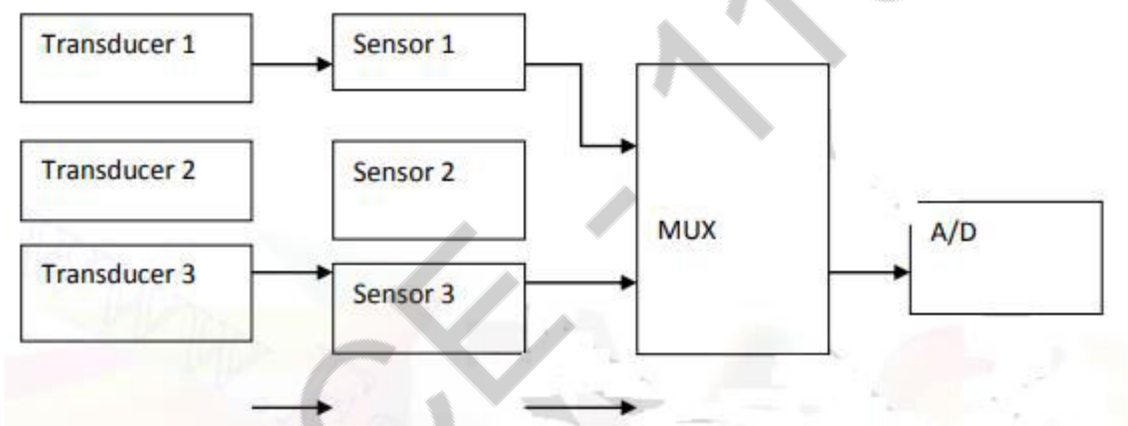
Explanation

- Data acquisition is the process of extracting, transforming, and transporting data from the source systems and external data sources to the data processing system to be displayed, analyzed, and stored.
- A data acquisition system (DAQ) typically consist of transducers for asserting and measuring electrical signals, signal conditioning logic to perform amplification, isolation, and filtering, and other hardware for receiving analog signals and providing them to a processing system, such as a personal computer.
- Data acquisition systems are used to perform a variety of functions, including laboratory research, process monitoring and control, data logging, analytical chemistry, tests and analysis of physical phenomena, and control of mechanical or electrical machinery.
- Data recorders are used in a wide variety of applications for imprinting various types of forms, and documents.
- Data collection systems or data loggers generally include memory chips or strip charts for electronic recording, probes or sensors which measure product environmental parameters and are connected to the data logger.

- Hand-held portable data collection systems permit in field data collection for up-todate information processing.

Source

- Data acquisition begins with the physical phenomenon or physical property to be measured. Examples of this include temperature, light intensity, gas pressure, fluid flow, and force. Regardless of the type of physical property to be measured, the physical state that is to be measured must first be transformed into a unified form that can be sampled by a data acquisition system.
- The task of performing such transformations falls on devices called sensors. A sensor, which is a type of transducer, is a device that converts a physical property into a corresponding electrical signal (e.g., a voltage or current) or, in many cases, into a corresponding electrical characteristic (e.g., resistance or capacitance) that can easily be converted to electrical signal.
- The ability of a data acquisition system to measure differing properties depends on having sensors that are suited to detect the various properties to be measured. There are specific sensors for many different applications.
- DAQ systems also employ various signal conditioning techniques to adequately modify various different electrical signals into voltage that can then be digitized using an Analog-to-digital converter (ADC).



Signals

- Signals may be digital (also called logic signals sometimes) or analog depending on the transducer used. Signal conditioning may be necessary if the signal from the transducer is not suitable for the DAQ hardware being used
- The signal may need to be amplified, filtered or demodulated. Various other examples of signal conditioning might be bridge completion, providing current or voltage excitation to the sensor, isolation, and linearization.
- For transmission purposes, single ended analog signals, which are more susceptible to noise can be converted to differential signals. Once digitized, the signal can be encoded to reduce and correct transmission errors.

DAQ hardware

- DAQ hardware is what usually interfaces between the signal and a PC. It could be in the form of modules that can be connected to the computer's ports (parallel, serial, USB, etc.) or cards connected to slots (S-100 bus, Apple Bus, ISA, MCA, PCI, PCI-E, etc.) in the mother board.
- Usually the space on the back of a PCI card is too small for all the connections needed, so an external breakout box is required. The cable between this box and the Transducer 1 Sensor 1 Transducer 2 Transducer 3 Sensor 2 Sensor 3 MUX A/D PC can be expensive due to the many wires, and the required shielding DAQ cards often contain multiple components (multiplexer, ADC, DAC, TTL-IO, high speed timers, RAM).

- These are accessible via a bus by a microcontroller, which can run small programs. A controller is more flexible than a hard wired logic, yet cheaper than a CPU so that it is alright to block it with simple polling loops.
- The fixed connection with the PC allows for comfortable compilation and debugging. Using an external housing a modular design with slots in a bus can grow with the needs of the user.
- Not all DAQ hardware has to run permanently connected to a PC, for example intelligent stand-alone loggers and oscilloscopes, which can be operated from a PC, yet they can operate completely independent of the PC.

DAQ software

DAQ software is needed in order for the DAQ hardware to work with a PC. The device driver performs low-level register writes and reads on the hardware, while exposing a standard API for developing user applications. A standard API such as COMEDI allows the same user applications to run on different operating systems, e.g. a user application that runs on Windows will also run on Linux and BSD.

Advantages

- Reduced data redundancy
- Reduced updating errors and increased consistency
- Greater data integrity and independence from applications programs
- Improved data access to users through use of host and query languages
- Improved data security
- Reduced data entry, storage, and retrieval costs
- Facilitated development of new applications program

Disadvantages

- Database systems are complex, difficult, and time-consuming to design
- Substantial hardware and software start-up costs
- Damage to database affects virtually all applications programs
- Extensive conversion costs in moving form a file-based system to a database system
- Initial training required for all programmers and users

8. Give a short notes on Smart Sensors. (Apr/May2016)
    - A smart sensor is a sensor with local processing power that enables it to react to local conditions without having to refer back to a central controller.
    - Smart sensors are usually at least twice as accurate as non-smart devices, have reduced maintenance costs and require less wiring to the site where they are used. In addition, long-term stability is improved, reducing the required calibration frequency.
    - The functions possessed by smart sensors vary widely, but consist of at least some of the following:
    - Remote calibration capability Self-diagnosis of faults
    - Automatic calculation of measurement accuracy and compensation for random errors Adjustment for measurement of non-linearity's to produce a linear output Compensation for the loading effect of the measuring process on the measured system.
    - Calibration capability Self-calibration is very simple in some cases. Sensors with an electrical output can use a known reference voltage level to carry out self-calibration. Also, load-cell types of sensor, which are used in weighing systems, can adjust the output reading to zero when there is no applied mass.
    - In the case of other sensors, two methods of self-calibration are possible, use of a look-up table and an interpolation technique. Unfortunately, a look-up table requires a large memory capacity to store correction points.
    - Also, a large amount of data has to be gathered from the sensor during calibration. In consequence, the interpolation calibration technique is preferable. This uses an

interpolation method to calculate the correction required to any particular measurement and only requires a small matrix of calibration points (van der Horn, 1996).

Self-diagnosis of faults

- Smart sensors perform self-diagnosis by monitoring internal signals for evidence of faults. Whilst it is difficult to achieve a sensor that can carry out self-diagnosis of all possible faults that might arise, it is often possible to make simple checks that detect many of the more common faults.
- One example of self-diagnosis in a sensor is measuring the sheath capacitance and resistance in insulated thermocouples to detect breakdown of the insulation. Usually, a specific code is generated to indicate each type of possible fault (e.g. a failing of insulation in a device).
- One difficulty that often arises in self-diagnosis is in differentiating between normal measurement deviations and sensor faults. Some smart sensors overcome this by storing multiple measured values around a set-point, calculating minimum and maximum expected values for the measured quantity.
- Uncertainty techniques can be applied to measure the impact of a sensor fault on measurement quality. This makes it possible in certain circumstances to continue to use a sensor after it has developed a fault.
- A scheme for generating a validity index has been proposed that indicates the validity and quality of a measurement from a sensor (Henry, 1995).

Automatic calculation of measurement accuracy and compensation for random errors

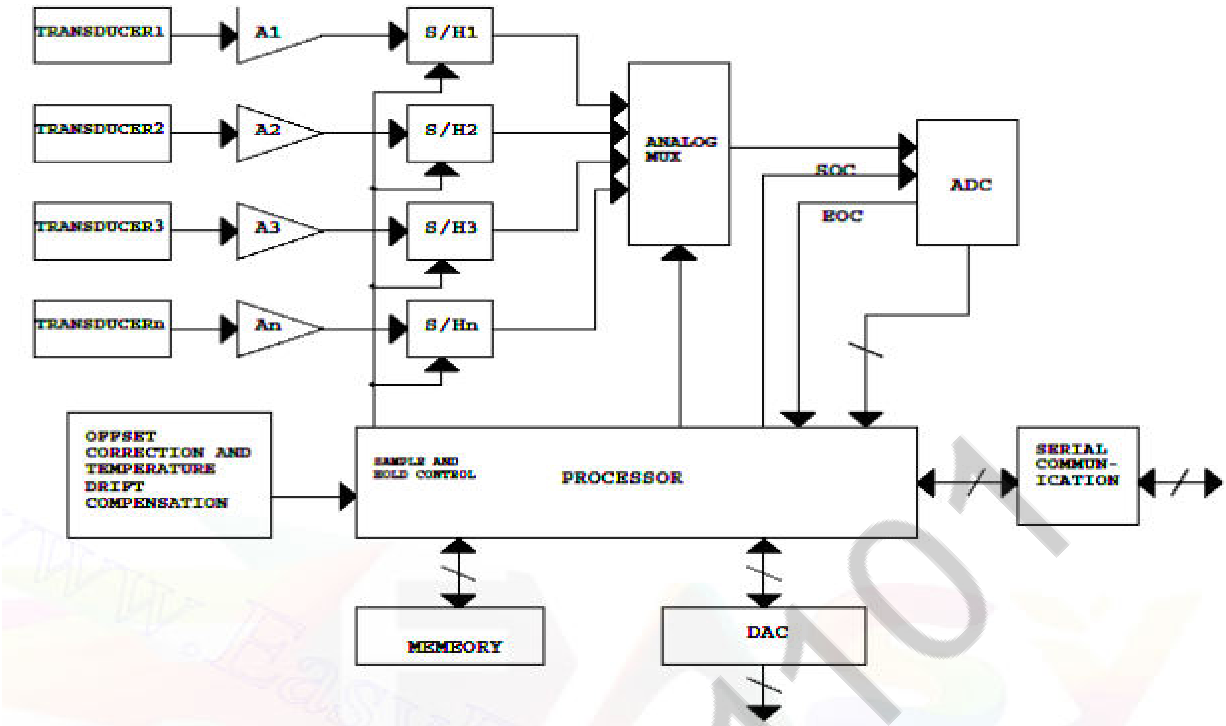
- Many smart sensors can calculate measurement accuracy on-line by computing the Mean over a number of measurements and analyzing all factors affecting accuracy.
- This averaging process also serves to greatly reduce the magnitude of random measurement errors.

Adjustment for measurement non-linearities

- In the case of sensors that have a non-linear relationship between the measured quantity and the sensor output, digital processing can convert the output to a linear form, providing that the nature of the non-linearity is known so that an equation describing it can be programmed into the sensor.

General Architecture of smart sensor:

- One can easily propose a general architecture of smart sensor from its definition, functions.
- From the definition of smart sensor it seems that it is similar to a data acquisition system, the only difference being the presence of complete system on a single silicon chip. In addition to this it has on–chip offset and temperature compensation.
- A general architecture of smart sensor consists of following important components: (1)Sensing element/transduction element, (2) Amplifier, (3) Sample and hold, (4) Analog multiplexer, (5) Analog to digital converter (ADC), (6) Offset and temperature compensation, (7) Digital to analog converter (DAC), (8) Memory, (9) Serial communication and o Processor
- The generalized architecture of smart sensor is shown below:



Architecture of smart sensor is shown.

- In the architecture shown A1, A2…An and S/H1, S/H2…S/Hn are the amplifiers and sample and hold circuit corresponding to different sensing element respectively. ¬ So as to get a digital form of an analog signal the analog signal is periodically sampled (its instantaneous value is acquired by circuit), and that constant value is held and is converted into a digital word.
- Any type of ADC must contain or proceeded by, a circuit that holds the voltage at the input to the ADC converter constant during the entire conversion time. Conversion times vary widely, from nanoseconds (for flash ADCs) to microseconds (successive approximation ADC) to hundreds of microseconds (for dual slope integrator ADCs).
- ADC starts conversion when it receives start of conversion signal (SOC) from the processor and after conversion is over it gives end of conversion signal to the processor. Outputs of all the sample and hold circuits are multiplexed together so that we can use a single ADC, which will reduce the cost of the chip. Offset compensation and correction comprise of an ADC for measuring a reference voltage and other for the zero.
- Dedicating two channels of the multiplexer and using only one ADC for whole system can avoid the addition of ADC for this. ¬ This is helpful in offset correction and zero compensation of gain due to temperature drifts of acquisition chain. In addition to this smart sensor also include internal memory so that we can store the data and program required.