Chettinad
College of Engineering & Technology
Approved by AICTE-New Delhi and Affiliated to Anna University-Chennai.

EE3403 – MEASUREMENTS AND INSTRUMENTATION (R2021)

QUESTION BANK
MODEL EXAM

UNIT I - CONCEPTS OF MEASUREMENTS
UNIT II - MEASUREMENT OF PARAMETERS IN ELECTRICAL SYSTEMS
UNIT III - AC/DC BRIDGES AND INSTRUMENTATION AMPLIFIERS
UNIT IV - TRANSDUCERS FOR MEASUREMENT OF NON- ELECTRICAL PARAMETERS
UNIT V - DIGITAL INSTRUMENTATION

UNIT I

PART-A

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

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)

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)

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 measurementsystem? (Apr / May 13)

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)

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 fromits true value	Precision of a measuring system gives its capability to reproduce a certain readingwith a given accuracy

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

International Ohms

International Amperes

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

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)

Absolute error e= A_t-A_m=40-39=1volt

9. Define limiting errors. (Dec 2007)

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)

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

11. Define fidelity (Nov 2009)

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)

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

PART-B

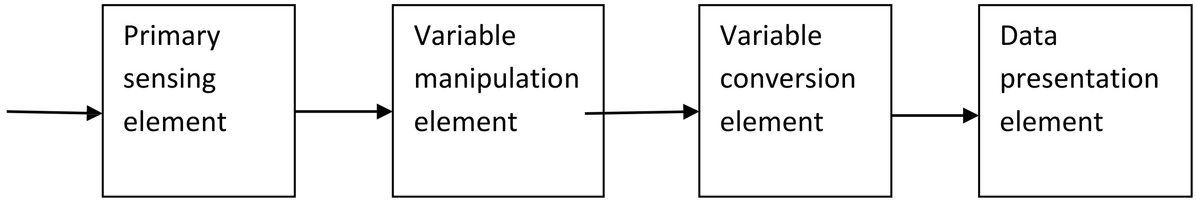
1. Explain the functional elements of measurement system with neat block diagram.(DEC 14)

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

i) Primary sensing element

ii) Variable conversion element &

iii) Data presentation element.



Primary sensing element:

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 isto 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'.

Variable conversion element:

The output of the primary sensing element may be electrical signal of any form, it may bevoltage, a frequency or some other electrical parameter For the instrument to perform thedesired 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 systemThis process of conversion is called µ signal conditioning'

Data presentation element:

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 maybe used. The final stage in a measurement system is known as terminating stage'.

2. Explain the static characteristics of measurement system in detail.(APR 2011/MAY 2013) 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 wbewrwep.eraetjeidnlpy amuela.csuormed. 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 unduewarming 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 iscalled 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 operatinglife.

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.

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

- Calibration is the process of making an adjustment 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 standardinstrument. 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

ii) Indirect comparisons

Direct comparisons:

- ➢ In a direct comparison, a source or generator applies a known input to the meterunder test.
- ➢ The ratio of what meter is indicating & the known generator values gives themeters 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 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.

4. 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 an d measures and are periodically evaluated and checked by absolute measurements in term s 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

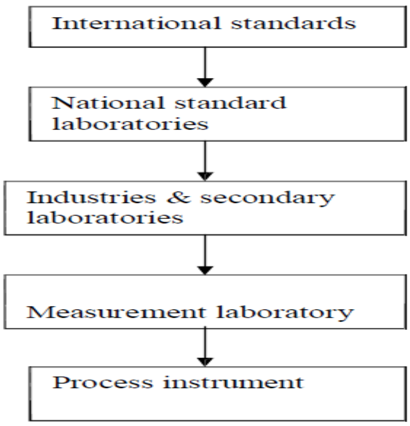
➢ As mentioned above, the primary standards are not available for use outside the national laboratories. The various industries need some reference standards.

➢ 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.



5.A) i) Explain the dynamic characteristics of measurement system in detail.(MAY2013)

Dynamic characteristics: The set of criteria defined for the instruments, which arechanges 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 systemresponds to changes in the measured quantity.

Measuring lag: It is the retardation or delay in the response of a measurement systemto 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 death time the application of the input.

Fidelity: It is defined as the degree to which a measurement system indicates changesin 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 isalso called measurement error.

ii) A circuit was tuned for resonance by eight different students and the values ofresonant frequency in KHz were recorded as 532, 548, 543, 535, 546, 531, 543, and 536. Calculate a) Mean b) Average deviation

a) Mean = (532+548+ 543+ 535+ 546+ 531+ 543+ 536)/8

= 4314/8

= **539.25**

b) SD:

Deviation from meanD1 = 532-539.25 = -7.25

D2 = 548-539.25= 8.75

D3 = 543-539.25= 3.75

D4= 535-539.25= -4.25

D5= 546-539.25=6.75

D6= 531-539.25= -8.25

D7= 543-539.25=3.75

D8= 536-539.25= -3.25

Average deviation = (7.25+8.75+3.75+4.25+6.75+8.25+3.75+3.25) /8

= 46/8

= **5.75**

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 humanbeing.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 use d in the instrument, such as defectiveor 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 frictionin 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:

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 im proper way of using the instrument cause the serious errors. The best ex ample of such loading effect error is connecting a w ell 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 themanufacturer 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 electrostaticshields 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 change in the variable to be measured.

Random errors:

Some errors still result, though the systematic and instrumental errors are reduced or at least 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? (8)(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 thedata'.**

For such statistical analysis, the same reading is taken number of times, generally using different observers, different instruments & by different ways of measurement. Thestatistical anlysis helps to determine analytically the uncertainty of the final test results. **Arithmetic mean& median**: When the n umber of readings of the same measurementare taken, the most likely value from the set of measured value is the arithmetic mean ofthe number of readings taken. The arithmetic mean value can be mathematicallyobtained 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 thenumber 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 meanof the data set di=xi- $\overline{X}$

Where di = deviation of ith reading Xi= value of ith reading

$\overline{X}$ = arithmetic mean The average deviation is defined as the sum of the absolutevalues 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 groupeddata 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, exceptthat square root is not extracted.

$V = (\text{standard deviation})^2$

$= d_1^2 + d_1^2 + d_1^2 + \ldots\ldots.\ d_1^2/n$

$= \sum d^2/n$

When the number of observations is less than 20,

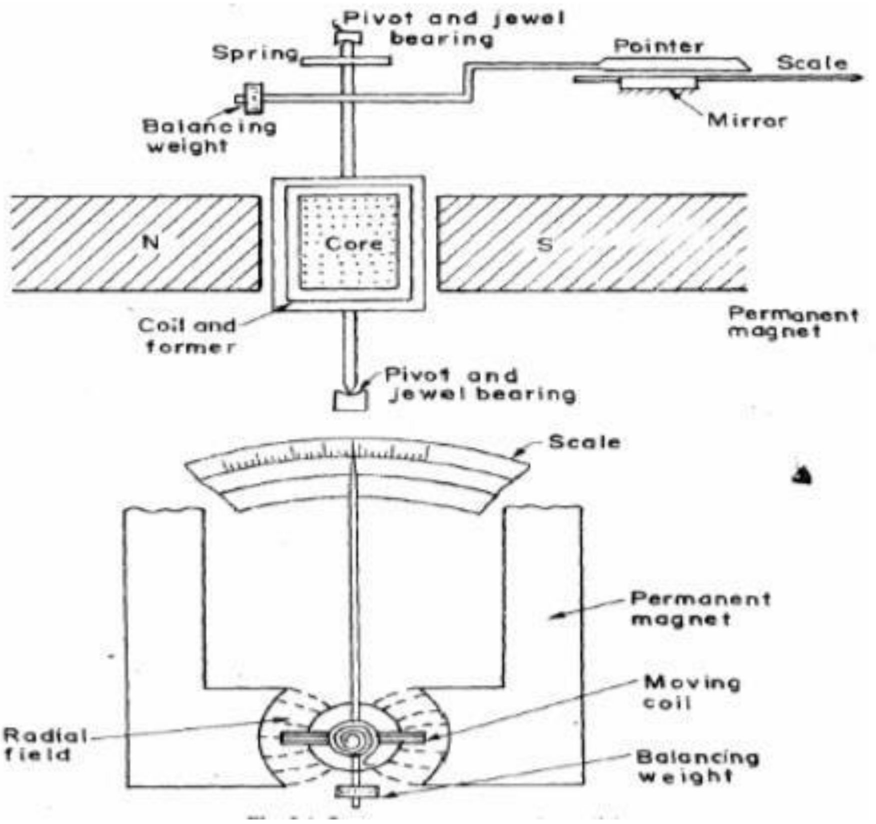
Variance $V = \dfrac{\sum d^2}{n - 1}$

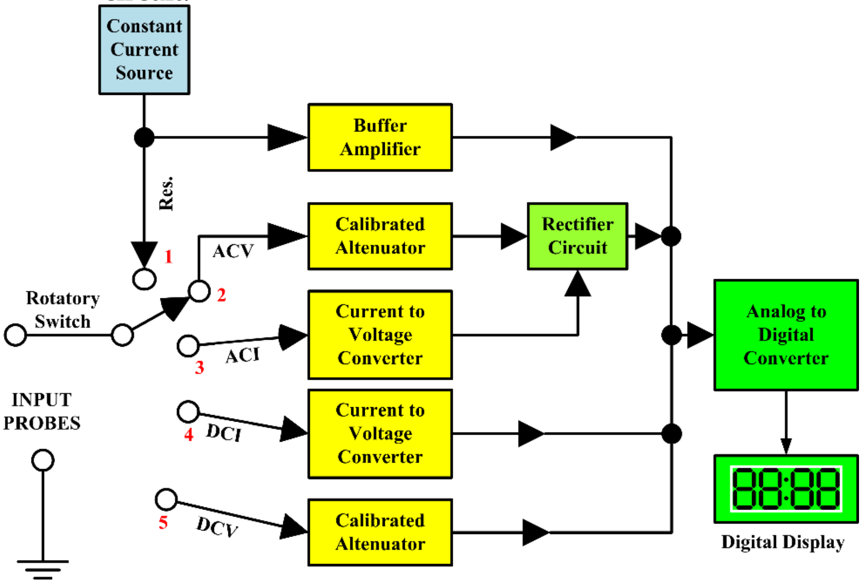
UNIT II – Measurements of Parameters in Electrical Systems

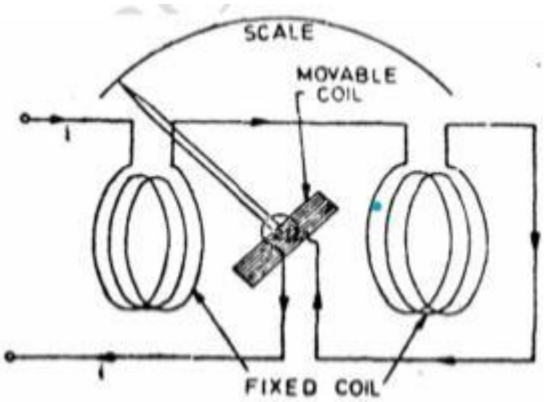
Syllabus: Analog instrument principle, operating force, Analog instrument controlling & damping system, moving coil and moving iron meters, Electrodynamometer type wattmeter, Induction type energy meter, Megger, Instrument transformer (C.T & P.T) Measurement of power & Energy using C.T, P.T.

1.	**State the essentials torque required for successful operation of instruments? (Nov/Dec 2018)** • Deflecting torque • Controlling torque • Damping torque
2.	**Why scale of gravity is non-uniform? (Apr/May 2021)** The quantity is to measure is proportional to sin rather than in gravity control which is not a uniform. Hence scale calibrated is not in uniform.
3.	**What is the basic principle of PMMC instruments?** A current carrying coil placed in the permanent magnet field experiences a force, proportional to the current it carries.
4.	**List the possible cause of errors in moving iron instruments? (Apr/May 2021)** • Hysteresis errors. • Temperature errors. • Stray magnetic field errors • Frequency & eddy current errors
6.	**What is loading effect? (Nov/Dec 2023)** The low sensitive instruments is used in high resistances circuit then its gives a lower reading than the true reading.
7.	**State the precautions to be taken while using d.c. voltmeter?** The voltmeter resistances are very high & it should always be connected across the circuit or component whose voltage is to be measure.
8.	**What are the requirements of a multiplier? (Nov/Dec 2018)** • Their resistances should not change with time. • They should not non-inductively wound for a.c.meters.
9.	**Which torque is absence in energy meter?** The controlling torque is absence in energy metering energy meter continues rotation of disc is required & it is not necessary to reset it to zero every time & hence controlling torque is absence.
10	**What are the constructional parts of dynamometer type wattmeter?** • Fixed coil • Moving Coil • Current limiting resister • Helical spring • Spindle attached with pointer • Graduated scale
11	**Name the errors caused in Dynamometer type wattmeter.(Nov/Dec 2013)** 2 • Error due to pressure coil inductance • Error due to pressure coil capacitance • Error due to methods of connection • Error due to stray magnetic fields • Error due to eddy current.
12	**Name the methods used for power measurement in three phase circuits.(Nov/Dec 2010)** • Single wattmeter method • Two wattmeter method • Three wattmeter method.

13	**What are the special features to be incorporated for LPF wattmeter? (Nov/Dec 2016)** BTL 2 • Pressure coil circuit • Compensation for Pressure coil current • Compensation for Pressure coil inductance.
14	**Define creeping. (May/June 2014)** Slow but continuous rotation of disc when pc is energized and cc is not energized.
15	**Name the types of instruments used for making voltmeter and ammeter. (Nov/Dec 2013)** • PMMC type • Moving iron type • Dynamometer type • Hot wire type • Electrostatic type • Induction type.
16	**State the applications of PMMC instruments. (May/June 2012)** • m/s of dc voltage and current • Used in dc galvanometer.
17	**How the range of instrument can be extended in PMMC instruments. (Nov/Dec 2011)** • In ammeter by connecting a shunt resister • In voltmeter by connecting a series resister.
18	**State the advantages of Hot wire type instruments. (Apr/May 2015)** • Can be used for both dc and ac • Unaffected by stray magnetic fields • Readings are independent of frequency and waveform.

1.	**Describe the construction and working of permanent magnet moving coil instrument. Also derive the expression for deflection. (Nov/Dec 2013)**  A moving-coil meter is a very commonly used form of analogue voltmeter because of its sensitivity, accuracy and linear scale, although it only responds to d.c. signals. As shown schematically in Figure 6.2, it consists of a rectangular coil wound round a soft iron core that is suspended in the field of a permanent magnet. The signal being measured is applied to the coil and this produces a radial magnetic field. Interaction between this induced field and the field produced by the permanent magnet causes a torque, which results in rotation of the coil. **Torque equation:** Deflecting torque Td= NBAI N=number of turns of coil B= Flux density in air gap A= coil area I= Current through moving coil Final steady deflection Tc=Td **Advantages & disadvantages:** Advantages: • The sensitivity is high

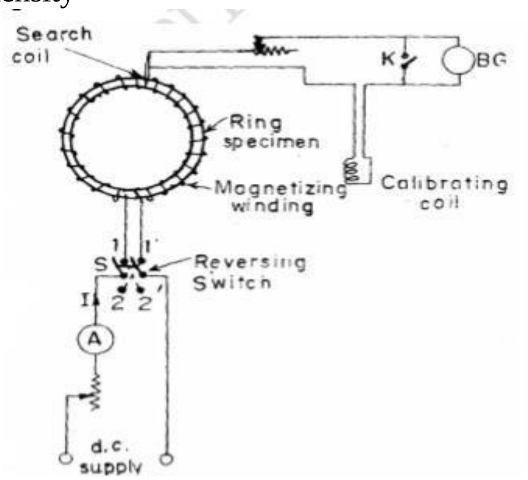
	• Uniform scale • Operating current is small Disadvantages: • Not suitable for AC measurements • Ageing of PMMC introduces the errors • Cost is high
2.	**With a neat block diagram explain the working of a digital multimeter.** • Digital multimeter is an instrument which can be used for measuring d.c and a.c voltages, direct and alternating currents, and resistances over several ranges. • For measurement of a.c voltages and currents, the ac values are converted to dc value by using rectifier and filter circuits & corresponding dc volatges are measured using the basic circuit.  • <u>Adv</u> 1. Highly accurate and the accuracy is around 0.03 % 2. Loading effect is nil because of high input impedance 3. Measurement speed is more <u>Dis-Adv:</u> 1. Interruption of electric noise 2. Requirement of external power supply 3. Isolation problems occurs in DMM.

3.	**With a neat diagram explain the construction and working of electrodynamometer type instruments. Also derive its torque equation. (Nov/Dec 2010)** • Circuit diagram  This instrument can be used for the measurement of voltage current and with some modification it can be used for the measurement of power factor and frequency. This instrument serves as a transfer instrument and provide same accuracy for both AC and DC. Instrument is calibrated with a de source and then the same instrument is used without modification to measure AC. This type of instruments is called as transfer instruments. Principle: Current through the fixed coil produces a magnetic field and the moving coil also produces a magnetic field when current flous through it moving coil is placed in between the two sections of fixed coil. These two fields creates a force between the two coils. This force causes the moving system to deflect. • <u>Adv</u> 1. As the coils are air cored, these instruments are free from hysteresis and eddy current losses. 2. They have a precision grade accuracy for frequencies from 40 HZ to 500 Hz. <u>Dis-Adv</u> 1. They have a low torque/ weight ratio hence have a low sensitivity 2. Increases frictional losses.

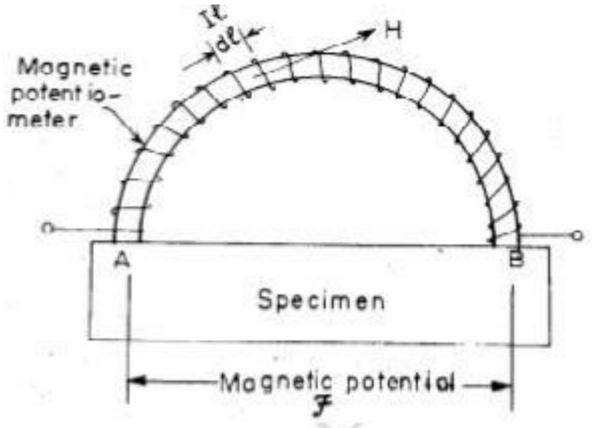
4.	**Explain the different methods of determination of B –H curve 13M (Nov/Dec 2011) (Nov/Dec 2010) (April/May 2011) (May /June2014)**

By plotting values of flux density, (B) against the field strength, (H) we can produce a set of curves called Magnetisation Curves, Magnetic Hysteresis Curves or more commonly B-H Curves for each type of core material used as shown below

- **Types of test**
  1. Ballistic test
  2. A.C Testing
  3. Steady state test
- **Determination of B-H curve methods**
  1. Measurements of flux density



  2. Magnetic potentiometer



(Fig) Magnetic potentiometer

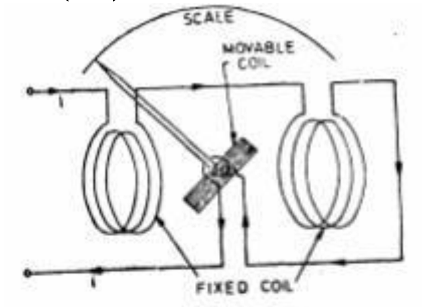
After reaching the point of maximum H i.e... when switch S is at tapping 10, the magnetizing current is next reduced, in steps to zero by moving switch 2 down through the tapping points 9, 8, 7 3, 2, 1.

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, 1O.

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.

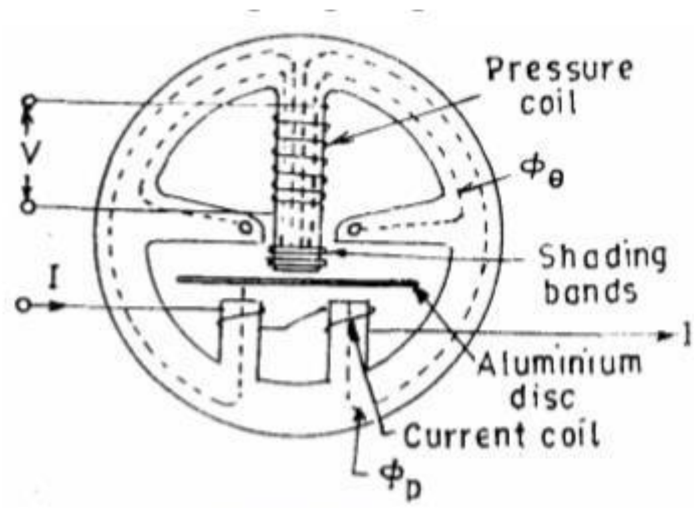
5.	**With a neat block diagram explain the working of digital frequency meter & digital phase meter. (Nov/Dec 2011) (Nov/Dec 2018)**

	• Circuit diagram & explanation (9M)  • Electrodynamic instruments are capable of service as transfer instruments. Indeed, their principal use as ammeters and voltmeters in laboratory and measurement work is for the transfer calibration of working instruments and as standards for calibration of other instruments as their accuracy is very high. • Electrodynamometer types of instruments are used as a.c. voltmeters and ammeters both in the range of power frequencies and lower part of the audio power frequency range. They are used as watt-meters, and with some modification as power factor meters and frequency meters. • Advantages (2M) 1. Simple in construction 2. Simple operation 3. Gives an accurate measurement. • Dis-advantages of phase meter(2M) 1. Poor accuracy **2.** The phase difference of 180 out of phase or inphase condition only can be detected. Other phase angles cannot be measured.

6.

Give the construction and principle of operation of single phase induction type energy meter. Also derive its torque equation. (April/May 2011) Nov/Dec 2009) (May /June2018)

The supply voltage is applied across the pressure coil. The pressure coil winding is highly inductive as it has a very large number of turns and the reluctance of its magnetic circuit is very small owing to the presence of air gaps of very small length. Thus the current I, through the pressure coil is proportional to the supply voltage and lags it by a few degrees less than 90°. This is because the winding has a small resistance and there are iron losses in the magnetic circuit.



(Fig) single phase energy meter

Advantages of Energy Meter

The Energy Meter gives accurate readings.

Energy meters require very little maintenance.

The energy consumption of an energy meter is very low.

Disadvantages of Energy Meter

Installing a meter is very time-consuming.

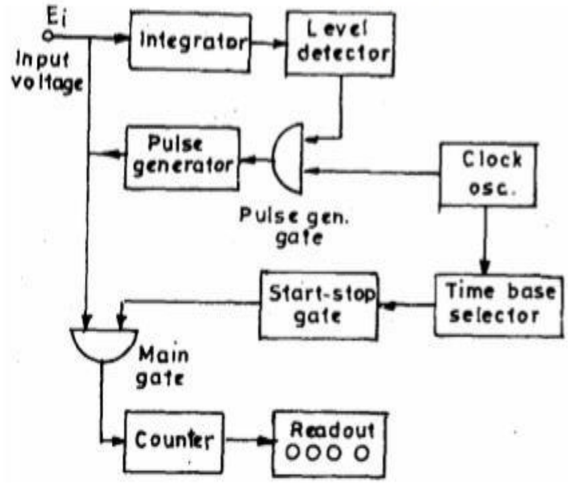
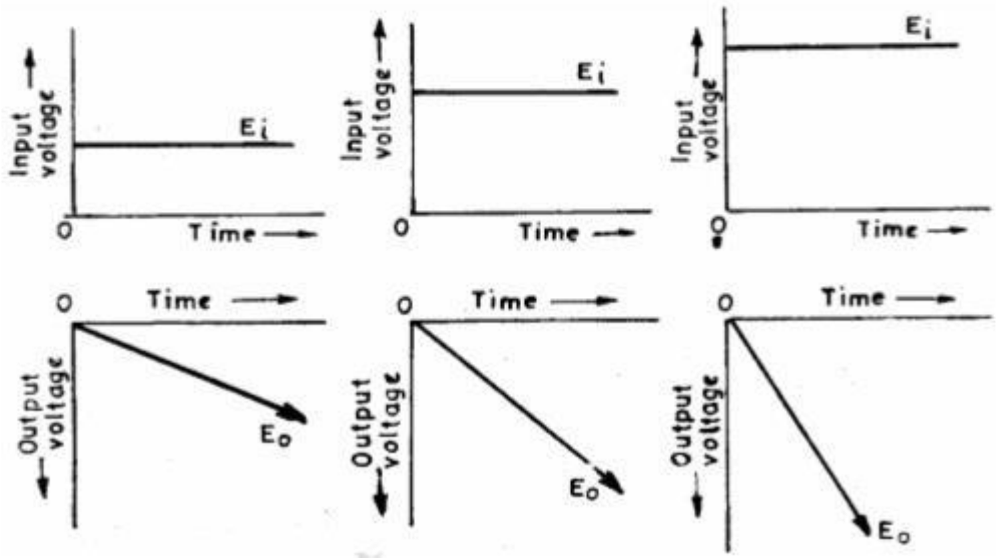
Electromagnetic interference changes the sensitivity of the energy meter.

Installation cost of energy meters is very high.

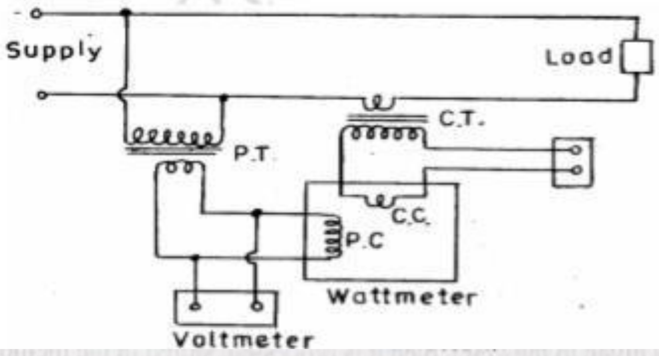
7.

Explain with neat diagram the working of linear ramp type & integrating type DVM. (April/May 2011)

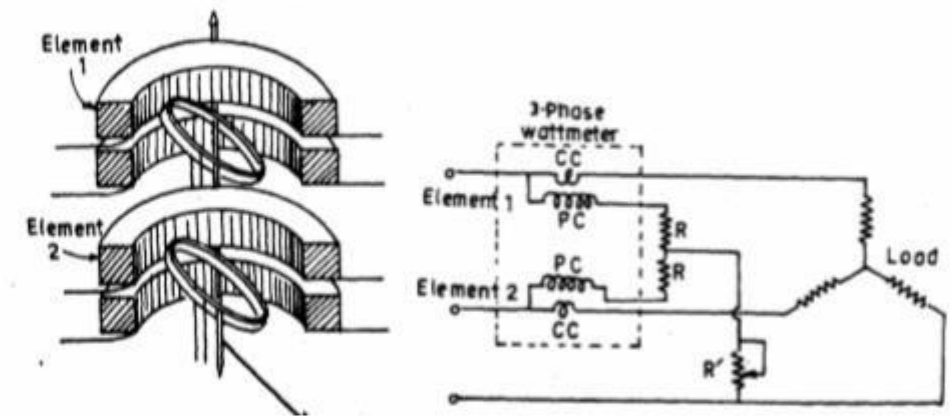
- **Ramp type DVM**
  1. The operating principle of a ramp type digital voltmeter is to measure the time that a linear ramp voltage takes to change from level of input voltage to zero voltage (or vice versa)
  2. This time interval is measured with an electronic time interval counter and the count is displayed as a number of digits on electronic indicating tubes of the output readout of the voltmeter.
- **Integrating type DVM**

	 
8.	**Explain the operating principle of Instrument Transformer and what are errors affecting its charactersistics. (April/May 2011) (Nov/Dec 2018)** For measuring a large current in a d.c. circuit, we use low-range ammeter with a suitable shunt. The measurement of high d.c. voltage is made using a low-range voltmeter with a multiplier. **Current Transformer (C.T.)** A current transformer (C.T.) is used to measure high alternating current in a power system. The primary of this transformer has a few turns of thick wire whereas the secondary has many turns of very fine wire as shown in Fig. 4.15. It is clear from the figure that a current transformer is simply a well designed step-up transformer. Since voltage is stepped up, the current is stepped down which can be measured with a low-range a.c. ammeter. **Potential Transformer (P.T.)** A potential transformer (P.T.) is used to measure high alternating potential difference (voltage) in a power system. The primary of this transformer has many turns while the secondary has few turns as shown in Fig. It is clear from the figure that a potential transformer is simply a well-designed step- down transformer. The stepped down voltage is measured with a low-range a.c. voltmeter. The magnetic core of a potential transformer usually has a shell-type construction for better accuracy. In order to

provide adequate protection to the operator, one end of the secondary winding is usually grounded.



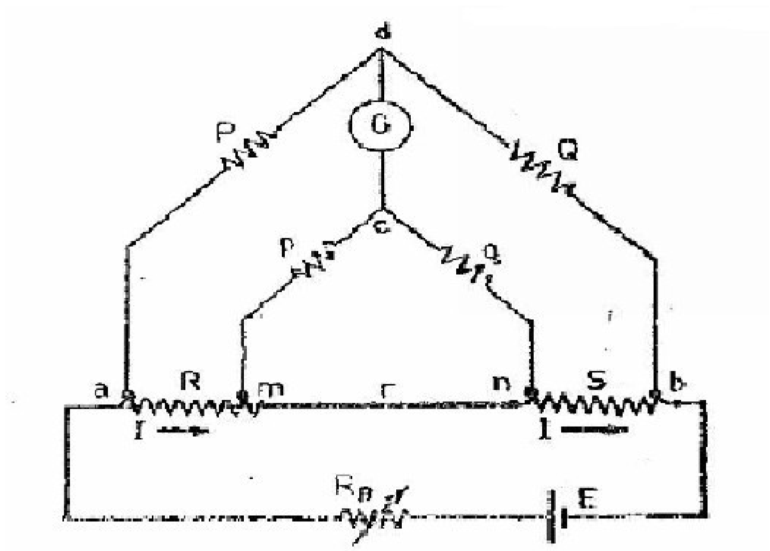
Sl.No.	Current Transformer (C.T.)	Potential Transformer (P.T.)
1	Connected in series with power circuit.	Connected in Parallel with Power circuit.
2	Secondary is connected to Ammeter.	Secondary is connected to Voltmeter.
3	Secondary works almost in short circuited condition.	Secondary works almost in open circuited condition.
4	Primary current depends on power circuit current.	Primary current depends on secondary burden.
5	Primary current and excitation vary over wide range with change of power circuit current	Primary current and excitation variation are restricted to a small range.
6	One terminal of secondary is earthed to avoid the insulation break down.	One terminal of secondary can be earthed for Safety.
7	Secondary is never be open circuited.	Secondary can be used in open circuit condition.

9.	**Explain the design of three phase wattmeter's and give the reactive power measurement in 3 phase circuits.** • **Three phase wattmeter circuit diagram** An electrical device or equipment works on supplying AC current. The power consumed by the device or equipment is measured using a wattmeter (in watts/ kilowatts/ megawatts). A wattmeter consists of 2 coils like current coil 'CC' of low resistance connected along with the load and potential coil "PC" which is connected across the load. The 3-phase power of a 3-phase circuit can be measured either using a 3 Wattmeter Method or a 2 Wattmeter Method or a 1 Wattmeter Method. This article describes measuring 3 phase power using a 3 wattmeter method.  **Advantages of Three Wattmeter Method** The following are the advantages Can measure power in the individual phase Can measure phase to neutral voltages In the absence of neutral wire, a duplicate neutral wire can be created. **Disadvantages of Three Wattmeter Method** The following are the disadvantage 3 wattmeter is used Highly sensitive to heavy loads. **Applications of Three Wattmeter Method** The following are the applications They are usually used in power system Used in refrigerators, electrical heaters Used in industries for measuring power rating and power consumption.

UNIT III AC/DC Bridges and Instrumentation Amplifier
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

Q.No	Questions
1.	**Name the bridge circuits used for the m/s of self-inductance. (Nov/Dec 2011)** • Maxwell's bridge • Maxwell-Wein Bridge • Anderson bridge • Hay's bridge.
2.	**Name the bridge circuits used for the m/s of mutual inductance.(May/June 2014)** • The Heaviside Campbell Bridge • The Campbell Bridge.
3.	**Name the ac sources used in ac bridges.(Nov/Dec 2012)** • AC supply with step-down transformer • Motor driven alternator • Audio frequency and radio frequency oscillator.
4.	**Name the sources of errors in ac bridge (May/June 2014)** • Errors due to stray magnetic fields • Leakage errors • Eddy current errors • Residual errors • Frequency and waveform errors.
5.	**Define Q-factor of the coil.** It is the ratio between Power stored in the coil to the power dissipated in the coil
6.	**Name the faults that occur in cables. (Apr/May 2010)** • Break down of cable insulation • Short circuit fault • Open conductor fault.
7.	**Name the methods used for low resistance measurement.(Apr/May 2010)** • Ammeter – voltmeter method • Potentiometer method • Kelvin double bridge method • Ohm meter method
8.	**Name the methods used for medium resistance measurement. (Nov/Dec 2009)** • Ammeter – voltmeter method • Substitution method • Wheatstone bridge method • Carey fosters bridge method.

9.	**Where high resistance measurements is required? (Nov/Dec 2009)** • Insulation resistance of cables • High resistance circuit elements • Volume resistivity of a material • Surface resistivity.
10.	**State the applications of ac potentiometers.(Nov/Dec 2010)** • Measurements of self-inductance. • Ammeter calibration • Voltmeter calibration • Wattmeter calibration.
11.	**State the advantages of Kelvin double bridge method.** Errors owing to contact resistance, resistance of leads can be eliminated by using This Electric Energy Generation, Utilization and Conservation
12.	**Name the sources of errors in ac bridge measurements. (May/June 2014)** • Errors due to stray magnetic fields • Leakage errors • Eddy current errors • Residual errors • Frequency and waveform errors.
13.	**How the earth resistance is measured.** By using earth megger the value of surface earth resistance can be measured.
	PART * B
.	**Explain the theory and working principle of Kelvin's double bridge method for the measurement of low resistance. Derive the relation for finding unknown resistance. (13M)(NOV/DEC 2011)(MAY/JUNE 2014) (APR/MAY 2015) (APR/MAY 2010)** • Kelvin's double bridge method circuit diagram & explanation (10M)  Kelvin Double Bridge

- A Kelvin bridge, also called a Kelvin double bridge and in some countries a Thomson bridge, is a measuring instrument used to measure unknown electrical resistors below 1 ohm. It is specifically designed to measure resistors that are constructed as four terminal resistors.
- Kelvin's bridge principle is not a practical way of desired result. There is some difficulty for determining the galvanometer connections. To avoid this difficulty, two resistances p & q can be connected between point's m and n.

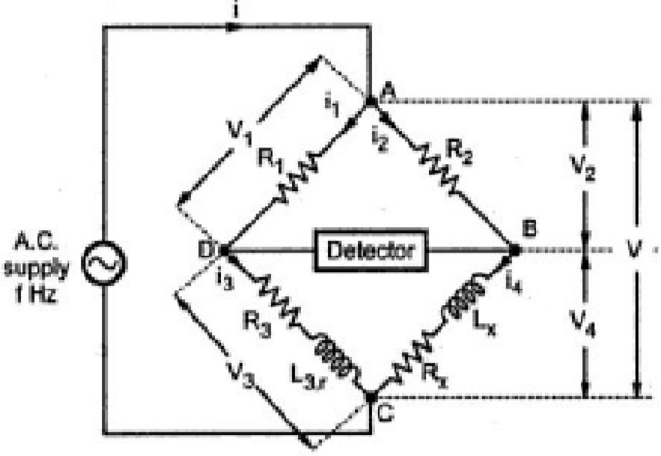
$$\frac{PI}{P+Q}[R+S+\frac{(p+q)r}{p+q+r}]=I[R+\frac{pr}{p+q+r}]$$

$$or\ R=\frac{P}{Q}S+\frac{qr}{p+q+r}[\frac{P}{Q}-\frac{p}{q}] ------------(1)$$

- $$now\ if\ \frac{P}{Q}=\frac{p}{q}\ Eq\ (1)\ becomes,\ R=\frac{P}{Q}S ---------(2)$$
- The ratio p/q is made equal to P/Q
- R= P/Q.S
- Advantages-Kelvin Bridge is a modified Wheatstone bridge and provides high accuracy especially in the measurement of low resistance below 1 Ω. The error introduced by the contact/lead resistance is quite large and hence, will give an inaccurate reading if measured through a Wheatstone bridge.

2.

Explain how inductance is measured by using Maxwell's bridge .Derive the condition for balance. (13M) (NOV/DEC 2013) (MAY/JUNE 2014)



- It is used to measure both a given inductance (with a Q between 1 and 10) and its series resistance by comparison to a standard capacitances.
- Capacitors are easy to shield and they produce almost no external field of their own.
- The balance is independent of frequency.

<table>
<tr><td></td><td>

- Using Q-factor for a series L-R equivalent circuit, the series resistances can be found from
  Rx=wLx/Q
- Advantages & disadvantages(3m)

<u>Adv:</u>

- The frequency does not appear in any of the two equations.
- The two balance equations are independent, if the values of R1 & C1 as variable elements.

<u>Dis adv:</u>

- This bridge is limited to measurement of low Q coils
- It requires a variable standard capacitor which may be very expensive if calibrated to a high degree of accuracy.

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Explain the working principle of Anderson's bridge and also derive its balance equations. (13M)

Adv:

- A fixed capacitor can be used instead of a variable capacitors in the case of Maxwell's bridge.
- This bridge may be used for accurate determination of capacitance in terms of inductance.

Dis-Adv:

- The Anderson's bridge is more complex than its prototype Maxwell's bridge.
- An additional junction increases the difficulty of shielding the bridge.

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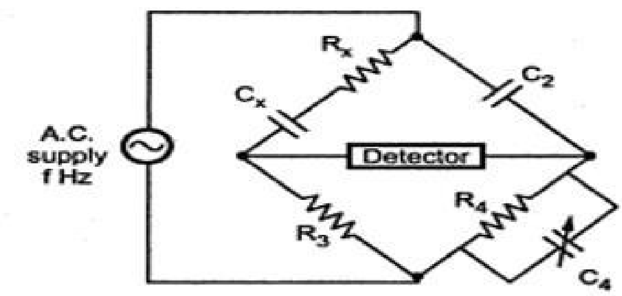
<tr><td>4.</td><td>

Explain the working principle of Schering Bridge and also derive its balance equations. (13M) (APR/MAY 2011)

- Schering bridge circuit diagram & explanation (10M)



- It is one of the most important AC bridges, is used extensively for measurement of capacitors with a low dissipation factor.
- Besides capacitances and dissipation factors it also measures the insulating properties of the electrical cables (for phase angle very close to 90^o) and equipment's.
- Advantages (3M)
  1. The balance equation is independent of frequency.
  2. It is used for measuring the insulating properties of electrical cables and equipmemts.

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Explain the working principle of Wheatstone Bridge and also derive its balance equations. (13M) (APR/MAY 2011) (NOV/DEC 2012)

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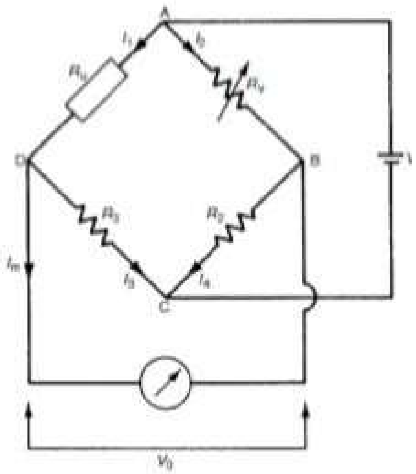
- Wheatstone bridge circuit diagram & explanation (5M& 8M)



- The simplest form of bridge is for the purpose of measuring resistance and is called Wheatstone's bridge.
- This bridge is widely used for precision measurement of resistance from 1Ω to the low mega ohm range.
- It is the most accurate method available for measuring and is popular for laboratory use.
- Here the bridge is balanced when the potential difference across C & D is zero.

$$I_1R_1 = I_2R_2$$

- The unknown resistor is R_4 or Rx can be found as follows:

$$Rx = R_4 = R_2/R_1 * R_3$$

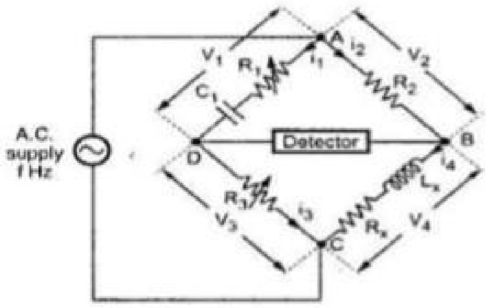
- The resistors r1 & r2 are called ratio arms and resistor r3 is called standard arm of the bridge.

6

Mention the importance of grounding. Explain the different techniques of grounding. (13M) (NOV/DEC 2011) (NOV/DEC 2013) (APR/MAY 2018)

- Grounding techniques(3M)
  1. Single point grounding
  2. Use of differential input amplifier
  3. Input guarding
  4. Using doubly shielded cables
- Single point grounding diagram (3M)
  1. Circuit diagram
  2. Limitations: single point grounding is impractical for the systems in which various units like power supply, amplifier etc. are located too fair.
- Use of differential input amplifiers: (3M)
  1. Circuit diagram
  2. Limitations: It is not applicable to the case where Ecm is so high that it exceeds the permissible level of input of differential amplifiers.
- Input guarding & Doubly shielded cables: (4M)
  1. Circuit diagram

	2. Rules for input guarding technique: connect the guard shield to the cable shield. Connect the cable shield to the transducer signal shield.
7	**Explain in detail the electrostatic and electromagnetic interference. (13M) (NOV/DEC 2011) (NOV/DEC 2013)(APR/MAY 2010)** • Sources of electromagnetic interferences are 1. Gas discharges in fluorescent lamp 2. Sparking in electric switches, relays 3. Arcing in electric switches relays etc • Formation of group loop diagram • Causes of ground loop current 1. Potential difference between two grounding points 2. Inductive interferences due to stray magnetic field and RF waves. 3. Sometimes capacitive interference also form a ground loop. • Common mode and series mode voltages
	PART*C
1	**A whetstones bridges is used to measure high resistance S whose ratio arms are 10000Ω & 10 ohm. The adjustable arm has a maximum value of 10000 ohm. A battery of 20 V, emf and negligible resistances forms the junction ratio arms to the opposite corner. What is the maximum resistance which can be measured? (15M)** R1/R2= 10000/10 Smax=R3max=10000 ohm We know that, R4= R3.R2/R1 Maximum value of R4 that can be measured = 10000/10 * 10000= 10Mohm.
2	**Discuss briefly how Hay's Bridge can be used for the measurement of inductance. Why hay's bridge is suited for measurement of inductance of high Q coils. (15M) (NOV/DEC 2011).**

	 • Hay bridge or opposite-angle bridge is used for the measurement of high –Q inductors(Q>10) • The hay bridge differs from Maxwell in that it has a standard capacitor in the arm opposite to the unknown inductor. • Unlike the capacitance and Maxwell inductance bridges, balance is dependent on frequency. • Advantages: (3M) 1. This bridges gives very simple expressions for unknown inductances for high Q coils, and is suitable for the coils having Q>10. 2. It also gives a simple expression for Q factor, Q= 1/ wC2R2.

UNIT IV

TRANSDUCERS AND SENSORS

1. What is mean by transducer? (Remembering)

A transducer is a device, usually electrical, electronic, electro-mechanical, electromagnetic, photonic, or photovoltaic, that converts one type of energy or physical attribute to another for various purposes including measurement or information transfer (for example: pressure sensors).

(Or)

A transducer may be defined as a device which converts a physical quantity or a physical condition into an electrical signal. Another name for a transducer is **pick up.**

2. Classification of transducers? (Remembering)

There are three kinds of transducers. A sensor is used to detect a parameter in one form and report it in another form of energy (usually an electrical or digital signal), such as a tachometer. An actuator is used for the transformation of energy. The third kind of transducer has both functions -- for example, a typical ultrasonic transducer switches back and forth many times a second between acting as an actuator to produce ultrasonic waves, and acting as a sensor to detect ultrasonic waves.

(Or)

The transducers can be classified,

- on the basis of transduction form used,
- as primary and secondary transducers,
- as passive and active transducers,
- as analog and digital transducers,
- as transducers and inverse transducers.

3. Classity the different types of transducers. (Remembering)

- **Electromagnetic:**
  - Antenna - converts electromagnetic waves into electric current and vice versa.
  - Cathode ray tube (CRT) - converts electrical signals into visual form
  - Fluorescent lamp, light bulb - converts electrical power into visible light
  - Magnetic cartridge - converts motion into electrical form
  - Photodetector or Photoresistor (LDR) - converts changes in light levels into resistance changes
  - Tape head - converts changing magnetic fields into electrical form
  - Hall effect sensor - converts a magnetic field level into electrical form only.
- **Electrochemical:**
  - pH probes
  - Electro-galvanic fuel cell
- **Electromechanical** (electromechanical output devices are generically called actuators):
  - Electroactive polymers
  - Galvanometer
  - MEMS

  - Rotary motor, linear motor
  - Vibration powered generator
  - Potentiometer when used for measuring position
  - Load cell converts force to mV/V electrical signal using strain gauge
  - Accelerometer
  - Strain gauge
  - String Potentiometer
  - Air flow sensor
- **Electroacoustic**:
  - Loudspeaker, earphone - converts electrical signals into sound (amplified signal → magnetic field → motion → air pressure)
  - Microphone - converts sound into an electrical signal (air pressure → motion of conductor/coil → magnetic field → signal)
  - Pick up (music technology) - converts motion of metal strings into an electrical signal (magnetism → electricity (signal))
  - Tactile transducer - converts solid-state vibrations into electrical signal (vibration → ? → signal)
  - Piezoelectric crystal - converts solid-state electrical moduluations into an electrical signal (vibration → ? → signal)
  - Geophone - convert a ground movement (displacement) into voltage - (vibrations → motion of conductor/coil → magnetic field → signal)
  - Gramophone pick-up - (air pressure → motion → magnetic field → signal)
  - Hydrophone - converts changes in water pressure into an electrical form
  - Sonar transponder (water pressure → motion of conductor/coil → magnetic field → signal)
- **Photoelectric**:
  - Laser diode, light-emitting diode - convert electrical power into forms of light
  - Photodiode, photoresistor, phototransistor, photomultiplier tube - converts changing light levels into electrical form
- **Electrostatic**:
  - Electrometer
- **Thermoelectric**:
  - RTD Resistance Temperature Detector
  - Thermocouple
  - Peltier cooler
  - Thermistor (includes PTC resistor and NTC resistor)
- **Radioacoustic**:
  - Geiger-Müller tube used for measuring radioactivity.
  - Receiver (radio)

4. **What are transducers? (Remembering)**

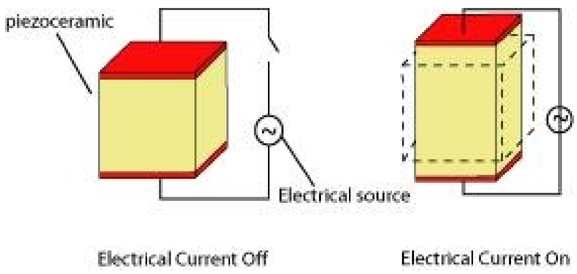
Transducers are electric or electronic devices that transform energy from one manifestation into another. Most people, when they think of transducers, think specifically of devices that perform this transformation in order to gather or transfer information, but really, anything that converts energy can be considered a transducer.

5. **How will you select the transducers for our need? (Understanding)**

To select the transducer that's best suited to your needs, you need to consider the transducer's *operating frequency*, *cone angle*, and *type of installation.*

6. **State Piezoelectric Transducers? (Remembering)**

The conversion of electrical pulses to mechanical vibrations and the conversion of returned mechanical vibrations back into electrical energy is the basis for ultrasonic testing. The active element is the heart of the transducer as it converts the electrical energy to acoustic energy, and vice versa.



7. Explain the Characteristics of Piezoelectric Transducers. (Understanding)

The transducer is a very important part of the ultrasonic instrumentation system. The transducer incorporates a piezoelectric element, which converts electrical signals into mechanical vibrations (transmit mode) and mechanical vibrations into electrical signals (receive mode). Many factors, including material, mechanical and electrical construction, and the external mechanical and electrical load conditions, influence the behavior of a transducer. Mechanical construction includes parameters such as the radiation surface area, mechanical damping, housing, connector type and other variables of physical construction. As of this writing, transducer manufacturers are hard pressed when constructing two transducers that have identical performance characteristics.

8. Define Electric Transducer. (Remembering)

In order to measure non-electrical quantities a detector is used which usually converts the physical quantity into a displacement. This displacement actuates an electric transducer, which acting as a secondary transducer, gives an output that is electrical in nature.

9. Mention the Advantages of Electrical Transducer. (Remembering)

The advantages of converting physical quantities into analogous electrical quantities are:

- Electrical amplification and attenuation can be done easily and that too with static devices.
- The mass-inertia effects are minimized.
- The effects of friction are minimized.
- The electrical or electronic systems can be controlled with a very small power level.
- The electrical output can be easily used, transmitted and processed for the purpose of measurement.

10. Mention the important parts of transducer. (Remembering)

- Sensing or Detector Element (a detector or sensing element is that part of a transducer which responds to a physical phenomenon or a change in a physical phenomenon. The response of the sensing element must be closely related to the physical phenomenon.
- Transduction Element (a transduction element transforms the output of a sensing element to an electrical output. The transduction element, in a way, acts as a secondary transducer.

11. Define Analog and Digital transducers. (Remembering)

- Analog Transducers (these transducers convert the input quantity into an analog output which is a continuous function of time. Thus a strain gauge, an L.V.D.T., a thermocouple or a thermistor may be called as “Analog Transducers” as they give an output which is a continuous function of time.
- Digital Transducers (these transducers convert the input quantity into an electrical output which is in the form of pulses.

12. List out the characteristics of Transducers. (Remembering)

When choosing a transducer for any application the following characteristics have to be taken into account.,

- Input characteristics,
- Transfer characteristics and
- Output characteristics.

13. Factors influencing the choice of Transducers.

The following factors influencing the choice of a transducer for measurement of a physical quantity,

- Operating Principle,
- Sensitivity,
- Operating Range,
- Accuracy,
- Cross Sensitivity,
- Errors,
- Transient and Frequency Response,
- Loading Effects,
- Environmental Compatibility,
- Insensitivity to Unwanted Signals,
- Usage and Ruggedness,
- Electrical aspects,
- Stability and Reliability and
- Static Characteristics.

14. What is mean by Helipots? (Remembering)

The resolution can be increased by using multi-turn potentiometers. These are called helipots.

15. What is mean by Rosettes? (Remembering)

In addition to single element strain gauges, a combination of strain gauges called “Rosetts” are available in many combinations for specific stress analysis or transducer applications.

16. State the principle of variable inductance transducers? (Remembering)

The variable inductance transducers work, generally, upon on of the following three principle:

- Change of self inductance,
- Change of mutual inductance, and
- Production of eddy current.

17. List the ddvantages of LVDT. (Remembering)

- High range

- Friction and electrical isolation
- Immunity from external effects,
- High input and high sensitivity
- Ruggedness
- Low hysteresis and
- Low power consumption

18. Define synchros. (Remembering)

A synchro is an electromagnetic transducer which is commonly used to convert the angular position of a shaft into an electric signal.

There are two types of synchro systems:

- Control or error detecting type and
- Torque transmission type.

19. State the principle of operation of capacitive transducers? (Remembering)

The principle of operation of capacitive transducers is based upon the familiar equation for capacitance of a parallel plate capacitor.

Capacitance (C) = ϵ A/d = $\epsilon_r \, \epsilon_0$ A/d

Where,

A = overlapping area of plates; m^2,

d = distance between two plates; m,

$\epsilon = \epsilon_r\epsilon_0$ = permittivity of medium; F/m.

20. Mention the advantages of capacitive transducers. (Remembering)

The major advantages of capacitive transducers are,

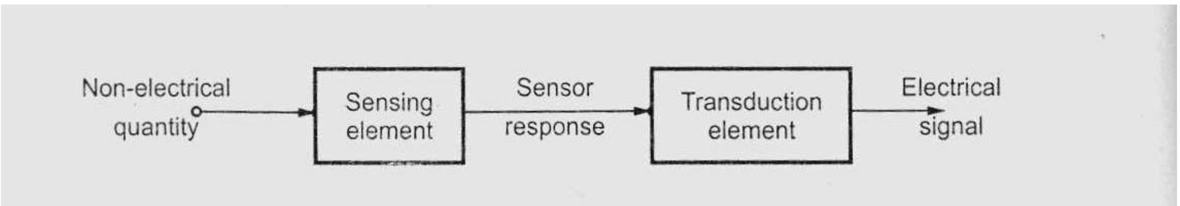
- They require extremely small forces to operate them and hence are very useful for in small systems.
- They are extremely sensitive.
- They have a good frequency response. This response is as high as 50 kHz and hence they are very useful for dynamic studies.
- They have a high input impedance and therefore the loading effects are minimum.
- A resolution of the order of 2.5 x 10-3 mm can be obtained with these transducers.
- The capacitive transducers can be used for applications where stray magnetic fields render the inductive transducers useless.

UNIT-IV TRANSDUCERS AND DATA ACQUISITION SYSTEMS

1. Write notes on transducer and also write its types.

TRANSDUCERS

- Ø The input quantity for most instrumentation systems is nonelectrical. In order to use electrical methods and techniques for measurement, the nonelectrical quantity is converted into a proportional electrical signal by a device called transducer.
- Ø Another definition states that transducer is a device which when actuated by energy in one system, supplies energy in the same form or in another form to a second system.
- Ø When transducer gives output in electrical form it is known as electrical transducer. Actually, electrical transducer consists of two parts which are very closely related to Each other.
- Ø These two parts are sensing or detecting element and transduction element. The sensing or detecting element is commonly known as sensor.
- Ø Definition states that sensor is a device that produces a measurable response to a Change in a physical condition.
- Ø The transduction element transforms the output of the sensor to an electrical output, as shown in the Fig.



(Fig)Transducer elements in cascade

Classification of Electrical Transducers

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

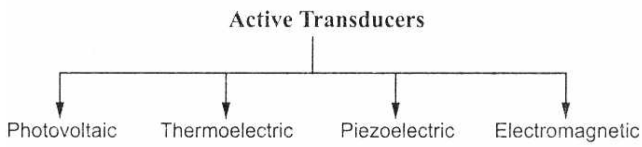
- As active and passive transducer
- According to transduction principle
- As analog and digital transducer
- As primary and secondary transducer
- As transducer and inverse transducer

Active and Passive Transducer

Active Transducers

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

Ø They can be subdivided into the following commonly used types



Passive Transducers

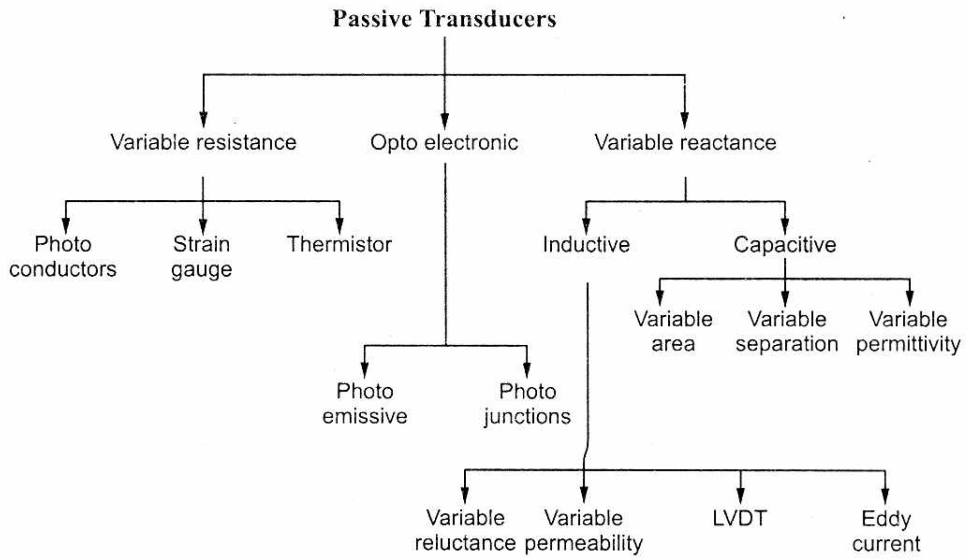
Ø Passive transducers do not generate any electrical signal by themselves.

Ø To obtain an electrical signal from such transducers, an external source of power is essential.

Ø Passive transducers depend upon the change in an electrical parameter (R, L, or C).

Ø They are also known as externally power driven transducers.

Ø 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
- Inductive transduction
- Piezoelectric transduction
- Photovoltaic transduction
- 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

Ø These transducers convert the input quantity into an analog output which is a continuous function of time.

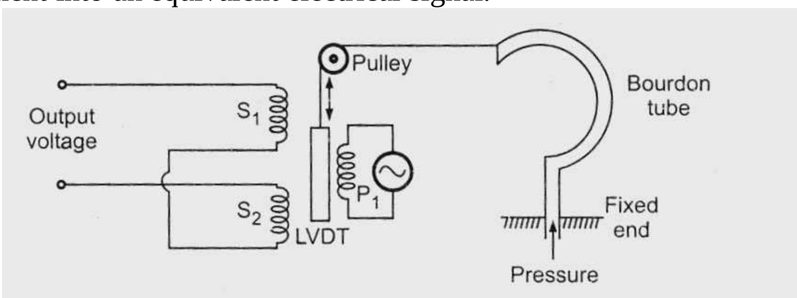
Ø A strain gauge, LVDT, thermocouples or thermistors are called analog transducers as they produce an output which is a continuous function of time.

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

- Some transducers consist of mechanical device along with the electrical device.
- In such transducers 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 electrical signal.



(Fig) pressure Measurement

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 an electrical signal whereas loudspeaker is an inverse transducer which converts electrical signal into sound signal.

Advantages of Electrical Transducers

1. 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 or recorder.
2. The electrical systems can be controlled with a very small level of power
3. The electrical output can be easily used, transmitted, and processed for the purpose of measurement.
4. With the advent of IC technology, the electronic systems have become extremely small in size, requiring small space for their operation.
5. No moving mechanical parts are involved in the electrical systems. Therefore there is no question of mechanical wear and tear and no possibility of mechanical failure.

Electrical transducer is almost a must in this modem world. Apart from the merits described above, some disadvantages do exist in electrical sensors.

Disadvantages of Electrical Transducers

- Ø The electrical transducer is sometimes less reliable than mechanical type because of the ageing and drift of the active components.
- Ø Also, the sensing elements and the associated signal processing circuitry are comparatively expensive.
- Ø With the use of better materials, improved technology and circuitry, the range of accuracy and stability have been increased for electrical transducers.
- Ø 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.

2. Explain the Characteristics of Transducers.

Characteristics of Transducer

1. **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 being measured.
2. **Ruggedness**: The transducer should be mechanically rugged to withstand overloads. It should have overload protection.
3. **Linearity**: The output of the transducer should be linearly proportional to the input quantity under measurement. It should have linear input - output characteristic. -
4. **Repeatability:** The output of the transducer must be exactly the same, under same environmental conditions, when the same quantity is applied at the input repeatedly.
5. **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 many applications;
6. **High Stability and Reliability:** The output of the transducer should be highly stable and reliable so that there will be minimum error in measurement. The output must remain unaffected by environmental conditions such as change in temperature, pressure, etc.
7. **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.
8. **Dynamic Range:** For a transducer, the operating range should be wide, so that it can be used over a wide range of measurement conditions.
9. **Size:** The transducer should have smallest possible size and shape with minimal weight and volume. This will make the measurement system very compact.
10. **Speed of Response:** It is the rapidity with which the transducer responds to changes in the measured quantity. The speed of response of the transducer should be as high as practicable.

3. Explain the Selection of Transducers.

Transducer Selection Factors

1. Nature of measurement
2. Loading effect
3. Environmental considerations
4. Measuring system
5. Cost & Availability

4. Explain in detail the working of Resistive Transducer, Inductive Tranducer, Temperature Transducers, Capacitive Transducer, Temperature Transducer, Piezo-electric Transducer, and Hall effect Transducer.

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 are observed. 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.

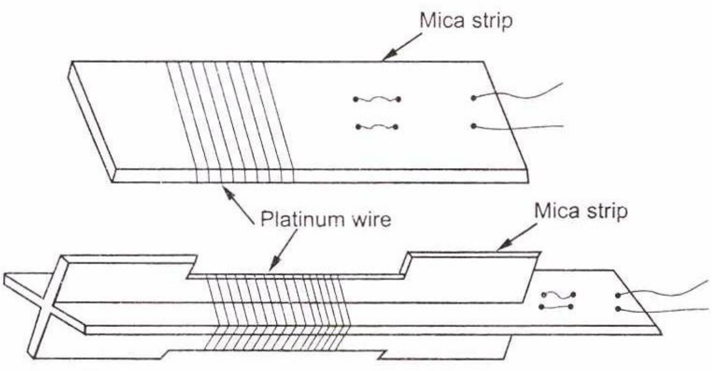
One of these effects can be employed for temperature measurement purposes. Electrical methods are the most convenient and accurate methods of temperature measurement. These methods are based on change in resistance with temperature and generation of thermal e.m.f. The change in resistance with temperature 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

Ø The wire resistance thermometer usually consists of a coil wound on a mica or ceramic former, as shown in the Fig.

Ø 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

1. The measurement is accurate.
2. Indicators, recorders can be directly operated.
3. The temperature sensor can be easily installed and replaced.
4. Measurement of differential temperature is possible.
5. Resistance thermometers can work over a wide range of temperature from -20' C to + 650° C.
6. They are suitable for remote indication.

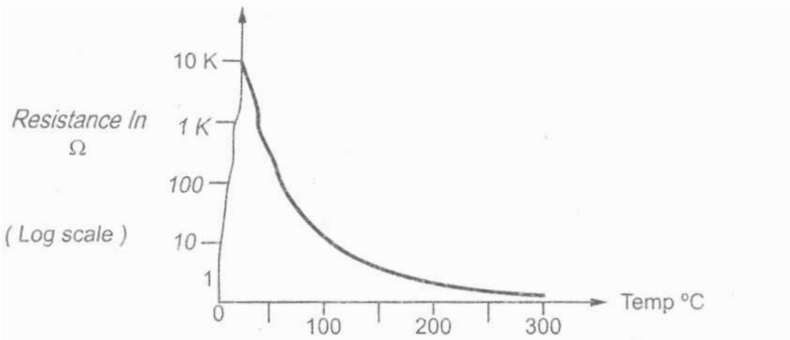
7. They are smaller in size
8. They have stability over long periods of time.

Limitations of Resistance Thermometers

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

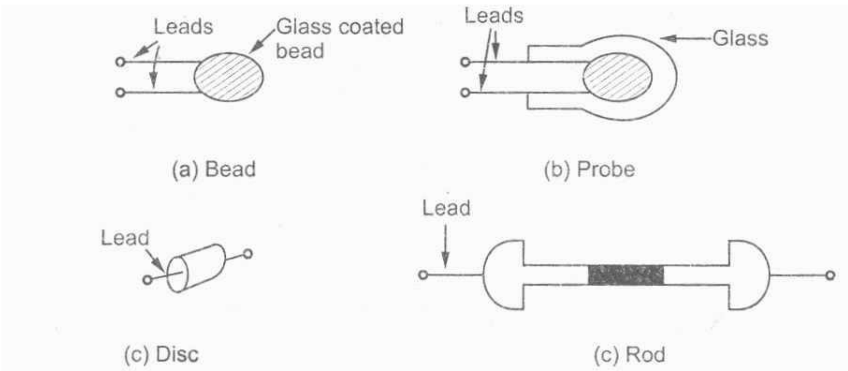
Thermistors

- 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

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

Applications of Thermistor

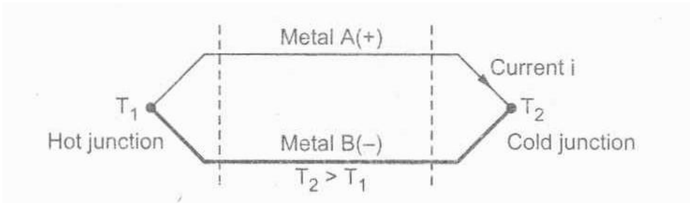
1. The thermistors relatively large resistance change per degree change in temperature [known as sensitivity] makes it useful as temperature transducer.
2. The high sensitivity, together with the relatively high thermistor resistance that may be selected [e.g. 100k .], makes the thermistor ideal for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

Temperature Transducers

They are also called thermo-electric transducers. Two commonly used temperature transducers are

• Resistance Temperature Detectors
• Thermocouples.

Thermocouples



(Fig) Basic circuit

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

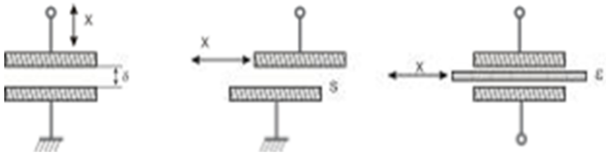
<u>Capacitive Transducers</u>

Capacitive transducers are capacitors that change their capacity under the influence of the input magnitude, which can be linear or angular movement. The capacity of a flat capacitor, composed of two electrodes with sizes **a´b**, with area of overlapping **s**, located at a distance **δ** from each other (in **d** << **a**/10 and **d** << **b**/10) is defined by the formula

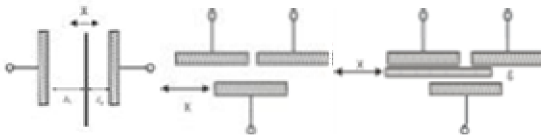
$$C=\varepsilon_0\, \varepsilon\, s/d$$

where: $\varepsilon_0=8,854.10^{-12}$ F/m is the dielectric permittivity of vacuum;
ε - permittivity of the area between the electrodes (for air **e**= 1,0005);
S=a.b – overlapping cross-sectional area of the electrodes. The capacity can be influenced by changing the air gap **d**, the active area

of overlapping of the electrodes **s** and the dielectric properties of the environment



Single capacitive transducers



Differential capacitive transducers

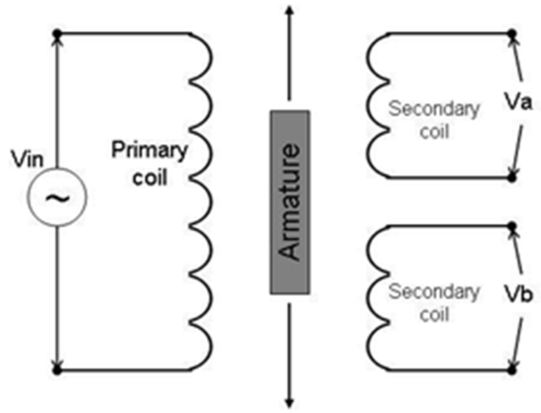
Application of capacitive transducers

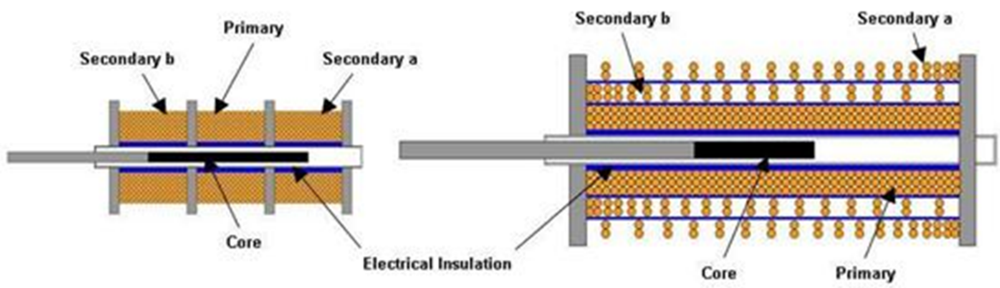
Capacitive sensors have found wide application in automated systems that require precise determination of the placement of theobjects, processes in microelectronics, assembly of precise equipment associated with spindles for high speed drilling machines, ultrasonic welding machines and inequipment for vibration measurement. They can be used not only to measure displacements (large and small), but also the level of fluids, fuel bulk materials, humidity environment, concentration of substances and others Capacitive sensors are often used for non-contact measurement of the thickness of various materials, such as silicon wafers, brake discs and plates of hard discs. Among the possibilities of the capacitive sensors is the measurement of density, thickness and location of dielectrics.

<u>Inductive Transducers</u>

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.





The LVDT: construction and principle of operation

When the primary coil is excited with a sine wave voltage (Vin), it generate 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.

Digital Transducers

A transducer measures physical quantities and transmits the information as coded digital signals rather than as continuously varying currents or voltages. Any transducer that presents information as discrete samples and that does not introduce a quantization error when the reading is represented in the digital form may be classified as a digital transducer. Most transducers used in digital systems are primarily analogue in nature and incorporate some form of conversion to provide the digital output. Many special techniques have been developed to avoid the necessity to use a conventional analogue- to-digital conversion technique to produce the digital signal. This article describes some of the direct methods which are in current use of producing digital outputs from transducers.

Some of the techniques used in transducers which are particularly adaptable for use in digital systems are introduced. The uses of encoder discs for absolute and incremental position measurement and to provide measurement of angul ar speed are outlined. The application of linear gratings for measurement of translational displacement is compared with the use of Moire fringe techniques used for similar purposes. Synchro devices are briefly explained and the various techniques used to produce a digital output from synchro resolvers are described. Brief descriptions of devices which develop a digital output from the natural frequency of vibration of some part of the transducer are presented. Digital techniques including vortex flowmeters and instruments using laser beams are also briefly dealt with. Some of them are as follows:

1. Shaft Encoders
2. Digital Resolvers
3. Digital Tachometers
4. Hall Effect Sensors
5. Limit Switches

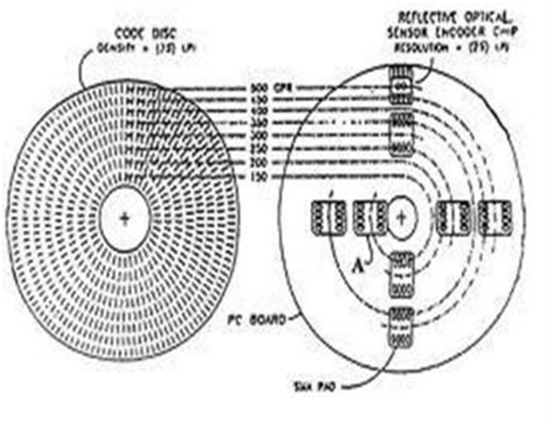
Shaft Encoders:

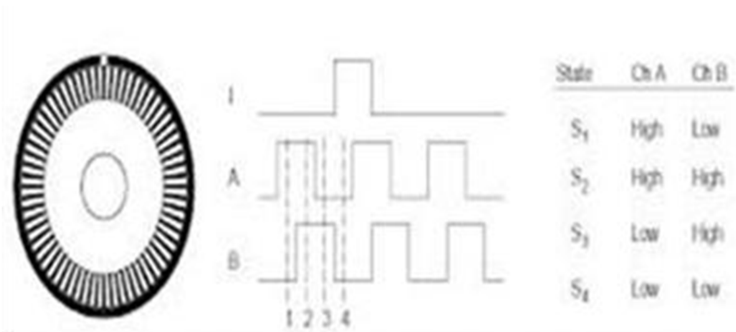
An encoder is a device that provides a coded reading of a measurement. A Shaft encoders can be one of the encoder that provide digital output measurements of angular position and velocity. This shaft encoders are excessively applicable in robotics, machine tools, mirror positioning systems, rotating machinery controls (fluid and electric), etc. Shaft encoders are basically of two types-Absolute and Incremental encoders.

An "absolute" encoder maintains position information when power is removed from the system. The position of the encoder is available immediately on applying power. The relationship between the encoder value and the physical position of the controlled machinery is set at assembly; the system does not need to return to a calibration point to maintain position accuracy. An "incremental" encoder accurately records changes in position, but does not power up with a fixed relation between encoder state and physical position. Devices controlled by incremental encoders may have to "go home" to a fixed reference point to initialize the position measurement. A multi-turn absolute rotary encoder includes additional code wheels and gears. A high-resolution wheel measures the fractional rotation, and lower-resolution geared code wheels record the number of whole revolutions of the shaft.

An absolute encoder has multiple code rings with various binary weightings which provide a data word representing the absolute position of the encoder within one revolution. This type of encoder is often referred to as a parallel absolute encoder.

An incremental encoder works differently by providing an A and a B pulse output that provide no usable count information in their own right. Rather, the counting is done in the external electronics. The point where the counting begins depends on the counter in the external electronics and not on the position of the encoder. To provide useful position information, the encoder position must be referenced to the device to which it is attached, generally using an index pulse. The distinguishing feature of the incremental encoder is that it reports an incremental change in position of the encoder to the counting electronics.





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:

$$V = \frac{kFd}{A}$$

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.

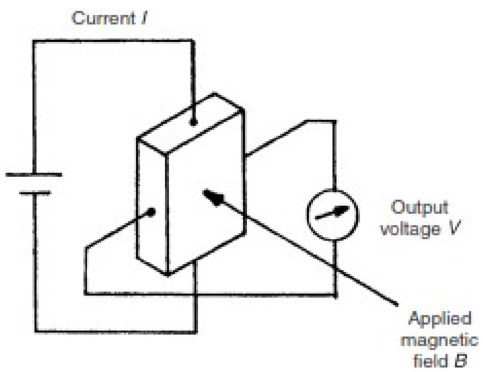
Where F is the applied force in g, A is the area of the material in mm, d is the thickness of the material and k is the piezoelectric constant. The polarity of the induced voltage depends on whether the material is compressed or stretched.

Materials exhibiting piezoelectric behaviour include natural ones such as quartz, synthetic ones such as lithiumsulphate andferroelectric 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 mm^2 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. This is considered further in the section below on ultrasonic transducers.

Hall-effect transducers

Basically, a 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.

6. Explain detail about the DATA ACQUISITION SYSTEMS

Definition:

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.

Diagram

Fundamental elements of data acquisition system

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-to-date 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 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

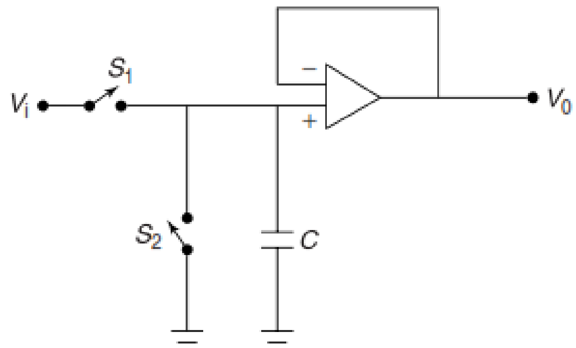
Disadvantages

- 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

Applications

- Temperature measurement
- Recommended application software packages and necessary toolkit
- Prewritten Lab VIEW example code, available for download
- Sensor recommendations
- Video tutorials for hardware setup and software programming

1. Explain details an Analogue-To-Digital Converters.

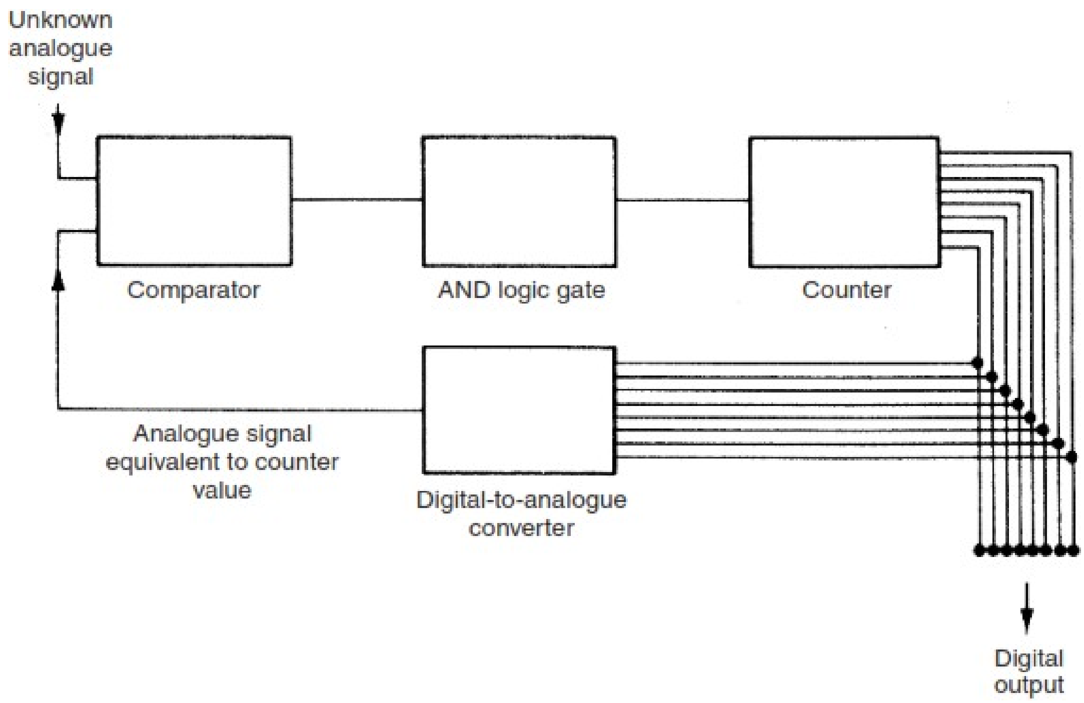


Important factors in the design of an analogue-to-digital converter are the speed of conversion and the number of digital bits used to represent the analogue signal level. The minimum number of bits used in analogue-to-digital converters is eight.

Operational amplifier connected as 'sample and hold' circuit

The use of eight bits means that the analogue signal can be represented to a resolutionof 1 part in 256 if the input signal is carefully scaled to make full use of the converter range. However, it is more common to use either 10 bit or 12 bit analogue-to-digital converters, which give resolutions respectively of 1 part in 1024 and 1 part in 4096. Several types of analogue-to-digital converter exist. These differ in the technique used to effect signal conversion, in operational speed, and in cost.

The simplest type of analogue-to-digital converter is the *counter analogue-to-digital converter*, as shown in Figure. This, like most types of analogue-to-digital converter, does not convert continuously, but in a stop-start mode triggered by special signals on the computer's control bus. At the start of each conversion cycle, the counter is set to zero. The digital counter value is converted to an analogue signal by a digital- to-analogue converter (a discussion of digital-to-analogue converters follows in the next section), and a comparator then compares this analogue counter value with the unknown analogue signal. The output of the comparator forms one of the inputs to an AND logic gate. The other input to the AND gate is a sequence of clock pulses. The comparator acts as a switch that can turn on and off the passage of pulses from the clock through the AND gate. The output of the AND gate is connected to the input of the digital counter. Following reset of the counter at the start of the conversion cycle, clock pulses are applied continuously to the counter through the AND gate, and the analogue signal at the output of the digital-to-analogue converter gradually increases in magnitude. At some point in time, this analogue signal becomes equal in magnitude to the unknown signal at the input to the comparator. The output of the comparator changes state in consequence, closing the AND gate and stopping further increments of the counter. At this point, the value held in the counter is a digital representation of the level of the unknown analogue signal.



Counter analogue – digital converter circuit.

2. Explain in detail about of Digital-To-Analogue (D/A) Conversion.

Digital-to-analogue conversion is much simpler to achieve than analogue-to-digital conversion and the cost of building the necessary hardware circuit is considerably less. It is required wherever a digitally processed signal has to be presented to an analogue control actuator or an analogue signal display device. A common form of digital-to-analogue converter is illustrated in Figure 5.24. This is shown with 8 bits for simplicity of explanation, although in practice 10 and 12 bit D/A converters are used more frequently. This form of D/A converter consists of a resistor-ladder network on the input to an operational amplifier

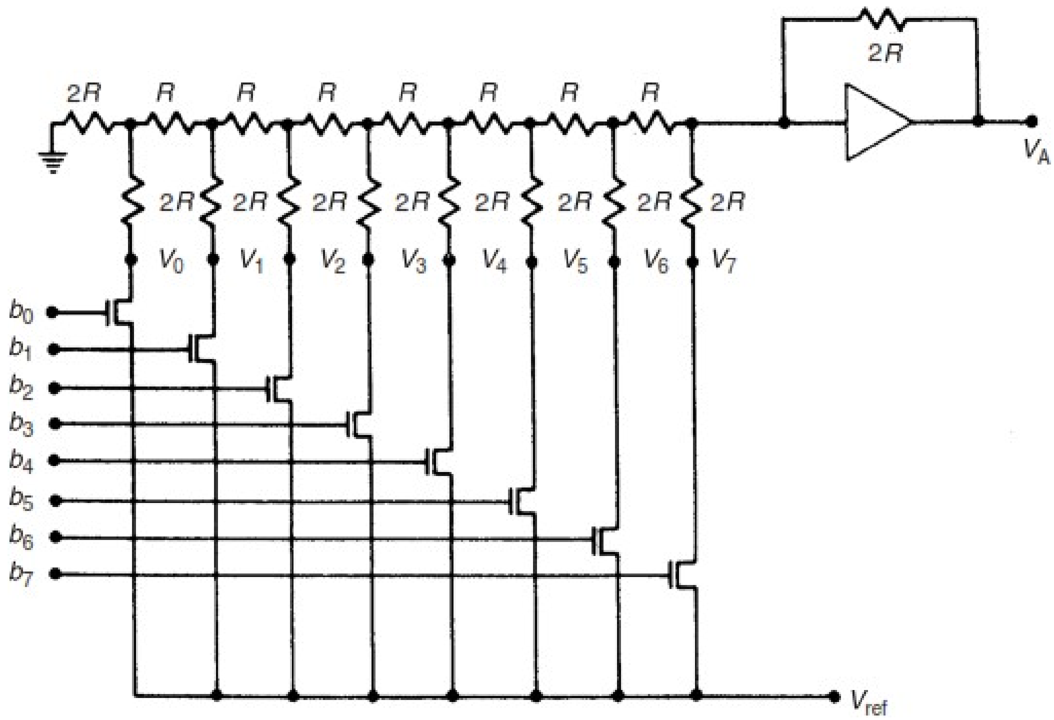
$$V_A = V_7 + \frac{V_6}{2} + \frac{V_5}{4} + \frac{V_4}{8} + \frac{V_3}{16} + \frac{V_2}{32} + \frac{V_1}{64} + \frac{V_0}{128}$$

V_0 to V_7 are set at either the reference voltage level V_{ref} or at zero volts according to whether an associated switch is open or closed. Each switch is controlled by the logic level of one of the bits 0 – 7 of the 8 bit binary signal being converted. A particular switch is open if the relevant binary bit has a value of 0 and closed if the value is 1. Consider for example a digital signal with binary value of 11010100. The values of V_7 to V_0 are therefore:

$$V_7 = V_6 = V_4 = V_2 = V_{ref}; \quad V_5 = V_3 = V_1 = V_0 = 0$$

The analogue output from the converter is then given by:

$$V_A = V_{ref} + \frac{V_{ref}}{2} + \frac{V_{ref}}{8} + \frac{V_{ref}}{32}$$



Common form of digital – analogue converter

a. Smart Sensors

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.

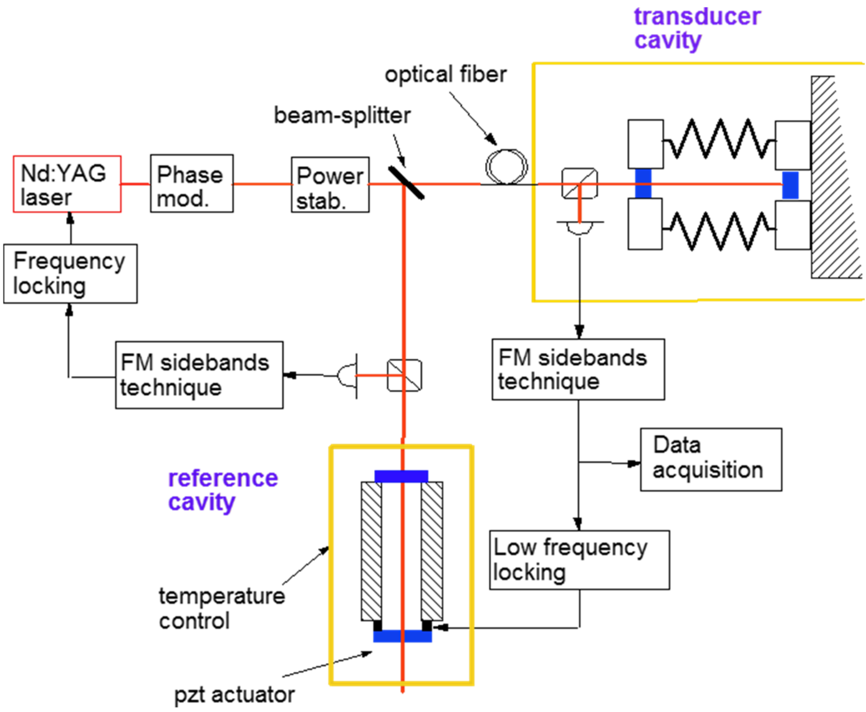
3. Describe the Optical TransducerTransducer cavity and also explain smart sensors.

A Fabry-Perot cavity between the bar and the resonant plate

Reference cavity:

A stable Fabry-Perot cavity acting as length reference

Laser source frequency locked to the reference cavity



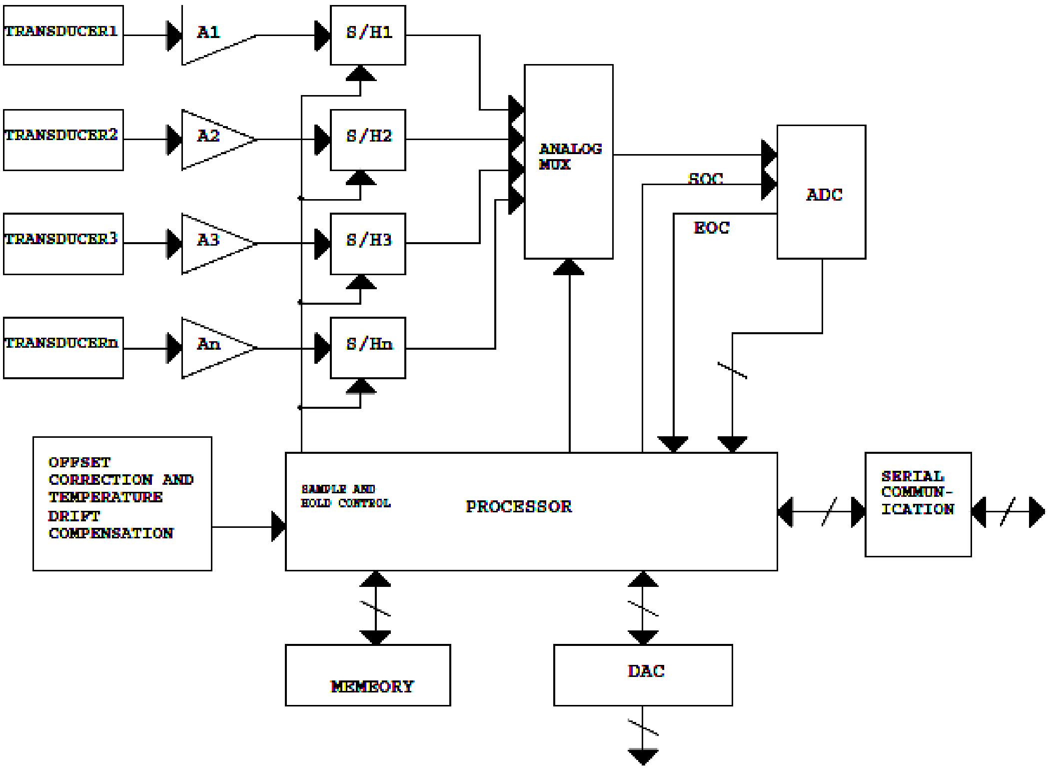
General Architecture of smart sensor:

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:

- Sensing element/transduction element,
- Amplifier,
- Sample and hold,
- Analog multiplexer,
- Analog to digital converter (ADC),
- Offset and temperature compensation,
- Digital to analog converter (DAC),

- Memory,
- Serial communication and
- Processor

The generalized architecture of smart sensor is shown below:



GENERAL ARCHITECTURE OF SMART SENSOR

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 words. 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 comprises 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.