# Bapuji Educational Association(Regd)

# Bapuji Polytechnic Shabanur,Davangere

# Department of Electronics and Communication Engineering

**Study Material on**

**ELECTRONIC MEASUREMENTS AND INSTRUMENTATION (15EC34T)**


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# Unit 1: Basics of measurements

## Necessity of measurements

Measurements play a very important role in every branch of scientific research and engineering. The whole area of automation is based on measurements. The very concept of control is based on the comparison of the actual condition and the desired performance. The measurement confirms the validity of a theory and also adds to its understanding. This eventually leads to new discoveries. Through measurement a product can be designed or a process be operated with maximum efficiency, minimum cost and with desired degree of reliability and maintainability.

## Methods of Measurement

Measurement of any quantity involves two parameters, the magnitude of the value and unit of measurement. For example if we have to measure voltage we can say it is 10volts. Here "10" is the magnitude and "volts" is the unit of measurement.

There are two methods of measurement: 1. Direct comparison method 2. Indirect comparison method

**Direct Comparison method**: In the direct comparison method of measurement, we compare the quantity directly with the primary or secondary standard. For example, if we have to measure the height of a person, we do it with the help of the measuring tape or scale that acts as the secondary standard. Here we are comparing the quantity to be measured (height) directly with the standard.

**Indirect comparison method:** In the indirect comparison method of measurement, the quantity to be measured is not measured directly but other parameters related to the quantity are measured. For example if you want to measure power we find voltage (V) and current (I) first and then calculate power using formula P=V*I.

### Basic terminology

**Instrument:** It is defined as a device for determining the value or magnitude of a quantity or variable.

**Accuracy**: It is defined as the closeness with which an instrument reading approaches the true value of the quantity being measured.

**Precision**: It is defined as how exactly the result is determined. i.e given a fixed value of the quantity, precision is a measure of the degree of agreement within a group of measurements.

**Sensitivity:** It is defined as the ratio of the magnitude of output signal to the input signal or response of measuring system to the quantity being measured.

**Resolution:** It is defined as the smallest change in measured quantity that causes a visible change in its output.

## Dynamic characteristics of an instrument

Dynamic characteristics of a measuring instrument refer to the case where the measured quantity changes rapidly with time.

The dynamic characteristics of any measurement system are:

1. Speed of response
2. Measuring Lag
3. Fidelity
4. Dynamic error

**Speed of Response (desirable):** It is defined as the speed with which an instrument or measurement system responds to changes in measured quantity.

**Response Time (desirable):** It is the time required by instrument or system to settle to its final steady position after the application of the input.

**Measuring lag:** It is the delay in the response of a measurement system to changes in measured quantity. It is of two types,

i) **Retardation type:** In this type of measuring lag the response begins immediately after a change in measured quantity has occurred.

ii) **Time delay:** In this type of measuring lag the response of the measurement system begins after a dead zone after the application of the input.

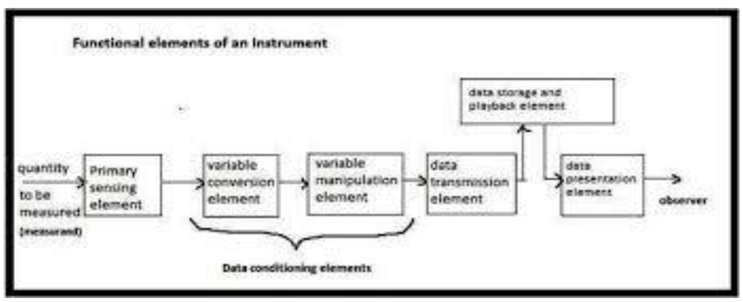
**Fidelity:** Fidelity of a system is defined as the ability of the system to reproduce the output in the same form as the input. It is the degree to which a measurement system indicates changes in the measured quantity without any dynamic error.

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

****Note:** Static error is the difference between the true value and the measured value of a quantity.

## Generalized electronic measurement system

The measurement of a given quantity is the result of comparison between the quantity (whose magnitude is unknown) & a predefined Standard. Since two quantities are compared, the result is expressed in numerical values.




**Primary sensing element:** The unknown quantity under measurement makes its first contact with the primary sensing element of a measurement system. The sensing elements sense the condition, state or value by taking out a small part of energy from the measured (the unknown quantity which is to be measured), and then produce an output.

**Variable conversion element:** The output from the primary sensing element may require to be converted to a more suitable form while saving its information contents. This conversion is performed by the variable conversion element called transducer.

**Variable manipulation element:** The function of this element is to manipulate the signal presented to it preserving the original nature of the signal. Some non-linear processes like modulation, detection, sampling, filtering, etc., are performed on the signal to bring it to the desired form to be accepted by the next stage of measurement system.

**Data transmission element:** This element transmits the signal from one location to another without changing the physical nature of the variable.

**Data Presentation element:** This element presents a display record or indication of the output from the manipulation elements to the person handling the instrument.

# Errors

Error is defined as the difference between the actual value of a quantity and the value obtained by a measurement. A study of errors is the first step in finding ways to reduce them. Errors may arise from different sources and they are mainly classified as shown below.

**Gross errors** This type of error occurs due to human mistakes, while reading, recording and calculating measurement results. For example the observer due to an oversight, may read the temperature as 30.50C while the actual reading may be 30.20 C, there is 0.30C error in the reading. Gross errors may be of any amount and therefore their mathematical analysis is impossible. But, the following precautions can be taken to avoid such errors.

They are: 1. Proper care should be taken while reading and recording the data. 2. More than one reading should be taken for the quantity under measurement preferably by different observers.

**Systematic errors** Systematic errors occur usually from the measuring instruments. They may occur because there is something wrong with the instrument or its data handling system, or because the instrument is wrongly used by the experimenter. These errors can be found by conducting repeated measurements under different conditions or with different equipment and if possible by entirely different method. These errors are further classified as follows.

**Instrumental errors:** These errors arise due to following reasons:

1. Due to inbuilt shortcomings in the instruments.

2. Due to misuse of the instruments.

3. Due to loading affects the instruments.

These errors can be minimized by using the following methods.

1. Measurement procedure must be carefully planned.

2. Correction factors should be adopted after finding the instrumental errors.

3. Instrument must be re-calibrated carefully.

**Environmental errors:** These errors arise due to conditions external to the measuring device (e.g. effects of temperature, pressure, humidity, dust etc.)

These errors can be minimised by using the following methods.

1. Temperature controlled enclosure can be used to avoid temperature variations.

2. The effect of humidity, dust etc. Can be entirely eliminated by sealing the equipment in an airtight container.

3. By providing shields the instrument can be protected against external magnetic and electrostatic fields.

**Observational errors:** These errors arise due wrong observations. The Observational errors arise due to following reasons1. Parallax error occurs on account of the pointer and the scale not being in the same plane (shown in figure 1.2.2.1. 2. Wrong scale reading and wrong recording of data. 3. Incorrect conversion of units in between consecutive readings. These errors can be eliminated by using digital display systems.

## Random errors

Random errors are accidental, small and independent. These errors arise due to following reasons:

1. Parallax: when an observer reads a scale from an incorrect direction

2. Variation in environmental conditions

3. Friction in instrument movement

4. Mechanical vibrations

These errors can be minimized by using the following methods.

1. Taking repeated readings to obtain an average value.

2. Maintaining good experimental technique (e.g. reading from a correct position).

**Sources of errors**

1. Insufficient knowledge of process parameters and design conditions.

2. Selection of improper instrument for measurement.

3. Poor design

4. Human error caused by person operating the instrument.

## Statistical analysis

Statistical analysis of measurement is a procedure of collection, analysis, interpretation, presentation, and organization of data.

**Arithmetic mean:**

It is the ratio of sum of readings taken to the total no. of readings.

Arithmetic Mean = (Sum of readings) / (Number of readings)

$$\overline{X} = \frac{X_1 + X_2 + X_3 \ldots X_N}{N}$$

Where
$\overline{X}$ = the mean
$X_1$ = the first value
$X_2$ = the second value
$X_3$ = the third value
$X_N$ = the last value
N = the number of valuse

$$\overline{x} = \frac{\sum_{i=1}^{N} x_i}{N}$$

### Deviation:

Deviation is the departure of the given reading from the arithmetic mean of the group of readings. Let the deviation of the first reading 1 be d1 and that of second reading 2 be d2 and so on. Then the deviation from the mean is expressed as di =Xi-Xbar

## Average deviation:

It is the ratio of sum of the absolute values of deviations to the no. of readings.

$$MAD = \frac{1}{n}\sum_{i=1}^{n}|x_i - m|$$

## Standard deviation:

The standard deviation also called as mean square deviation of N no. of data is defined as the square root of the sum of individual deviations squared(d1 2 , d2 2 , .................... dN 2 ) divided by the no. of readings(N).

Standard Deviation

$$\sigma = \sqrt{\frac{(\bar{x} - x_1)^2 + (\bar{x} - x_2)^2 + \ldots + (\bar{x} - x_n)^2}{n}}$$

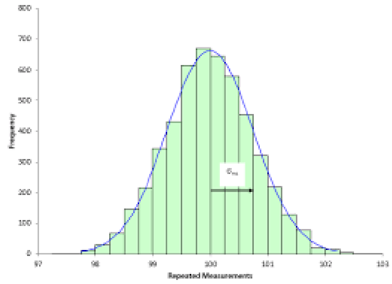
## Limiting errors:

Limiting error is used to indicate the accuracy of an instrument. The limiting error (or guarantee error) is given by the manufacturer to define the maximum limit of the error that may occur in the instrument. For example, if the resistance of a resistor is given as 50Ω ± 5%, it means that the resistance value falls between the limits 45Ω and 55Ω.In other words the manufacturer of the resistor guarantees its value lie between 45 Ω to 55 Ω.

## Probable errors:

It defines the half-range of an interval about a central point for the distribution, such that half of the values from the distribution will lie within the interval and half outside. Thus it is equivalent to half the interquartile range, or the median absolute deviation. The probable error can also be expressed as a multiple of standard deviation σ,

i.e. Probable error ϒ= 0.675x σ




## Variance:

The square of the standard deviation is called variance.

i.e. V= (standard deviation)2

$$V = \sigma 2$$

# Standards

A standard is a physical representation of unit of measurement. Standards have been developed for all the fundamental units as well as some of the derived mechanical and electrical units. Standards are classified as follows:

**1. Primary standards:** Primary standards are standards of such high accuracy which can be used as ultimate reference standards. These standards are maintained by national standard laboratories in different parts of the world.

### 2. Secondary standards:

Secondary standards are basic reference standards used by measurement and calibration laboratories. It is obtained by comparing with primary standard. For measurement of a quantity using secondary standard instrument, pre-calibration is required. Calibration of a secondary standard is made by comparing the results with a primary standard instrument or with an instrument having high accuracy or with a known input source.

### 3. Working standards:

These standards are used to check and calibrate general laboratory instrument for their accuracy and performance. Working standards are checked against the secondary standards.

### 4. International standards:

The Institute of Electrical and Electronics Engineers Standards Association (IEEE) is an organization within IEEE that develops global standards in a broad range of industries, including: power and energy, biomedical and healthcare, information technology and robotics, telecommunication etc.

These standards are not physical items that are available for comparison and checking of secondary standards but are standard procedure, nomenclature, definitions etc. These standards have been kept updated and some of the IEEE standards have been adopted by other organizations as standards. One of the most important standards is the IEEE 4888 digits interface for programmable instrumentation for test and other equipment standardizing.

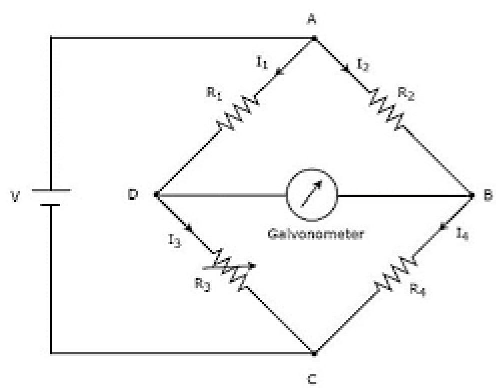
## 1.5 Comparison of AC and DC bridges

| AC BRIDGES | DC BRIDGES |
|---|---|
| Has four resistive arms | Has four reactive arms |
| Uses DC sources | Uses AC sources |
| Uses galvanometer as null detector | Uses headphones as null detector |
| Bridge is balanced when galvanometer shows mid zero | Bridge is balanced when headphones hear zero sound |
| Under balanced condition, products of opposite arm resistances are equal. | Under balanced condition, products of opposite arm impedances are equal. |
| Ex. Wheatstone Bridge, Kelvin Bridge- for measuring unknown resistance. | Ex .Maxwell Bridge,Hay Bridge-for measuring unknown inductance<br>Schearing Bridge, De Sauty Bridge- for measuring unknown capacitance |

## Wheatstone bridge

Whetstone's bridge is the most accurate method available for measuring resistances and is popular for laboratory use. The circuit diagram of a Wheatstone bridge is given in Fig2.1. The source of emf and switch is connected to points A and S, while a sensitive current indicating meter, the galvanometer, is connected to points C and D. The galvanometer is a sensitive micro ammeter a zero center scale. When there is no current through the meter, the galvanometer pointer rests at 0, i.e. mid scale. Current in one direction causes the points deflect on one side and current in the opposite direction to the other side. When SW1 is closed, current flows and divides into the two arms at point A i.e. I1 and I2. The bridge is balanced when there is no current through the galvanometer, or when the potential difference at points

C and D is equal, i.e. the potential across the galvanometer is zero. For the galvanometer current to be zero, the following conditions should be satisfied.




Unknown Resistance,R4=R2 R3/R1