FUNCTIONAL ELEMENTS OF AN INSTRUMENT

Precision:

It is the measure of consistency or repeatability of measurements.

Let us see the basic difference between accuracy and precision. Consider an instrument on which, readings upto 1/1000th of unit can be measured. But the instrument has large zero adjustment error. Now every time reading is taken, it can be taken down upto '1000th of unit. So as the readings agree with each other, we say that the instrument is highly precise. But, though the readings are precise upto 10100th of unit, the readings are inaccurate due to large zero adjustment error. Every reading will be inaccurate, due to such error. Thus a precise instrument may not be accurate. Thus the precision means sharply or clearly defined and the readings agree among themselves. But there is no guarantee that readings are accurate. An instrument having zero error, if calibrated properly, can give accurate readings but in that case still, the readings can be obtained down upto l~OOth of unit only. Thus accuracy can be improved by calibration but not the precision of the instrument.

The precision is composed of two characteristics:

- Conformity and
- Number of significant figures.

Conformity:

Consider a resistor having true value as 2385692 0, which is being measured by an ohmmeter. Now, the meter is consistently measuring the true value of the resistor. But the reader, can read consistently, a value as 2.4 MD due to nonavailability of proper scale. The value 2.4 MO is estimated by the reader from the available scale. There are no deviations from the observed value. The error created due to the limitation of the scale reading is a precision error.

The example illustrates that the conformity is a necessary, but not sufficient condition for precision. Similarly, precision is necessary but not the sufficient condition for accuracy.

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 and the measurement precision of the quantity.

The **precision** can be mathematically expressed as :

$$P = 1 - \left| \frac{X_n - \overline{X}_n}{\overline{X}_n} \right|$$

where P = Precision

X_n = Value of n^{th} measurement

$\overline{X}_n$ = Average of the set of measured values

Example:

The table shows the set of 5 *meaSl/relll l.!llts recorded 111 a laboratory .Calculate the precision of the 3rd measurement*

Measurement Number	Value of Measurement
1	49
2	51
3	52
4	50
5	49

Solution : The average value for the set of measurements is,

$$\overline{X}_n = \frac{\text{Sum of the readings}}{\text{Number of readings}} = \frac{251}{5} = 50.2$$

The value of 3rd measurement is $X_n = 52$ where $n = 3$

$$\therefore \quad P = 1 - \left| \frac{X_n - \overline{X}_n}{\overline{X}_n} \right| = 1 - \left| \frac{52 - 50.2}{50.2} \right| = 0.964 \text{ i.e. } \mathbf{96.4\ \%}$$

This is the precision of the 3rd measurement.

Errors:

The most important static characteristics of an instrument is its accuracy, which is generally expressed in terms of the error called static error.

Mathematically it can be expressed as,

e = *At* - Am J

where e = Error

A_m = Measured value of the quantity

A_t = True value of the quantity

In this expression, the error denoted as e is also called absolute error. The absolute error does not indicate precisely the accuracy of the measurements. For example, absolute error of ± 1 V is negligible when the voltage to be measured is of the order of 1000 V but the same error of ±1 V becomes significant when the voltage under measurement is 5 V or so. Hence, generally instead of specifying absolute error, the relative or percentage error is specified.

Mathematically, the **relative error** can be expressed as,

$$e_r = \frac{\text{Absolute Error}}{\text{True value}} = \frac{\text{True value} - \text{Measured value}}{\text{True value}}$$

$$= \frac{A_t - A_m}{A_t}.$$

The percentage relative error is expressed as,

$$\% \, e_r = \frac{A_t - A_m}{A_t} \times 100$$

From the **relative percentage error**, the accuracy can be mathematically expressed as,

$$A = 1 - e_r = 1 - \left| \frac{A_t - A_m}{A_t} \right|$$

where A = Relative accuracy

and $a = A \times 100 \, \%$

where a = Percentage accuracy

The error can also be expressed as a percentage of full scale reading as,

$$\text{Error as a percentage of full scale reading} = \frac{A_t - A_m}{\text{f.s.d.}} \times 100$$

where f.s.d. = Full scale deflection

If the calibration curve is not linear as shown in the Fig. 1.3 (b), then the sensitivity varies with the input. The sensitivity is always expressed by the manufacturers as the ratio of the magnitude of quantity being measured to the magnitude of the response. Actually, this definition is the reciprocal of the sensitivity is called inverse sensitivity or deflection factor. But manufacturers call this inverse sensitivity as a sensitivity.

Inverse sensitivity = Deflection factor

$$\therefore \quad \text{Deflection factor} = \frac{1}{\text{Sensitivity}} = \frac{\Delta q_i}{\Delta q_o}$$

The units of the sensitivity are millimeter per micro-ampere, millimeter per ohm, counts per volt, etc. while the units of a deflection factor are micro-ampere per millimeter, ohm per millimeter, volts per count, etc. The sensitivity of the instrument should be as high as possible and to achieve this range of an instrument should not greatly exceed the value to be measured.

Resolution:

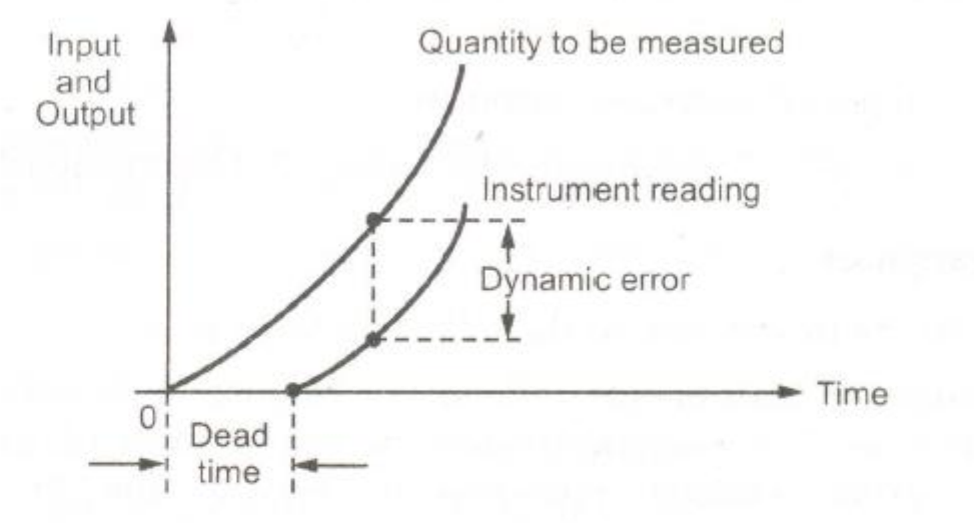
It is the smallest increment of quantity being measured which can be detected with certainty by an instrument.

So if a nonzero input quantity is slowly increased, output reading will not increase until some minimum change in the input takes place. This minimum change which causes the change in the output is called resolution. The resolution of an instrument is also referred to as discrimination of the instrument. The resolution can affect the accuracy of the measurement.

Dynamic error:

It is the difference between the true value of the variable to be measured, changing with time and the value indicated by the measurement system, assuming zero static error.

The Fig. 1.13 shows the dead time, i.e. time delay and the dynamic error.



Source : http://elearningatria.files.wordpress.com/2013/10/ece-iii-electronic-instrumentation-10it35-notes.pdf