Measurement and its role in System control and processes

Measurement (Definition)

The measurement process involves the use of an instrument as a physical means to determine the magnitude of a quantity or a variable being measured.

The word process underline above signifies that the process measurements is not just an event but a sequence of events which help the experimenter to arrive at the best approximate value of the quantity under measurement.

There are three agencies responsible for arriving at an best approximate value of the quantity under measurement.

1. The instrument 2. The experimenter or user of instrument 3. The environment in which the process of measurement takes place.

All the three agencies are responsible and play their role in the entire process of measurement.

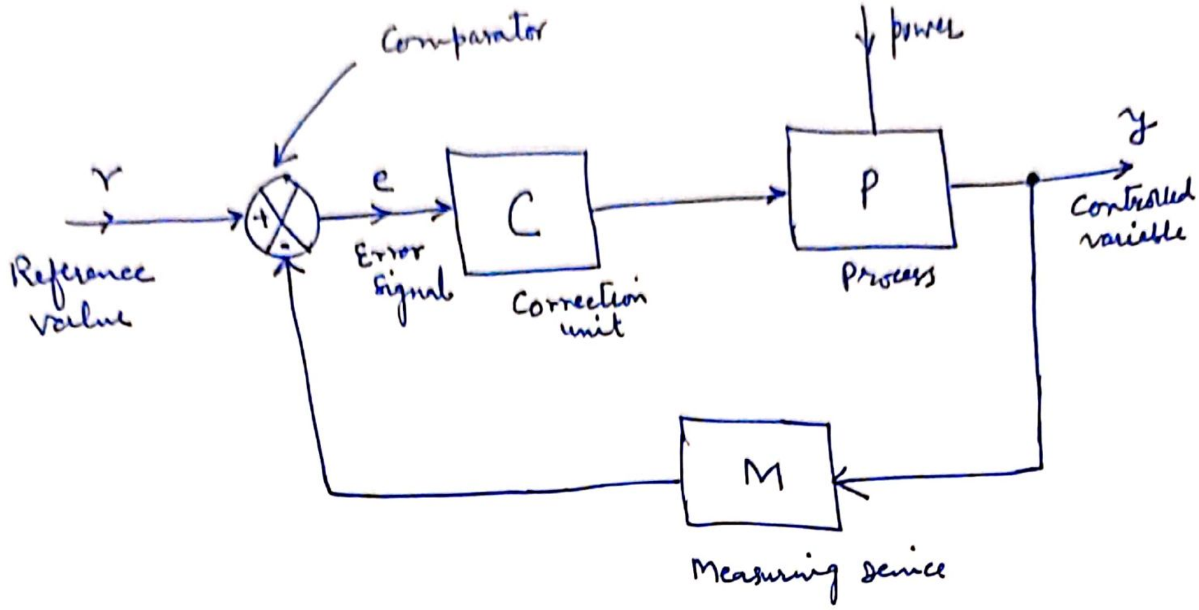
Present day applications of measurement are of immense importance in most facets of human civilization. present day applications of measuring instruments can be classified into three major areas.

1. Their use in regulating trade and includes instruments which measure physical quantities such as length, volume and mass in terms of standard units.

2. The second area for application of measuring instruments is in monitoring functions. These provide information which enables human beings to take some prescribed action accordingly. e.g. The gardener uses a thermometer to determine whether to turn the heat on in the greenhouse or open the windows if it is too hot. Another example is regular study of a barometer to allow to decide whether we should take our umbrellas if we are planning to go out for few hours. There are many such uses of measurement and instrumentation in our normal domestic lives, the majority of monitoring functions exist to provide the information necessary to allow a human being to control some industrial operation or process.

3. The third area of application is use as part of automatic control systems. The figure 1A shows a functional block diagram of a simple control system where some output variable y of a controlled process P is

is maintained at a reference value r.



The value of controlled variable y as determined by a measuring instrument M, is compared with the reference value r, and the difference value e is applied as an error signal to the correcting unit C. The correcting unit then modifies the process output such that output variable y = r.

Thus the role of measurement explains how important it is in automatic control systems. If we do not measure with accuracy and unnecessary error signal is generated which will lead a signal e because of faulty measuring device and thus may not help in getting output y = r.

Nomenclature in the field of Measurement

There are some basic terms which are frequently used in the field of measurement. like every field/area has its nomenclature, measurement has also its own nomenclature which is expressed by definition of various terms used in the field of measurement.

1. **Accuracy** :- It is the closeness with which the instrument reading approaches the true value of the quantity or variable being measured.

For example, if a pressure gauge of range 0-10 bar has a quoted inaccuracy of ±1.0% f.s. (±1% of full-scale reading), then the maximum error to be expected in any reading is 0.1 bar $\left[\frac{1}{100}\times 10 = 0.1\right]$; This means that when instrument is reading 1.0 bar, the possible error is 10% of this value. Thus in system design, the instruments are chosen such that their range is appropriate to the spread of values being measured, in order that best possible accuracy is maintained in instrument readings.

2. **Resolution** :-

Resolution is defined as the smallest change in the input or measured variable to which the instrument responds. i.e. a detectable change is observed in the instrument.

If the input is slowly increased from some arbitrary (non-zero) value, it will be found that output value does not change at all until a certain increment/decrement is exceeded. This increment/decrement is refered to as resolution of the instrument.

Quantatively a small value of resolution is referred to a better instrument and a large value of resolution signified a poor quality instrument.

3. <u>Precision</u> :- Precision is a degree of measure of reproducibility of readings. i.e. given a fixed no. of readings of the same quantity or variable being measured under similar conditions, precision is a measure by which the measurements differs from each other within a group of measurements.

4. <u>Tolerance</u> is a term which is closely related to accuracy and defines the maximum error which is to be expected in some value. Accuracy of some instruments is sometimes quoted as a tolerance figure.

Tolerance, when used correctly, describes the maximum deviation of a manufactured component from some specified value. e.g. resistances have tolerance of about 5% or 2.5%. A resistance of 1000 Ωs and tolerance of 5% might have actual value b/w 950 Ω & 1050 Ωs.

5. Range or span

The range or span of an instrument defines the minimum and maximum values of a quantity that the instrument is designed to measure. e.g. 0 – 10V voltmeter can measure voltages from 0 to 10V. Range is 10 – 0 = 10V.

6. Sensitivity

The sensitivity of measurement is a measure of the change ~~of~~ in instrument output which occurs when the quantity being measured changes by a given amount. Sensitivity is thus ratio of.

$$\text{Sensitivity} = \frac{\text{Scale deflection}}{\text{Value of measurand causing deflection}}$$

7. Measurand :- The quantity or variable under measurement by any instrument is defined as the measurand. e.g. for voltmeter, voltage is the measurand, ammeter, current is measurand, energy meter (KWhrmeter), energy is the measurand, and so on.

Distinction Between Accuracy and Precision

In fact even some dictionaries invariably link the definition of one with other. But as far as field of measurements is concerned, there is a difference between the two terms as they have sharp differences in their meanings.

As far as accuracy is concerned, it is deviation from true value and precision means deviation from one another in a ~~session~~ series of measurements of the same quantity quite a no. of times. The distinction can be explained with the help of following examples.

(i) An ammeter possessing high degree of precision by virtue of its clearly legible, finely divided, distinct scale and a knife edge pointer with mirror arrangements to remove parallax. Let us say that readings can be taken to $\frac{1}{100}$ of an ampere. At the same time its zero adjustment is wrong. Now every time we take a reading, the ammeter is as precise as ever, we can take readings down to $\frac{1}{100}$ of an ampere and the readings are consistent and 'clearly defined'. However the readings taken with this ammeter are not accurate, since they did not conform to its faulty zero adjustment.

(ii)

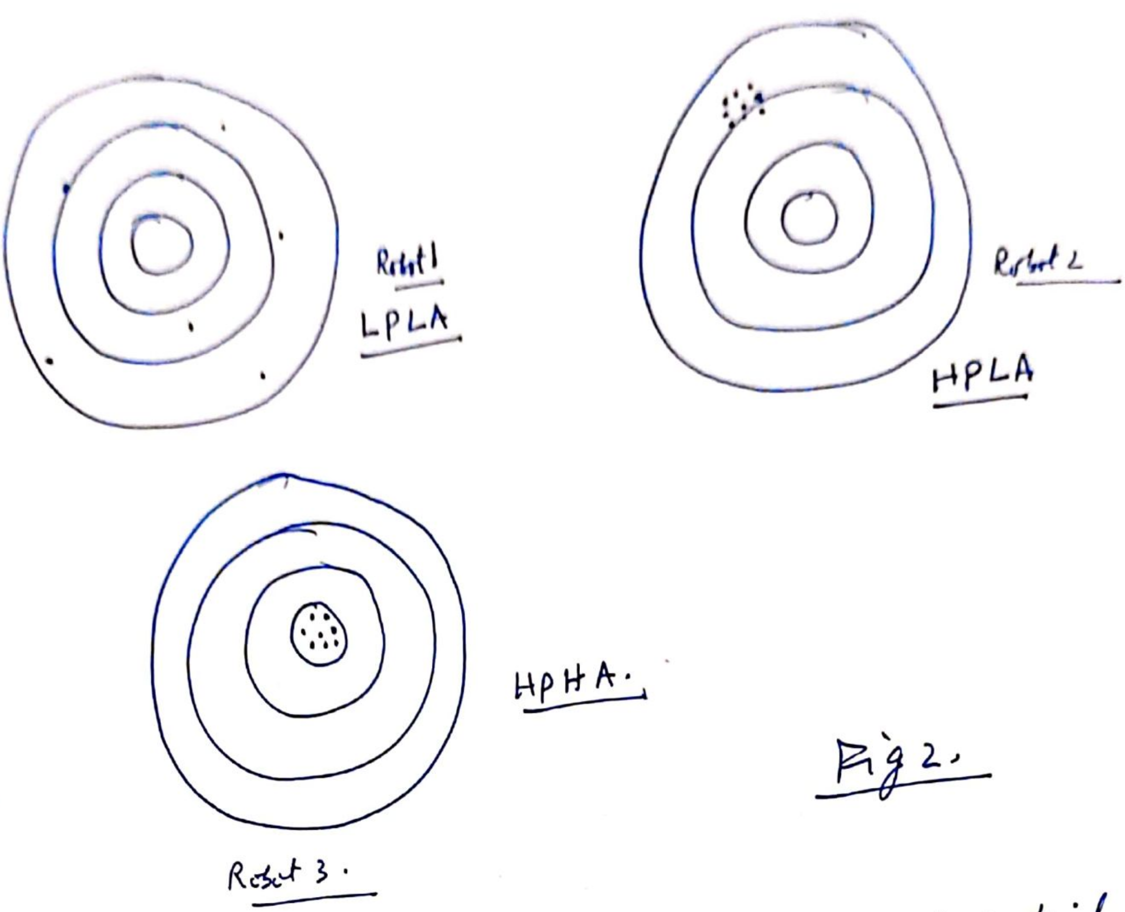


Fig 2.

Figure 2 shows the resuets on three industrial Robots which were programmed to place components at a particular point on a table. The target point was at the centre of concentric circles shown, and the dots represent the points where each robot actually deposited components at each attempt. Both accuracy and precision of Robot 1 are shown to be low in this trial. Robot 2 consistently puts the down at approximately same place but this is the wrong point, therefore it has high precision but low accuracy. Finally, Robot 3 has both high precision and high accuracy, because it consistently places the components at the correct target position.

Example 1.

A moving coil voltmeter has a uniform scale with 100 divisions, the full scale reading is 200V and $\frac{1}{10}$ of a scale division can be estimated with a fair degree of certainty. Determine the resolution of the instrument in volts.

Sol.

$$1 \text{ Scale div} = \frac{200}{100} = 2V$$

$$\text{Resolution} = \frac{1}{10} \text{ of scale div} = \frac{1}{10} \times 2 = 0.2V.$$

Exp 2. A digital voltmeter has a read out range from 0 – 9999 counts. Determine the resolution of instrument in volts when full scale reading is 9.999V.

Sol. The resolution for this instrument is 1 count.

Since 9999 counts = 9.999 Volts.

$$\therefore 1 \text{ count} = \frac{9.999}{9999} = 1mV.$$

$\therefore$ Resolution = 1mV

Exp 3. A 0–100 V voltmeter has 400 scale divisions and the measurand can be read to $\frac{1}{2}$ division. Determine the resolution of the instrument.

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