1.3 <u>Static Characteristics of Sensors</u>

The characteristics of the sensor are given below that are determined by examining the output response of a sensor to a variety of input signals.

So, it is very important to know the characteristics of sensors for proper selection. Performance characteristics of sensors can be further classified into two types: 1. Static Characteristics

2. Dynamic Characteristics

1.3.1 Static Characteristics:

Some applications involve the measurement of quantities that are either constant or vary slowly with time. Under these circumstances it is possible to define a set of criteria that gives a meaningful description of quality of measurement without interfering with dynamic descriptions that involve the use of differential equations. These criteria are called Static Characteristics. Normally static characteristics of a measurement system are, in general, those that must be considered when the system or instrument is used to measure a condition not varying with time.

The main static characteristics discussed here are,

i. Accuracy and Precision
ii. Sensitivity
iii. Linearity
iv. Hysteresis
v. Repeatability and Reproducibility
vi. Drift
vii. Static error

viii. Threshold
ix. Dead Time
x. Dead Zone
xi. Loading Effect
xii. Resolution

1.3.2 Accuracy and Precision :

Accuracy is the closeness with which an instrument reading approaches the true value of the quantity being measured. Accuracy of a sensor is usually specified by error. The lower the error, the better is the accuracy.

Accuracy as "Percentage of Full -Scale Range":

For example, a sensor having an accuracy of ± 10% of full range output of 0 to 500 ℃, then the reading can be expected from plus or minus 50 ℃ of the true reading i.e., from 450 ℃ to 550℃.

$$E_f\ (\%) = \frac{(A_{m-} A_t)}{A_{FSO}}\ X\ 100$$

Accuracy as "Percentage of True Value" :

For example, if the temperature of the system has a specified accuracy of ± 5℃, this means that the reading given by the instrument to be lie within plus or minus 5 ℃ of the true value.

$$E_a(\%) = \frac{A_{m-} A_t)}{A_t}\ X\ 100$$

Where,

$E_a - Absolute\ Error$

$A_m - Measured\ value$

$A_t - True\ Value$

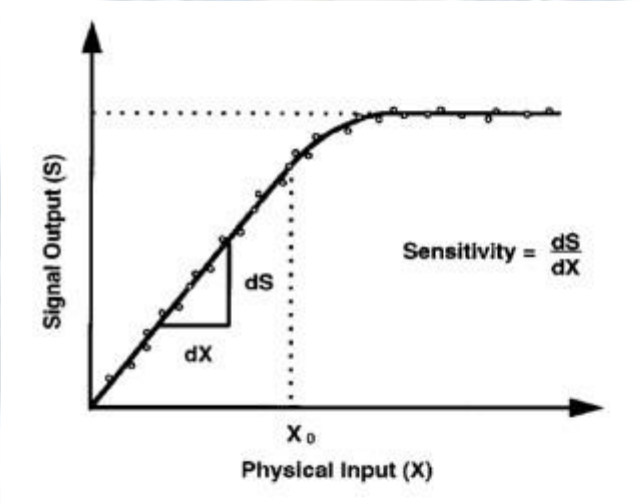
$A_{FSO} - Full\ Scale\ Output$

Precision is a measure of the reproducibility of the measurements, i.e., given a fixed value of a quantity, precision is a measure of the degree of agreement within a group of measurements. The high precision means the result of the measurements are consistent or the repeated values of the reading are obtained.

Let us cite example. Consider the measurement of a known voltage of 100 V with ammeter. Five readings are taken, and the indicated values are 104, 103, 105, 103 and 105 V. From these values it is seen that the instrument cannot be depended on for an accuracy better than 5% (5 V in this case), while a precision of ± 1% is indicated since the maximum deviation from the mean reading of 104 V is only 1.0 V.

2. Sensitivity:

Sensitivity is ratio of magnitude of the output signal or response to the magnitude of input signal.



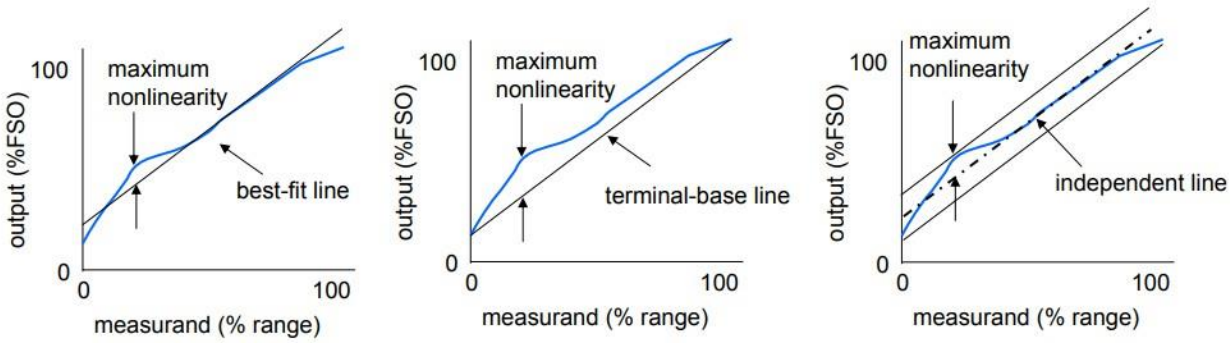
Example: For example, a resistance thermometer has sensitivity of 1Ω/℃. This shows that the thermometer having sensitivity, where there is a deflection of 1Ω for every 1℃.

3. Linearity:

Linearity refers to how well the relationship between the input and output of the measurement system follows a straight line. A perfectly linear system would produce output values proportional to the input values.

Linearity error is the deviation of the sensor output curve from a specified straight line over an input range. This linearity error is also defined as non-linearity.

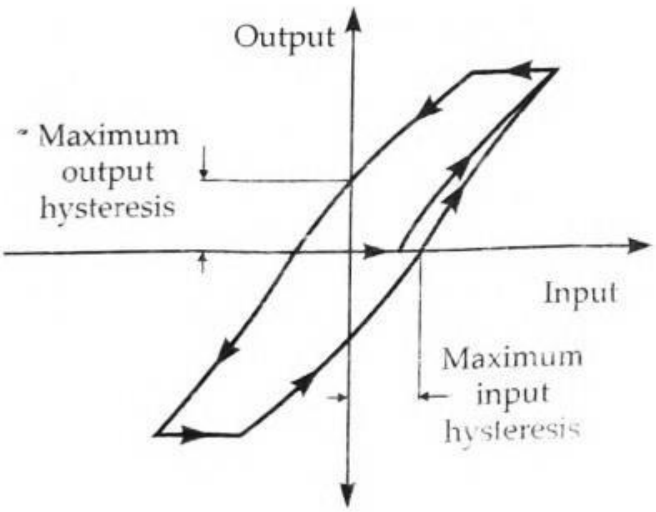
(1) best-fit straight line (2) terminal-based straight line (3) independent straight line



Source: https://www.idc-online.com/technical_references/pdfs/instrumentation/Sensors.pdf

4. Hysteresis:

Hysteresis occurs when the output of a measurement system varies depending on whether the input is increasing or decreasing. It's a type of nonlinearity and can introduce errors, especially in systems that encounter changing conditions frequently.



Hysteresis effects

Source: A.K.Shawhney, "A Course in Electrical and Electronic Measurements and Instrumentation

5. Repeatability and Reproducibility:

Repeatability /reproducibility in sensor is defined as the ability to give the same output for the applications of the same input value.

Repeatability is the closeness of measured values between repeated measurements of the same thing, carried out at the same conditions as follows,

i. At the same place
ii. By the same person
iii. By the same Method
iv. On the same equipment
v. Over short period of time.

Example: If a person measures repeated readings of an object by micrometer as 15.01 mm, 15.02 mm, and 15.01 mm. means the person can repeat the readings, and the level of competence is high.

Reproducibility is the closeness of measured values between measurements of the same thing carried out in different conditions as follows,

i. At the different place
ii. By the different person
iii. By the different method
iv. On the different equipment
v. At the different time

If three different person measures reading of the same object by micrometer as 15.54 mm,15.64 mm,15.49 mm, then the reproducibility of this measurement is 0.15 mm.

6. Drift:

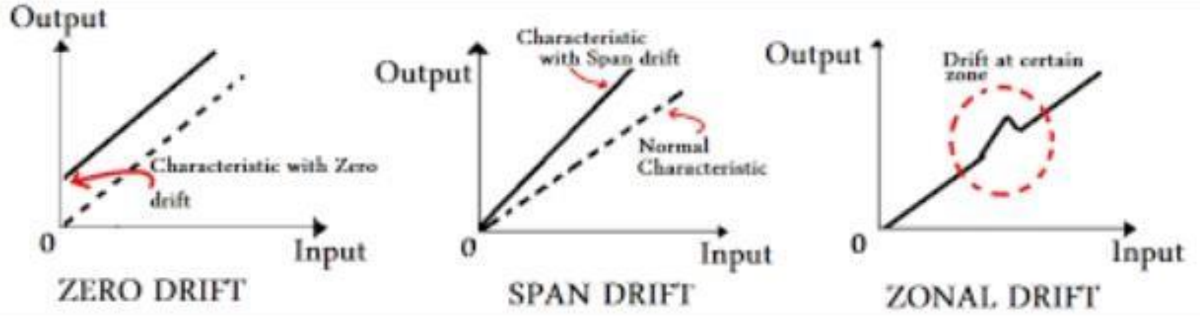
Drift refers to the change in the output of a measurement system over time, even when the input remains constant. This can be caused by factors such as temperature variations, component aging, and environmental changes.

Drift may be classified into three categories;

(i) Zero drift. If the whole calibration gradually shifts due to slippage, permanent set, or due to undue warming up of electronic tube circuits, zero drift sets in. This can be prevented by zero setting. The input-output characteristics with zero drift are shown in figure.

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

(iii) Zonal drift: In case the drift occurs only over a portion of span of an instrument, it is called zonal drift.



7. Static Error:

Static error is defined as the difference between the measured value and true value of the quantity.

$$\delta_A = (A_{m-} A_t)$$

Where δ_A = error

A_m= measured value of quantity

A_t = true value of quantity

δ_A is also called **the absolute static error** of quantity A

$$E_o = \delta_A$$

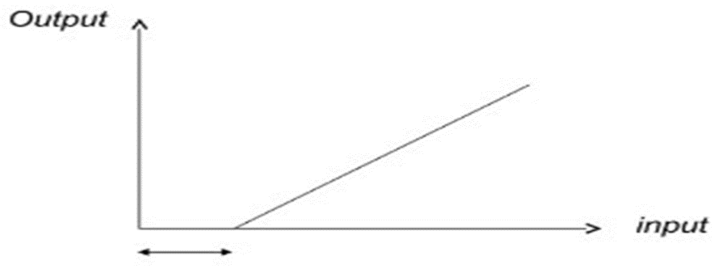
Where E_0 = absolute static error of quantity A under measurement

The ratio of absolute static error δ_A to the true value A_t of the quantity under measurement. Therefore, the **relative static error** E_r, is given by

$$E_r = \frac{Absolute\ Error}{True\ Value} = \frac{\delta_A}{A_t} = \frac{E_r}{A_t}$$

8. Threshold:

The threshold is the minimum value of the input below which no output is detected.



Threshold

9. Dead Time:

Dead time is defined as the time required by a measurement system to begin to respond to a change in the measurand.

10. Dead Zone:

It is defined as the largest change of input quantity for which there is no output of the instrument.

11. Loading Effect :

A sensor used for any measurement normally extracts some energy from the measuring medium and thereby disturbs the value of the measured quantity. This property is known as the loading effect of the sensor.

Example: When we connect a load with that power source the load impedance will affect the source impedance, usually, it reduces the supply voltage.

12. Resolution:

If the input is slowly increased from some arbitrary (non-zero) 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 or discrimination of the instrument.

Resolution defines the smallest measurable input change while the threshold defines the smallest measurable input.

13. Range and Span:

The scale range is defined as the largest reading that an instrument can read. Span is the difference between the highest reading & the lowest reading.

Example: Consider thermometer that is calibrated between 300 to 900 °C.

Range of Instrument: 900 °C (or 300-900 °C range)
Span of Instrument: (900 – 300) °C = 600 °C

14. Static Calibration:

Calibration procedures involve a comparison of the particular instrument with either (1) a primary standard, (2) a secondary standard with a higher accuracy than the instruments be calibrated, or (3) an instrument of known accuracy.

A static calibration is a calibration where the physical input does not vary significantly as a function of time.