Static & Dynamic Characteristics of Instruments

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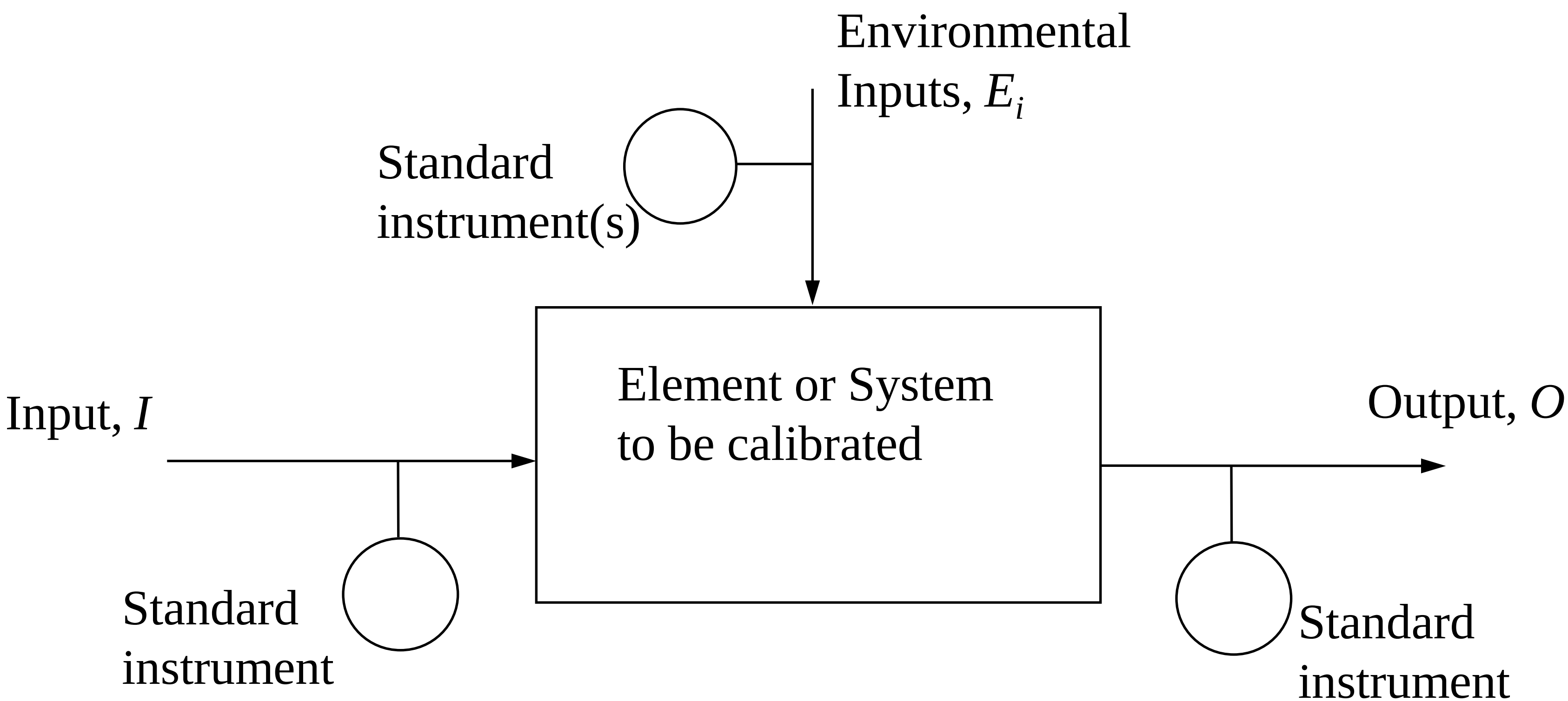
A Step Towards Design of Instruments….

Characteristics of measurement systems

- The system characteristics are to be known, to choose an instrument that most suited to a particular measurement application.
- The performance characteristics may be broadly divided into two groups, namely ‘***static***’ and ‘***dynamic***’ characteristics.
- **Static characteristics**
- the performance criteria for the measurement of quantities that remain constant, or vary only quite slowly.
- **Dynamic characteristics**
- the relationship between the system input and output when the measured quantity (measurand) is varying rapidly.

Static characteristics

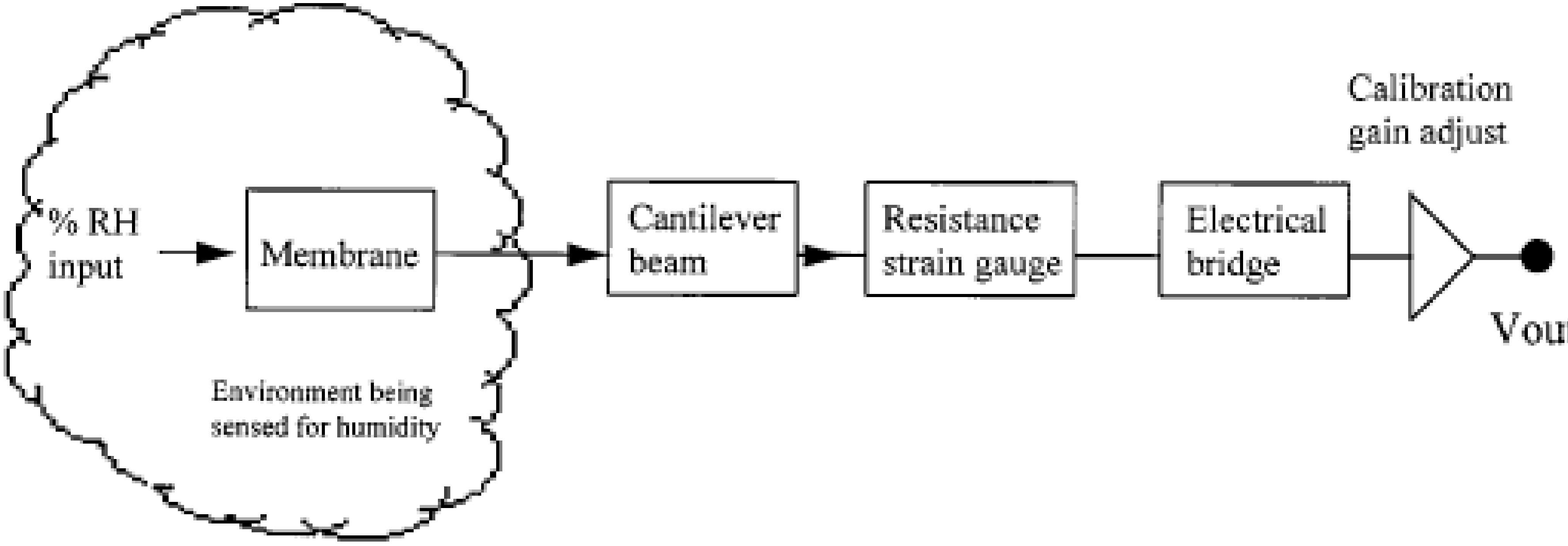
Determination of static characteristics is mostly done by <u>calibration</u>:



Static and Dynamic Characteristics

- Instrument systems are usually built up from a serial linkage of distinguishable building blocks.
- The actual physical assembly may not appear to be so but it can be broken down into a representative diagram of connected blocks.
- The sensor is activated by an input physical parameter and provides an output signal to the next block that processes the signal into a more appropriate state.
- A fundamental characterization of a block is to develop a relationship between the input and output of the block.
- All signals have a time characteristic.
- It is essential to consider the behavior of a block in terms of both the static and dynamic states.
- The behavior of the static regime alone and the combined static and dynamic regime can be found through use of an appropriate mathematical model of each block.

Instruments formed from a connection of blocks.



The output/input ratio of the whole cascaded chain of blocks 1, 2, 3, etc. is given as:

$$\left[\frac{output}{input}\right]_{total} = \left[\frac{output}{input}\right]_1 \times \left[\frac{output}{input}\right]_2 \times \left[\frac{output}{input}\right]_3 \ldots.$$

The output/input ratio of a block that includes both the static and dynamic characteristics is called the *transfer function* and is given the symbol *G*.

$$G_{total} = G_1 \times G_2 \times G_3 \ldots..$$

$$G_{total} = \prod_{i=1}^{n} G_i$$

The equation for G_i can be written as two parts multiplied together.

$$G_i = \left[Static \times dynamic\right]_i$$

- One expresses the static behavior of the block, that is, the value it has after all transient (time varying) effects have settled to their final state.
- The other part tells us how that value responds when the block is in its dynamic state.
- The static part is known as the *transfer characteristic* and is often all that is needed to be known for block description.
- The static and dynamic response of the cascade of blocks is simply the multiplication of all individual blocks.

• As each block has its own part for the static and dynamic behavior, the cascade equations can be rearranged to separate the static from the dynamic parts.

$$G_{total} = \left[Static \times dynamic\right]_1 \times \left[Static \times dynamic\right]_2 \times \left[Static \times dynamic\right]_3 ....$$

• Multiplying the static set and the dynamic set gets the overall response in the static and dynamic states.

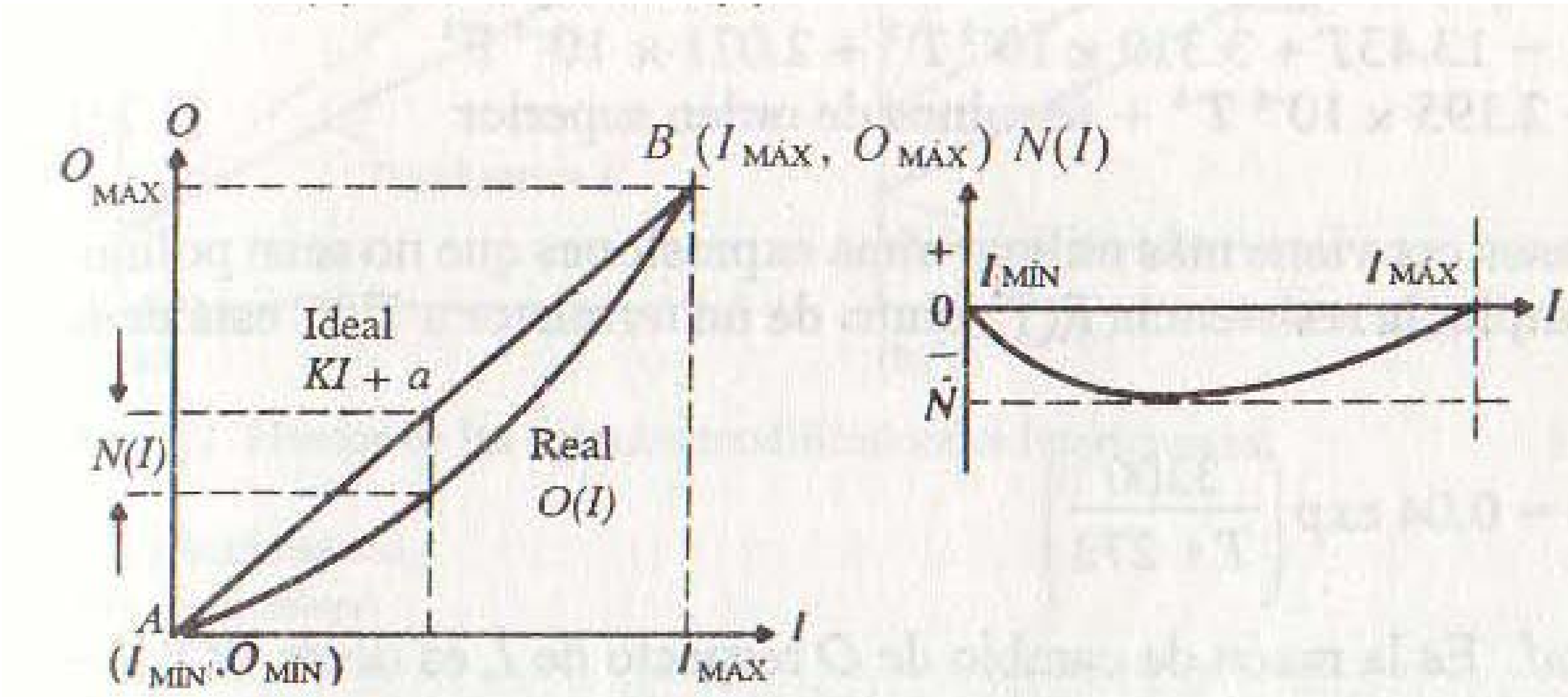
$$G_{total} = \left[Static_1 \times Static_2 \times Static_3 ...\right] \times \left[dynamic_1 \times dynamic_2 \times dynamic_3 ...\right]$$

$$G_{total} = \left[Static\right]_{total} \times \left[dynamic\right]_{total}$$

Static Performance of Instrument

- The static characteristics of instruments are related with steady state response.
- The relationship between the output and the input when the input does not change, or the input is changing at a slow rate.
- Range & Span
- Linearity & Sensitivity
- Environmental effects
- Hysteresis
- Resolution
- Repeatability
- Death space

Linearity & Sensitivity

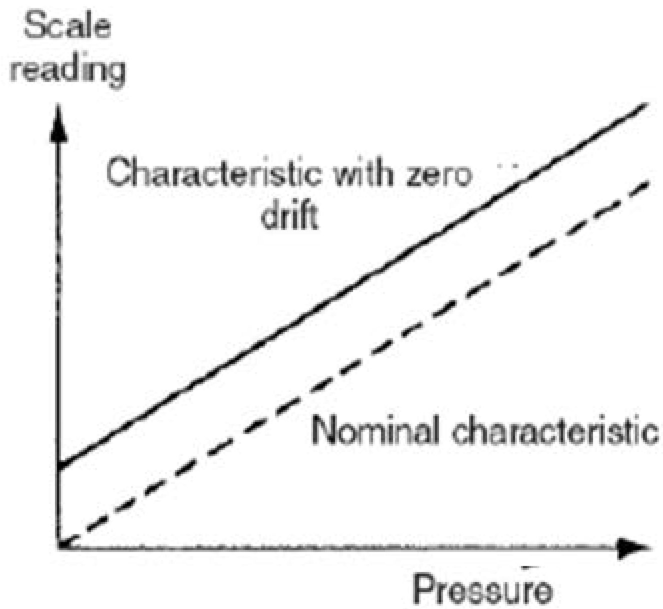


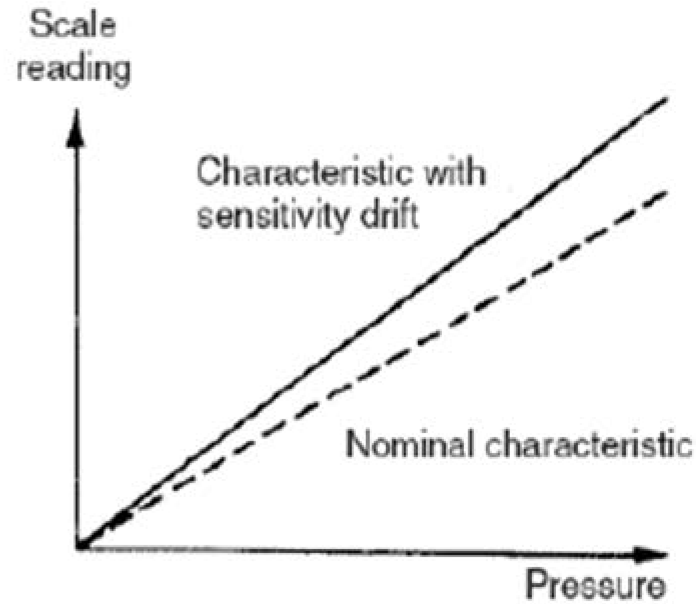
Environmental effects

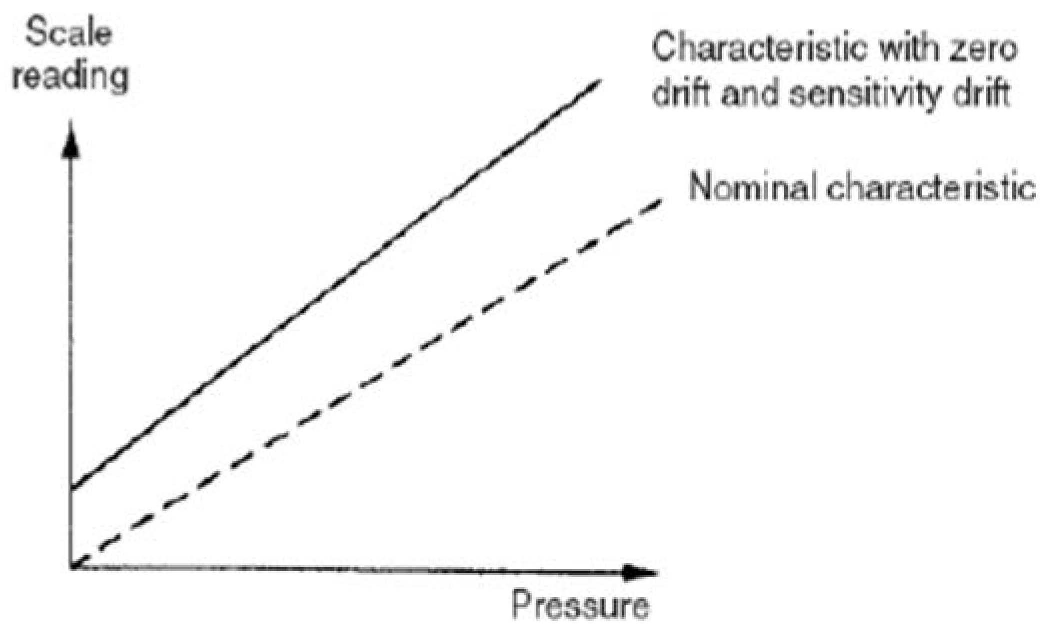
- All calibrations and specifications of an instrument are only valid under controlled conditions of temperature, pressure etc.
- These standard ambient conditions are usually defined in the instrument specification.
- As variations occur in the ambient temperature, etc., certain static instrument characteristics change, and the sensitivity to disturbance is a measure of the magnitude of this change.
- Such environmental changes affect instruments in two main ways, known as zero drift and sensitivity drift.
- Zero drift is sometimes known by the alternative term, bias.

Instrument Drift

- This is caused by variations taking place in the parts of the instrumentation/environment over time.
- Prime sources occur as chemical structural changes and changing mechanical stresses.
- Drift is a complex phenomenon for which the observed effects are that the sensitivity and offset values vary.
- It also can alter the accuracy of the instrument differently at the various amplitudes of the signal present.

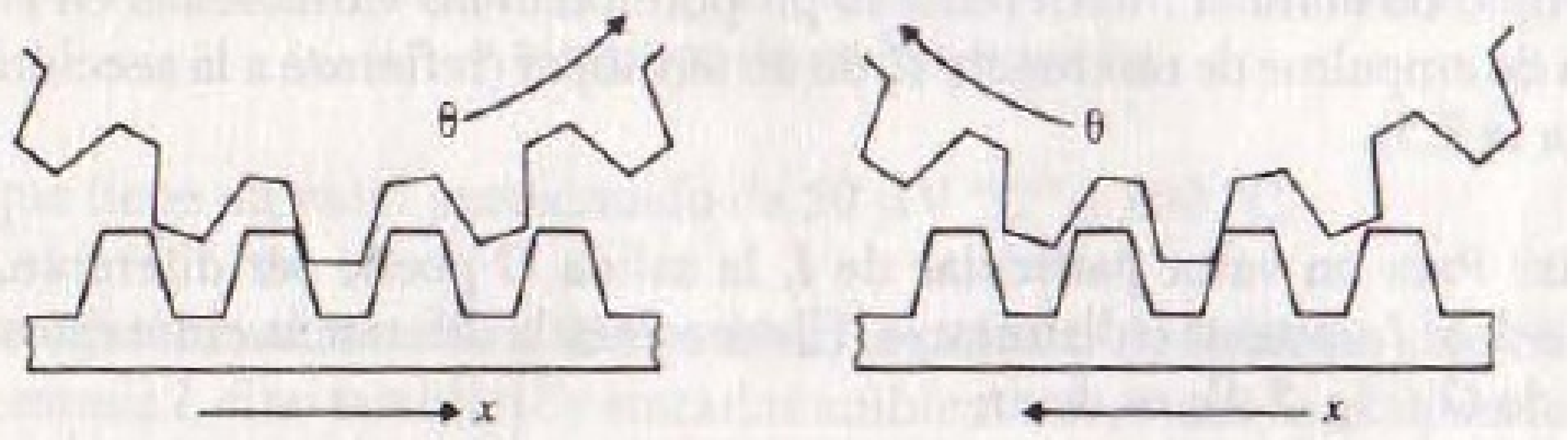

Scale
reading
Characteristic with zero
drift
Nominal characteristic
Pressure


Scale
reading
Characteristic with
sensitivity drift
Nominal characteristic
Pressure

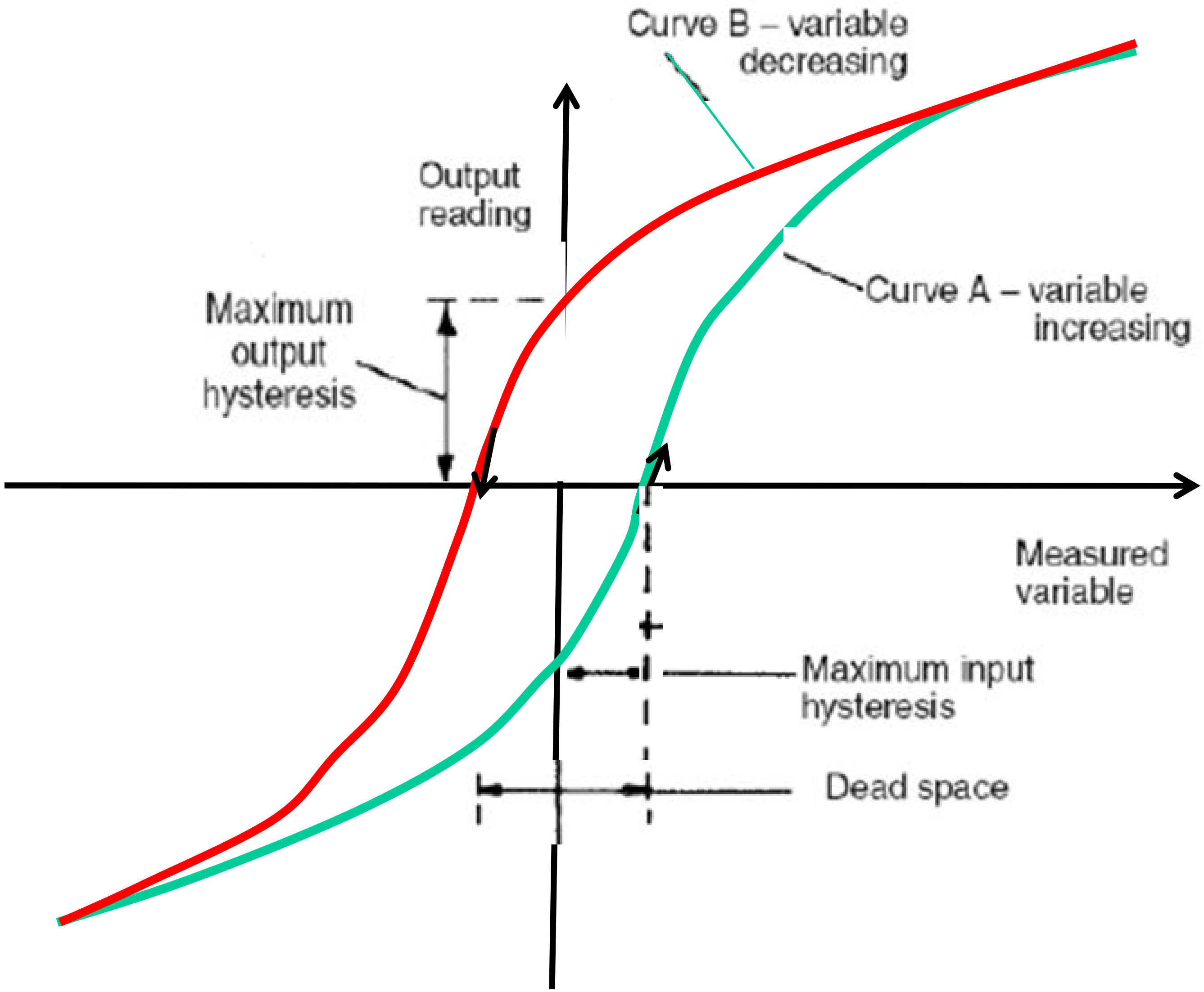

Scale
reading
Characteristic with zero
drift and sensitivity drift
Nominal characteristic
Pressure

Hysteresis and Backlash

- Careful observation of the output/input relationship of a block will sometimes reveal different results as the signals



- Where this is caused by a mechanism that gives a sharp change, such as caused by the looseness of a joint in a mechanical joint, it is easy to detect and is known as *backlash.*



Curve B – variable decreasing
Output reading
Maximum output hysteresis
Curve A – variable increasing
Measured variable
Maximum input hysteresis
Dead space

Repeatability

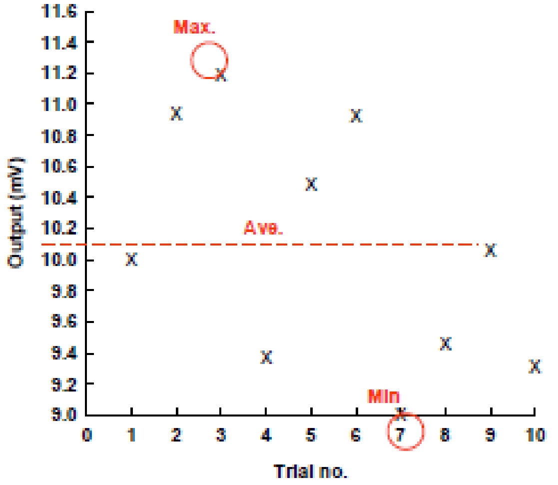
Repeatability: a measure of how well the output returns to a given value when the same precise input is applied several times.
Or the ability of an instrument to reproduce a certain set of reading within a given accuracy.
Precision: how exactly and reproducibly an unknown value is measured

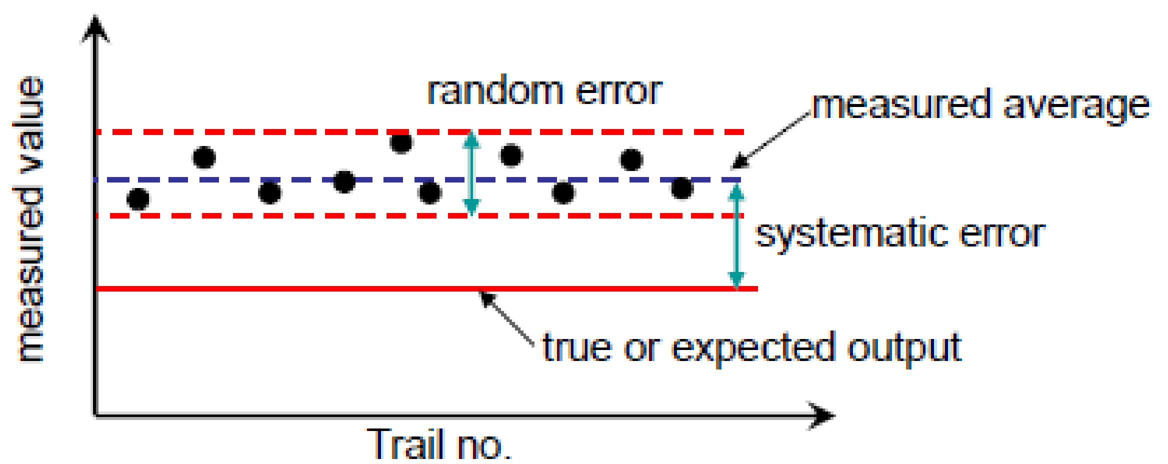
$$\text{repeatability} = \frac{\text{maximum} - \text{minimum}}{\text{full scale}} \times 100\%$$

$$\text{repeatability} = \frac{\text{largest deviation} - \text{average}}{\text{full scale}} \times 100\%$$

Load cell A

- Global accurate but not repeatable





Death Space : Threshold

Dead space is defined as the range of different input values over which there is no change in output value.