MECHANCIAL MEASUREMENTS AND METROLOGY(BTME-3503)

Course Name: MMM

Semester: 5th

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Metrology and Measurements

METROLOGY

- The word derived from Greek “METRON” means to MEASURE.
- “Science of measurement”.
- Measurement is the language of science.
- Metric System(Seven Basic units)

Mass	Kilogram (kg)
Length	Meter (m)
Time	Second (s)
Temperature	Kelvin (K)
Electric Current	Ampere (A)
Amount of Substance	Mole (mol)
Luminous Intensity	Candela (cd)

Metrologist

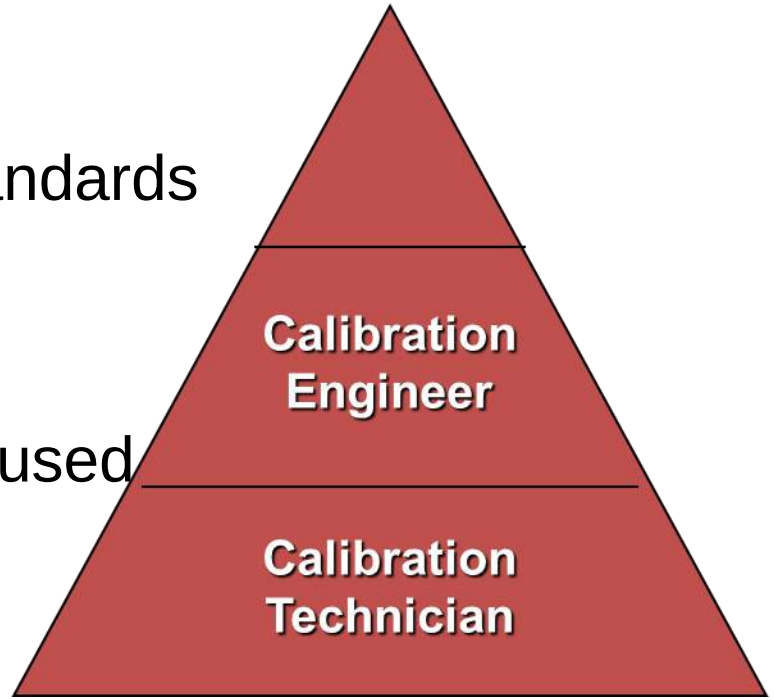
- Designs and runs measurement calibrations & tests
- Analyzes the results
- Determines the final accuracy of the device under test

Scientific Metrology

– Organization and development of measurement standards and their maintenance (highest level)

Industrial Metrology

– Adequate functioning of measurement instruments used well as production and testing processes



Metrology

Legal Metrology

– Measurements that influence economic transactions, health and safety

Who Needs Accurate Measurements?

Metrology

Pharmaceuticals Industry:

- Metrology laboratories test weights and volume standards for pharmaceutical companies
- Products include medicines like aspirin, antibiotics, vaccines, insulin, & vitamins

Defense Industry:

- Metrology laboratories test standards for many military and defense companies
- These companies make the guidance systems for the Patriot missiles and other things that are confidential
- Metrology laboratories test standards for many companies that provide parts of the space shuttle

Space station and Satellites:

- These parts include the metal, heat shield, electronics, fabrics, o-rings, optics, and tires.
- State metrology laboratories test standards used to test retail scales and meters

Retail measurements:

- These include gas pumps, produce scales, milk, bread and other packaged items, and price scanning systems

Engineering Metrology

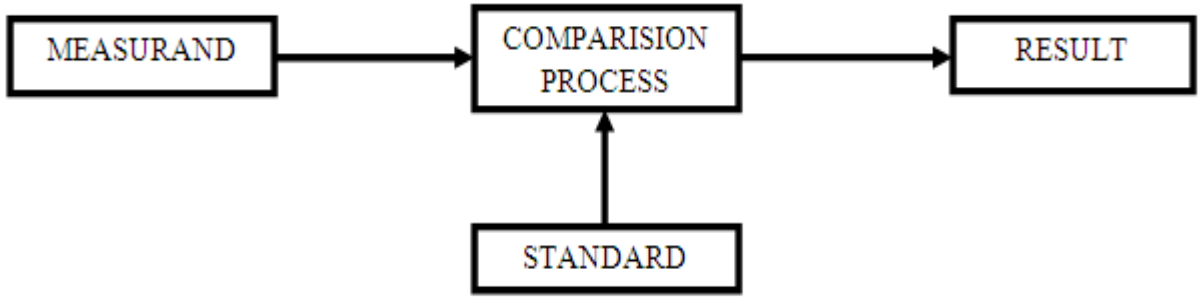
- It mainly used for measurement of length, measurement of angle and other quantities, which expressed in linear and angular terms.
- In industry it is very necessary to maintain the quality in international standard or national standard.
- It is not limited to length and angle measurement but also concerned with numerous problems. Theoretical as well as practical related with measurement such as
    a. Units of measurement and their standard
    b. Method of measurement
    c. Errors of measurement
    d. Measuring instrument and devices
    e. Accuracy of measuring devices
    f. Inspection and various techniques
    g. Design, manufacturing, testing of gauges of all kinds

Examples of measurement

LENGTH	ANGLE	PLANE & SURFACE
(a)Vernier caliper	(a) Sine bar	(a) Sprit level
(b)Micrometer	(b) Bevel protractor	(b) Surface Gauge
(c)Depth Gauge	(c) Angle gauge	(c) Optical flat
(d)Height gauge	(d) Auto-collimator	

Elements of Measurement systems

- Measurand : It is physical quantity to be measured.
- Reference : Phy-quantity – property to which Quantitative Comparison are made.
- Comparator : Comparing Measurand with some reference.
- Example
  - ❖ Length of table – Measurand
  - ❖ Steel rule – Reference
  - ❖ Eye – Comparator



Metrology

Needs for measurement

1. To ensure public health and human safety
2. To determine true dimension part
3. To evaluate the performance of a system
4. To ensure interchangeability of parts
5. To study some basic law of nature
6. To establish the validation of design and for finding new idea and new design

Application of measurement

1. Fundamental basis for research and development
2. Fundamental element of any automatic control system
3. To evaluate the performance of any plant or process
4. Forecasting weather and predicting the onset of earth quakes
5. It establishes the validity of design and determines data for new and improved design

Metrology

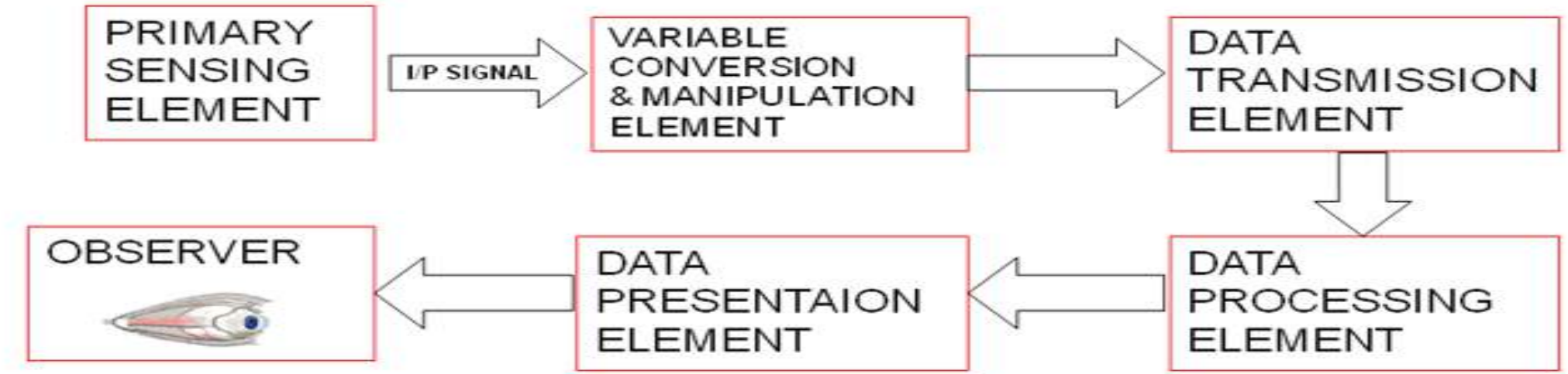
LEGAL	DETERMINISTIC
1. Part of metrology ❖Units of measurement ❖Method of measurement ❖Measuring instrument 2. Mandatory organization ❖ International organization of weight and measures. ❖National services of legal metrology.	1. New Philosophy in which part measurement is replaced by process and production measurement. 2. Full advantage in nature of production –m/c- Mfg- Sub-system. Ex-Monitoring of temp, press, finger printing sensor.

Metrology

GENERALISED MEASURING SYSTEM

It consists of following common elements.

1. Primary sensing element.
2. Variable conversion element.
3. Variable manipulation element
4. Data transmission element.
5. Data processing element.
6. Data presentation element.



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Primary sensing element:

- 1st element which receives energy from the measuring medium.
- It produces an output corresponding to the Measurand.
- O/p is converted into analogous electrical signal by transducer.

Variable conversion element:

- It convert o/p signal from 1st one.
- The o/p may be voltage, force, frequency or some other.
- It is more suitable without any changes in the i/p signal.

Variable manipulation element:

- It gives original nature of the signal.
- It amplifies the I/p signal to required magnification.

Data transmission element:

- It transmits data from one element to other.
- It transmit signal from one place to another.

Data processing element:

- To convert data into useful form.
- To separate signal hidden noise.

Data presentation element:

- To easy understand of measured variable – this will communicate the information to human observer for monitoring.
- Analog indicator- pointer or scale
- Digital indicator – LED
- Recorder – magnetic tape, camera, equipment, storage type.

Metrology

ELEMENTS OF MEASUREMENT SYSTEM

1. Measuring instruments
2. Calibration standards
3. Workpiece
4. Person who is carrying out the measurement
5. Environment

The above said five elements composed into the acronym "SWIPE"

Where. **S**- Standard

W-Workpiece

I-Instrument

P-Person

E-Environment

The factors affecting these five elements:

Metrology

The factors affecting these five elements:

1. Standard
    a. Affected by temperature
    b. Time
    c. Thermal expansion
    d. Elasticity
2. Workpiece
    a. Surface finish
    b. Cleanliness
    c. Supporting element
    d. Elastic properties
3. Instruments
    a. Friction
    b. Error
    c. Mechanical parts
4. Person
    a. Ability to measure
    b. Training
5. Environment
    a. Light
    b. Temperature
    c. Humidity

Metrology

ACCURACY

- Closeness to the true value of the quantity under measurement.
- The difference between the true value and measured value is known as measurement error. In actual case, it is very difficult to find out exact true value.
- Therefore set of measurement are made from this set of value the mean value is taken for the comparisons of true value.

The accuracy of measurements depends upon

a. The ability of the operator
b. Variation of the temperature
c. Method adopted for measurement
d. Deformation of the instrument

PRECISION

- It refers to the "Repeatability of a measuring process".
- The ability of the instrument to reproduce its readings again and again in the same manner for a constant input signal, that is, if a number of measurements are made on the same true value, the degree of closeness of these measurements is called as precision.
- Now let us differentiate between accuracy and precision. As discussed earlier, accuracy refers to the closeness of the measured value with respect to the true value. But precision refers to the ability of the instrument to reproduce its readings again and again in the same manner for a constant input signal. In short, precision is the degree of agreement with in a group of measurements.

Metrology

Sl.No	ACCURACY	PRECISION
1	Closeness to the true value of the quantity under measurement	The ability of the instrument to reproduce its readings again and again in the same manner for a constant input signal.
2	The relative between observed value and true values	The fitness of the instrument of the dispersion of the repeated readings
3	Accuracy may designate to precision.	Precision never designate to accuracy.
4	It is defines as the relationship between the value of observed	It is define as the close relationship of the observed readings with average value.
5	The difference between the measured value and true value is the error of measurement, if the error is less, then the accuracy is more.	Standard deviation is the index of precision for the less value of σ, more precision is the instruments.

Static and Dynamic Characteristics of Instru in Metrology

Basic steps:

- Development of Mathematical Model for Identification of Parameters to be measured.
- Identification of characteristics to be possessed by a general Instruments.
- Qualitative and Quantitative models for determination of Instrument design details.
- Selection of geometrical and physical parameters.

Characteristics in instruments

- To choose the instrument, most suited to a particular measurement application, we have to know the system characteristics.
- The performance characteristics may be broadly divided into two groups, namely '***static***' and '***dynamic***' characteristics.

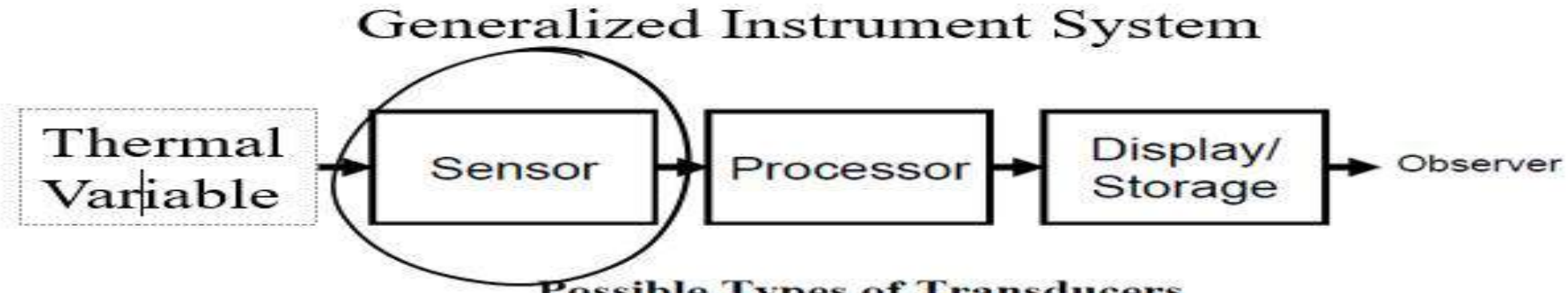
Static characteristics

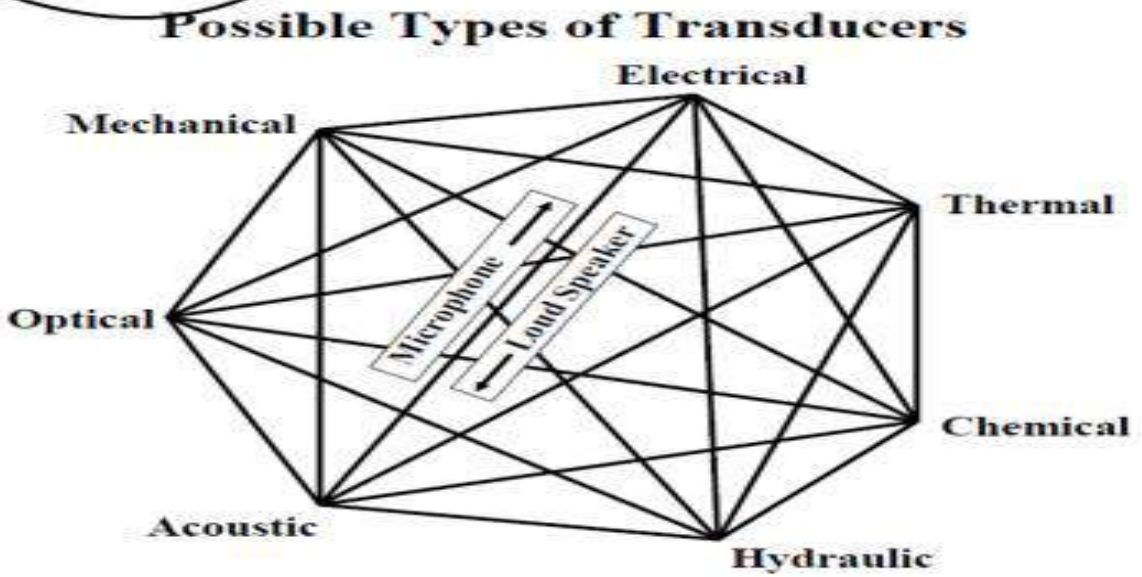
- the performance criteria for the measurement of quantities that remain constant, or vary only quite slowly.

Dynamic characteristics

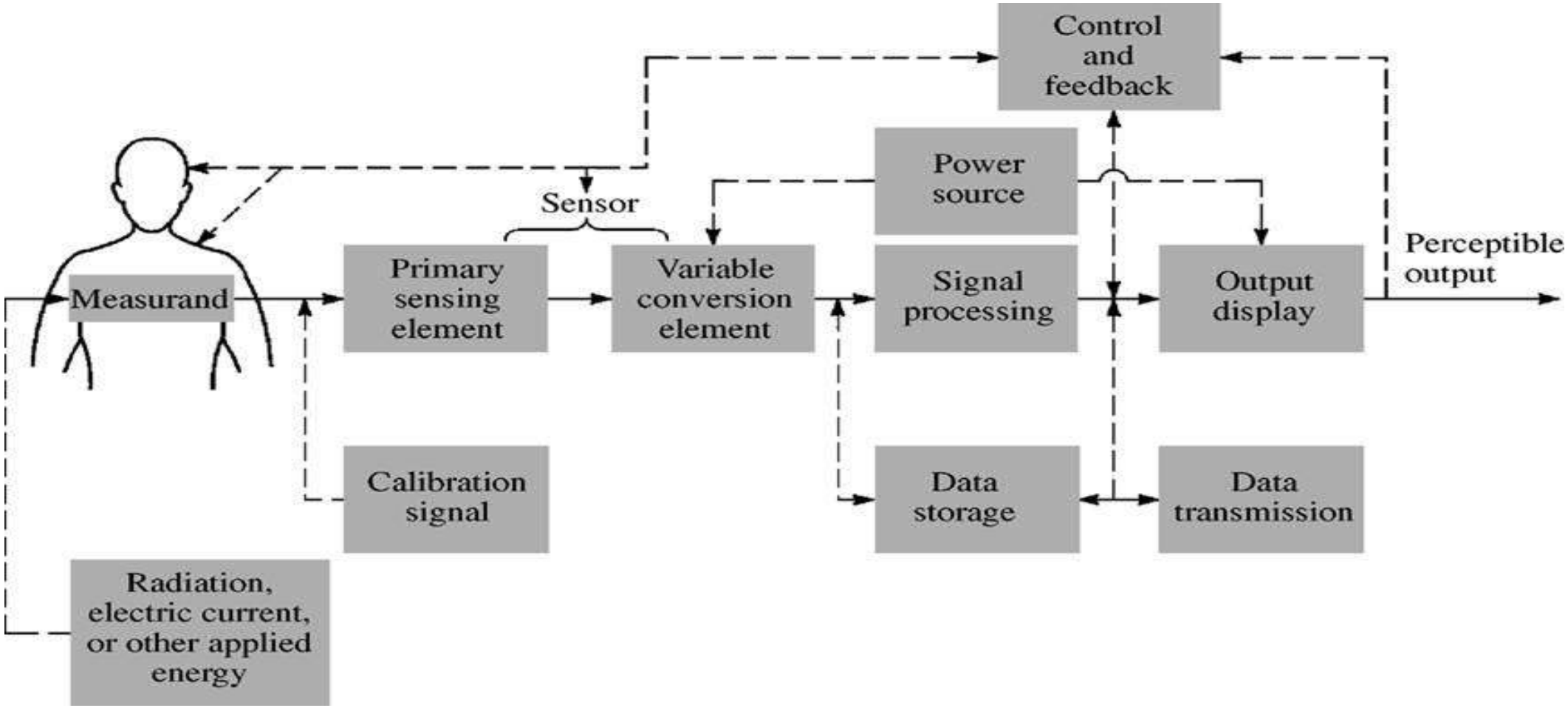
- the relationship between the system input and output when the measured quantity (measurand) is varying rapidly.

Generalised System





Characteristics in instruments



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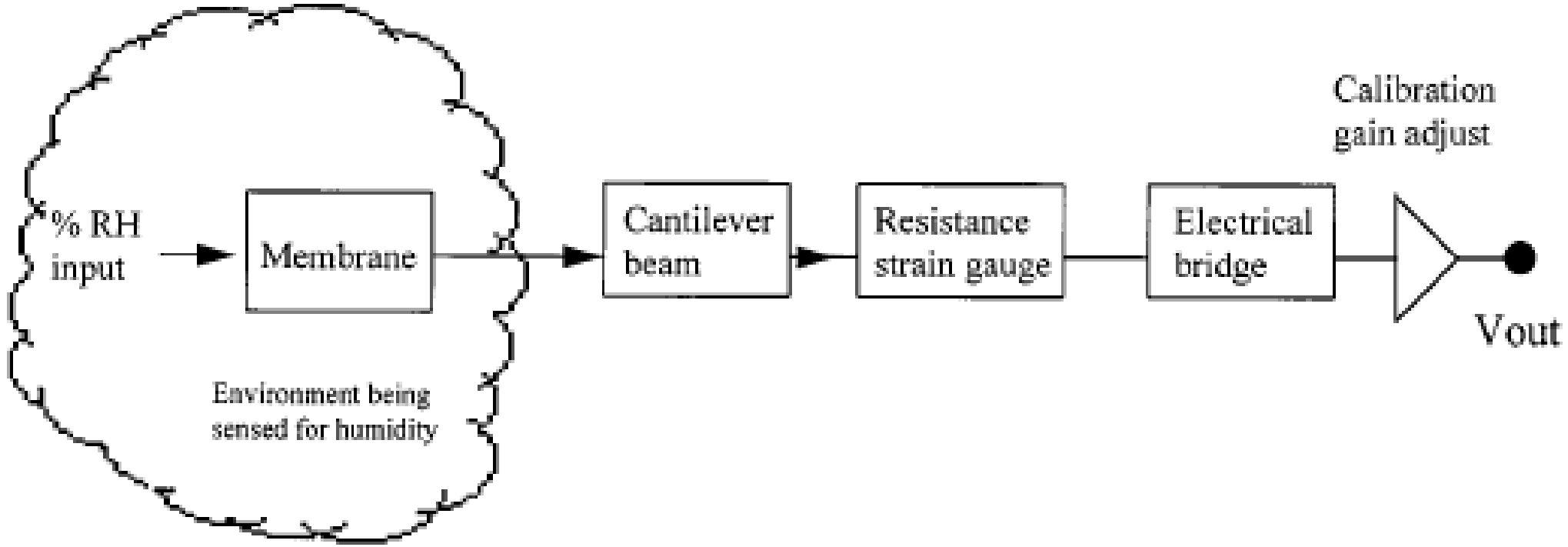

% RH
input
Membrane
Environment being
sensed for humidity
Cantilever
beam
Resistance
strain gauge
Electrical
bridge
Calibration
gain adjust
Vout

Metrology

SYSTEMATIC CHARACTERISTICS

- Range
- Span
- Linearity
- Sensitivity
- Environmental effects
- Hysteresis
- Resolution

Metrology

Range:

- The input range defines the minimum and maximum value of the variable to measure.
- The output rage defines the minimum and maximum value of the signal given by the transducer.
- Assume a temperature transducer which temperature range is from 100°C to 250°C and the output range is given from 4 to 10 mV.

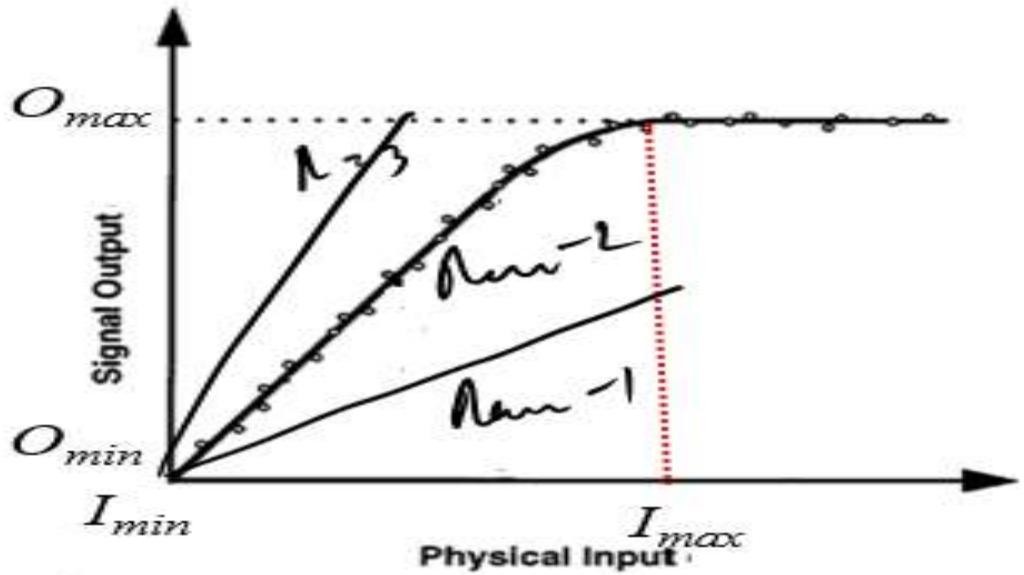
Span:

- The input span is the maximum change of the input and the output span is the maximum change of the output.
- Input span: $I_{MAX} - I_{MIN}$

Metrology

Linearity

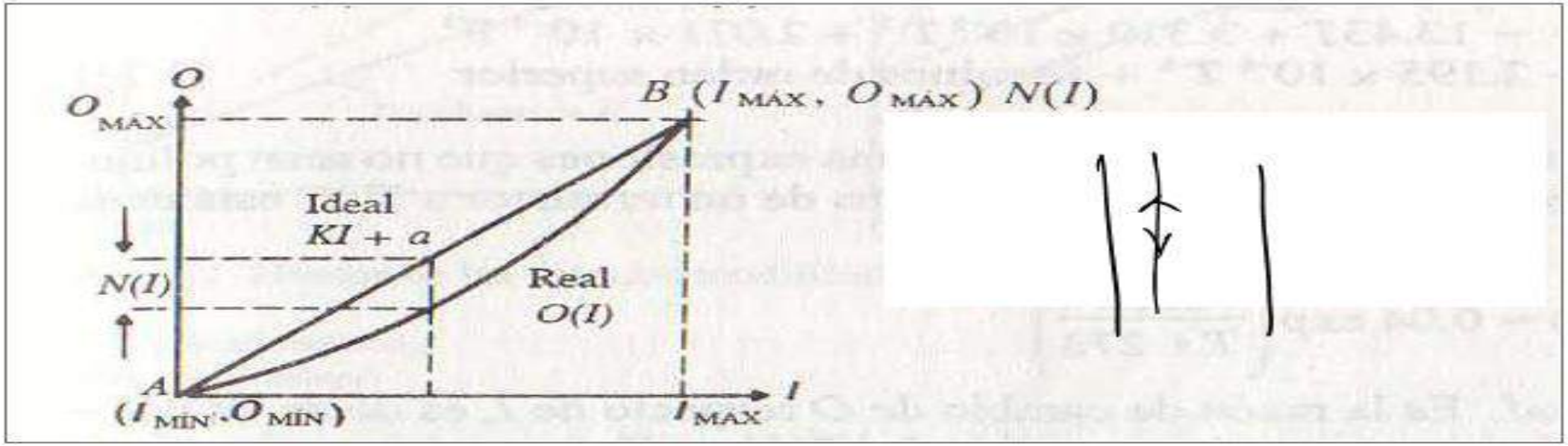
- It is normally desirable that the output reading of an instrument is linearly proportional to the quantity being measured.
- An instrument is considered if the relationship between output an input can be fitted in a line.



$$O - O_{MIN} = \left\{ \frac{O_{MAX} - O_{MIN}}{I_{MAX} - I_{MIN}} \right\} \times (I - I_{MIN})$$

Metrology

- No-linearity is defined as the maximum deviation of the output over the straight line



No-Linearity can be quoted by: $N(I) = O[I] - \{K \times I + a\}$

Maximum % of No-Linearity : $= \dfrac{N_{max}(I)}{O_{MAX} - O_{MIN}} \times 100$

Metrology

Sensitivity:

- The sensitivity of measurement is a measure of the change in instrument output that occurs when the quantity being measured changes by a given amount.
- Thus, sensitivity is the ratio:

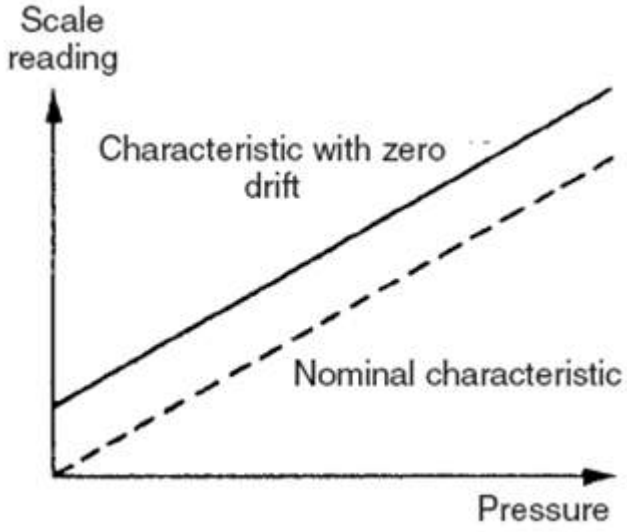
$$\frac{\text{scale deflection}}{\text{value of measurand producing deflection}}$$

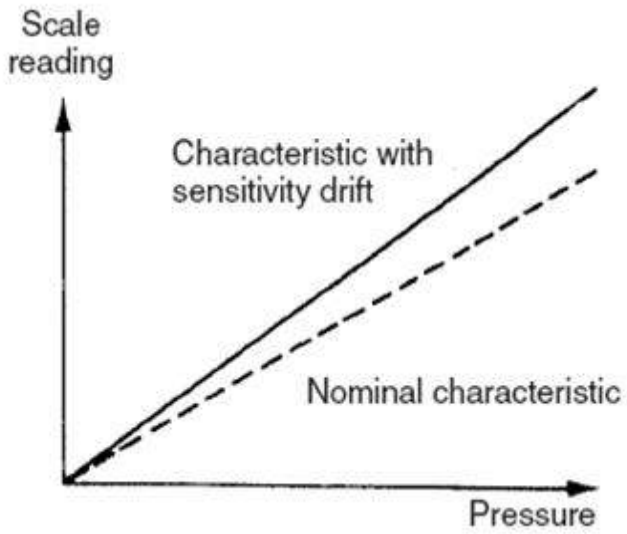
Environmental Effects:

- 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.

Drift

- This is caused by variations taking place in the parts of the instrumentation 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.





Hysteresis and Backlash

- Careful observation of the output/input relationship of a block will sometimes reveal different results as the signals vary in direction of the movement.
- Mechanical systems will often show a small difference in length as the direction of the applied force is reversed.
- The same effect arises as a magnetic field is reversed in a magnetic material.
- This characteristic is called *hysteresis*
- 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.*

Summary

In this chapter, an introduction to the field of the metrology was given and some significant to be noticed are given below;

- Generalised measurement system and its elements
- Characteristics of the instruments

Topics to be Discussed in Next Lecture

- Errors in measurement