UNIT I INTRODUCTION

Introduction to Mechatronics

- Sensors and Transducers
- Static and dynamic Characteristics of Sensor

Presented by

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Sensors

- A sensor is defined as an element which when subjected to some physical change experiences a relative change.
- Devices which respond directly to any physical phenomenon such as force, temperature, heat, light etc. are called sensors.

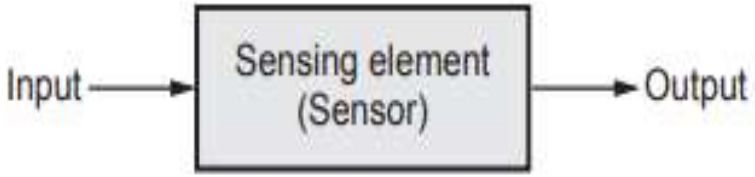


Fig. 1.7.1 Function of a sensor

- The sensor produces a proportional output signal mechanical, electrical or magnetic when exposed to physical phenomenon.

Classification of sensor

Detail classification of sensors in view of their applications in manufacturing is as follows.

A. Displacement, position and proximity sensors

1. Potentiometer
2. Strain-gauged element
3. Capacitive element
4. Differential transformers
5. Eddy current proximity sensors
6. Inductive proximity switch
7. Optical encoders
8. Pneumatic sensors
9. Proximity switches (magnetic)
10. Hall effect sensors

B. Velocity and motion sensors

1. Incremental encoder
2. Tachogenerator
3. Pyroelectric sensors

C. Force sensor

1. Strain gauge load cell

D. Fluid pressure sensors

1. Diaphragm pressure gauge
2. Capsules, bellows, pressure tubes
3. Piezoelectric sensors
4. Tactile sensor

E. Liquid flow sensor

1. Orifice plate
2. Turbine meter

F. Liquid level sensor

1. Floats
2. Differential pressure

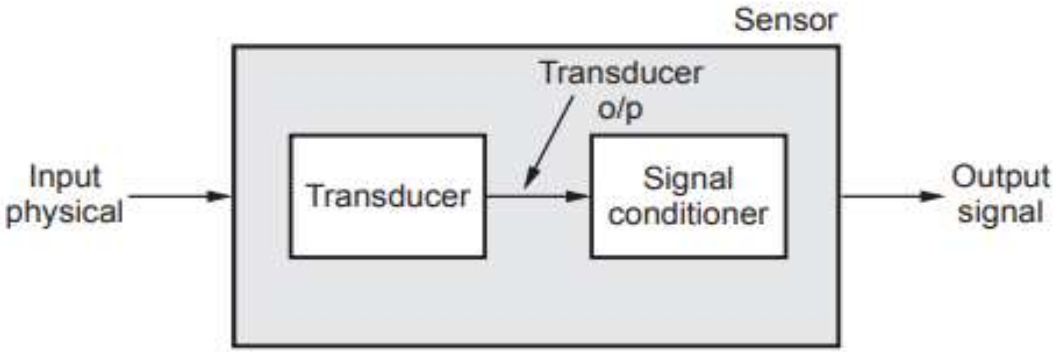
G. Temperature sensors

1. Bimetallic strips
2. Resistance temperature detectors
3. Thermistors
4. Thermo-diodes and transistors
5. Thermocouples
6. Light sensors
7. Photo diodes
8. Photo resistors

Transducer

Transducers are devices which converts one form of energy into other form of energy.

- For example, microphones, thermometers, position and pressure sensors and antenna ; LEDs etc.
- The term transducer is synonymously used with sensors although the principles are different.
- Transducers are physical element and is an essential part of sensor.
- The transducers refers to sensing element itself where as sensors refers to sensing element along with signal conditioning circuitry.
- Fig. 1.7.2 shows sensor with it's energy conversion function.



1.7.3.1 Classification of Transducers

- Transducers can be classified on many ways. Broadly they can be categorized as -
  1. Active and passive transducers.
  2. Analog and digital transducers.

1. Active transducers

- The transducer which generates an electrical signal directly in response to the physical parameter being measured are called as **active transducers**.
- Active transducers are self generating devices i.e. they does not require an external power source for its operation. Active transducers operate under energy conversion principle that generates an equivalent output signal.

Examples of active transducers -

a) Photo voltaic cells

b) Thermocouples

c) Piezoelectric transducer

2. Passive transducers

- The transducer which requires external energy source for its operation is called as **passive transducer.**
- Passive transducer works under energy controlling principle, which makes it necessary to use an external electrical source for its operation.

Examples of passive transducers -

a) Thermistor

b) Strain gauge

c) Load cell

1.2.4 Characteristics of Measurement System

- In an industrial process, measuring device senses various parameters under observation. Therefore, it is necessary that the device must measure that parameter accurately. To obtain better performance from any measuring device, a number of its characteristics must be considered.
- The performance characteristics of any measuring device can be divided into two characteristics :

1. Static characteristics
2. Dynamic characteristics.

The overall performance of an instrument or measuring device is determined by its static and dynamic characteristics.

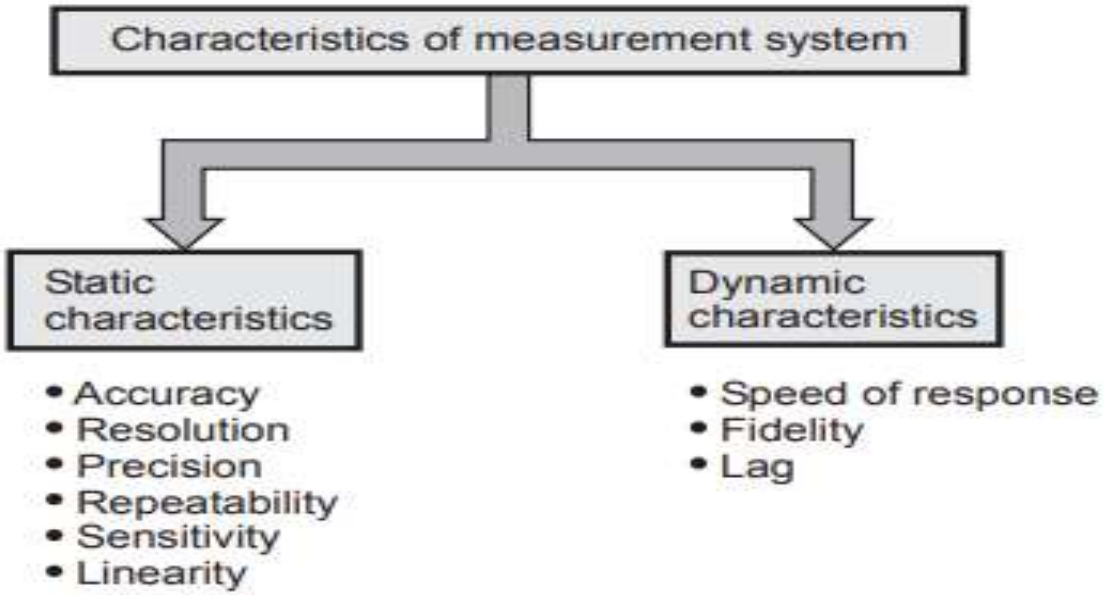


Fig. 1.2.6 Characteristics of measurement system

1.2.4.1 Static Characteristics of Sensors

☞ [AU : Dec.-2016, 8 Marks]

- Static characteristics describe performance at room temperature conditions, with very slow changes in measurement quantities.
- In some applications, measurement quantities are constant or varying quite slowly, the set of characteristics that defines the performance of device under such condition is known as **static characteristics** of device.
- Static characteristics of a device can be defined as the characteristics describing the relationship between specified points when system variable are not changing.
- Examples of static characteristics are - accuracy, precision, resolution, repeatability (reproducibility), zero drift, lag, sensitivity threshold and linearity.
- Accuracy is highly desirable and repeatability is certainly the most important static feature of any measuring device.

1. Accuracy

- Accuracy is defined as the ability of the instrument to respond to the true value of the measure variable under the reference conditions.

2. Precision

- **Precision** is defined as the closeness with individual measurements are distributed about their mean value.

  Precision is the difference between a measured variable and best estimate of the true value of the measured variable.
- Precision is a measure of repeatability as it is the consistency of the instrument output for a given value of input.
- Accuracy and precision have totally distinct meanings.
- Precision consists of three characteristics :
  I. Conformity
  II. Number of significant figures
  III. Range of doubt.

3. Resolution

- Resolution is defined as the smallest increment in the measured value that can be detected.
- The resolution is the smallest change in the input value which will produce an observable change in the input.

4. Repeatability

- **Repeatability** is defined as the measure of the deviation of test results from the mean value.
- It is the closeness of a group of measurements of the same measured quantity made by the same observer, using the same conditions, methods and apparatus. Repeatability is affected by internal noise and drift.

  For example, if a displacement transducer is repeatedly subjected to an accurately known displacement, then its repeatability would be ± 1 percent if all the readings within these limits.
- Repeatability is also referred to as reproducibility. The perfect reproducibility indicates no drift in the instrument.

5. Stability

- Stability is defined as the ability of transducer to give same output for constant input over a period of time.

6. Drift

- **Drift** is a variation in the instrument output which is not caused by any change of input, it may be caused by internal temperature changes and component instability. The drift is a gradual shift of the instrument indication.

7. Hysteresis

- **Hysteresis** is the maximum difference in output, at any measurand value, within the specified range, when the value is approached first with increasing and then with decreasing value of parameter.
- Hysteresis can be defined as the maximum difference in any part of output readings so obtained during any one calibration cycle. Fig. 1.2.7 shows hysteresis curve.

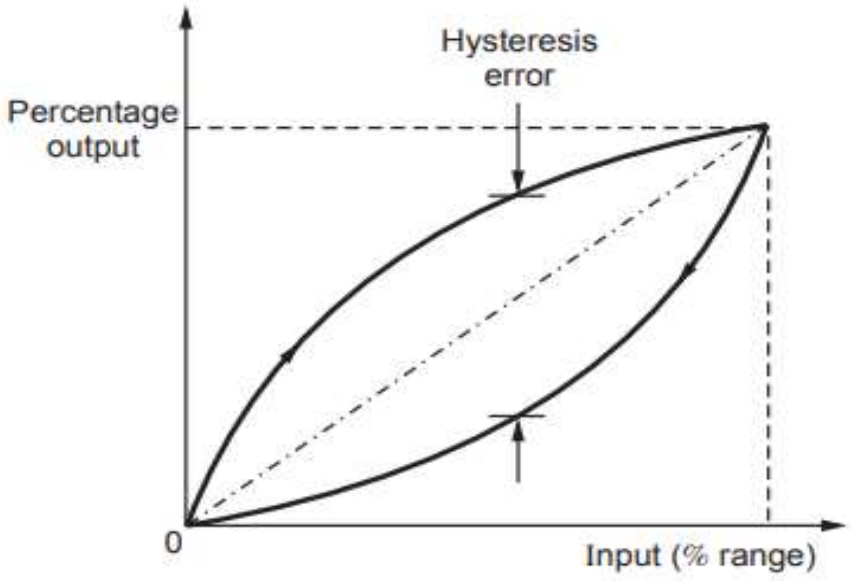


Fig. 1.2.7 Hysteresis error

8. Linearity

- **Linearity** describes the maximum deviation of the output of a device from a best fitting straight line through the calibration data. Most devices are designed such that the output is a linear function of input. i.e. sensitivity remains constant for all values of measurand.

9. Sensitivity

- **Sensitivity** is defined as the ratio of change in the magnitude of instrument output to the corresponding change in the magnitude of the measurand.

10. Threshold

- Threshold of a device is the minimum input for which there will be an output. Below this minimum input, the instrument will read zero.
- The resolution is the smallest measurable input change while threshlod is smallest measurable input.

11. Deadband

- Deadband is the largest change of measurand to which the instrument does not respond and is produced by friction, backlash or hysteresis in the device.
- It is defined as the largest change of input quantity for which there is no output from the instrument. It is produced by friction, backlash or hysteresis in the device.

12. Backlash

- Backlash is the maximum distance or angle through which any part of a mechanical system may be moved in one direction without applying appreciable force or motion to the next part in mechanical sequence.

13. Range and span

- The scale **range** of an instrument is the difference between the largest and smallest reading of the instrument. The selection of proper range is important in measurement.
- The difference between highest calibration point and lowest calibration point of an instrument is called **span** of instrument.

14. Output impedance

- The impedance across the sensor when it is giving electrical output is called output impedance of that sensor. This output impedance is either connected in series or parallel with the circuit to be interfaced. Therefore, the output impedance is an important parameter for any sensor or transducer.

15. Reproducibility

- The reproducibility of a transducer (instrument) is defined as the degree of closeness among the repeated measurements of the output for the same value of input under the same operating conditions at different times.
- Perfect reproducibility means that transducer has no drift i.e. transducer calibration does not gradually shift over a long period of time such as week, month or even a year.

1.2.5 Response of System

- The system does not respond instantaneously to any input to it. **Dynamic characteristics** determines the behavior of the system between the time when input value changes and time when output settles down to steady state.
- Dynamic characteristics of a control system are specified by rise time, response time and settling time as shown in Fig. 1.2.9.

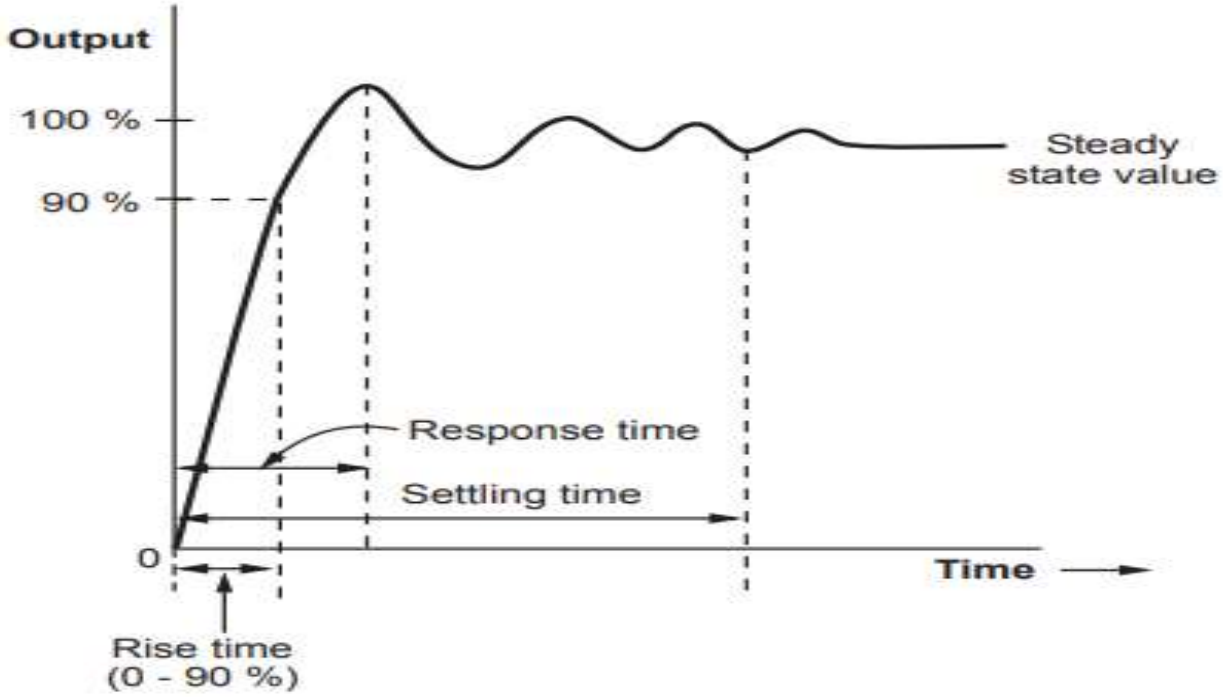


Fig. 1.2.9 Rise, response and settling time

1.2.5.1 Rise Time

- It is the time taken for the output to rise to some specified percentage of the steady state value, e.g. - in some system it is taken as time for 0 - 90 % of output also in some system rise time is taken as 10 % to 90 % of output.

1.2.5.2 Time Constant

- Response time is defined as time taken for the output to reach 63 % of its steady state value or time taken to reach its first peak of oscillation.

1.2.5.3 Settling Time

- Settling time is the time taken for the output to settle to within some percentage e.g. 2.5 % of steady state value.

Thank you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