EEE 432
Measurement and Instrumentation
Lecture 2
Instrument Types and Performance Characteristics

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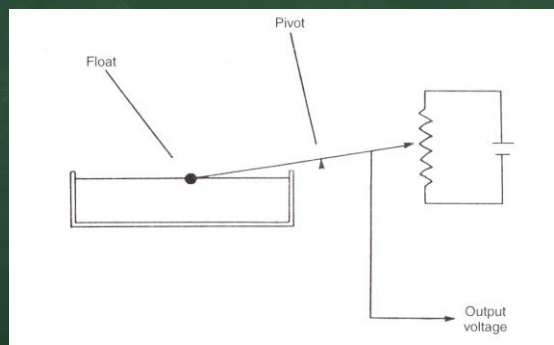
Instrument Types
Active and Passive Instruments

- Active Instruments
  – the quantity being measured simply modulates (adapts to) the magnitude of some external power source.
- Passive Instruments
  – the instrument output is entirely produced by the quantity being measured

- Difference between active & passive instruments is the level of measurement resolution that can be obtained.

Instrument Types
Active Instruments-1

e.g. Float-type petrol tank level indicator



Instrument Types
Active Instruments-2

- The change in petrol level moves a potentiometer arm, and the output signal consists of a proportion of the external voltage source applied across the two ends of the potentiometer.
- The energy in the output signal comes from the external power source: the primary transducer float system is merely modulating the value of the voltage from this external power source.

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Active Instruments-2

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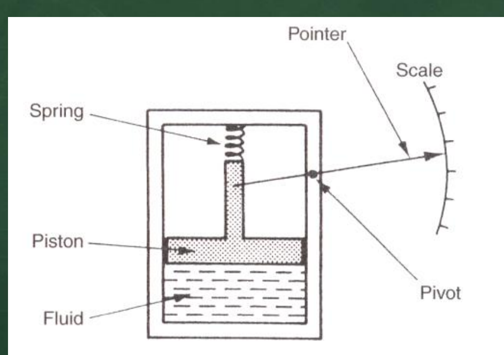
Instrument Types
Passive Instruments-1

e.g. Pressure-measuring device



Instrument Types
Passive Instruments-2

- The pressure of the fluid is translated into a movement of a pointer against scale.
- The energy expanded in moving the pointer is derived entirely from the change in pressure measured: there are no other energy inputs to the system.

Instrument Types
Analog and Digital Instruments-1

Analog Instrument

- An analogue instrument gives an output that varies continuously as the quantity being measured; e.g. *Deflection-type of pressure gauge*

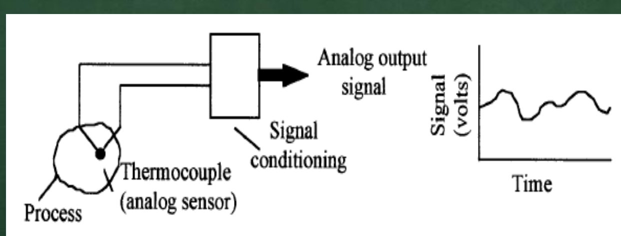


FIGURE 2.5 A thermocouple provides an analog signal for processing.

Instrument Types
Analog and Digital Instruments-2

Digital Instrument

- A digital instrument has an output that varies in discrete steps and only have a finite number of values; e.g. *Revolution counter*

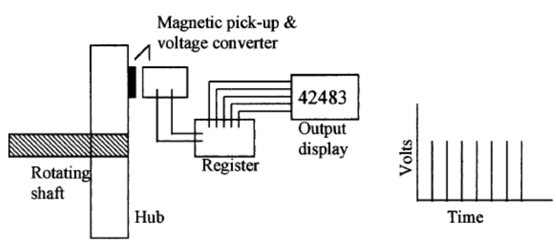


FIGURE 2.6 A rotating shaft with a revolution counter produces a digital signal.

Instrument Types
Smart and Non-smart Instruments

Smart Instrument

- An instrumnet with a microprocessor to do some operations during and after measurements

Non-Smart Instrument

Static Characteristics
Definiton

- The steady state relationship between input and output of an instrument
- Measurement of quantities that are constant or vary quite slowly with respect to time.
- It does not involve differential equations.

Static Characteristics
Important Parameters

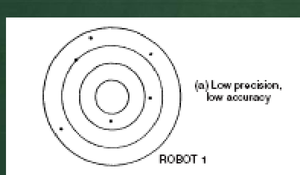
- Accuracy and Precision
- Repeatability/Reproducibility
- Tolerance
- Range or span
- Linearity
- Sensitivity of measurement
- Threshold
- Resolution
- Sensitivity to disturbance
- Hysteresis effects
- Dead space

Static Characteristics
Accuracy and Precision-1

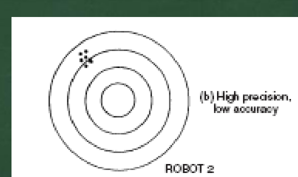
- The accuracy of an instrument is a measure of how close the output reading of the instrument is to the correct value.
- Measurements that are close to each other are precise
- Measurements can be:
  - *Precise but inaccurate*
  - *Neither precise nor accurate*
  - *Precise and accurate*

Static Characteristics
Accuracy and Precision-Example

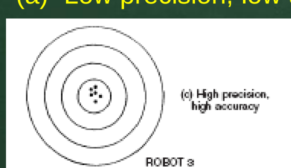
- Three industrial robots were programmed to place components at a particular point on a table. The target point was the center of a circle shown below. The results are:



(a) Low precision, low accuracy



(b) Precise not accurate



(c) Precise and accurate

Static Characteristics
Repeatability/Reproducibility

- *Repeatability describes the closeness* of output readings when the same input is applied repetitively over a short period of time, with the same measurement conditions, same instrument and observer, same location and same conditions of use maintained throughout.
- *Reproducibility describes* the closeness of output readings for the same input when there are changes in the method of measurement, observer, measuring instrument, location, conditions of use and time of measurement.
- Both terms thus describe the spread of output readings for
- the same input.
- This spread is referred to as repeatability if the measurement conditions are constant and as reproducibility if the measurement conditions vary.

Static Characteristics
Tolerance

- Tolerance is a term that is closely related to accuracy and defines the maximum error that is to be expected in some value.

Example

- Electric circuit components such as resistors have tolerances of perhaps 5%. One resistor chosen at random from a batch having a nominal value 1000Ω and tolerance 5% might have an actual value anywhere between 950Ω and 1050 Ω.

Static Characteristics
Range or span

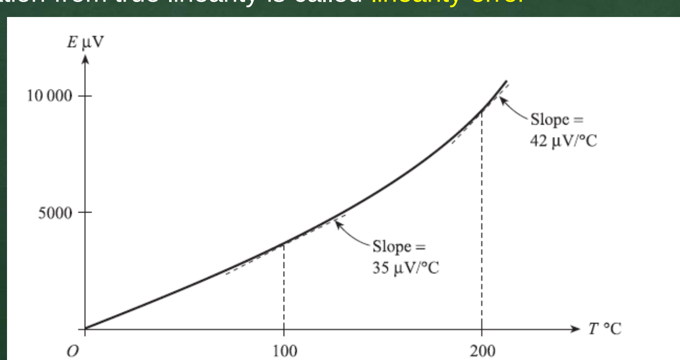
- The *range or span of an instrument defines the minimum and maximum values of a* quantity that the instrument is designed to measure.

Example:

- 0-20 V range of a multimeter
- 0-1 V range of an oscilloscope.

Static Characteristics
Linearity

- It is highly desirable that the measurement system has a linear relationship between input and output means that the change in output is proportional to the change in the value of the measurand.
- Deviation from true linearity is called linearity error



Static Characteristics
Sensitivity of measurement

- Sensitivity is the ratio of change in magnitude of the output to the change in magnitude of the measurand

  Sensitivity = Δ(output) / Δ(input)

Example:

If the measured output is increased by 100 mV for a temperature change of 4^0C, the the sensitivity is

$S = \Delta V/\Delta T = 100\ mV/4^0C = 25\ V/^0C$

Static Characteristics
Threshold

- If the input to an instrument is gradually increased from zero, the input will have to reach a certain minimum level before the change in the instrument output reading is of a large enough magnitude to be detectable. This minimum level of input is known as the *threshold* of the instrument.

Static Characteristics
Resolution

- Resolution is the lower limit on the magnitude of the change in the input measured quantity that produces an observable change in the instrument output.

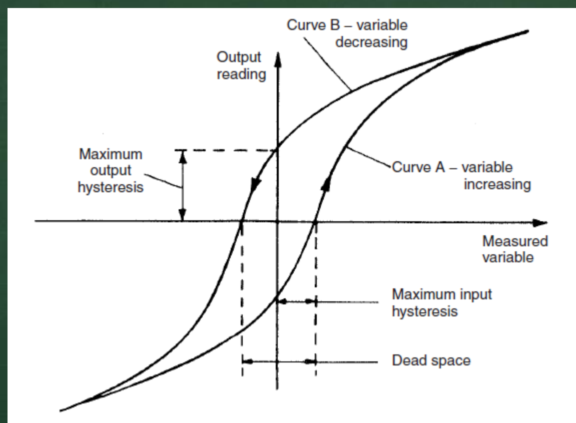
Example

- Using a car speedometer as an example again, this has subdivisions of typically 20 km/h. This means that when the needle is between the scale markings, we cannot estimate speed more accurately than to the nearest 5 km/h. This figure of 5 km/h thus represents the resolution of the instrument.

Static Characteristics
Sensitivity to disturbance

- 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. Zero drift or bias describes the effect where the zero reading of an instrument is* modified by a change in ambient conditions.
- *Sensitivity drift (also known as scale factor drift) defines the amount by which an* instrument's sensitivity of measurement varies as ambient conditions change.

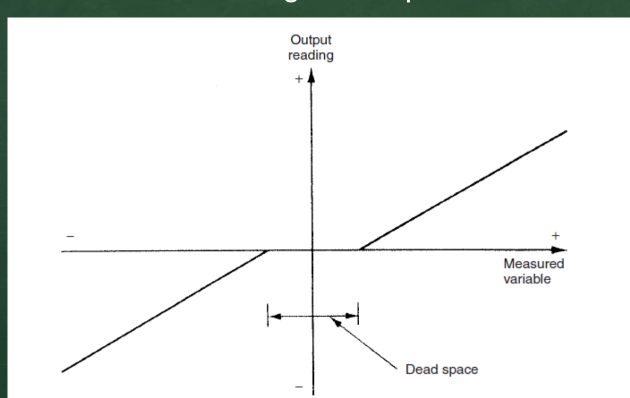
Static Characteristics
Hysteresis effects



Examples: Iron core, spring

Static Characteristics
Dead space

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



Dynamic Characteristics

In any linear, time-invariant measuring system, the following general relation can be written between input and output for time t > 0:

$$a_n \frac{d^n q_0}{dt^n} + a_{n-1} \frac{d^{n-1} q_0}{dt^{n-1}} + \cdots + a_1 \frac{dq_0}{dt} + a_0 q_0 = b_m \frac{d^m q_i}{dt^m} + b_{m-1} \frac{d^{m-1} q_i}{dt^{m-1}} + \cdots + b_1 \frac{dq_i}{dt} + b_0 q_i$$

where q_i is the measured quantity, q_0 is the output reading and $a_0 \ldots a_n$, $b_0 \ldots b_m$ are constants.

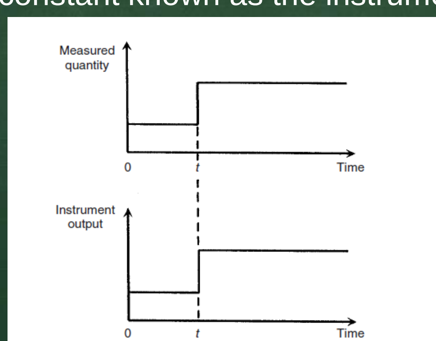
- Zero order instrument
- First order instrument
- Second order instrument

Dynamic Characteristics
Zero order instrument

- If all the coefficients $a_1 \ldots a_n$ other than a_0 are assumed zero, then

  $a_0 q_0 = b_0 q_i$ or $q_0 = b_0 q_i / a_0 = K q_i$

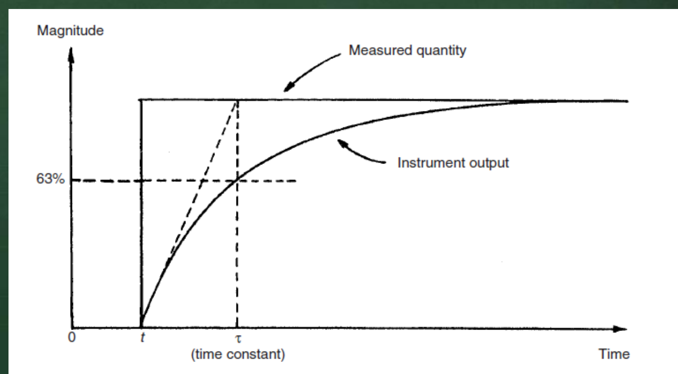
  where K is a constant known as the instrument sensitivity.



Dynamic Characteristics
First order instrument

- If all the coefficients $a_1 \ldots a_n$ other than a_0 and a_1 are assumed zero, then

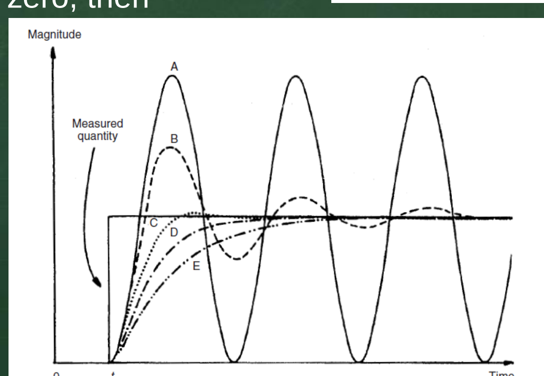
$$a_1 \frac{dq_0}{dt} + a_0 q_0 = b_0 q_i$$



Dynamic Characteristics
First order instrument

- If all the coefficients $a_1 \ldots a_n$ other than a_0, a_1 and a_2 are assumed zero, then

$$a_2 \frac{d^2 q_0}{dt^2} + a_1 \frac{dq_0}{dt} + a_0 q_0 = b_0 q_i$$



Instruments
Calibration and Recalibration

- A new instrument will have been calibrated when it is obtained from an instrument manufacturer, and will therefore initially behave according to the characteristics stated in the specifications.
- During use, however, its behaviour will gradually diverge from
- the stated specification for a variety of reasons. Such reasons include mechanical wear, and the effects of dirt, dust, fumes and chemicals in the operating environment.
- The rate of divergence from standard specifications varies according to the type of instrument, the frequency of usage and the severity of the operating conditions.
- When the characteristics of the instrument will have drifted from the standard specification by an unacceptable amount, then it is necessary to recalibrate the instrument to the standard specifications.