NAZARBAYEV UNIVERSITY

SCHOOL OF ENGINEERING

Sensors and Actuators

Part 1

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Sensors and Transducers (definition)

- ***Sensors** are used for an element which produces a signal relating the quantity being measured (example, temperature sensor transforms an input temperature into a change in resistance)*

- **Transducers** *are defined as elements that when subject to some physical change experience a related change*

- Sensors are transducers

Sensors performance terminology and specifications

I. Range and span

Range defines the *limits* between which the *input* can vary

Span is the maximum value of the input minus the minimum value. Example, a load cell for the measurement of forces might have a range of 0 to 50 kN and span of 50 kN

2. Error is the difference between the *results of the measurement* and the *true value* of the quantity being measured

Error= measured value – true value

Example, if the measured temperature is 25°C when the actual is 24°, then the error is +1°C. Instead if the measured value was 26°, then the error should be -1°

Sensors performance terminology and specifications

3. *Accuracy* is the extend to which the value indicated by a measurement system might be wrong. In other words, it is the *summation* of all the possible errors that are likely to occur
Example, the temperature – measuring instrument may be specified as having an accuracy of ± 2°C of the true value . It means that the reading given by the instrument can be expected to lie within + or – 2°C of the true value

Accuracy is often expressed as a *percentage of the full range output* or full-scale deflection
Example, the reading may be specified as having an accuracy of ± 5% of full range output. Then if the range of the sensor is 0 to 200° the reading given can be expected to be within + or – 10°C of the true reading

Sensors performance terminology and specifications

4. *Sensitivity* is relationship indicating how much output you get per unit of input, i.e. input/output relationships.

Example, a resistance thermometer may have a sensitivity of 0.5 Ω/°C. The higher sensitivity is the better quality of it.

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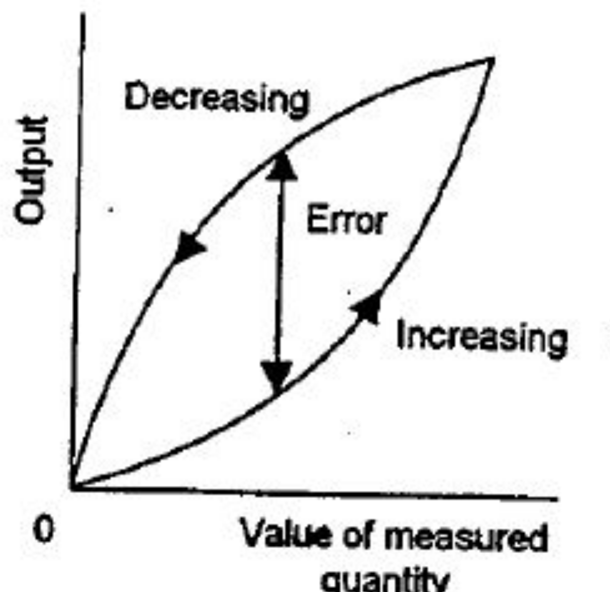
This term is also frequently used to indicate the sensitivity to inputs other than being measured, i.e. environmental changes such *environmental temperature* or fluctuation the in the *mains voltage supply*. Example, the pressure transducer may have a temperature sensitivity of ±0.1 % of the reading per °C change in temperature.

Sensors performance terminology and specifications

5. Hysteresis error is due to the fact that transducers can give different outputs from the same value of quantity being measured according to whether that value has been reached by a continuously *increasing* or *decreasing* change . It is the maximum difference in output for increasing and decreasing values



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Sensors performance terminology and specifications

6. <u>Non-linearity error</u> is due to the fact that most of the transducers have nonlinear relationships between the output and input. However, a *linear relationship is assumed in many cases.* The error is defined as the maximum difference from the linear behavior.

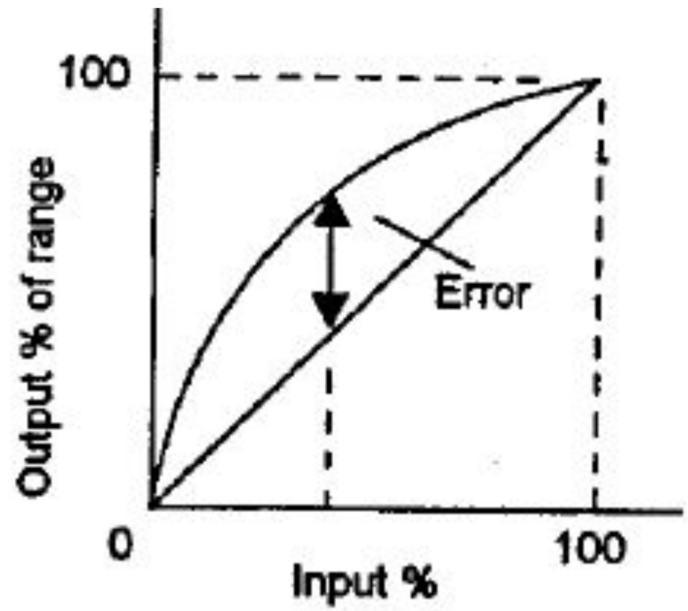
Various methods are used for the numerical expression of the non-linearity error . The error is generally quoted as a percentage of the full range output.

Example, ±0.5 % of the full range.

Sensors performance terminology and specifications

6. <u>Non-linearity error</u>

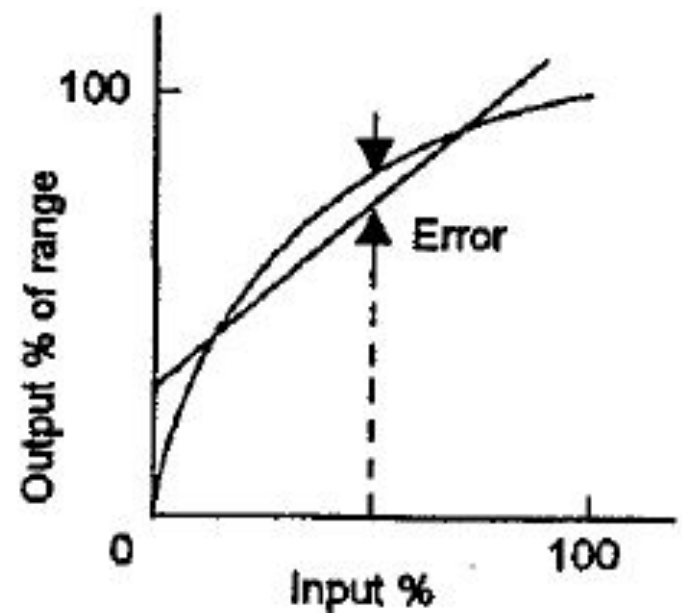
a. The error is defined as the difference between the curve and the straight line joining the output values *at the end points* of the range



Sensors performance terminology and specifications

6. <u>Non-linearity error</u>

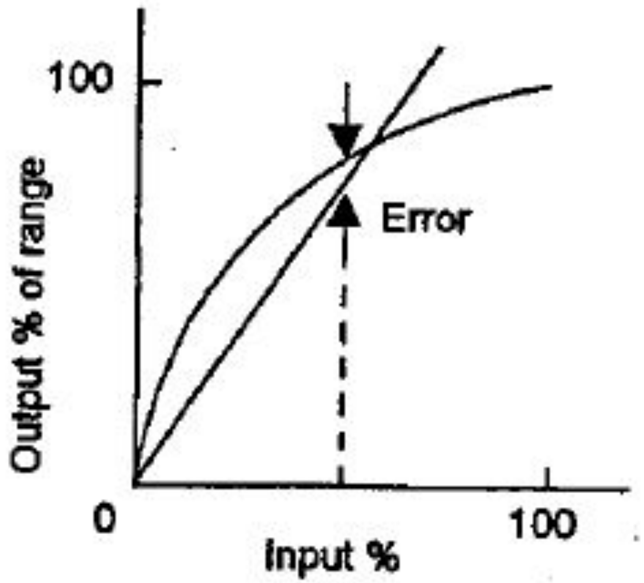
b. The error is defined as the difference between the curve and the straight line drawn by using the method of *least squares* that defines the *best fit line* when all data values are considered *equally likely to be in error.*



Sensors performance terminology and specifications

6. Non-linearity error

c. The error is defined as the difference between the curve and the straight line drawn by using the method of least squares that defines the best fit line which passes through the zero point.



Sensors performance terminology and specifications

7. Repeatability/reproducibility of a transducer are used to describe its ability to give the same output for *repeated application* of the same input value. It is usually expressed as a percentage of the full output.

$$\text{Repeatability} = \frac{max. - min.\ values\ obtained}{full\ range} \times 100\%$$

Sensors performance terminology and specifications

8. Stability of a transducer is its ability to give the same output when used to *measure a constant input over a period of time*.

The term *drift* is often used to describe the change in output that *occurs over time.* Can be expressed as a percentage of the full range output.

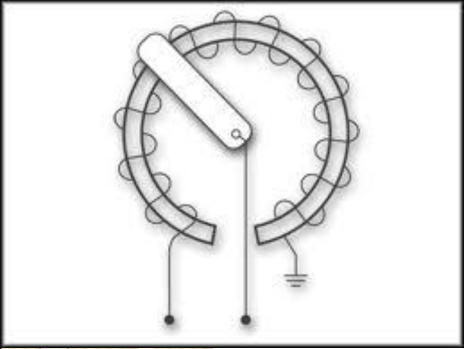
The term *zero drift* is used for the change that occur in the output when there is zero input.

Sensors performance terminology and specifications

9. Dead band/time of a transducer is the range of input values for which there is no output.

Example, bearing friction in a *flow meter* using a rotor might mean that there is no output until the input has reached a particular velocity threshold .

The *dead time* is the length of time from the application of an input until the output begins to respond and change.



Sensors performance terminology and specifications

10. *<u>Resolution</u>*.

When the input varies *continuously* over the range, the output signals for some sensors may change *in small steps*.

The *resolution* is *the smallest change* in the input value that will produce an observable change in the output

Example, in *wire-wound potentiometer* the output going up in steps as the potentiometer slides mover from one wire turn to the next. The resolution of it can be specified, say, 0.5° or percentage of the full-scale deflection.

For a sensor giving a *digital output* the smallest change in output is 1 bit. The higher number of bits the better is the resolution, i.e. it is smaller. The sensor with data word of *N* bits digital or a total of 2^N decimal, the resolution is 1/ 2^N

Sensors performance terminology and specifications

11. <u>Output impedance</u>

When a sensor giving an electrical output is interfaced with an electronic circuits it is necessary to know the output impedance since this impedance is being connected in either series or parallel with that circuit.

The inclusion of the sensor can *significantly modify the behavior of the system* to which it is connected.

Sensors performance terminology and specifications

Example of the specification of a *stain gauge pressure sensor*

Ranges: 70 to 1000 kPa, 2000 to 70 000 kPa
Supply voltage: 10 V d.c. or a.c. r.m.s.
Full range output: 40 mV
Non-linearity and hysteresis: ±0.5% full range output
Temperature range: –54°C to +120°C when operating
Thermal zero shift: 0.030% full range output/°C

Static and Dynamic Characteristics of Sensors

- The *static characteristics* are the values given when steady-state conditions occur, i.e. the values given when the transducer *has settled* after having received some input

- The *dynamic characteristics* refer to the behavior (or system response) between the *time that the input value changes* and the time when the output settles down to the steady-state value

Example, the input might be a *step input* when the input is suddenly changed from 0 to a constant value, or a *ramp input* when the input is changed at a steady rate, or a *sinusoidal input* of a specified frequency

Static and Dynamic Characteristics of Sensors

- *Response time* is the time which elapses after a constant step input is applied to the transducer up to the point at which the transducer gives an output corresponding to some percentage, e.g. 95% of the input
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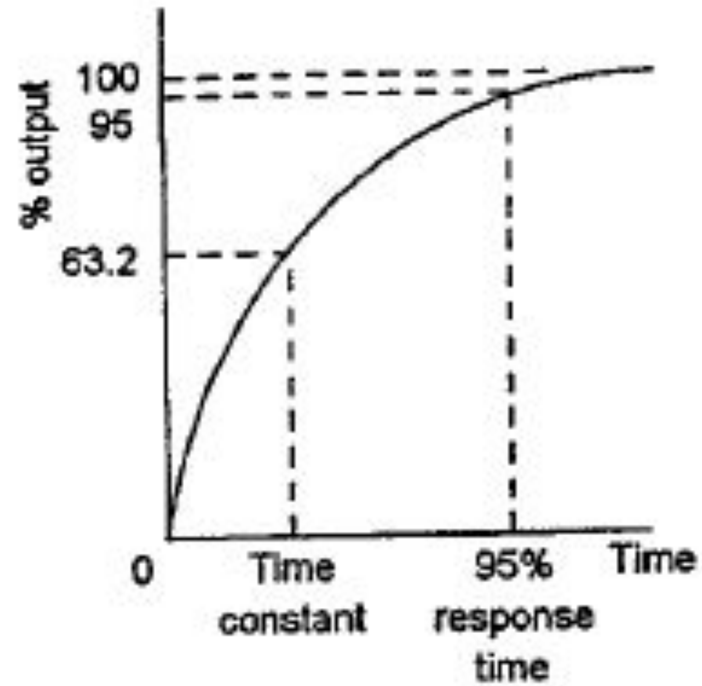
Example, mercury-in-glass thermometer is put into a hot liquid there can be as much as 100 s elapsed before the thermometer indicates 95% of the actual temperature of the liquid.



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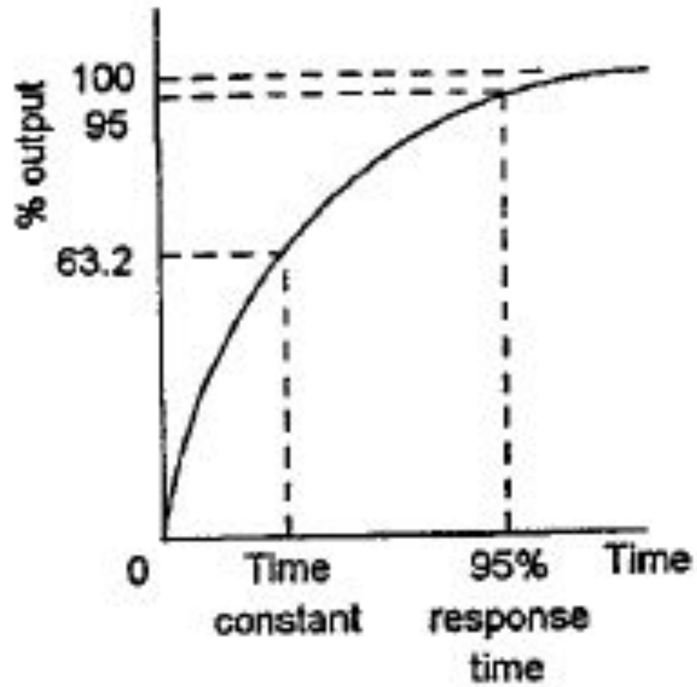
Static and Dynamic Characteristics of Sensors

•*Time constant* is the 63.2% response time. It is a measure of the inertia of sensor and so how fast it will react to changes in its input. The bugger the time constant the slower will be its reaction to a changing input

• *Rise time* is the time taken for the output to rise to some specified percentage of the steady-state output, for example from 10% to 90% of the steady-state



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Static and Dynamic Characteristics of Sensors

• *Settling time* is the time taken for the output to settle to within some percentage, e.g. 2% of the steady-state value

Example. Consider the following data which indicates how an instrument reading changed with time, being obtained from a thermometer plunged into a liquid at time *t*=0 s. The 95% response time is required

Time (s)	0	30	60	90	120	150	180
Temp. (°C)	20	28	34	39	43	46	49

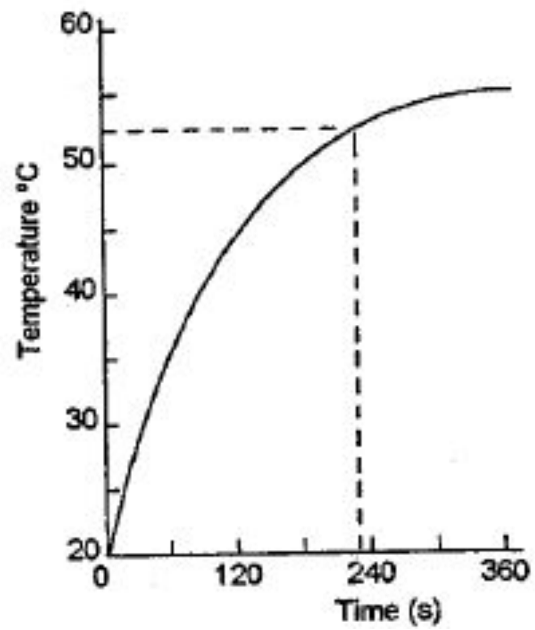
Time (s)	210	240	270	300	330	360
Temp. (°C)	51	53	54	55	55	55

Static and Dynamic Characteristics of Sensors

Time (s)	0	30	60	90	120	150	180
Temp. (°C)	20	28	34	39	43	46	49

Time (s)	210	240	270	300	330	360
Temp. (°C)	51	53	54	55	55	55

Example. Fig. shows the graph of how the temperature indicated by the thermometer varies with time. The steady-state value is 55°C and so, since 95% of 55 is 52.25, the 95% repose time is about 228 s.



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