Accuracy and Errors:

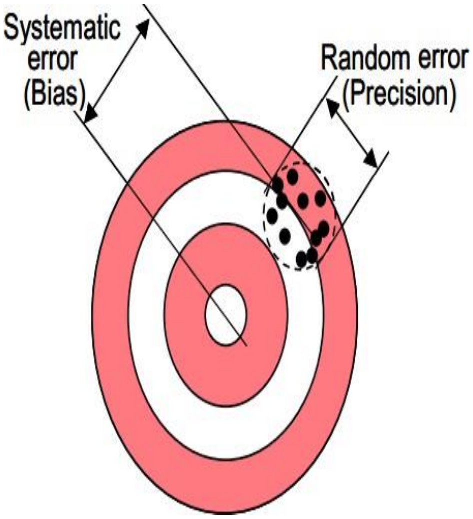
Systematic errors: Result from a variety of factors

- ✓ Interfering or modifying variables (i.e., temperature)
- ✓ Drift (i.e., changes in chemical structure or mechanical stresses)
- ✓ The measurement process changes the measurand (i.e., loading errors)
- ✓ The transmission process changes the signal (i.e., attenuation)
- ✓ Human observers (i.e., parallax errors)

Systematic errors can be corrected with compensation methods (i.e., feedback, filtering)

Random errors (NOISE):

A signal that carries no information.



- ➢ Sources of randomness:
- ✓ Repeatability of the measurand itself (i.e., height of a rough surface)
- ✓ Environmental noise (i.e., background noise picked by a microphone)
- ✓ Transmission noise (i.e., 60Hz hum)
- ➢ Signal to noise ratio (SNR) should be >>1

Other Static Characteristics:

Input range: The maximum and minimum value of the physical variable that can be measured (i.e., -40F/100F in a thermometer)

Output range: can be defined similarly

Sensitivity: The slope of the calibration curve. An ideal sensor will have a large and constant sensitivity.

- A nonlinear transfer function exhibits different sensitivities at different points, in this case the sensitivity is defined as a first derivative of the transfer function:

$$\text{sensitivity} = b_i(s_i) = \frac{dS(s_i)}{ds} \approx \frac{\Delta S_i}{\Delta s_i}$$

Linearity: The closeness of the calibration curve to a specified straight line (i.e., theoretical behavior, least-squares fit)

Hysteresis: The difference between two output values that correspond to the same input depending on the trajectory followed by the sensor (i.e., magnetization in ferromagnetic materials)

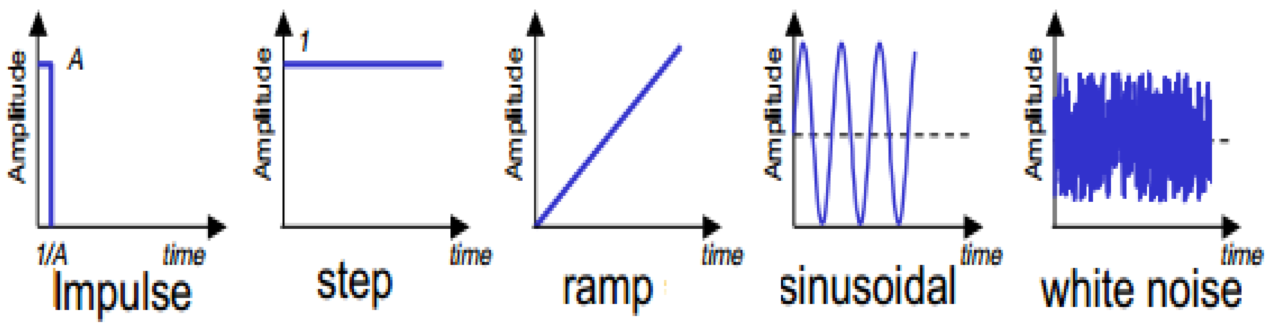
Backslash: hysteresis caused by looseness in a mechanical joint

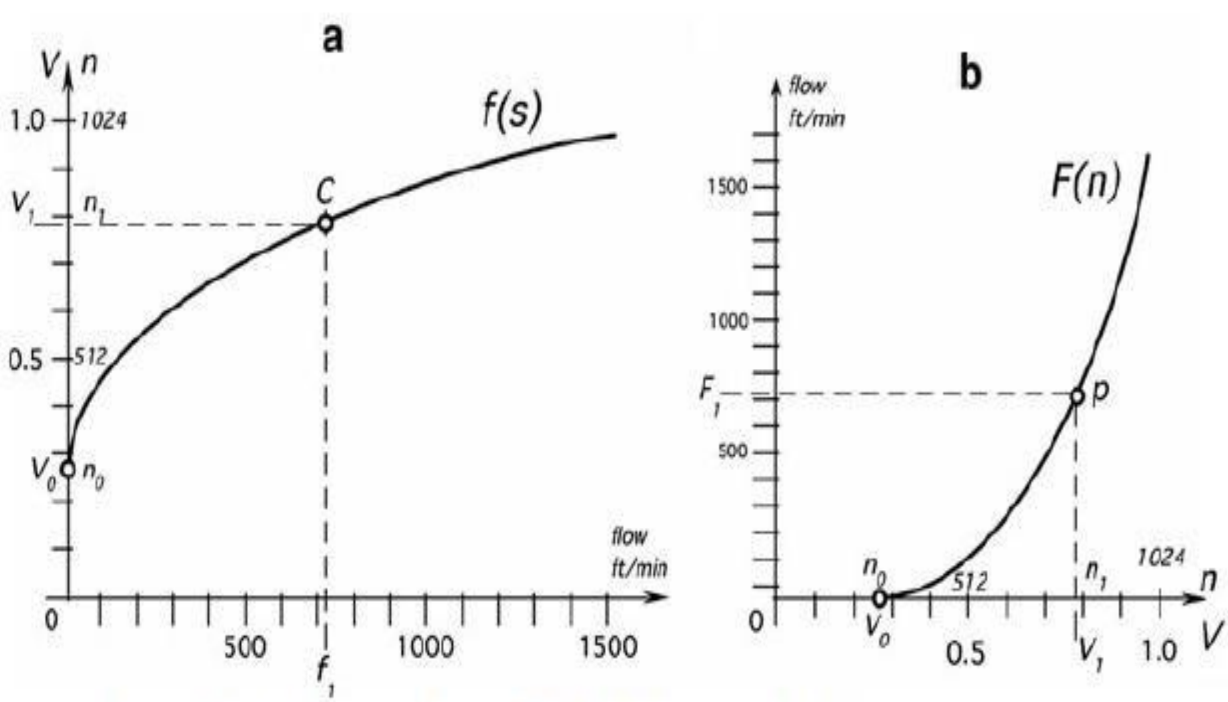
Dynamic Characteristics:

- The sensor response to a variable input is different from that exhibited when the input signals are constant (the latter is described by the static characteristics)
- The reason for dynamic characteristics is the presence of energy-storing elements:

- Inertial: masses, inductances
- Capacitances: electrical, thermal

➢ Dynamic characteristics are determined by analyzing the response of the sensor to a family of variable input waveforms:





Transfer function (a) and inverse transfer function (b) of a thermo-anemometer

1. Sensor Transfer Function:

- The transfer function represents the relation between stimulus (s) and response electrical signal (S) produced by the sensor. This relation can be written as S= f(s).
- Normally, stimulus (s) is unknown while the output signal S is measured. An inverse $f^{-1}(S)$ of the transfer function is required to compute the stimulus from the sensor's measured response (S).

Mathematical Model:

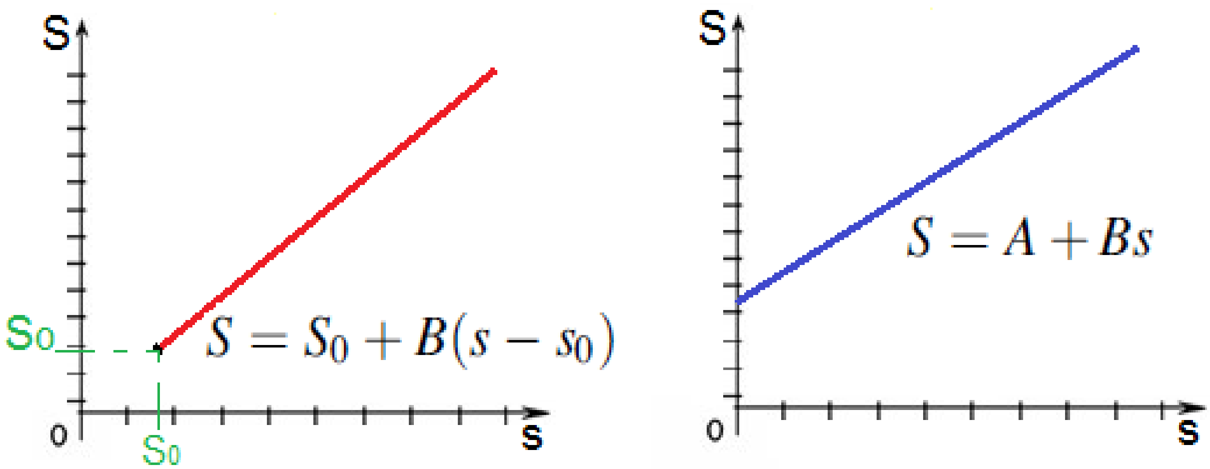
Example: A linear resistive potentiometer is used for sensing displacement (d). Ohm's law can be applied to compute the transfer function of the sensor. The response (S) is the measured voltage (v) and the inverse transfer function F(S) can be given as;

$$\text{Displacement (d)} = \frac{v}{E} D$$

where; E is the reference voltage and D is the maximum displacement (full scale); both are constants.

From this function we can compute displacement (d) from the measured voltage (v).

Functional Approximations:



➢ The simplest transfer function is linear, and is given by:

$$S = A + Bs$$

It represents a straight line with intercept A, and slope B, which is called **sensitivity**, since the larger B the greater the influence of the stimulus).

➢ In many cases, it is required to reference the sensor not to **zero** but to some more practical input reference value (s_0). If the sensor response (S_0) is known for that input reference, the above equation can be rewritten as;

$$S = S_0 + B(s - s_0)$$

➢ The above represent linear approximation of a nonlinear sensor's response.