Introduction

In automation industry every mechatronic system has some sensors to measure the status of the process variables.

The analogy between the human controlled system and a computer controlled system is describe as follows:-

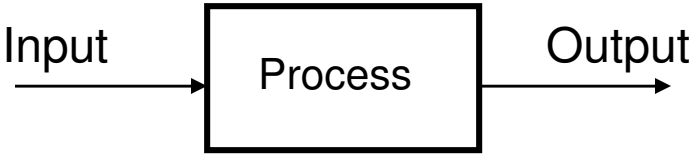
-The operator observes the behavior of the system, makes a decision and then, using his muscular power to take a particular control action is taken.

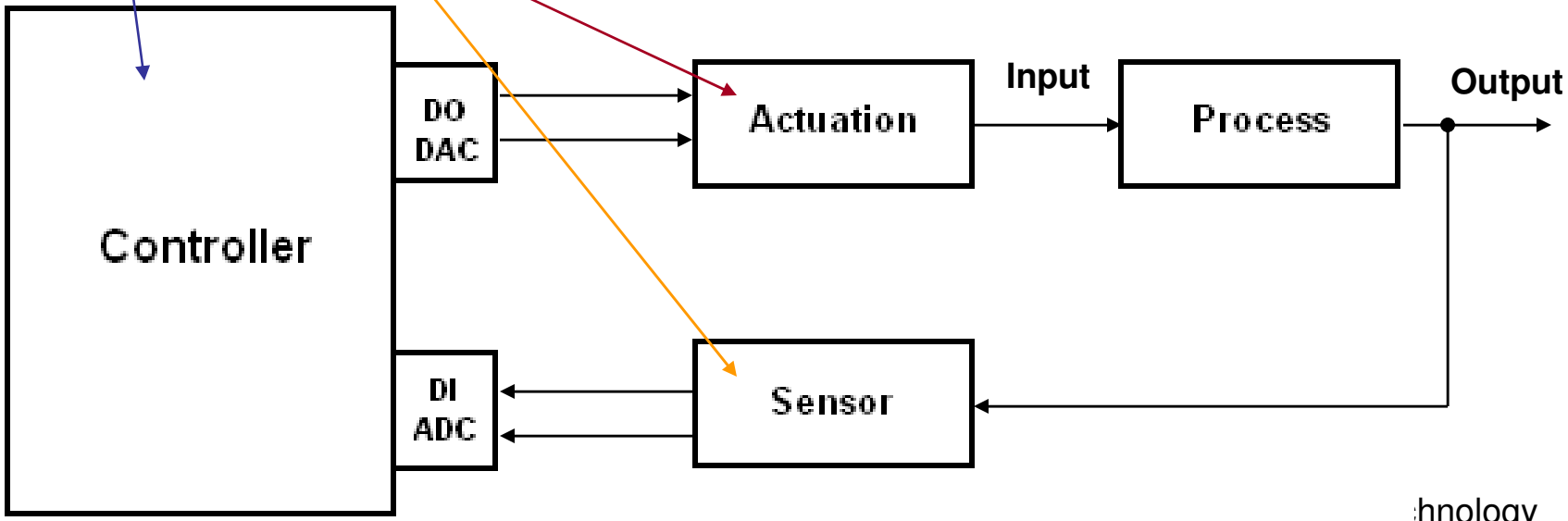
-The sensors replaces the eyes for observation, actuators replace the muscle, and the computer replaces the human brain.

Brain for decision making

Eye for sensing

Muscles for actuation





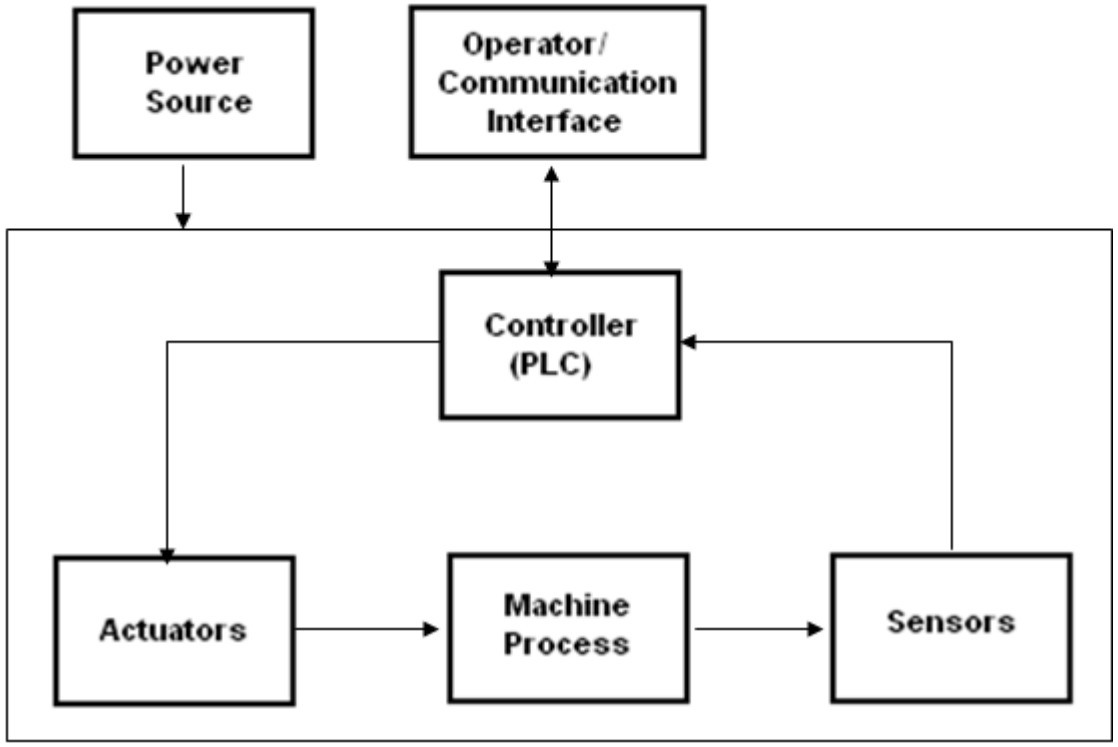
Every computer controlled system has these four basic functional blocks:-

1- Process to be controlled.

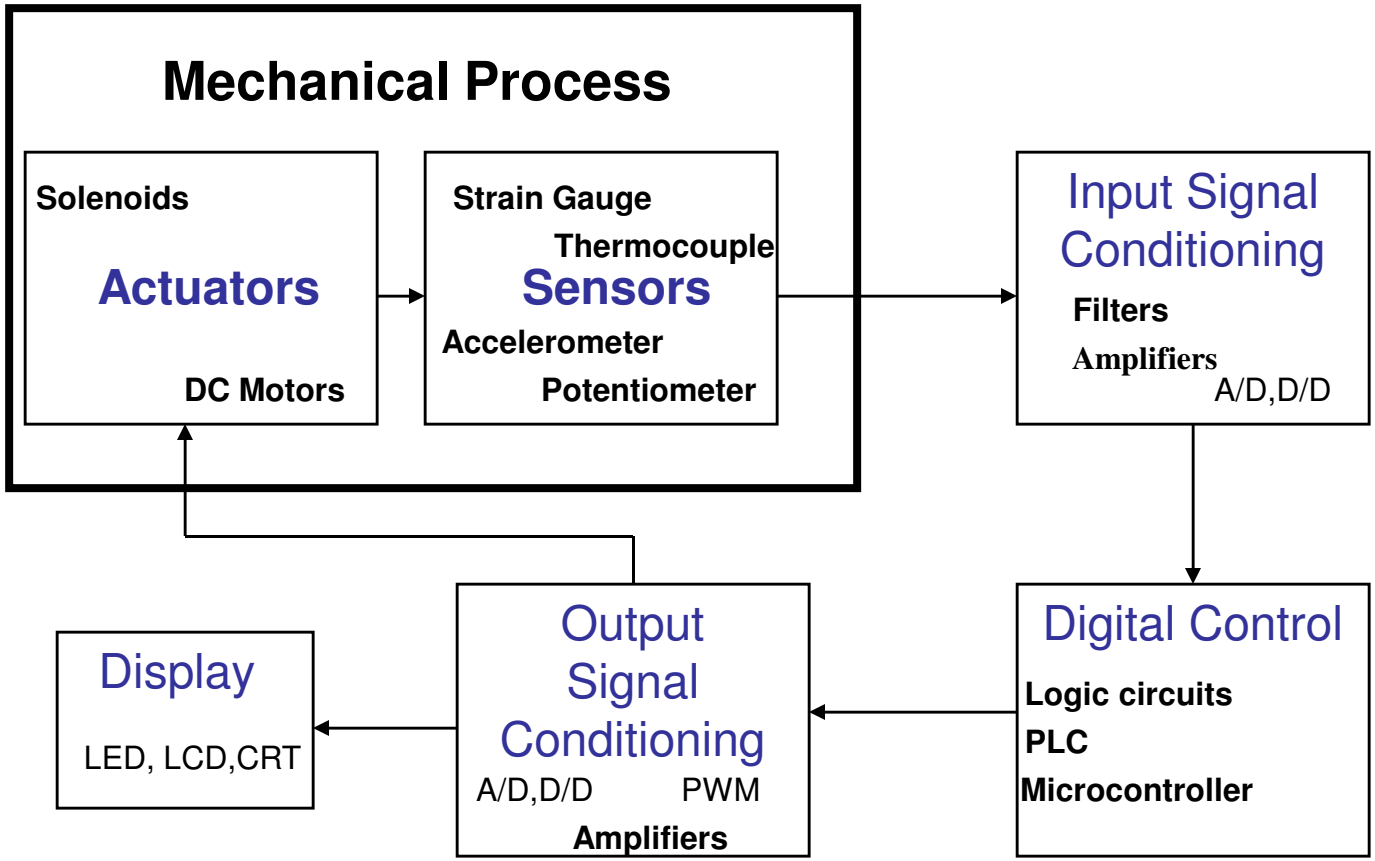
2- Actuators.

3- Sensors.

4- Controller.



The main components of any automated system; mechanical structure, sensors, actuators decision making, power sources and human interface.



Sensors

Sensors are used to

-Inspect work

-Evaluate the conditions of work under progress.

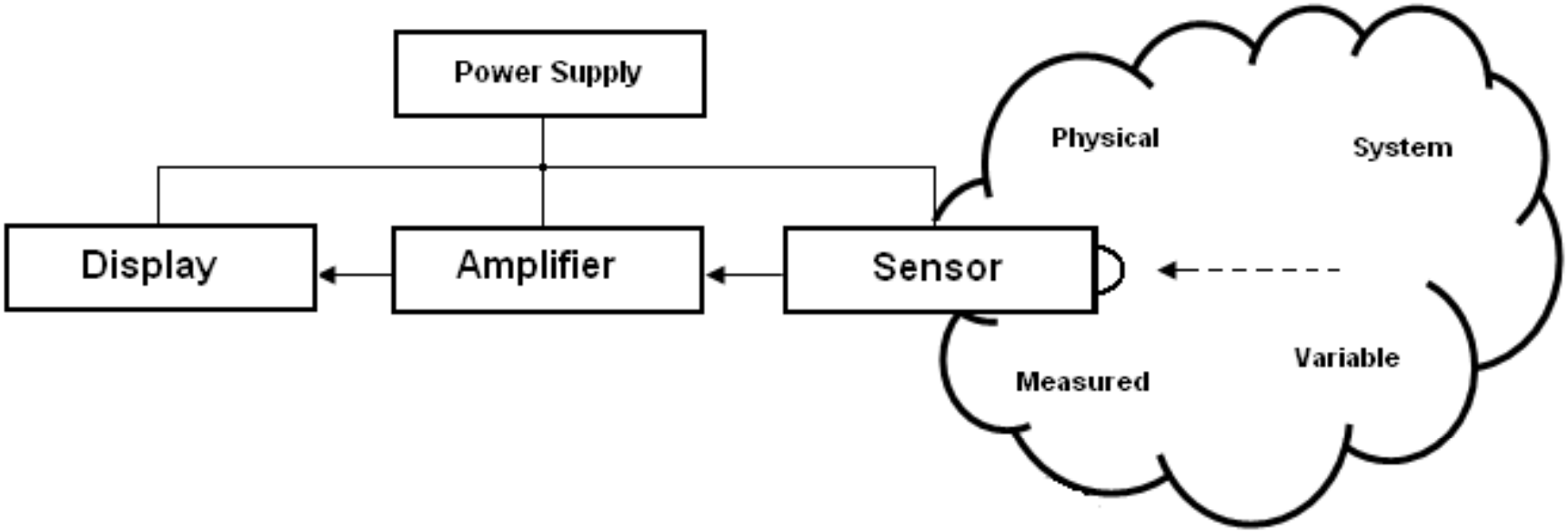
-Facilitate the higher level monitoring of the manufacturing operation.

-Are used to translate a physical phenomenon into an acceptable signal that can be analyzed for decision making

> Sensor is a device that produces an output signal for the purpose of sensing of a physical phenomenon.

Sensors are also referred as a transducer

The basic concept of a measurement device



-The measurement device is called the sensor.

-The sensor is placed in the environment where a variable is to be measured.

-The sensor is exposed to the effect of the measured variable.

The operation of sensor is effected by the following phenomenon's

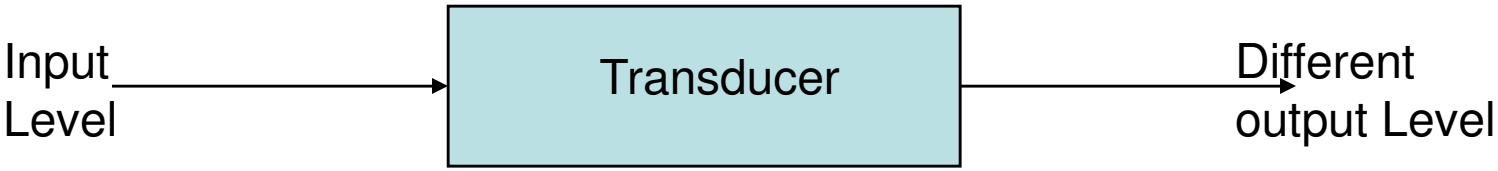
-The change of the absolute value in the measured physical variable (pressure, temperature, displacement….etc. is translated into a change in the property (capacitance, resistance magnetic) coupling of the sensor. This is called transduction.

-The change in the property of the sensor is translated into a low power level electrical signal in the form of voltage or current.

-This low power signal is amplified, conditioned and transmitted to an intelligent device for processing

Transducer

A transducer is a device that converts a signal from one physical form to a corresponding signal that has a different physical form



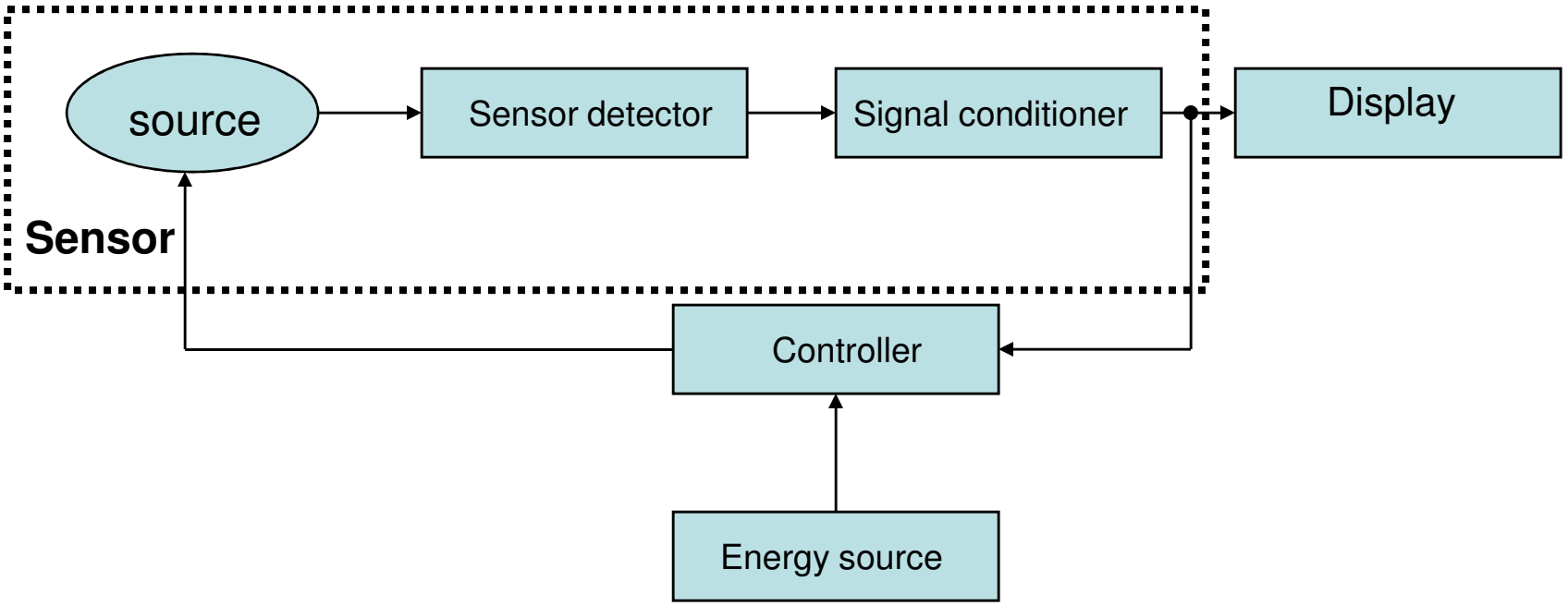
- Electrical - Mechanical

-Thermal - Optical

Complex control systems have introduced a need of faster, sensitive and precise measuring devices. Due top these demands sensors are being implemented in a solid state

Two important components in modern control systems are sensors and transducers. They are known as primary elements, convert varying information into another form.

The maximum accuracy is controlled by the sensitivity of the sensor and the internally generated noise of the sensor itself.

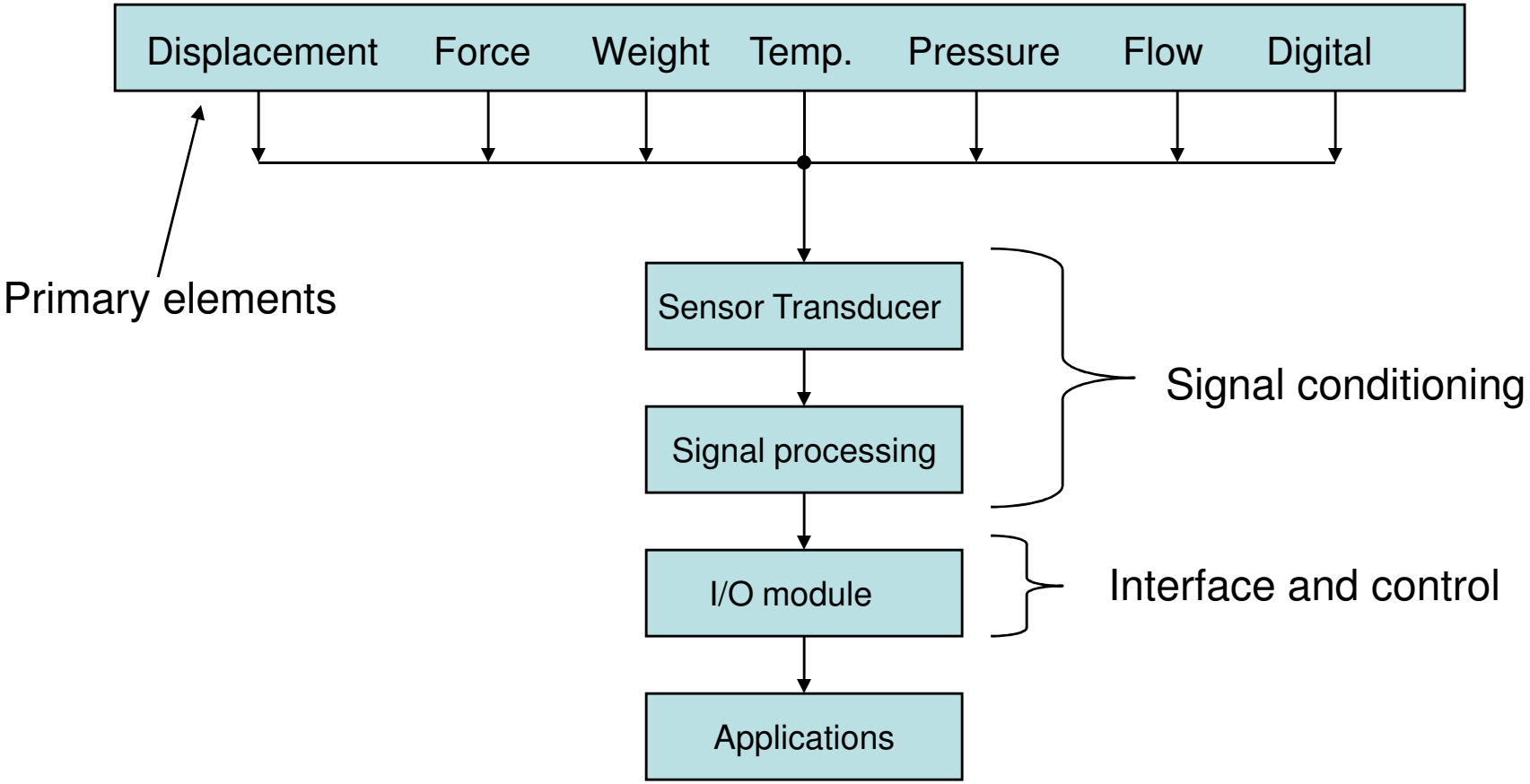


Sensor detector :- to sense the information of interest and convert this information into an acceptable form of signal conditioner.

Signal conditioner:- to accept the signal from the detector and to modify it in a way acceptable to the display unit.

Display :- to present the information in a displayable fashion.

Output:- can be in the form of reading or a printer, or passed to the controller, or implemented and feedback to the source



Instrumentation used for general sensing applications

Primary Elements:- sense and convert information into a form suitable to be handed by the measurement system

Signal conditioning :- for processing and modifying the information.

I/Output :- for interface and control with the external process

Sensor Classification

Classification	**Sensor**
Signal characteristic →	Analog Digital
Power Supply →	Active Passive
Mode of operation →	Null Type Deflection Type
Subject of Measurement →	Acoustic Biological Chemical Electric Mechanical Optical Radiation Terminal ……..others

Analog Sensors:- to convey the meaning of a continuous, uninterrupted, unbroken series of events. Typically have an output that is proportional to the variable being measured.

The output changes in a continuous way and this information is obtained on the basis of amplitude. The output is supplied to the controller by analog or digital converter.

Digital Sensors:- digital refers to a sequence of discrete events. Each event is separate from the previous and the next event. The sensors are digital if their level outputs are of a digital nature. they are accurate and precision and don't require converters,

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Active Sensors:- most of the output is produced from a separate power source. The external signal is modified by the sensor to produce the output signal .

The active sensors require external power for their operation, which is called an excitation signal.

example, a thermistor is a temperature-sensitive resistor. It does not generate any electric signal, but by passing an electric current through it (excitation signal), its resistance can be measured by detecting variations in current and/or voltage across the thermistor.

Passive Sensors:- the output is produced from the input parameters. The passive sensor (self generating) produce an electrical signal in response to an external stimulus.
Example :- piezoelectric, thermocouple, photodiode and radioactive.

A passive sensor does not need any additional energy source and directly generates an electric signal in response to an external stimulus; that is, the input stimulus energy is converted by the sensor into the output signal.

Deflection Type :- are used in a physical setup where the output is proportional to the measured quantity that is displayed.

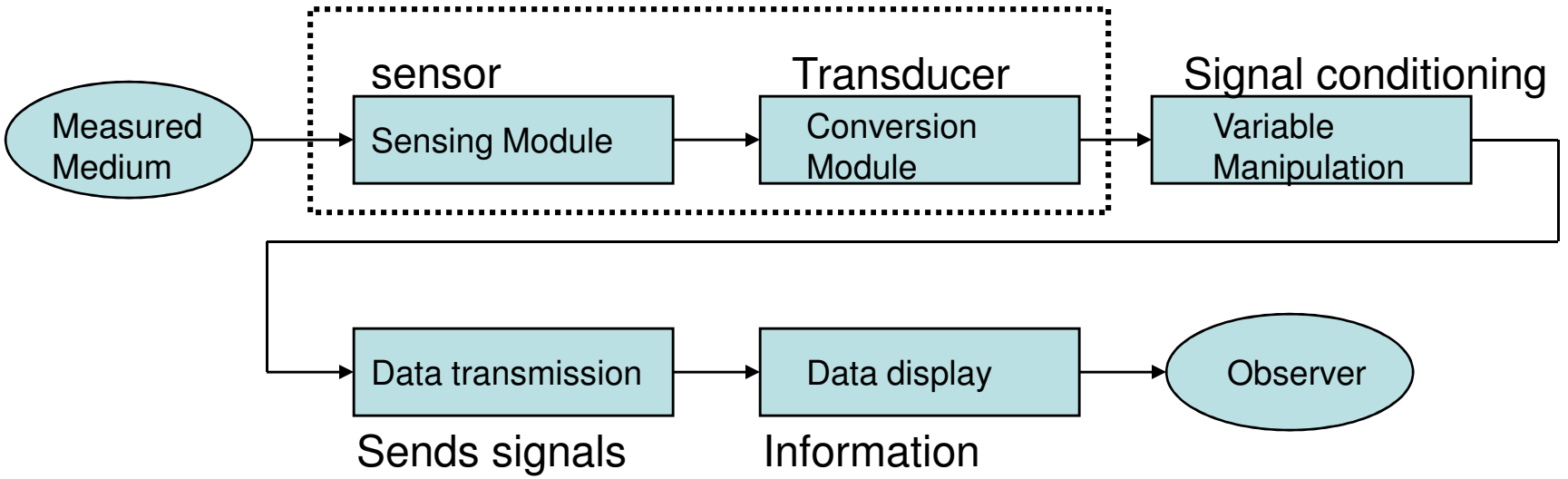
Example:- potentiometer

Null Type:- any deflection due to the measured quantity is balanced by the opposing calibrated force so that any imbalance is detected.

Example:- Wheatstone bridge

Subject of measurement:- such subject includes acoustic, biological, chemical, electric, magnetic, optical, mechanical, thermal……

Parameter Measurement in Sensors and Transducers



Sensing Module:- is the first element to receive a signal from the measured medium and produces an output depending on the measured quantity. The measured quantity gets distributed by the act of measurement, good instruments are normally designed to minimize the error of measurement

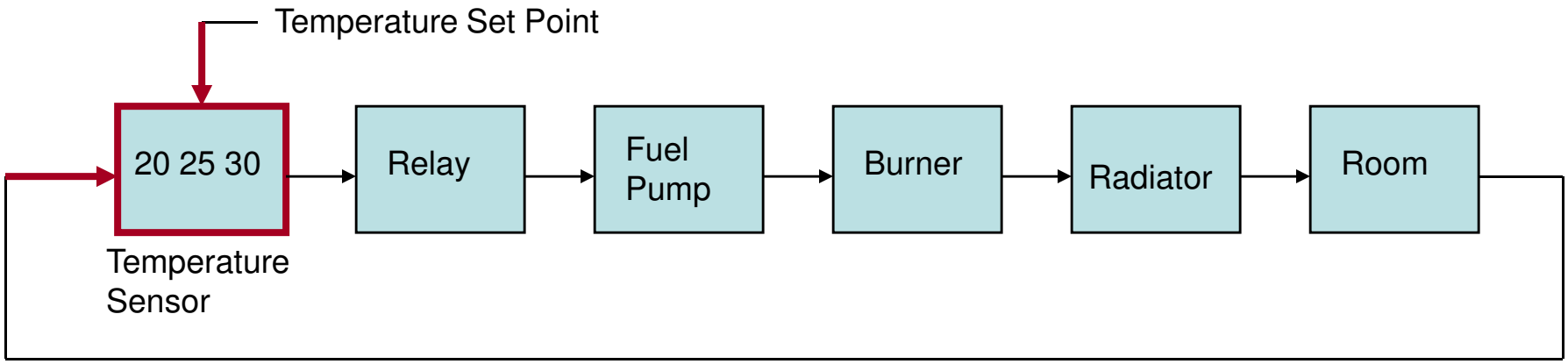
Conversion Module:- Transducer Module - converts one physical variable to another. In certain cases, the transduction of the input signal may take place in stages such as primary, secondary, and tertiary transduction.

Variable Manipulation Module:- usually involves signal conditioning; like amplifiers, linkage mechanisms, gear boxes, . An electronic amplifier accepts a small voltage signal as an input signal and generates a signal that is many times larger than the input signal.

Data Transmission Module: sends a signal from one point to another, the transmission element could be shaft device or could be complicated such as transmitting signals from ground to satellite.

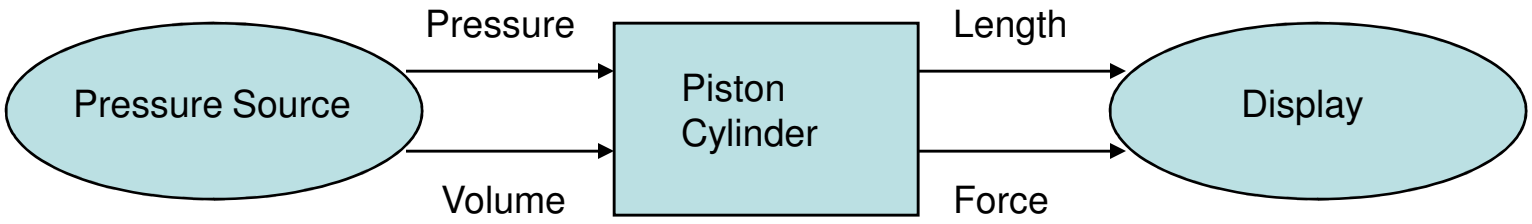
Data Display module:- produces information about the measured quantity in a form that can be recognized

Example 1 : Home Heating System



The block diagram represents the system components, the thermostat block process two input signals, a room temperature and a temperature set point to produce one output signal that is sent to a mechanical relay switch. The thermostat acts as a primary sensor and transducer.

Example 2 :- Pressure Sensor



A pressure sensor in the form of a spring loaded piston. The pressure acts on the piston and spring mechanism. The spring works as a primary sensor and variable conversion element.

The deflection of the spring is transferred to the display as a movement of the dial indicator

Quality Parameters of an Instrumentation System

Sensors and transducers are often used under environmental conditions, they are sensitive to environmental inputs such as pressure, motion, temperature, radiation and magnetic fields.

Sensors characteristic are described in terms of seven properties:-

Sensitivity

Resolution

Accuracy

Precision

Backlash

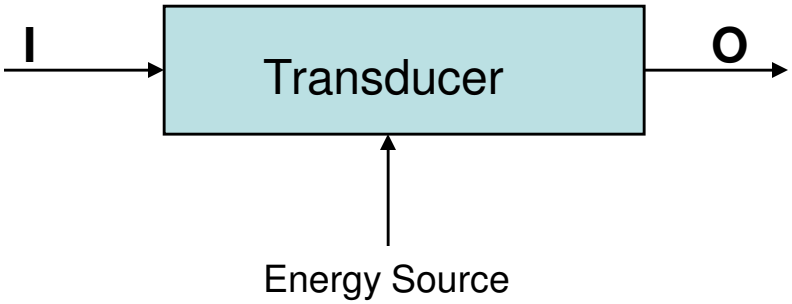
Repeatability

Linearity

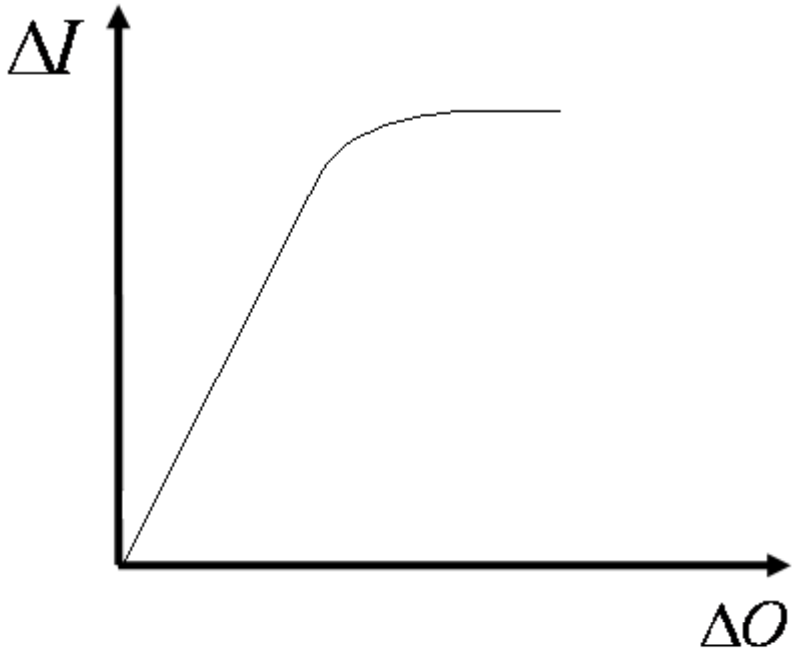
Sensitivity:-

It is the ability of the measuring instrument to responded to the changes of the measured quantity.

The ratio of change of output to change of input



$$S = \frac{\Delta O}{\Delta I}$$



Where

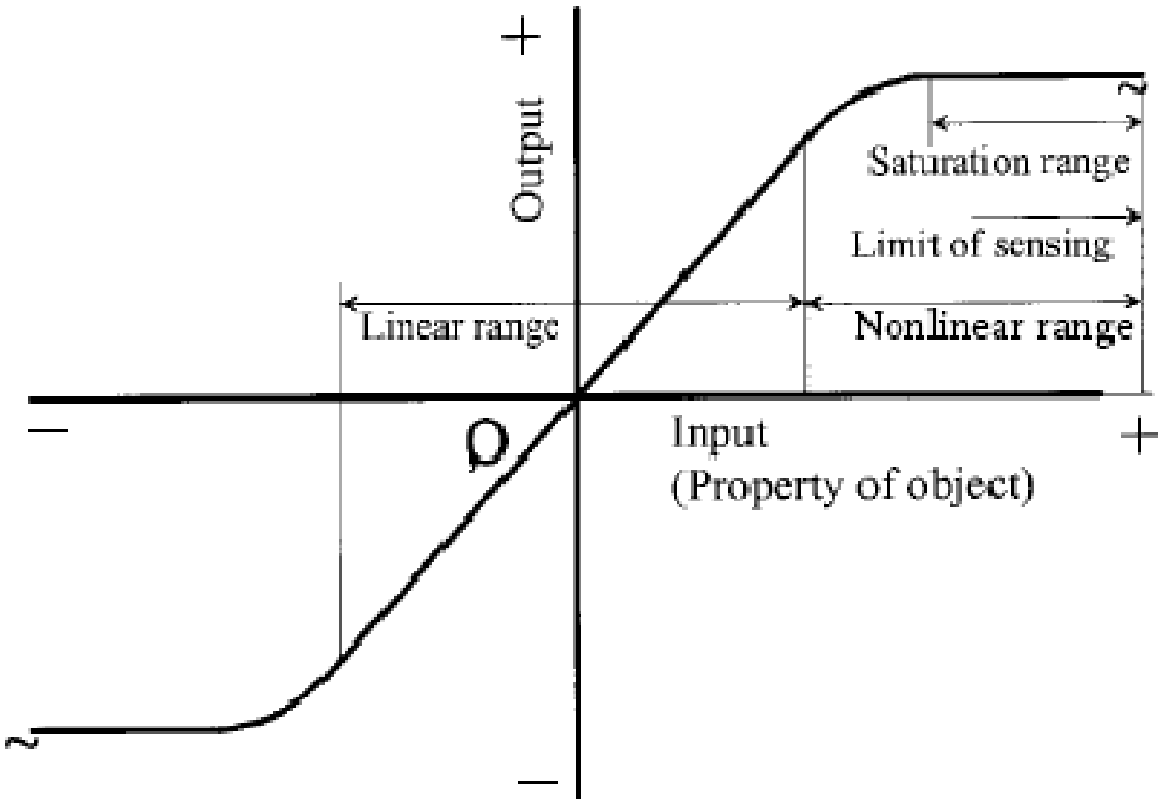
S is the sensitivity

ΔO is the change in output

ΔI is the change in input

Example , if a movement of 0.001mm causes an output voltage change of 0.02V, the sensitivity of the measuring instrument is

$$S = \frac{\Delta O}{\Delta I} = \frac{0.02}{0.001} = 20V / mm$$


+
Output
Saturation range
Limit of sensing
Linear range
Nonlinear range
O
Input
(Property of object)
+
−
−

Resolution:-

Is the smallest increment in the measured value that can be detected

The degree of fineness with which measurements can be made

Example , if a micrometer with a minimum graduation of 1mm is used to measure to the nearest 0.5 mm, then by interpolation the resolution is estimated as 0.5mm

Accuracy:-

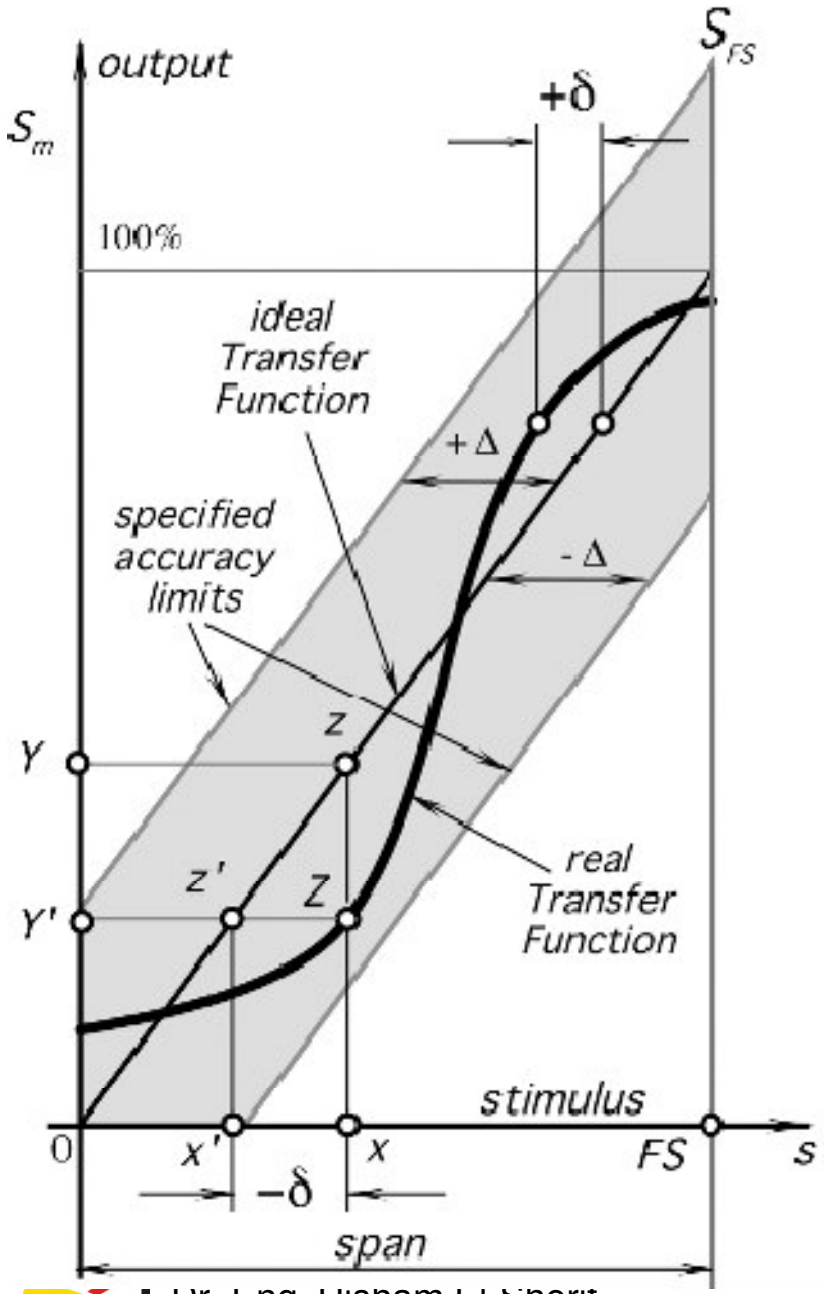
Is the measure of the difference between the measured value and the actual value.

An experiment is said to be accurate if is unaffected by experimental error

Accuracy is defined as the percentage of the true value

$$\text{percentage of true value} = \frac{\text{measured value} - \text{true value}}{\text{true value}}(100)$$

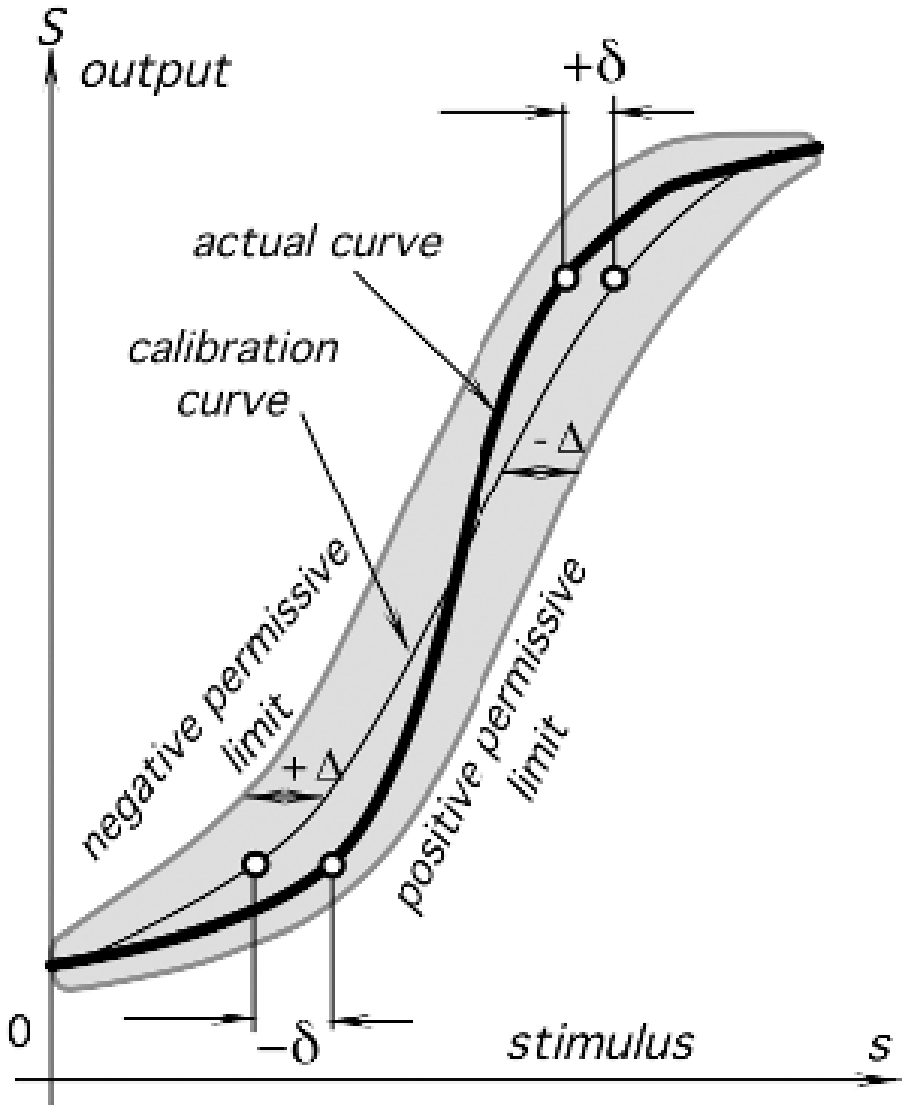
The difference between the measured value and the true value is called bias error



The Figure shows an ideal or theoretical transfer function. In the real world, any sensor performs with some kind of imperfection. A possible *real* transfer function is represented by a thick line, which generally may be neither linear nor monotonic. A real function rarely coincides with the ideal.

the real transfer functions must fall within the limits of a specified accuracy.
These permissive limits differ from the ideal transfer function line by $\pm\Delta$
The real functions deviate from the ideal by

$$\pm\delta, \text{ where } \delta \leq \Delta$$

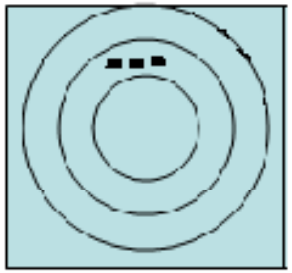


The Figure shows that ±Δ may be more closely follow the real transfer function, meaning better tolerances of the sensor's accuracy.
This can be accomplished by a multiple-point calibration. Thus, the specified accuracy limits are established not around the theoretical (ideal) transfer function, but around the calibration curve, which is determined during the actual calibration procedure.

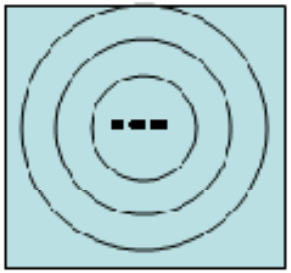
Precision:-

It is the ability of the instrument to reproduce a certain set of readings within a given accuracy. It is dependent on the reliability of the instrument

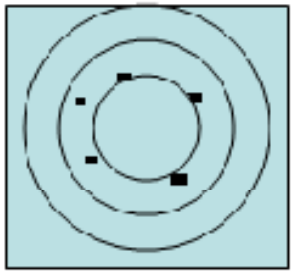
Example



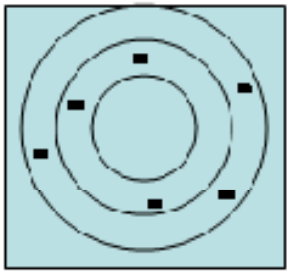
Poor Accuracy
High Precision



High Accuracy
High Precision



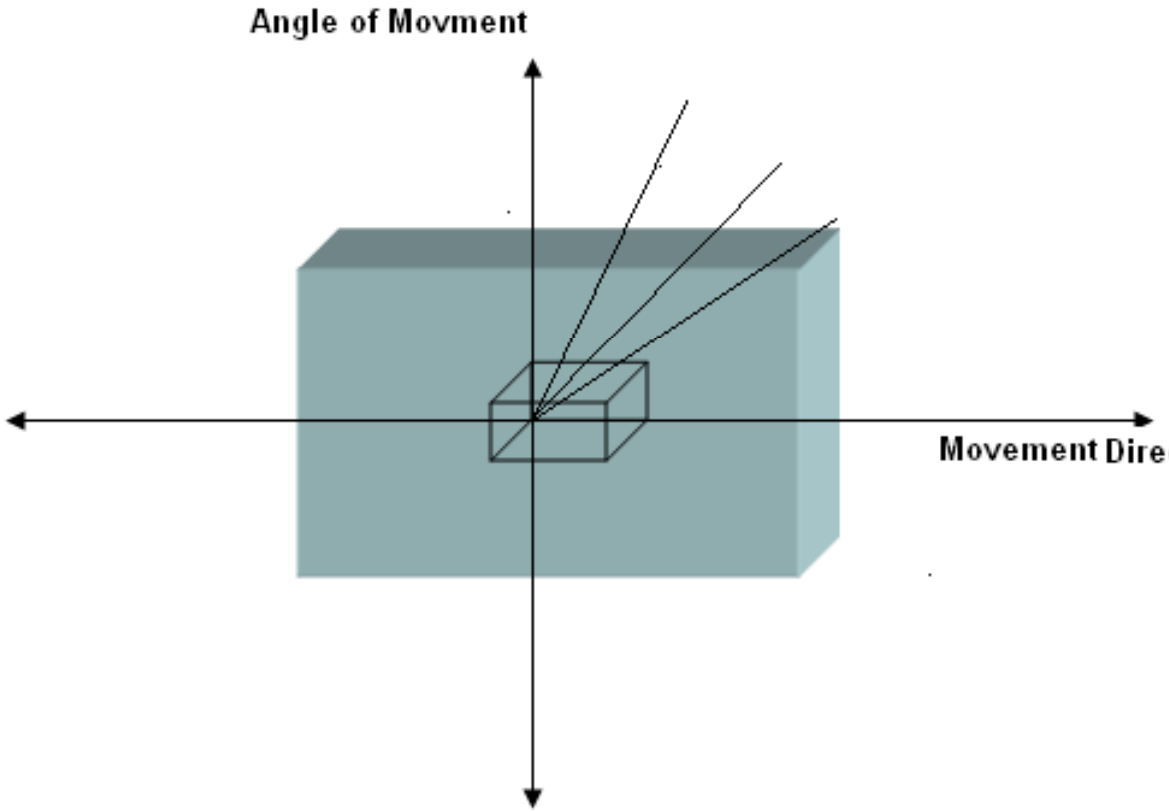
Good Average Accuracy
Poor Precision

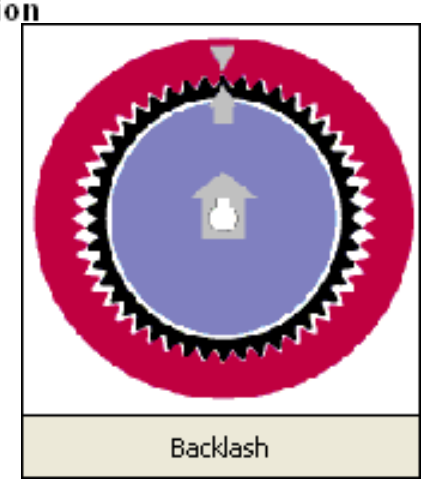


Poor Accuracy
Poor Precision

Backlash:-

Is defined as the maximum distance or angle through which any part of a mechanical system can be moved in one direction without causing any motion of the attached part.





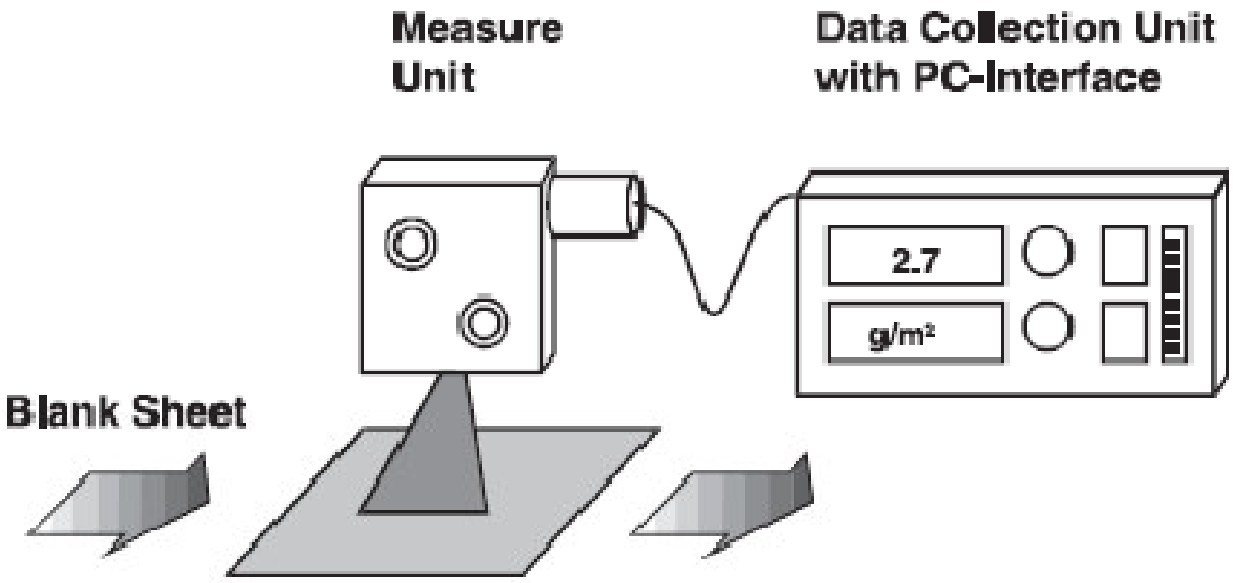
Repeatability

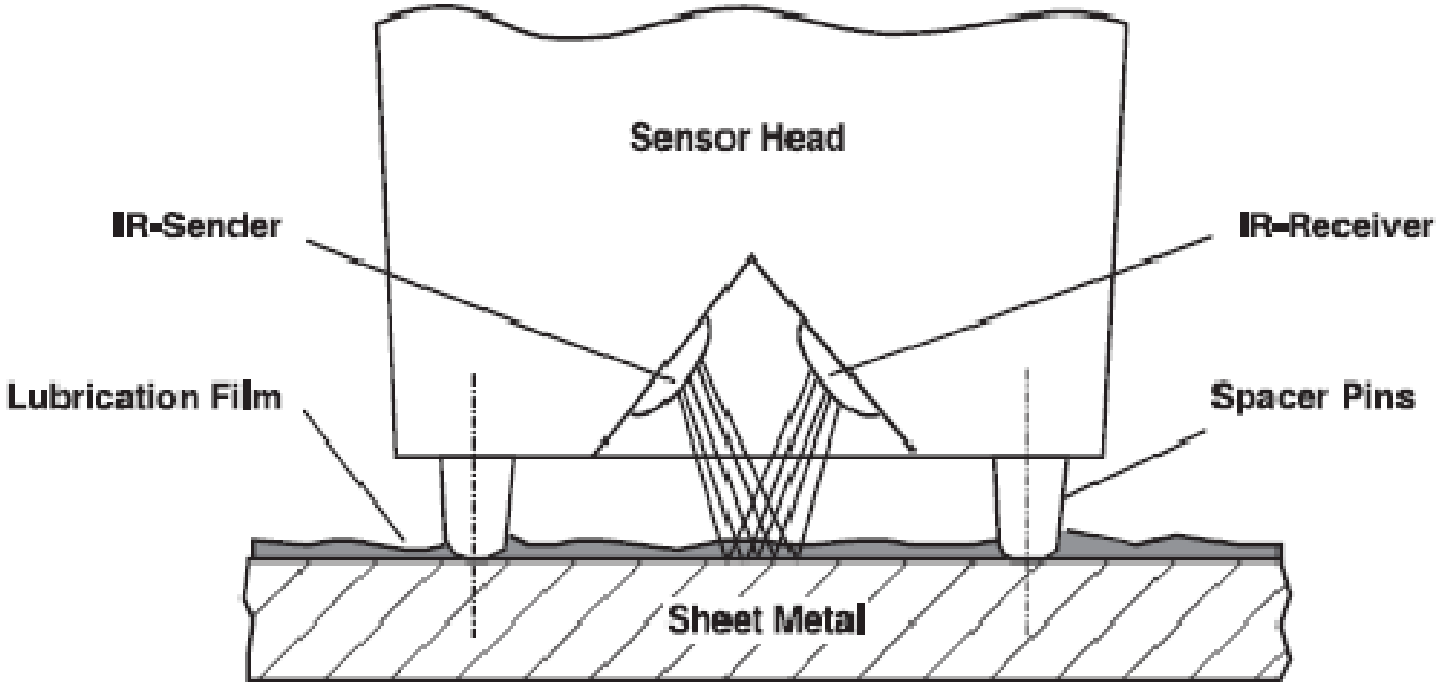
Is the ability to reproduce the output signal exactly when the same measured is applied repeatedly under the same environmental conditions

Example

The repeatability of the analyzer, which can be expressed by the standard deviation of readings in a single-point measurement, depends on the oil film thickness.

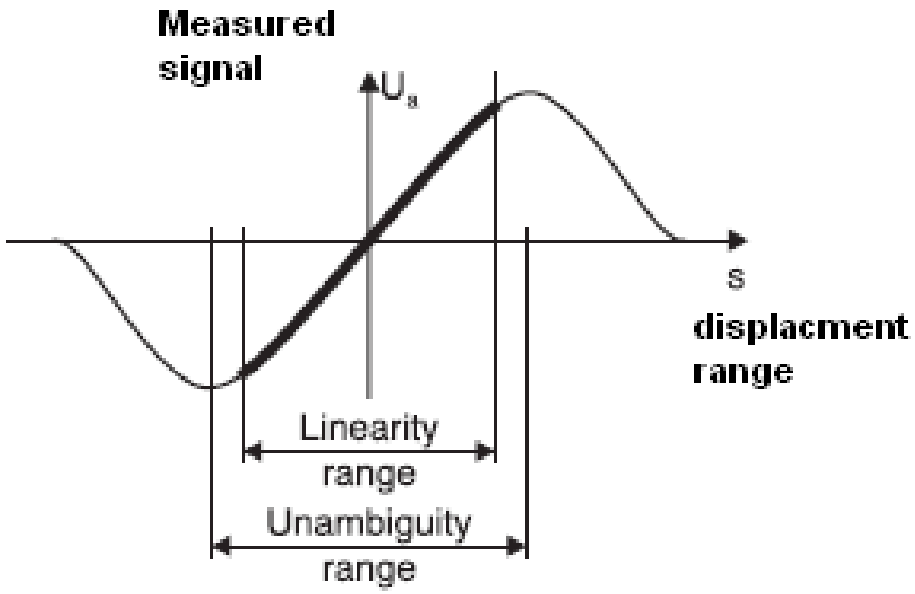
In the case of cleaned cold-rolled steel the standard deviation is of the order of 1 g/m2. The influence of surface textures increases the standard deviation when measurements are performed at separate points on the surface.


Measure
Unit
Data Collection Unit
with PC-Interface
2.7
g/m²
Blank Sheet


Sensor Head
IR-Sender
IR-Receiver
Lubrication Film
Spacer Pins
Sheet Metal

Linearity:-

The output is a linear function of the input. Linearity is never completely achieved, and the deviations from the ideal are termed linearity tolerances



Linearity of the measurement signal of an inductive displacement sensor

Linearity is expressed as the percentage of departure from the linear value . i.e. maximum deviation of the output curve from the best fit straight line during a calibration cycle

The non linearity is normally caused by nonlinear elements such as mechanical hysteresis and electronic amplifiers

General diagram for sensor characteristic and quality parameters