SENSORS/TRANSDUCERS

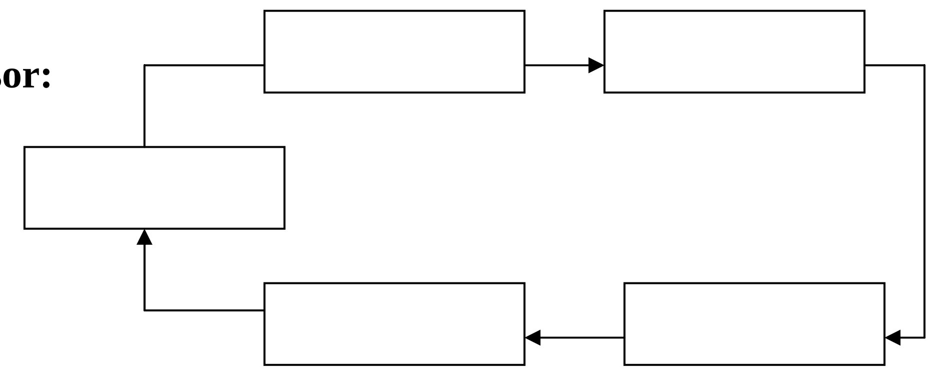
Sensors are critical components used in almost everywhere:

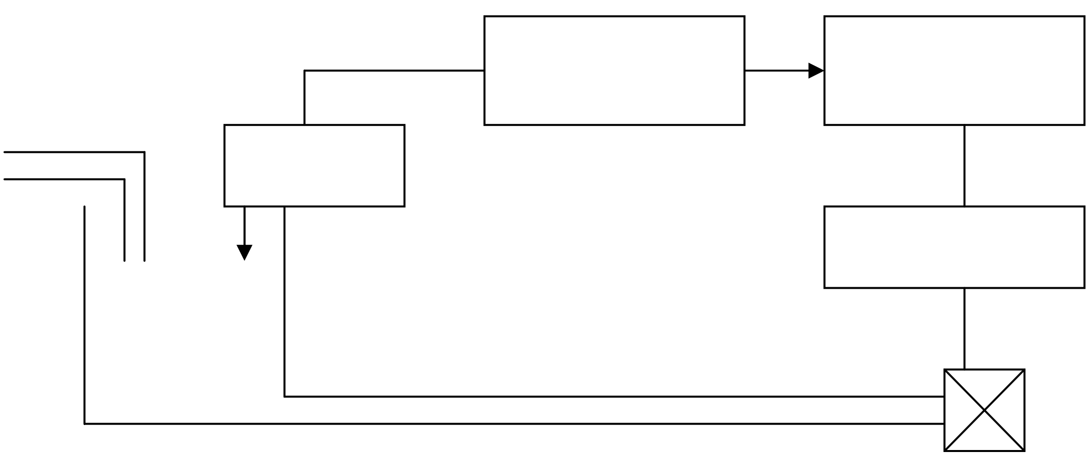
Definition:

Transducer: A device which provides a usable output is response to a specified measurand. It is a device that converts energy from one form to another.

Usable output refers to an optical, electrical or mechanical signal. The measurand can be a physical, chemical or biological property or condition to be measured.

Actuator & sensor:





Sensor to measure the level actuator to control the value

They produce an electrical output such as voltage or current to allow required signal conditioning and signal processing steps to be completed.

Transducers can be compared based on their operating principles, the measured range interface design and reliability.

Definition of terms:

Micro sensor: A sensor fabricated using IC.

Repeatability: The ability of a sensor to reproduce output readings for the same value of the measurand when applied consecutively and under the same conditions.

Sensitivity: The ratio of the change in sensor output to change in the value of the measurand.

Stability: The ability of sensor to retain its characteristics over a relatively long period of time.

Representative physical variables:

Variable	Unit
Current	Amper
Energy	J
Force	N
Flow	Value flow rate m^3/s
Frequency	Hz
Length	m
Mass	kg
Pressure	N/m^2
Power	watt
Resistance	Ω
Temp.	Kalven
Time	sec
Velocity	m/s
Voltage	V

Some common representation transducers:

Measurand — Transducer: Resistive, Capacitive, Inductive

* Displacement (length)

Operating principlment: Change in resistance capacitance or inductance caused by linear or angular displacment of transducer element.

*	Force	Strain gage	→	(Resistive)
*	Temp.	Thermister	→	Resistive
		Thermocouple	→	Resistive
*	Pressure	Diaphram (Diaphrum motion sensed by sensed by a displacement technique).		
*	Flow	Differential pressure Across restriction		
		Turbine Angular velocity proportional to flow rate		

Factors affecting choice of sensors:

* Environment factors:

Temp range, humidity effects, corrosion, size, over-range protection susceptibility to EM interference, ruggedness, power consumption, self-test capability.

* Economic factors:

(Cost, Availably, life time)

* Sensor characters:

Sensitivity, range, stably, repeatability, linearity error, response time frequency response).

Some of these factors: Can be compensated by signal conditioning such as linearity ets.

More factors:

* Construction
* Signal condity
* Time response
* Calibration (reference compensators)

(1) Sensor time response:

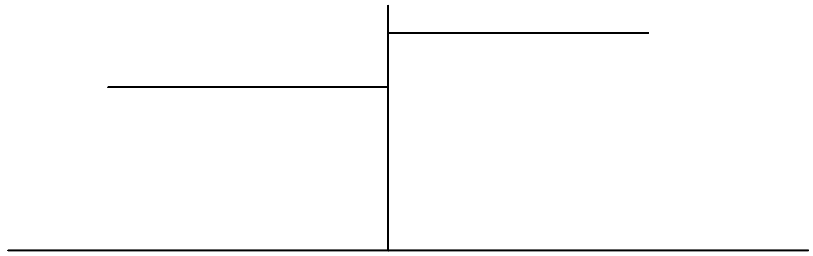
There are two most common types of sensor time response. First and second orders. These are static and dynamic effects that determine the output response of an input to the sensor.

First-order response:

The transfer functioning T.F. between input & output is given in the general form: $b(t) = bi + (bf - bi)\,[1 - e^{-t/}\tau]$

Where: b_i initial sensor output form static T.F. and initial input.
b_f & final sensor output from static T.F and the final input

τ = Sensor time constant.



Figure

Second order response:

Some sensors have the 2nd order T.F:

$$R(t)\,\alpha\, R_o e^{-at}\sin(2\pi f_n t)$$

Where

R(t) transducer output

a : output damping constant

f_n : natural frequency

R_o: amplitude

Type of sensors:

They are most often classified by the type of measurand i.e. physical, chemical or biological.

(1) Physical sensor:

Temp., displacement, optical radiation.

(2) Chemical sensors:

Ion-selection electrode (ISE), Gas chromatograph.

(3) Bio sensors:

Imusensor, Enzyme sensor

(4) Micro sensor

Thermal sensors (Temperature)

(1) Metal Resistance Temperature detectors (RTD):

Metal resistance increase with temp.

Ex: Nickel and platinum

Figure

$R(t) = R(T_o)\,[1 + \alpha_o\, \Delta T]$

- Sensitivity depends on α_o (slop)
    - Response time 0.5 → 5 sec.

Construction: A wire whose R is be measurand

Signal conditioning: A bridge is generally used to measure resistance since the change is very small.

(2) Thermistors:

Resistance of a semiconductor change with temp.

- Sensitivity: May be 10% per (good)
- Range : Depends on semiconductors (it may melt as T)
- Response time 0.5 → 10 sec.
- Signal conditioning A bridge may be used because of the non linear featehers of the thermistor.

(3) Thermocouples

A thermocouple device is a voltage-generator sensor in which an electromotive force (e.m.f) is produced that is propontial to temp.

[J] Iron-constantan - 190° → 760°C

[T] Copper-constantan - 200° → 371°C

[R] Constantan is an alloy 87% platinum + 13% rhodium-platium.

* Type and character is depend on material used.

Sensitivity	Type J	0.05 mV/°C
	Type R	0.006 mV/°C

Range greatest

Time responses depends on thickens of wire used, vary as low 10-20 as high as 10- 20 m.

Signal conditioning small values of volt the force need to be amplified.

The types of thermal sensors:

- Gas thermometers
- Solid state temp. sensors.

  The voltage vary linearly with temp. over a specified range (diode and transistors).

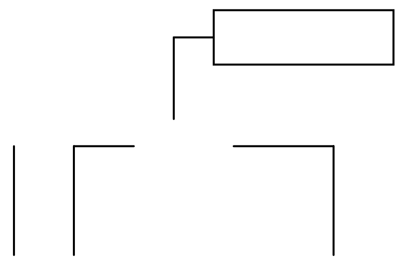
Ex: Zener diod -50 → 150°C.

- Easy to interface to control system and computers. Widely used in computer and consumer products.

Mechanical sensors:

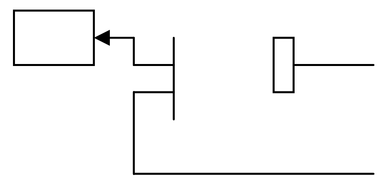
Position sensors: Displacement and location.

(1) Potention meters.



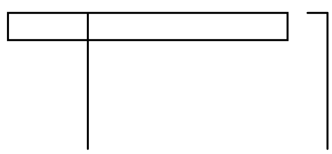
Figure

(2) Capacitive



Figure

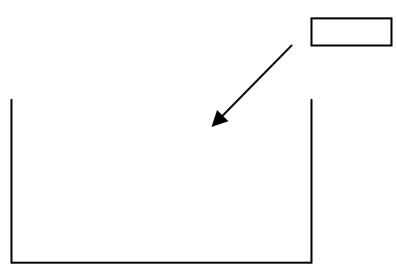
(3) Variable Relactance



Figure

(4) Level sensors:

1. Mechanical



Figure

2. Ultra sound

3. Pressure

(5) Strain sensors

The resistance change with force to metal (semiconductors silicon).

(6) Flow sensor

(1) Restrictive flow sensors:

Installing a restriction in the pipe and measuring the pressure drop.

Q(rate)=k $\sqrt{\Delta P}$

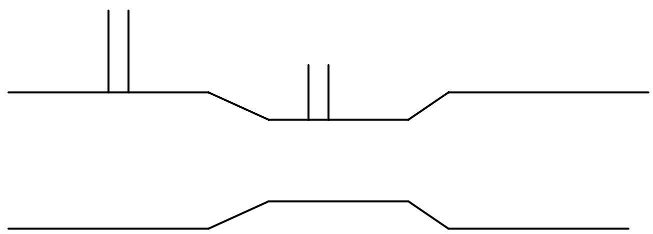


Figure 8

K: constant

ΔP: drop in pressure

Q: flow rate

(2) Obstructions flow sensors.

(3) Magnetic flow meter

Only with conducting fluids.

Optical sensors:

* Photo detectors:

ex: Photo voltic detectors.

Photo diode detectors.

Optical sources:

Ex: Incandescent source (wire heated)

Atomic sources heat & fluorcent

Laser

Applications:

- Label inspection
- Bar code readers.
- Distance
- Intruder deteors
- Weld joint tracking.
- Fill control
- Weld depth penetration

Infrared sensing:

Applications:

- Weld sensing
- Cooling rate measurement
- Discontinuity sensing
- Data transfer
- Intruder detection

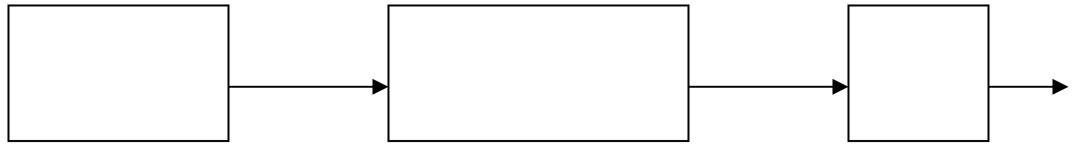
A acoustical sensing:

* Laser misfiring
* Loss of power
* Improper focus

Signal conditioning:

- Consists of amplification, filtering, limiting.
- May be performed using analog or digital or using combination of methods. Analog methods offer bandwidth advantage, whereas digital tech. offer algorithm support and long term stability.

Real -Time control.



Figure