

## Sensor and Transducers

### Measurement System:

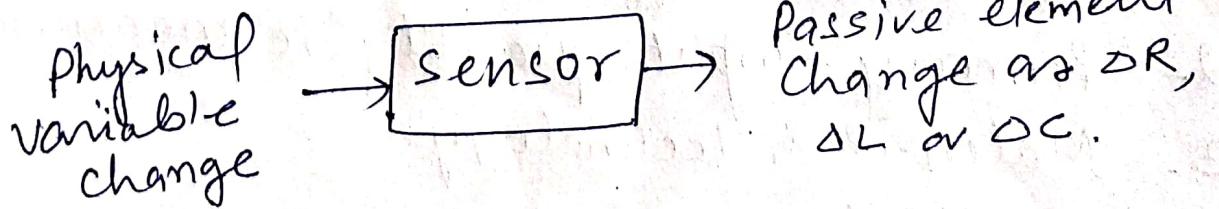
The main function is to collect the information on system status and to feed it to the microprocessor(s) for controlling the whole systems.

Measurement system comprises of sensors, transducers and signal processing devices. Sensors is basically employed to automatically carry out the information as well as process monitoring activity.

Sensor has following important advantage.

- Reduce the requirement of skilled and experienced labors.
- Ultra precision can be achieved.
- Reduce downtime, Alarm the failure of any subsystem,

### Sensor(s) / Detector(s)



"A device which provides a usable output in response to a specified measurand."

In measuring systems sensor or sensing element takes information about the

variable been measured and transform it into a suitable form to be measured. sensor is also called primary sensing element.

### § Transducers :

The sensor sense the condition, state or value of the process variable and produce an output which reflects this condition, state or value. The transducers transform the energy of the process variable to an output of some other type of energy which is able to operate some control device.

### § classification of sensor.

It is very difficult to classify sensor under one criterion and hence different criterion criteria may be adopted for the purpose.

- 1- Transduction principle using physical or chemical effect.
- 2- Primary input quantity (ie measurand)
- 3- Material & Technology
- 4- Application
- 5- Properties
- 6- cost & accuracy.

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classification of sensors on the basis of  
their applications :

A - Displacement, position & proximity sensors.

- potentiometer
- strain-gauged element
- capacitive element
- Differential transformers
- Eddy current proximity sensors
- Inductive proximity sensors. switch
- optical encoders
- Pneumatic sensors
- Proximity switches (magnetic)
- Hall effect sensors.

B - Velocity and motion:

- Incremental encoder.
- Tachogenerator
- Pyroelectric sensors.

C - Force:

strain gauge & load cell.

D - Fluid pressure:

- Diaphragm pressure gauge
- Capsules, bellows, pressure tubes
- Piezoelectric sensors
- Tactile sensor.

E - Liquid flow

- Orifice plate
- Turbine meter

## F-Liquid levels:-

- Floats
- Differential pressure

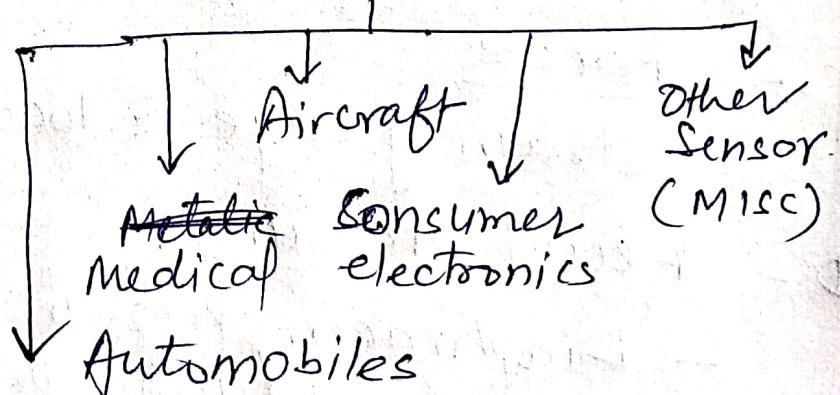
## G-Temperature:

- Bimetallic strip
- Resistance temperature detectors
- Thermistors
- Thermodiodes & transistors
- Thermocouples
- Light sensors
- Photo diodes
- Photo resistors.
- Photo transistors

## Application

Industrial  
Process control,  
Measurement  
and automation.

### Non industrial



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## SENSORS Classification Based on property:

	Flow	Level	Property	Pressure	Proximity and displacement
			Temperature		
Technology	Differential Pressure, positional displacement, vortex, thermal mass, electromagnetic, Coriolis, ultrasonic, anemometer open channel.	Mechanical, magnetic, differential pressure, thermal displacement, vibrating rod, magnetostriuctive, ultrasonic, radio frequency, capacitance type, microwave/radar, nuclear.	Filled-in systems, RTDs, thermistors, IC, thermocouples, inductively coupled, radiation (IR).	Elastic, liquid-based manometers, inductive/LVDT piezoelectric, electronic, fibre optic, MEMS, vacuum.	Potentiometric inductive/LVDT, capacitive, magnetic, photoelectric, magnetostrictive, ultrasonic.

	Acceleration	Image	Property	Biosensors	Other
			Gas and Chemical		
Technology	Accelerometers, gyroscopes.	CMOS, CCDs (charge coupled devices).	Chemical bead, electrochemical, thermal conductance, paramagnetic, ionization, infrared, semiconductor.	Electrochemical, light-addressable potentiometric (LAP), surface plasmon resonance (SPR), resonant mirror	Mass, force, load humidity, moisture, viscosity.

CMOS

## SENSORS Classification based on Technology:

Applications	Sensors			
	Image sensors	Motion detectors	Biosensors	Accelerometers
	Technology: CMOS-based	Technology: IR, ultrasonic, microwave/radar	Technology: electrochemical	Technology: MEMS-based
Traffic and security surveillance, blind-spot detection as autosensors (robots etc.), video conferencing, consumer electronics, biometrics, PC imaging	Obstruction detection (robots, auto), security detection (intrusion), toilet activation, kiosks videograms and simulations, light activation	Water testing, food testing (contamination detection), medical care device, biological warfare agent detection	Vehicle dynamic system (auto) patient monitoring (including pace makers etc.)	

## Transducers

Basically transducer is defined as a device, which converts energy or information from one form to another. These are widely used in measurement work because not all quantities that need to be measured can be displayed as easily as others. A better measurement of a quantity can usually be made if it may be converted to another form, which is more conveniently or accurately displayed. For example, the common mercury thermometer converts variations in temperature into variations in the length of a column of mercury. Since the variation in the length of the mercury column is rather simple to measure, the mercury thermometer becomes a convenient device for measuring temperature. On the other hand, the actual temperature variation is not as easy to display directly. Another example is manometer, which detects pressure and indicates it directly on a scale calibrated in actual units of pressure.

Thus the transducer is a device, which provides a usable output in response to specific input measurand, which may be physical or mechanical quantity, property or condition. The transducer may be mechanical, electrical, magnetic, optical, chemical, acoustic, thermal nuclear, or a combination of any two or more of these.

### Mechanical transducers:

Are simple and rugged in construction, cheaper in cost, accurate and operate without external power supplies but are not advantageous for many of the modern scientific experiments and process control instrumentation owing to their poor frequency response, requirement of large forces to overcome mechanical friction, in compatibility when remote control or indication is required, and a lot of other limitations. All these drawbacks have been overcome with the introduction of electrical transducers.

### Electrical Transducers:

Mostly quantities to be measured are non-electrical such as temperature, pressure, displacement, humidity, fluid flow, speed etc., but these quantities cannot be measured directly. Hence such quantities are required to be sensed and changed into some other form for easy measurement.

Electrical quantities such as current, voltage, resistance inductance and capacitance etc. can be conveniently measured, transferred and stored, and therefore, for measurement of non-electrical quantities these are to be converted into electrical quantities first and then measured. The function of converting non-electrical quantity into electrical one is accomplished by a device called the electrical transducer. Basically an electrical transducer is a sensing device by which a physical, mechanical or optical quantity to be measured is transformed directly, with a suitable mechanism, into an electrical signal (current, voltage or frequency). The production of these signals is based upon electrical effects which may be resistive, inductive, capacitive etc in nature. The input versus output energy relationship takes a definite reproducible function. The output to input and the output to time behavior is predictable to a known degree of accuracy, sensitivity and response, within the specified environmental conditions.

### Basic Requirements of a Transducer:

The main function of a transducer is to respond only for the measurement under specified limits for which it is designed. It is, therefore, necessary to know the relationship between the input and output quantities and it should be fixed. Transducers should meet the following basic requirements.

1. **Ruggedness.** It should be capable of withstanding overload and some safety arrangement should be provided for overload protection.
2. **Linearity.** Its input-output characteristics should be linear and it should produce these characteristics in symmetrical way.

3. **Repeatability.** It should reproduce same output signal when the same input signal is applied again and again under fixed environmental conditions e.g. temperature, pressure, humidity etc.
4. **High Output Signal Quality.** The quality of output signal should be good i.e. the ratio of the signal to the noise should be high and the amplitude of the output signal should be enough.
5. **High Reliability and Stability.** It should give minimum error in measurement for temperature variations, vibrations and other various changes in surroundings.
6. **Good Dynamic Response.** Its output should be faithful to input when taken as a function of time. The effect is analyzed as the frequency response.
7. **No Hysteretic.** It should not give any hysteretic during measurement while input signal is varied from its low value to high value and vice-versa.
8. **Residual Deformation.** It should be no deformation on removal of load after long period of application.

#### **Selection of Transducers:**

In a measurement system the transducer (or a combination of transducers) is the input element with the critical function of transforming some physical quantity to a proportional electrical signal. So selection of an appropriate transducer is most important for having accurate results.

The first step in the selection procedure is to clearly define the nature of quantity under measurement (measurand) and know the range of magnitudes and frequencies that the measurand is expected to exhibit. Next step will be to examine the available transducer principles for measurement of desired quantity.

The type of transducer selected must be compatible with the type and range of the quantity to be measured and the output device.

In case one or more transducer principles are capable of generating a satisfactory signal, decision is to be taken whether to employ a commercially available transducer or build a suitable transducer. If the transducers are available in the market at a suitable price, the choice will probably be to purchase one of them, otherwise own transducer will have to be designed, built and calibrated.

The points to be considered in determining a transducer suitable for a specific measurement are as follows:

1. **Range.** The range of the transducer should be large enough to encompass all the expected magnitudes of the measurand.
2. **Sensitivity.** The transducer should give a sufficient output signal per unit of measured input in order to yield meaningful data.
3. **Electrical Output Characteristics.** The electrical characteristics-the output impedance, the frequency response, and the response time of the transducer output signal should be compatible with the recording device and the rest of the measuring system equipment.
4. **Physical Environment.** The transducer selected should be able to withstand the environmental conditions to which it is likely to be subjected while carrying out measurements and tests. Such parameters are temperature, acceleration, shock and vibration, moisture, and corrosive chemicals might damage some transducers but not others.
5. **Errors.** The errors inherent in the operation of the transducer itself, or those errors caused by environmental conditions of the measurement, should be small enough or controllable enough that they allow meaningful data to be taken.

However the total measurement error in a transducer-activated system may be reduced to fall within the required accuracy range by adopting the following techniques.

1. Calibrating the transducer output against some known standards while in use under actual test conditions. This calibration should be performed regularly as the measurement proceeds.

- (b)
- Continuous monitoring of variations in the environmental conditions of the transducer and correcting the data accordingly.

Controlling the measurement environment artificially in order to reduce possible transducer errors artificial environmental control includes the enclosing of the transducer in a temperature-controlled housing and isolating the device from external shocks and vibrations.

### Classification of Transducers:

The transducers may be classified in various ways such as on the basis of electrical principles involved, methods of application, methods of energy conversion used, nature of output signal etc as shown in table (1.1).

- Primary and Secondary Transducers:** Transducers, on the basis of methods of applications, may be classified into primary and secondary transducers. When the input signal is directly sensed by the transducer and physical phenomenon is converted into the electrical form directly then such a transducer is called the primary transducer.

For example a thermistor used for the measurement of temperature fall in this category the thermistor senses the temperature directly and causes the change in resistance with the change in temperature.

When the input signal is sensed first by some detector or sensor and then its output being of some form other than input signals is given as input to a transducer for conversion into electrical form, then such a transducer falls in the category of secondary transducers.

For example, in case of pressure measurement, bourdon tube is a primary sensor which converts pressure first into displacement, and then the displacement is converted into an output voltage by an LVDT. In this case LVDT is secondary transducer.

- Active and Passive Transducers:** Transducers, on the basis of methods of energy conversion used, may be classified into active and passive transducers. Self-generating type transducers i.e. the transducers, which develop their output in the form of electrical voltage or current without any auxiliary source, are called the active transducers. Such transducers draw energy from the system under measurement. Normal such transducers give very small output and, therefore, use of amplifier becomes essential.

Transducers, in which electrical parameters i.e. resistance, inductance or capacitance changes with the change in input signal, are called the passive transducers. These transducers require external power source for energy conversion. In such transducer electrical parameters i.e. resistance, inductance or capacitance causes a change in voltages current or frequency of the external power source. These transducers may draw power energy from the system under measurement. Resistive, inductive and capacitive transducer falls in this category.

- Analog and Digital Transducers:** Transducers, on the basis of nature of output signal, may be classified into analog and digital transducers. Analog transducer converts input signal into output signal, which is a continuous function of time such as thermistor, strain gauge, LVDT, thermo-couple etc. Digital transducer converts input signal into the output signal of the form of pulse e.g. it gives discrete output. These transducers are becoming more and more popular now-a-days because of advantages associated with digital measuring instruments and also due to the effect that digital signals can be transmitted over a long distance without causing much distortion due to amplitude variation and phase shift.

Sometimes an analog transducer combined with an ADC (analog-digital converter) is called a digital transducer.

- Transducers and Inverse Transducers:** Transducer, as already defined, is a device that converts a non-electrical quantity into an electrical quantity. Normally a transducer and associated circuit has a non-electrical input and an electrical output, for example a thermo-couple, photoconductive cell, pressure gauge, strain gauge etc. An inverse transducer is a device that converts an electrical quantity into a non-electrical quantity. It is a precision actuator having an electrical input and a low-power non-electrical output. For examples a

(7) piezoelectric crystal and transnational and angular moving-coil elements can be employed as inverse transducers. Many data-indicating and recording devices are basically inverse transducers. An ammeter or voltmeter converts electric current into mechanical movement and the characteristics of such an instrument placed at the output of a measuring system are important. A most useful application of inverse transducers is in feedback measuring systems.

### Classification of Electrical Transducers

Class	Electrical Parameters	Types of Transducers	Principle of Operation	Typical Applications
Passive Transducers	Resistance	Potentiometer	Variation of resistance in a potentiometer or a bridge circuit due to positioning of a slide contact by an external force.	Pressure, displacement, position
		Resistance strain gauge	Variation of resistance of a wire or a semi-conductor by elongation or compression due to externally applied stress.	Force, torque, displacement.
		Pirani gauge or hot-wire meter	Variation of resistance of a heating element by convection cooling of a stream of gas.	Gas flow, gas pressure.
		Resistance thermometer or pyrometer	Variation of resistance of pure metal wire with the variation in temperature	Temperature, radiant heat.
		Thermistor	Variation of resistance of certain metal oxides having negative temperature coefficient of resistance with the variation in temperature.	Temperature
		Resistance hygrometer	Variation of resistance of a conductive strip with moisture content.	Relative humidity.
		Photoconductive cell	Variation of resistance of a cell as a circuit element with incident light.	Photosensitive relay.
Passive Transducers	Inductance	Magnetic circuit breaker	Variation of self or mutual inductance of an ac-excited coil by changes in the magnetic circuit	Pressure, displacement
		Reluctance pick up	Variation of reluctance of the magnetic circuit by changing the position of the iron core of a coil.	Pressure, displacement, vibration position.
		Differential transformer	Variation of differential voltage of two secondary windings of a transformer by varying the position of the magnetic core by an externally applied force.	Force, pressure, position, displacement
		Eddy current gauge	Variation of coil inductance by the proximity of an eddy current plate	Displacement, thickness

	Magnetostriction gauge	Variation of magnetic properties by pressure and stress.	Force, pressure, sound.
capacitance	Variable capacitance pressure gauge	Variation in capacitance due to variation of distance between two parallel plates by an externally applied force.	Pressure, displacement.
	Capacitor microphone	Variation of capacitance between a fixed plate and a movable diaphragm due to sound pressure.	Speech, music, noise.
	Dielectric gauge	Variation in capacitance because of changes in dielectric.	Liquid level, thickness.
Passive Transducers	Voltage and current	Hall effect pickup	Magnetic flux, current.
		Ionization chamber	Induced electron flow by gas ionization due to radioactive radiation. Particle counting.
		Photoemissive cell	Electron emission due to incident radiation on photoemissive surface. Light and radiations.
		Photomultiplier tube	Secondary electron emission due to incident radiation on photosensitive cathode. Light and radiation, photosensitive relays.
Active Transducers	Voltage and current	Thermocouple and thermopile	Development of an emf across the junction of two dissimilar metals or semi conductors when that junction is heated. Temperature, heat flow, radiation
		Moving-coil generator	Generation of an emf due to motion of a coil in a magnetic field. Velocity, vibration
		Piezoelectric pickup	Generation of an emf on applying an external force to a certain crystalline material such as quartz. Sound, vibration, acceleration, pressure variations.
		Photovoltaic cell	Generation of a voltage in a semiconductor junction device when radiant energy stimulates the cell. Light meter, solar cell
Digital transducers	Train of pulses	Encoders	Translation of the shaft angular position into a digital number. Angular position
		Even counting	Conversion of angular and translational motions into train of pulses by using either electromagnetic, capacitive or photo-electric method. Motion.
		Frequency output	Conversion of analog signals into frequency. For example inductive or capacitive transducers can be incorporated in the tuned resonant circuit of an LC oscillator. Displacement, force, pressure, vibration

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## § Characteristics of Transducers -

while choosing a transducer for any application the input, transfer and output characteristics have to be taken into account.

- 1 - Input characteristics.
- 2 - Transfer characteristics
- 3 - Transducer Response.
- 4 - Output characteristics.

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## § Factors affecting the choice of transducers

Followings are the factor influencing the choice of transducer for the measurement of a physical quantity.

- 1 - operating principle
- 2 - sensitivity
- 3 - operating Range
- 4 - Accuracy
- 5 - cross sensitivity.
- 6 - Errors
- 7 - Transient and frequency response.
- 8 - Loading effect
- 9 - Environmental compatibility.