A- Sensors & Transducers:

Sensor is used for an element produces signal related to the measured quantity (Unusable signal).

Transducer is used for an element when subject to physical change experiences a related change (i.e produces a usable signal).

B- Performance Terminology:

These terms used to define the performance of sensors & transducers:

1- Range & Span: Range means the limits for input to vary between, while span means maximum input value - minimum input value.

2- Error: Difference between measured value & true value.

3- Accuracy: Summation of all possible errors that are likely to occur.

4- Sensitivity: the ratio between how much o/p you get per unit input.

5- Hysteresis error: Different o/p values from the same value of measured quantity.

6- Non linearity error: it’s assumed the relation between i/p & o/p to be linear & so error is the difference from the straight line.

7- Repeatability: Ability to give the same o/p for repeated applications of the same i/p

\[
\text{Repeatability} = \left( \frac{(\text{Max} - \text{Min Values given}) \times 100}{\text{Full range}} \right)
\]

8- Stability: Ability to give the same o/p for the same i/p measured over a period of time.

9- Dead Band: The range of i/p for which there is no o/p.

10- Resolution: Smallest change in i/p that produce an observable change in the o/p.

11- Output impedance of the sensor or the transducer.
C- Static & Dynamic Characteristics:

Static Characteristics: Values given when steady state condition occurs.

Dynamic Characteristics: Behavior between the time of i/p values change & the time that the o/p value settles to steady state values.

There are some terms for dynamic behavior:

1- Response time: Time elapse after a constant i/p is applied to the sensor up to the point at which it gives 95% of the o/p value.

2- Time constant: 63.2% of the response time.

3- Rise time: Time taken for o/p to raise to specified percentage of steady-state o/p.

4- Settling time: Time taken for o/p to settle within some percentage (commonly 2% of the steady-state value).

D- Displacement, Position & Proximity:

Displacement sensors --> used to measure amount how much object has moved.

Position sensors ------> used to determine position with reference point.

Proximity sensors ------> used to determine when object has moved to with particular distance.

There are some point to consider when selection which of them to use:

1- The size of displacement.

2- The type of displacement.

3- The resolution required.

4- The accuracy required.

5- Measured object material.

6- The cost.

There are two basic types of displacement sensors:

Contact Sensors : where the object is in physical contact with the sensor.

Non - Contact Sensors: where the object is not in contact with the sensor.
The most commonly used displacement sensors are:

1- Potentiometer sensor:

Consists of a resistance element with a sliding contact can be moved over the element length, this displacement is changed to potential difference.

2- Strain gauged element:

It is a metal wire & metal foil strip can be stuck onto surfaces like stamp, When it is subjected to strain, it's resistance change proportional to the strain.

3- Capacitive element:

The capacitance (C) consists of two parallel plates & it is value depends on the overlapped area between the two plates, When one of the two plates is displaced away from its position, the capacitance value changes due to the overlap area.

4- Differential transformers:

Known as Linear Variable Differential Transformer (LVDT) consists of three coils symmetrically spaced along an insulated tube, The middle coil is the primary one while the other two are identical secondary coils connected in series. a magnetic core moves through the tube so the displacement is being monitored from the change of change in e.m.f induced in each of the secondary coils due to the magnetic core displacement.

5- Eddy current proximity sensors:

If a coil is supplied with AC current, an alternating magnetic field is produced and if there is a metal object proximity to this field eddy currents are induced in it, these eddy currents produce an other magnetic field distorts the original magnetic field form the AC current, So the impedance of the coil changes and so the amplitude of the AC current.
6- Inductive proximity switch:

It consists of a coil wound around a core, when the end of the coil is close to a metal object its inductance changes, this change could be monitored by its effect on an electric circuit and the change used to trigger a switch.

7- Pneumatic sensors:

Pneumatic sensors involve the use of compressed air as the displacement or the proximity of an object is changed into a change in pressure.

8- Proximity switches:

The switch is a small electrical device requires a physical contact and a small operating force to close the contacts and so the switch is on or off, there are many types of them can be used to detect an object proximity. Reed switch is the most commonly used for checking the closure of doors, it is considered non-contacting switch since it depends on magnet on the proximate object to close or open the switch.

9- Photosensitive devices:

These devices can be used to detect the presence of an opaque object by it breaking a beam of light or infrared radiation, falling on such device or by detecting the light reflected back by the object.

E- Velocity & Motion:

The following sensors can be used to detect velocity & motion:

1- Tachogenerator:

It is used to measure the angular velocity, it consisted of a toothed wheel of ferromagnetic material attached to the rotating shaft, pick up coil is wound on a magnet, as the wheel rotates, the teeth move past the coil and the air gap between the coil & the ferromagnetic material changes thus the flux linked by a pick up coil changes resulting in producing an alternative e.m.f in the coil.
2- Pyroelectric sensors:

Pyroelectric materials are crystalline materials which generates charge in response to heat flow, when this material is heated to temp. just below the curie temp. in an electric field and then cooled while remaining in this field electric dipoles in this material line up & it becomes polarized, when the field is removed the material remain polarized. When the pyroelectric material is exposed to infrared radiation, its temperature rises leading to reduce the amount of polarization in the material.

The pyroelectric sensor consists of a polarized pyroelectric crystal with thin metal film electrodes on opposite faces, since this crystal is polarized, ions are drawn from air & electrons from any connected circuit to the sensor to balance the surface charge. if IR is incident on the crystal and changes the temp. reducing polarization and there is then an excess of charge on crystal surface which leaks away to the connected circuit and thus the pyroelectric sensor behaves as a charge generator.

To detect the motion of heat source. the sensing element has to be between general background heat radiation & the moving heat source, dual element is used when they both receive a heat signal their o/p is cancelled, & when a heat source moves the heat radiation moves from one of the sensing elements to the other resulting in current flow.

F- Force:

Force are commonly measured by the measurement of displacements Strain gauge load cell is the best example for this.

A cylindrical tube with attached strain gauges, when forces are applied to the cylinder to compress it, the strain gauges give a resistance change which is a measure of the strain and hence the applied forces.
G- Fluid Pressure:

Many of the devices used to monitor fluid pressure involve monitoring the elastic deformation of diaphragms, capsules, bellows & tubes.

For diaphragms when there is a pressure difference the diaphragm centre’s becomes displaced, this displacement could be monitored by displacement sensors.

Capsules can be considered two corrugated diaphragms combined and give even greater sensitivity.

Bellows is a stack of capsules and even more sensitive.

A different form of deformation is by using tube with an elliptical cross section, by increasing pressure, it tends to more circular cross section, The helical shapes gives more sensitivity.

When such tube in C shaped (Bourdon tube) the c opens up when the pressure increased.

Also there are some other sensors used to measure the pressure:

1- Piezoelectric sensors:

Piezoelectric materials when stretched or compressed they generate electric charge with one face of the material +ve and other -ve charged, this result in producing voltage. For piezoelectric sensors the net charges is is proportional with the amount of displacement & since the displacement is proportional to the applied force.

Piezoelectric sensors are used for measurements of pressure, forces & acceleration & they are mainly used for transient rather than steady pressures.

2- Tactile sensors:

Tactile sensor is form of pressure sensor used on the fingertips of robotic hands to determine when hands contacts a certain object, also used in touch screens, one form of the tactile sensor uses a piezoelectric polyvinylidene fluoride film (PVDF), two layers of the film are used separated by another soft one for the vibrations, the lower one has AC voltage, results in mechanical oscillation of the film transmitted to the upper film causing an AC voltage, when pressure is applied to the upper film these voltage changes.
H- Liquid Flow:

Measuring flow rate of liquids involves devices based on the measurement of the pressure drop occurring when the fluid flows through a construction. The following devices are used to measure the flow rate:

1- Orifice plate:

It is a disc with a hole inside, placed on the tube through which the fluid flows. The pressure is measured between a point equal to the diameter of the tube upstream and a point equal to half the diameter downstream.

2-Turbine meter:

It consists of multi bladed rotor supported centrally in the pipe along which the flow occurs. The fluid rotates the rotor the angular velocity is approximately proportional to the flow rate. The rate of rotor revolution is determined using a magnetic pick-up. The pulses is counted and so the number of revolutions of rotor is determined.

I- Liquid Level:

Liquid level could be directly monitored by the position of liquid surface in a vessel, or indirectly through the vessel weight or by measuring the pressure at certain points. The following devices are used to measure the liquid level:

1- Floats:

A direct method depends on monitoring the movement of a float. This float may cause a lever arm to rotate to move a slider across a potentiometer. The result of o/p voltage related to the liquid height.

2- Differential pressure:

This determines the pressure difference between the liquid at the base of vessel and atmospheric pressure, the vessel being open to the atmospheric pressure, it is easily to calculate the liquid level.
J- Temperature:

The following methods are used to measure temperature:

1- Bimetallic Strips:

It consists of two different metal strips bounded together, have different coefficients of expansion, when temp. change they bends into curved strip, with the higher coefficient metal on the outside curve.

2- Resistance temperature detectors (RTD):

It is based on that the resistance of metals increase over a limited temp. it consists of coils of wire from metal wounded, held by a high temperature glass adhesive inside a ceramic tube.

3- Thermistors:

Small pieces of material made of mixtures of metal oxides, they are formed in many shapes, however their resistance decrease with the temp. increase. they have very rapid response to temp. change.

4- Thermocouples:

If two metals are joined a potential difference occurs across this junction, it depends on the metal & the junction temp. The thermocouples is a complete circuit of two junctions if both are at the same temp. there is no e.m.f. however there is a temp. difference there is e.m.f. these junctions are kept in a sheath to protect them this sheath depends on the temp. at which thermocouples will be used.

K- Light Sensors:

Photodiodes are semiconductors diodes connected to a circuit in reverse bias, giving high resistance so when light falls the diode resistance drops and the current in the circuit rises. it has a very rapid response. it is used in cameras to adjust the exposure that will most appropriate.
L- Selection of Sensors:

The are some factors that needed to be considered to select sensors for a particular application:

1- The nature of the measurement required (The variable, it’s nominal value, range of values, accuracy required, required speed of the measurement).

2-The nature of the o/p required from the sensor.

3- The possible sensors can be identified taking into account their factors such as range, accuracy, linearity, speed of response, power supply requirements, life, cost.

The sensors selection cannot be taken in isolation from considering the form of o/p after the signal conditioning.

M- Inputting Data By Switches:

Mechanical switches consist of one or more pairs of contacts which can be mechanically opened or closed.

1- Debouncing:

Switch bounce is a problem occurs when mechanical switch is switched to close the contacts, it hits the other and because the contacting elements are elastic bounce for a number of times before finally settled down, This leads to problem with microprocessor. & to over come way may use a software to make the microprocessor detect the switch after a certain period of time. Or we may use a hardware to use a flipflop changes its value when switch change the contact, Or we may use schmitt trigger also to solve this problem.

2- Keypads:

It is an array of switches, when the switch area on the keypad is pressed, the top contact layer close with the bottom one to make the connection and then opens with a help of a spring when the pressure is released.