Chapter 5

Sensors & Transducers

I. Introduction to Sensors and Transducers

Sensors: A sensor is a device that detects and responds to some type of input from the physical environment. The input can be light, heat, motion, moisture, pressure, or any number of other environmental phenomena. The output is generally a signal that is converted to a human-readable display at the sensor location or transmitted electronically over a network for reading or further processing.

Sensors play a pivotal role in the Internet of things (IoT). They make it possible to create an ecosystem for collecting and processing data about a specific environment so it can be monitored, managed, and controlled more easily and efficiently. IoT sensors are used in homes, out in the field, in automobiles, on airplanes, in industrial settings, and in other environments. Sensors bridge the gap between the physical world and the logical world, acting as the eyes and ears for a computing infrastructure that analyzes and acts upon the data collected from the sensors

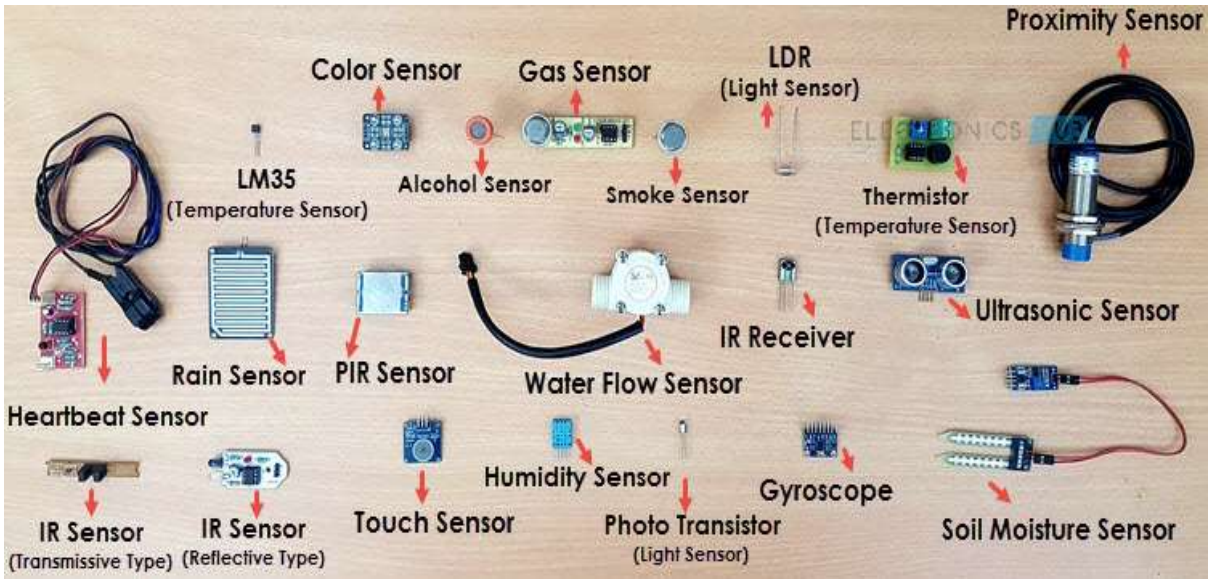


Figure:5.1 Sensors

Example: The simplest example of a sensor is an LDR or a Light Dependent Resistor. It is a device, whose resistance varies according to intensity of light it is subjected to. When

the light falling on an LDR is more, its resistance becomes very less and when the light is less, well, the resistance of the LDR becomes very high.

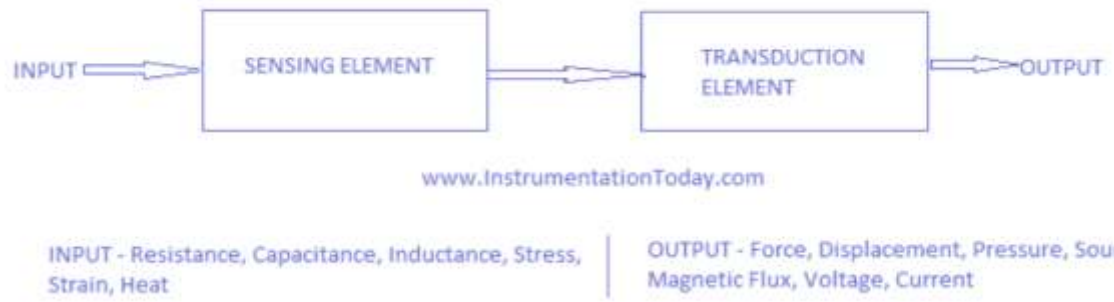
We can connect this LDR in a voltage divider (along with other resistors) and check the voltage drop across the LDR. This voltage can be calibrated to the amount of light falling on the LDR. Hence, a Light Sensor.

Transducer: A transducer is defined as a device that receives energy from one system and transmits it to another, often in a different form.

Broadly defined, the transducer is a device capable of being actuated by an energizing input from one or more transmission media and in turn generating a related signal to one or more transmission systems. It provides a usable output in response to a specified input measured, which may be a physical or mechanical quantity, property, or condition. The energy transmitted by these systems may be electrical, mechanical or acoustical.

The input quantity for most instrumentation systems is nonelectrical. In order to use electrical methods and techniques for measurement, the nonelectrical quantity is converted into a proportional electrical signal by a device called a “transducer”.

Actually, an electrical transducer consists of two parts that are very closely related to each other. These two parts are the sensing or detecting element and the transduction element. The sensing or detecting element is commonly known as the sensor.



Sensing Element: The physical quantity or its rate of change is sensed and responded to by this part of the transistor.

Transduction Element: The output of the sensing element is passed on to the transduction element. This element is responsible for converting the non-electrical signal into its proportional electrical signal.

II. Comparison between sensors and Transducers

Sr. No	Sensors	Transducers
1	A sensor is a device which converts the physical parameter of a quantity into corresponding electrical output.	A transducer is a device that transforms energy from one form to another, such as speed into electrical signal.
2	A sensor does not have any other component except itself.	The components of a transducer are − input device (sensor), processing device (signal conditioning), and output device.
3	All the sensors are not transducers.	A sensor is the part of all the transducers.
4	A sensor is less complicated in its construction and processing.	Transducer is a relatively more complex device because it involves the transformation of energy from one form to another.
5	A sensor detects the change in the physical parameter of quantity to produce a corresponding electrical signal.	The transducer converts the energy into a different form.
6	The sensor does not provide any feedback to the system. This means, it only measures the change in the physical quantity and cannot give input to the system on its own.	Transducer generally provides feedback to the system through the output device after processing.
7	Common examples of sensors are temperature sensors, photo sensors, proximity sensors, etc.	Examples of transducers are: strain gauge, microphones, loudspeakers, piezoelectric elements, etc.

III. Applications of Sensors and Transducers

Application of Sensors

Top Applications of Sensors. Sensors find usage in various industries like Automotive, Manufacturing, Aviation, Marine, Medical, Telecom, Chemical, and Computer Hardware. Let's examine some of the applications of sensors in these Industries.

1.Automotive: Antilock Braking System (ABS) Sensors connected to the wheel, measure the speed of the wheel and braking pressure and keep sending them to ABS controlling When the driver applies the sudden brake, the ABS system, with breaking pressure and speed data received from the sensors, releases the braking pressure to avoid skidding/locking of wheels. It is one of the critical safety aspects of vehicles.

2.Manufacturing: Predictive maintenance of the machinery, Assembly equipment using the data collected from sensors in the machines. Optimal utilization of Machines by continuously monitoring the performances and effectively rejigging the operations with the data collected from sensors. Fine-tuning the Quality systems and enhancing the quality standards using the data collected from sensors. Design notifications and alerts in case of a deterioration of quality and process standards. Agility in reacting to market demands.

3.Aviation: Sensors deployed in the aviation industry measure the data during the navigation of aircraft, monitoring various systems, and controlling instruments. These data are utilized for inefficient flight operations, improve aircraft performance, and design improvements. Some of the instrumentation sensors are tachometers, gauges to measure engine pressure and oil& fuel quantity, Altimeters, airspeed meters, etc. Sensors help measure the testing of the ground conditions, vibration, and environmental factors and provide useful inputs to the pilot to manage the general operation and emergency conditions.

IV.Medical & Healthcare

- ✓ Blood pressure monitoring (self).
- ✓ Continuous glucose monitoring by Individuals.
- ✓ Automatic measurement of the vitals of the patient and sending it to the patient's doctor.
- ✓ More home care facilities and ambulatory treatments.
- ✓ Automatic detection of visitors spreading the disease to patients in hospitals.
- ✓ Decentralized laboratories.
- ✓ Robotics in Operation Theater.

Application of Transducers

Ultrasonic Transducer

This transducer can be used to measure the distance of the sound based on reflection. This measurement is based on a suitable method compared to the straight methods which use different measuring scales. The areas which are hard to find, such as pressure areas, and very high temperatures, using conventional methods the measurement of the distance is not a simple task. So, this transducer-based measuring system can be used in this kind of zone.

Figure:5.3 Ultrasonic Transducer

Temperature Transducer

A temperature transducer is used to measure the temperature of the air such that to control the temperature of several control systems like air-conditioning, heating, ventilation, and so on.

Figure:5.4 Temperature Transducer

Piezoelectric Transducer

Piezoelectric transducers are a type of electroacoustic transducer that convert the electrical charges produced by some forms of solid materials into energy. The word "piezoelectric" literally means electricity caused by pressure.

This transducer is mainly used to detect the stick drummer's impact on electronic drum pads. And also used to detect the movement of the muscle, which can be named acceleromyograph.

The load of the engine can be determined by calculating diverse absolute pressure, which can be done by using these transducers as the MAP sensor in fuel injection systems.

This sensor can be used as a knock sensor in automotive engine management systems for noticing the knock of the engine.

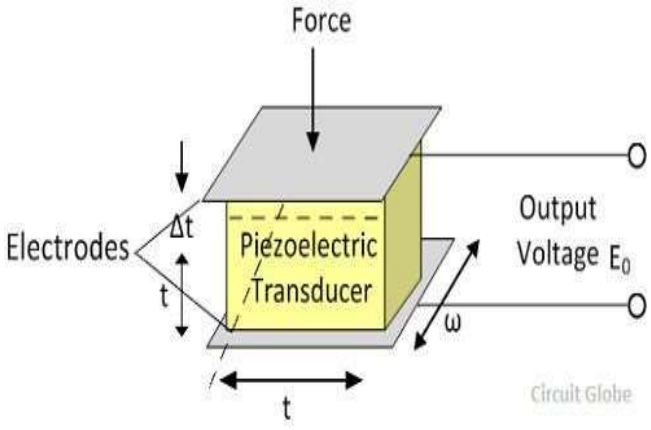
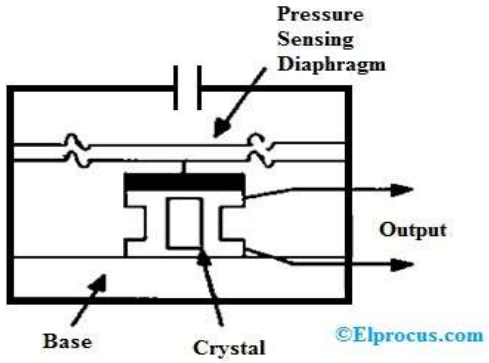


Figure:5.5 Piezoelectric Transducer

Pressure Transducer



The applications of pressure transducers mainly involve altitude sensing, pressure sensing, level or depth sensing, flow sensing, and leak testing. These transducers can be used for generating electrical power under the speed breakers on the highways or roads where the force of the vehicles can be converted into electrical energy.

Figure:5.6 Pressure Transducer

The common application of transducers in different parts of electronics:

1. Strain gauge
2. Hall Effect
3. Force
4. Torque
5. Power
6. Position
7. Displacements
8. Humidity
9. Temperature
10. Pressure

IV. Types of Electronic sensors

Temperature Sensor

One of the most common and most popular sensors is the Temperature Sensor. A Temperature Sensor, as the name suggests, senses the temperature i.e., it measures the changes in the temperature.

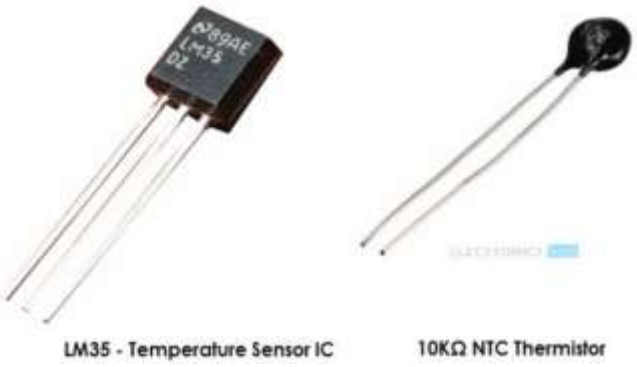


Figure:5.7 Temperature Sensor

There are different types of Temperature Sensors like Temperature Sensor ICs (like LM35, DS18B20), Thermistors, Thermocouples, RTD (Resistive Temperature Devices), etc.

Temperature Sensors can be analog or digital. In an Analog Temperature Sensor, the changes in the Temperature correspond to changes in its physical property like resistance or voltage. LM35 is a classic Analog Temperature Sensor.

Proximity Sensors

A Proximity Sensor is a non-contact type sensor that detects the presence of an object. Proximity Sensors can be implemented using different techniques like Optical (like Infrared or Laser), Sound (Ultrasonic), Magnetic (Hall Effect), Capacitive, etc.

Figure:5.8 Proximity Sensor

Some of the applications of Proximity Sensors are Mobile Phones, Cars (Parking Sensors), industries (object alignment), Ground Proximity in aircraft, etc.

Infrared Sensor (IR Sensor)

IR Sensors or Infrared Sensors are light-based sensors that are used in various applications like Proximity and Object Detection. IR Sensors are used as proximity sensors in almost all mobile phones.

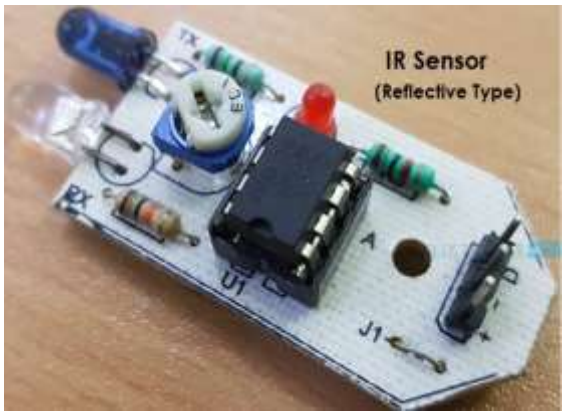


Figure:5.9 Infrared Sensor

There are two types of Infrared or IR Sensors: Transmissive Type and Reflective Type. In Transmissive Type IR Sensor, the IR Transmitter (usually an IR LED) and the IR Detector (usually a Photo Diode) are positioned facing each other so that when an object passes between them, the sensor detects the object.

Ultrasonic Sensor

An Ultrasonic Sensor is a non-contact type device that can be used to measure distance as well as velocity of an object. An Ultrasonic Sensor works based on the properties of the sound waves with frequency greater than that of the human audible range.

Using the time of flight of the sound wave, an Ultrasonic Sensor can measure the distance of the object (similar to SONAR). The Doppler Shift property of the sound wave is used to measure the velocity of an object.

Figure:5.10 Ultrasonic Sensor

Light Sensor

A simple Light Sensor available today is the Light Dependent Resistor or LDR. The property of LDR is that its resistance is inversely proportional to the intensity of the ambient light i.e., when the intensity of light increases, its resistance decreases and vice-versa.

Figure:5.11 Light Sensor

Smoke and Gas Sensors

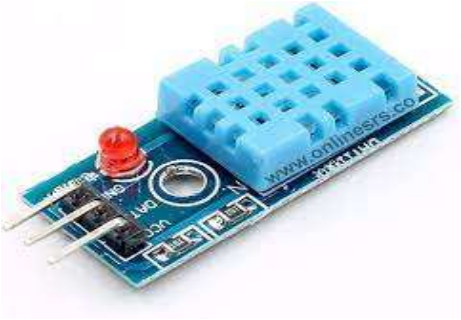
One of the very useful sensors in safety related applications are Smoke and Gas Sensors. Almost all offices and industries are equipped with several smoke detectors, which detect any smoke (due to fire) and sound an alarm.

Gas Sensors are more common in laboratories, large-scale kitchens, and industries. They can detect different gases like LPG, Propane, Butane, Methane (CH4), etc.

Figure:5.12 Smoke Sensor

Humidity Sensor

If you see Weather Monitoring Systems, they often provide temperature as well as humidity data. So, measuring humidity is an important task in many applications.



Often all humidity sensors measure relative humidity (a ratio of water content in the air to the maximum potential of air to hold water). Since relative humidity is dependent on the temperature of the air, almost all Humidity Sensors can also measure Temperature.

Figure:5.13 Humidity Sensor

V. Types of Transducers.

There are of many different types of transducers, they can be classified based on various criteria as:

Types of Transducers based on Quantity to be Measured

- ✓ Temperature transducers (e.g., a thermocouple, RTD)
- ✓ Pressure transducers (e.g., a diaphragm)
- ✓ Displacement transducers (e.g., LVDT)
- ✓ Oscillator transducer
- ✓ Flow transducers
- ✓ Inductive Transducer

Types of Transducers based on the Principle of Operation

- ✓ Photovoltaic (e.g., a solar cell)
- ✓ Piezoelectric transducer
- ✓ Chemical
- ✓ Mutual induction
- ✓ Electromagnetic
- ✓ Hall effect
- ✓ Photoconductors

Types of Transducers based on Whether an External Power Source is required or not

1. Active Transducer

Active transducers generate electric signals in response to an external signal without the need of an additional energy source.

For example, a thermistor does not generate any electric signal, but by-passing electric current through it, its resistance can be measured by detecting variations in current and/or voltage across the thermistor.

2. Passive Transducers

Passive transducers require an external power source to operate, which is called an excitation signal.

For example, a thermistor does not generate any electric signal, but by-passing electric current through it, its resistance can be measured by detecting variations in current and/or voltage across the thermistor.