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Sensors

2.1 Sensors Classification

Sensors are classified as follows:

1. Primary input quantity
2. Transduction principles
3. Technology and material
4. Property
5. Application

Classification of sensors can also be done on the basis of different areas:

1. **Classification based on application:** Sensors are chosen on the basis of application where they need to be implemented, such as industrial process control, measurement and automation, automobiles, consumer electronics, aircraft, and medical products. As with the change in application, the selection criteria changes, so the application needs to be considered.
2. **Classification based on power or energy supply requirement**

   Active sensor: Active sensors are those where a power supply is required to measure the physical quantity, e.g., temperature sensor, ultrasonic sensor, and light-dependent resistor (LDR).

   Passive sensor: Sensors that do not need a power supply are called passive sensors, and they measure the parameters, e.g., radiometers film photography.
3. **Classification based on output of sensor**

   Digital sensor: The output of sensor is in binary or digital form, which can be directly processed through a controller or processor.

   Analog sensors: The output of a sensor is in the form of a continuous signal. An analog-to-digital converter is required to read the sensor by microcontroller or processor.

4. **Classification based on the type of sensor:** There are several sensors available with different applications. Sensors can be categorized on the basis of types of sensors. A few types of sensors are discussed as follows:

   Accelerometers: Accelerometers are based on the technology named "microelectromechanical sensor." They can be used in dynamic systems.

   Biosensors: Biosensors are based on the electrochemical technology. They can be used for medical care devices, water testing, food testing, etc.

   Image sensors: These are developed on the basics of the complementary metal oxide semiconductor (CMOS) technique. These are widely used in to video surveillance, biometrics, and traffic management.

   Motion detectors: Motion detectors are based on the infrared, ultrasonic, and microwave/radar technology. These are used in security purposes.

5. **Classification based on property:** The sensors are also classified on the basis of the property of the physical parameter. A few examples are as follows:

   Temperature: Thermocouples, thermistors, resistance temperature detectors (RTDs)

   Flow: Thermal mass, differential pressure, electromagnetic, positional displacement, etc.

   Pressure: Fiber optic, linear variable differential transformer (LVDT), elastic liquid-based manometers, vacuum, electronic

   Level sensors: Ultrasonic radio frequency, radar, thermal displacement, etc.

   Proximity and displacement: Capacitive, LVDT, magnetic, photoelectric, ultrasonic

   Biosensors: Electrochemical, resonant mirror, surface plasmon resonance

   Image: Charge-coupled devices, CMOS

   Gas and chemical: Semiconductor, conductance, infrared, electrochemical

   Acceleration: Accelerometers, gyroscopes

2.2 Working Principle of Sensors

The working principle of each sensor is different, as it is designed to measure a specific quantity. The principle of few basic sensors is as follows:

1. **Temperature sensor:** The temperature sensor measures the environmental temperature and converts it to an electrical signal. The principle of the thermometer is expansion and contraction of mercury in glass. With an alteration in temperature, mercury expands and contracts proportionally.

   Two types of temperature sensors are available:

   Contact sensor: The sensor that needs to be in physical contact with the object, temperature of which is to be sensed, is known as a contact sensor.

   Noncontact sensor: The sensor that needn't to be in physical contact with the object, temperature of which is to be sensed, is known as a noncontact sensor. This type of sensor uses Plank's Law to measure temperature, which senses the heat radiated from the source to measure the temperature.

   Examples of temperature sensors:

   Thermocouple: Thermocouple is made of two wires, each with different metals. A junction is formed by joining the ends. This junction is open to the object for which temperature needs to be measured; the other end is connected to a measuring device. The current will flow through the metal, due to a difference in temperature of two junctions.

   Resistance temperature detectors (RTDs): An RTD is type of thermal resistor that is designed to alter the electrical resistance with a change in temperature.

   Thermistors: It is type of thermal resistor that changes the resistance in proportion with small changes in temperature.

2. **IR sensor:** An IR sensor emits and detects the infrared rays to sense a specific environment. It is easily available in the market, but it is sensitive toward noise and light.

   The application of an IR sensor includes thermography, heating, meteorology, climatology, spectroscopy, and communications.

3. **UV sensor:** A UV sensor measures the intensity or the power of an incident ultraviolet radiation. This electromagnetic radiation has longer a wavelength than x-rays but smaller than visible radiation. A polycrystalline diamond material is used for ultraviolet sensing. It can transmit different types of energy signals but can accept only one type of signal. The electrical meter is used to read the output signals and processed to the computer through analog-to-digital converters. The UV sensor is used in UV water treatment, light sensors, UV spectrum detectors, etc.
4. **Touch sensor:** A touch sensor is a variable resistor that changes its resistance as per the location where it gets touched. It is made of a conductive and a partially conductive substance and insulated in a plastic cover. The flow of current is due to a conductive material that allows current partially. The touch sensor is a cost-effective solution for many applications, such as washing machines, fluid-level sensors, and dishwashers.
5. **Proximity sensor:** A proximity sensor can detect the presence of an object without any contact point. The working principle is electromagnetic waves that are emitted by the sensor and return when the object is in range of the waves. The presence of the object is detected with the change in filed radiation. The proximity sensors working are of different types, like inductive, capacitive, photoelectric sensor, ultrasonic, and Hall-effect.

   Inductive proximity sensor: This type of sensor has an oscillator as an input, which changes the loss resistance by the proximity of an electrically conductive medium. For metal detection, these types of sensors are used.

   Capacitive proximity sensor: This type of sensor converts capacitance by changing electrode displacement. It can be done by bringing the object within the variable frequencies. The object is detected with the help of the oscillated frequency, which is converted into a DC voltage. This current is compared with a fixed value to detect the object. For plastic targets, these types of sensors are used.
6. **Ultrasonic sensor:** An ultrasonic sensor is used to detect the distance of an object. The working principle is the time duration between the emission and receiving of the waves after reflecting from the object. Ultrasonic sensors use sound waves to measure the distance of an object.

2.3 Criteria to Choose a Sensor

There are a few features that need to be addressed, along with the sensor to be selected. The features are as follows:

1. Accuracy
2. Cost
3. Range of communication
4. Repeatability
5. Resolution
6. Environmental constraints
7. Data calibration

2.4 Generation of Sensors

First generation: The first-generation sensors were associated with electronics. Most of the structures were based on silicon structure. Few sensors had the facility of analog amplification on a microchip.

Second generation: This generation of sensors was analog in nature with MEMS element combined with analog amplification. These had the facility of an analog-to-digital converter on one microchip.

Third generation: This generation of sensors had a combination of sensor element, analog amplification, and analog-to-digital converter with the on-chip digital intelligence and temperature compensation.

Fourth generation: This generation of sensors had an additional feature of memory cell for calibration and temperature compensation, along with the features of the third generation.

Fifth generation: This is generation of intelligent sensors with the capability of communication.