Sensors and Transducers - Overview

An electronic sensor detects and measures a physical phenomenon, such as temperature, pressure, force, or acceleration, and provides a corresponding output signal, usually in the form of an electrical, mechanical, magnetic, etc. The actuating unit consists of an actuator and optionally a power supply and a coupling mechanism. Sensors and actuators are broadly termed as transducer devices which convert one form of energy into another form of energy.

Furthermore, sensors are classified as analog or digital based on the type of output signal. Analogue sensors produce a continuous output signal or voltage which is generally proportional to the quantity being measured. Physical quantities such as Temperature, Speed, Pressure, Displacement, Strain etc are all analogue quantities as they tend to be continuous in nature. Microcontroller are used to sense the analog signals, sometimes high resolution ADC's are interfaced externally to get precision and accuracy (where microcontroller does not supports) and do the required processing and send the output.

Digital Sensors produce a discrete digital output signals or voltages that are a digital representation of the quantity being measured. Digital sensors produce a binary output signal in the form of logic "1" or logic "0". Compared to analogue signals, digital signals or quantities have very high accuracies and can be both measured and "sampled" at a very high clock speed. The accuracy of the digital signal is proportional to the number of bits used to represent the measured quantity.

There are various types of sensors that are classified by their measurement objectives. Linear/Rotational sensors, Acceleration sensors, Force torque and pressure sensor, Flow sensors, Temperature sensors, Proximity sensors, Light sensors, Smart material sensors, Micro- and Nano-sensors, Level sensors, Ultrasonic Sensor, Vibration Sensor. Sensors can also be classified as passive or active, In passive sensors the power required to produce the output is provided by the sensed physical phenomenon itself (such as a thermometer) whereas the active sensors require external power source (such as a strain gage).

Types of Sensors - Overview

Accelerometer:

An accelerometer is an electromechanical device that will measure acceleration forces. These forces may be static, like the constant force of gravity pulling at your feet, or they could be dynamic which is caused by moving or vibrating the accelerometer.

Some accelerometers use the piezoelectric effect in which they contain microscopic crystal structures that get stressed by accelerative forces, which causes a voltage to be generated. Another way to do is by sensing changes in capacitance. If you have two microstructures next to each other, they have a certain capacitance between them. If an accelerative force moves one of the structures, then the capacitance will change. Add some circuitry to convert from capacitance to voltage and you will get accelerometer.

Accelerometer can produce either analog or digital outputs. Analog style accelerometers output a continuous voltage that is proportional to acceleration. e.g 2.5V for 0g, 2.6V for 0.5g, 2.7V for 1g. Digital accelerometers usually use pulse width modulation (PWM) for their output. This means there will be a square wave of a certain frequency, and the amount of time the voltage is high will be proportional to the amount of acceleration.

Accelerometers have multiple applications in industry and science. Highly sensitive accelerometers are components of inertial navigation systems for aircraft and missiles. They are used to detect and monitor vibration in rotating machinery. They are used in tablet computers and digital cameras so that images on screens are always displayed upright. They are used in drones for flight stabilisation. Coordinated accelerometers can be used to measure differences in proper acceleration, particularly gravity, over their separation in space; i.e., gradient of the gravitational field.

Temperature Sensor:

Temperature Sensors are the device which measures the amount of heat energy or coldness that is generated by an object or system. It allows sensing/detecting any physical change to that temperature producing either an analogue or digital output.

A temperature sensor consists of two basic physical types: Contact temperature sensor types and Non-contact temperature sensor types. Contact types of temperature sensor are required to be in physical contact with the object being sensed and use conduction to monitor changes in temperature. Non-contact types of temperature sensor use convection and radiation to monitor changes in temperature.

A variety of devices are available to measure temperature, the most common of which are thermocouples, thermisters, resistance temperature detectors (RTD), and infrared types. Thermocouples are the most versatile, inexpensive, and have a wide range (up to 1200 deg C typical). These consist of two dissimilar metal wires joined at the ends to create the sensing junction. When used in conjunction with a reference junction, the temperature difference between the reference junction and the actual temperature shows up as a voltage potential.

Thermisters are semiconductor devices whose resistance changes as the temperature changes. They are good for very high sensitivity measurements in a limited range of up to 100 deg C. The relationship between the temperature and the resistance is nonlinear. The RTDs use the phenomenon that the resistance of a metal changes with temperature. They are linear over a wide range and most stable and have better accuracy and resolution than thermocouples. RTDs use precision wire, usually made of platinum, as the sense element.

Infrared type sensors use the radiation heat to sense the temperature from a distance. These noncontact sensors can also be used to sense a field of vision to generate a thermal map of a surface.

Proximity Sensor:

Proximity sensors are discrete sensors that sense when an object has come near to the sensor face. They are able to detect the presence of nearby objects without any physical contact. A proximity sensor emits a beam of electromagnetic radiation and looks for changes in the field or return signal. Proximity sensors are commonly used on Smartphone's to detect accidental touch screen taps when held to the ear during a call. Typical applications include the detection, position, inspection and counting on automated machines and manufacturing systems. There are four fundamental types of proximity sensors Inductive proximity sensor, Capacitive proximity sensor, Ultrasonic proximity sensor and the Photoelectric or Opto-electronic Sensors.

Inductive proximity sensors respond to ferrous and non - ferrous metal objects. They will also detect metal through a layer of non - metal material. Inductive proximity sensors consist of a coil wound around a soft iron core. The inductance of the sensor changes when a ferrous object is in its proximity. This change is converted to a voltage-triggered switch. Capacitive sensors respond to a change in the dielectric medium surrounding the active face without necessarily making physical contact and can thus be tuned to sense almost any substance. Capacitive sensors can also sense a substance through a layer of glass, plastic or thin carton.

Photoelectric sensors offer non-contact sensing of almost any substance or object up to a range of 10 meters. It consists of a light source (usually an LED, light emitting diode, in either infrared or visible light spectrum) and a detector (photodiode). Ultrasonic sensor utilizes the reflection of high frequency (20 KHz) sound waves to detect parts or distances to the parts. Ultrasonic sensors are the best choice for transparent targets.

Optical / Light Sensor:

The light sensor is a passive device that converts the light energy into an electrical signal output. Light sensors are more commonly known as Photoelectric Devices or Photo Sensors because they convert light energy (photons) into electronic signal (electrons). Phototransistors, photoresistors, and photodiodes are some of the more common type of light intensity sensors.

Photoelectric sensors use a beam of light to detect the presence or absence of an object. It emits a light beam (visible or infrared) from its light-emitting element. A reflective-type photoelectric sensor is used to detect the light beam reflected from the target. A beam of light is emitted from the light emitting element and is received by the light receiving element. Both the light emitting and light receiving elements are contained in a single housing. The sensor receives the light reflected from the target.

A phototransistor, on the other hand, uses the level of light it detects to determine how much current can pass through the circuit. So, if the sensor is in a dark room, it only lets a small amount of current to flow. If it detects a bright light, it lets a larger amount of current flow. A photoresistor is made of cadmium sulphide whose resistance is maximum when the sensor is in dark. When the photoresistor is exposed to light, its resistance drops in proportion to the intensity of light. When interfaced with a circuit and balanced with potentiometer, the change in light intensity will show up as change in voltage. These sensors are simple, reliable, and cheap, used widely for measuring light intensity.

Touch Sensor:

A touch sensor is a type of device that captures and records physical touch or embrace on a device and/or object. It enables a device or object to detect touch or near proximity, typically by a human user or operator. Touch sensing input devices offer numerous possibilities for novel interaction techniques and it reliably replaces mechanical buttons and switches to eliminate mechanical wear and tear. These can be configured into simple sliders, rotary wheels, or touch pads for intuitive user interfaces.

A touch sensor primarily works when an object or individual gets in physical contact with it. Touch sensors are also called as tactile sensors and are sensitive to touch, force or pressure. It can be implemented using Capacitive or Resistive sensing technology.

Capacitive sensing is a technology based on capacitive coupling that can detect and measure anything that is conductive or has a dielectric difference from air. Capacitive touch screens distinguish and sense specific touch location based on the electrical impulses in a human body, typically the fingertip. This enables capacitive touch screens to not require any actual force to be applied to the screen's surface.

Capacitive touch screen technology is a popular and durable technology that is used in a wide range of applications. Capacitive touchscreens are very clear, offering up to 90 percent transparency. Due to its higher clarity than resistive technology it is used in smartphones.

The resistive touchscreen is the most common type of touchscreen. Except for modern smartphones, tablets and trackpads, most touchscreens we come in contact with are actually resistive touchscreens. It is employed in wide range of applications such as camcorder, PC, automotive navigation device, factory automation, medical equipments, office automation, Kiosk, in-flight entertainment, and so on. Resistive touch screen displays are composed of multiple layers that are separated by thin spaces. Pressure applied to the surface of the display by a finger or stylus causes the layers to touch, which completes electrical circuits and tells the device where the user is touching.

Current Sensor:

A current sensor is a device that detects and converts current to an easily measurable output voltage, which is proportional to the current through the measured path. There are a wide variety of sensors, and each sensor is suitable for a specific current range and environmental condition. Among these sensors, a current sensing resistor is the most commonly used. It can be considered a current-to-voltage converter, where inserting a resistor into the current path, the current is converted to voltage in a linear way. The technology used by the current sensor is important because different sensors can have different characteristics for a variety of applications.

Current sensors are based on either open or closed loop hall effect technology. A closed-loop sensor has a coil that is actively driven to produce a magnetic field that opposes the field produced by the current being sensed. The hall sensor is used as a null-detecting device, and the output signal is proportional to the current being driven into the coil, which is proportional to the current being measured.

In an open loop current sensor, the magnetic flux created by the primary current is concentrated in a magnetic circuit and measured using a hall device. The output from the hall device is the signal conditioned to provide an exact (instantaneous) representation of the primary current.

Pressure Sensor:

A pressure sensor is a device which senses pressure and converts it into an analog electric signal whose magnitude depends upon the pressure applied. Pressure is defined as force per unit area that a fluid exerts on its surrounding. Since they convert pressure into an electrical signal, they are also termed as pressure transducers.

Absolute pressure is measured relative to a perfect vacuum, atmospheric pressure is an example. A common unit of measurement is pounds per square inch absolute (psia). Differential pressure is the difference in pressure between two points of measurement. This is commonly measured in units of pounds per square inch differential (psid). Gauge pressure is measured relative to ambient pressure, blood pressure is one example. Common measurement units are pressure per square inch gauge (psig).

The SI unit for pressure is the Pascal (N/m2), but other common units of pressure include pounds per square inch (PSI), atmospheres (atm), bars, inches of mercury (in Hg), and millimetres of mercury (mm Hg).

Pressure sensors have been widely used in fields like automobile, manufacturing, aviation, bio medical measurements, air conditioning, hydraulic measurements etc. In automotive industry, pressure sensors form an integral part of the engine and its safety. In the engine these sensors monitor the oil and coolant pressure and regulate the power that the engine should deliver to achieve suitable speeds whenever accelerator is pressed or the brakes are applied to the car. In instruments like digital blood pressure monitors and ventilators, pressure sensors are needed to optimize them according to patient’s health and his requirements.

Gyroscope / Gyro Sensor:

A gyroscope is a device that uses Earth’s gravity to help determine orientation. Gyro sensors are devices that sense angular velocity which is the change in rotational angle per unit of time. Angular velocity is generally expressed in deg/s (degrees per second). There are three basic types of gyroscope Rotary (classical) gyroscopes, Vibrating Structure Gyroscope and Optical Gyroscopes.

Its design consists of a freely rotating disk called a rotor, mounted onto a spinning axis in the centre of a larger and more stable wheel. As the axis turns, the rotor remains stationary to indicate the central gravitational pull, and thus which way is down. The gyroscope maintains its level of effectiveness by being able to measure the rate of rotation around a particular axis. When gauging the rate of rotation around the roll axis of an aircraft, it identifies an actual value until the object stabilizes out. Using the key principles of angular momentum, the gyroscope helps indicate orientation.

Gyroscopes are available that can measure rotational velocity in 1, 2, or 3 directions. 3-axis gyroscopes are often implemented with a 3-axis accelerometer to provide a full 6 degree-of-freedom (DoF) motion tracking system. A gyroscope would be used in an aircraft to help in indicating the rate of rotation around the aircraft roll axis. As an aircraft rolls, the gyroscope will measure non-zero values until the platform levels out, whereupon it would read a zero value to indicate the direction of down.

Humidity Sensor:

Humidity is the presence of water in air. The amount of water vapour in air can affect human comfort as well as many manufacturing processes in industries. The presence of water vapour also influences various physical, chemical, and biological processes.

Humidity sensors work by detecting changes that alter electrical currents or temperature in the air. There are three basic types of humidity sensors: capacitive, resistive and thermal. All three types will monitor minute changes in the atmosphere in order to calculate the humidity in the air.

A capacitive humidity sensor measures relative humidity by placing a thin strip of metal oxide between two electrodes. The metal oxide’s electrical capacity changes with the atmosphere’s relative humidity. Weather, commercial and industries are the major application areas. Resistive humidity sensors utilize ions in salts to measure the electrical impedance of atoms. As humidity changes, so does the resistance of the electrodes on either side of the salt medium. Two thermal sensors conduct electricity based upon the humidity of the surrounding air. One sensor is encased in dry nitrogen while the other measures ambient air. The difference between the two measures the humidity.

Inductive Sensor:

Inductive sensing is a contactless, magnet-free sensing technology that can precisely measure the position, motion, or composition of a metal or conductive target as well as detect the compression, extension, or twist of a spring. They are frequently used to measure position or speed, especially in harsh environments. All inductive sensors can be said to work using transformer principles. Inductive sensors can output appropriate signals for positions and limits as well as act as pulse pick-ups for monitoring rotational speed and counting tasks. It includes simple proximity switches, variable inductance sensors, variable reluctance sensors, synchros, resolvers, rotary and linearly variable differential transformers (RVDTs & LVDTs), and new generation inductive encoders..

Inductive sensors are designed based on proximity sensor technology to detect metallic or conductive parts without physical contact or where access is difficult. Their operating principle is based on a coil and oscillator that creates an electromagnetic field in the close surroundings of the sensing surface. The presence of a metallic object (actuator) in the operating area causes a dampening of the oscillation amplitude. The rise or fall of such oscillation is identified by a threshold circuit that changes the output of the sensor.

The operating distance of the sensor depends on the actuator's shape and size and is strictly linked to the nature of the material.

Common applications of inductive sensors include metal detectors, traffic lights, car washes, and a host of automated industrial processes. Because the sensor does not require physical contact it is particularly useful for applications where access presents challenges or where dirt is prevalent.