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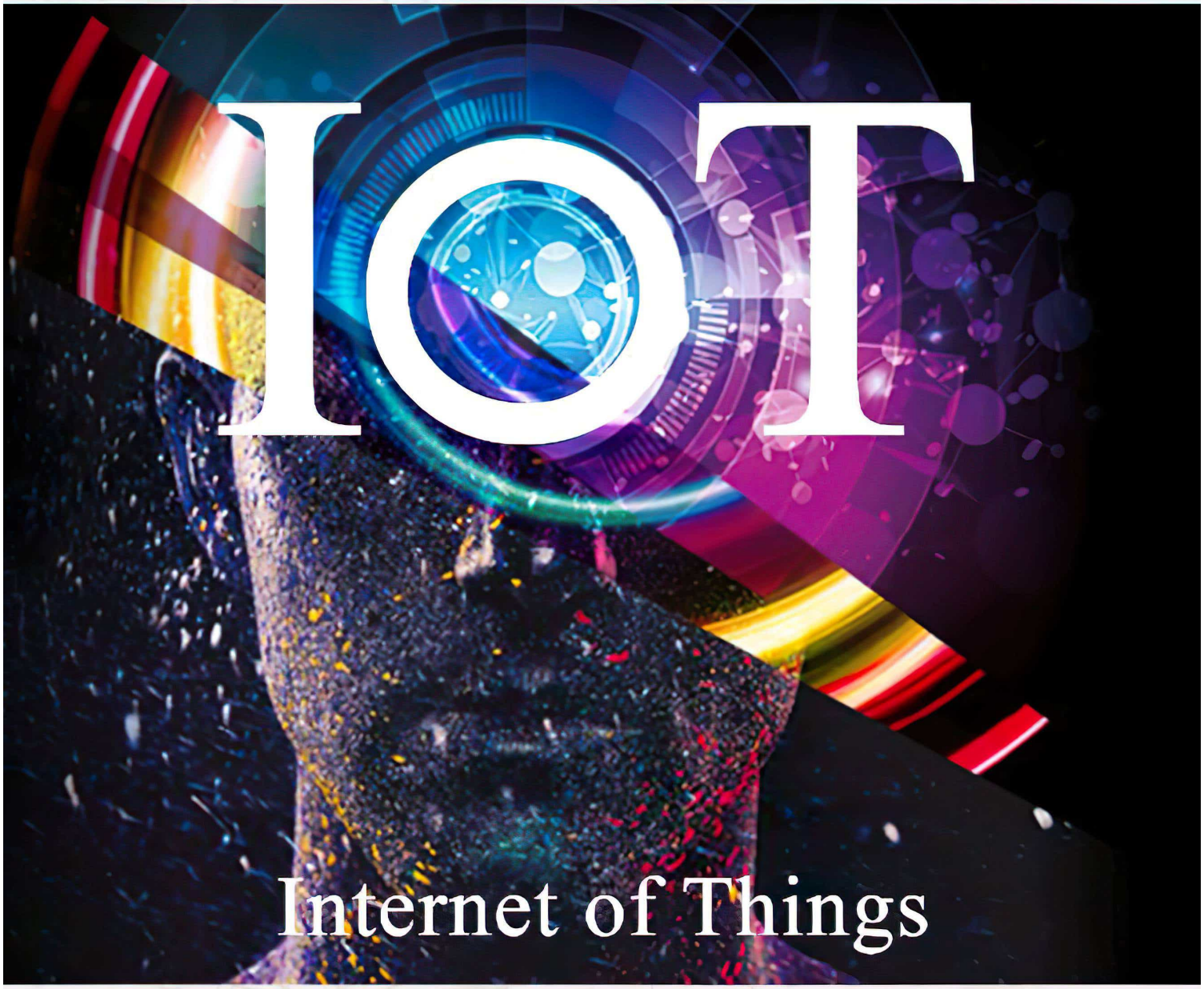

Internet of Things

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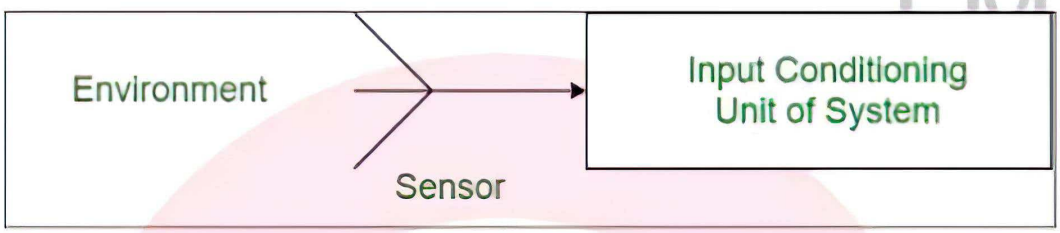
UNIT – 3 SENSORS AND ACTUATORS IN IOT

3.1 Definition of Sensors

"Sensor is a device used for the conversion of physical events or characteristics into theelectrical signals. This is a hardware device that takes the input from environment and gives to the system by converting it."

For example, a thermometer takes the temperature as physical characteristic and thenconverts it into electrical signals for the system.



Sensors made it possible to collect data in most any situation and are now used in various fields - medical care, nursing care, industrial, logistics, transportation, agriculture, disaster prevention, tourism, regional businesses and many more.

These three features should be at the base of a good sensor:

- It should be sensitive to the phenomenon that it measures.
- It should not be sensitive to other physical phenomena.
- It should not modify the measured phenomenon during the measurement process.

A few examples of the many different types of sensors:

In a mercury-based glass thermometer, the input is temperature. The liquid contained expands and contracts in response, causing the level to be higher or lower on the marked gauge, which is human-readable.

An oxygen sensor in a car's emission control system detects the gasoline/oxygen ratio, usuallythrough a chemical reaction that generates a voltage. A computer in the engine reads the voltage and, if the mixture is not optimal, readjusts the balance.

Motion sensors in various systems including home security lights, automatic doors and bathroom fixtures typically send out some type of energy, such as microwaves, ultrasonic waves or light beams and detect when the flow of energy is interrupted by

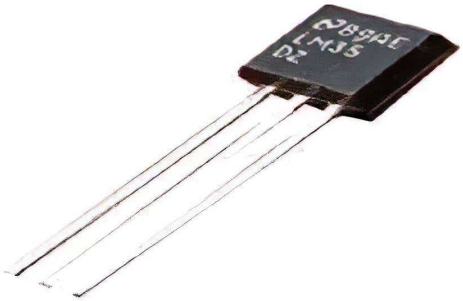
something entering its path.

A photo sensor detects the presence of visible light, infrared transmission (IR), and/or ultraviolet (UV) energy.

3.2 Types of sensors and its usage

1. 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.



LM35 - Temperature Sensor IC

10KΩ NTC Thermistor

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 changesin the Temperature correspond to change in its physical property like resistance or voltage. LM35 is a classic Analog Temperature Sensor.

Coming to the Digital Temperature Sensor, the output is a discrete digital value (usually, somenumerical data after converting analog value to digital value). DS18B20 is a simple Digital Temperature Sensor.

Temperature Sensors are used everywhere like computers, mobile phones, automobiles, air conditioning systems, industries etc.

A simple project using LM35 (Celsius Scale Temperature Sensor) is implemented in this project: TEMPERATURE CONTROLLED SYSTEM.

2. Humidity Sensor

If you see Weather Monitoring Systems, they often provide temperature as well as humiditydata. So, measuring humidity is an important task in many applications and Humidity Sensorshelp us in achieving this.

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

Humidity Sensors are classified into Capacitive Type, Resistive Type and Thermal Conductive Type. DHT11 and DHT22 are two of the frequently used Humidity Sensors in DIY Community (the former is a resistive type while the latter is capacitive type).

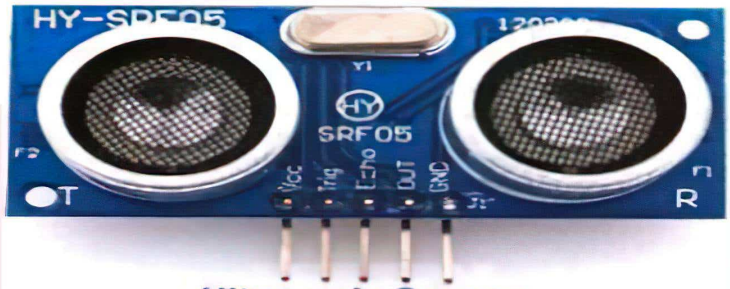
3. Gas Detector Sensor

A gas detector is a device that detects the presence of gases in an area, often as part of a safety system. A gas detector can sound an alarm to operators in the area where the leak is occurring, giving them the opportunity to leave. This type of device is important because there are many gases that can be harmful to organic life, such as humans or animals.

Gas detectors can be used to detect combustible, flammable and toxic gases, and oxygen depletion. This type of device is used widely in industry and can be found in locations, such as on oil rigs, to monitor manufacturing processes and emerging technologies such as photovoltaic. They may be used in firefighting.

4. Ultrasonic Sensor

Ultrasonic sensors are used to measure distance or travel time using ultrasonic waves. A source will be used to emit ultrasonic wave. After wave hits the target, the waves are reflectedand the detector collects the signal. The travel time between the transmitted wave and reflected wave is measured using Ultrasonic sensor. Optical sensors use two different element for transmitter and receiver. Whereas ultrasonic sensor uses single element for transmission and reception.



Ultrasonic Sensor

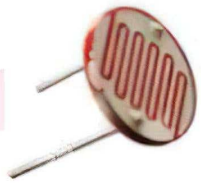
5. Fire detector Sensor

Fire-detection systems play a pivotal role in green buildings. Kate Houghton, director of marketing for Kidde Fire Systems says, By detecting a fire quickly and accurately (i.e., by not sacrificing speed or causing false alarms)and providing early warning notification, a fire-detection system can limit the emission of toxic products created by combustion, as well as global-warming gases produced by the fire itself. These environmental effects often are overlooked, but undoubtedly occur in all fire Scenarios. Therefore, reducing the likelihood of a fire is an important part of designing a greenbuilding.

6. Light Sensor

Sometimes also known as Photo Sensors, Light Sensors are one of the important sensors. 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 vise-versa.

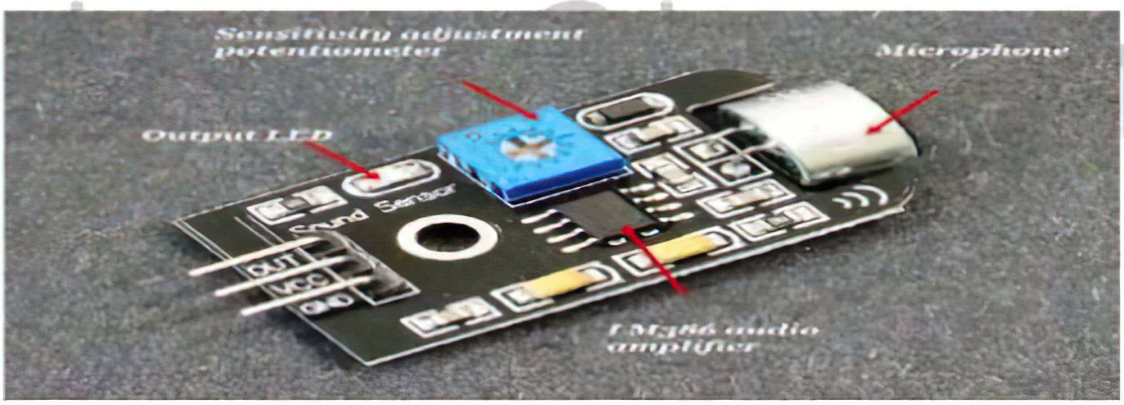
By using LDR is a circuit, we can calibrate the changes in its resistance to measure the intensityof Light. There are two other Light Sensors (or Photo Sensors) which are often used in complex electronic system design. They are Photo Diode and Photo Transistor. All these are Analog Sensors.



7. Sound Sensor

Sound is a waveform of energy which is produced by the form of mechanical vibration. The type of sound determines its frequency.

For example, a bass drum has a low-frequency sound and a cymbal has a higher frequencysound. The sound sensor is a simple device which can detect the sound. The sound sensors are very simple to use.



8. IR Sensor

When we look into electromagnetic spectrum, infrared region is divided into three regions asNear Infrared, mid Infrared and far Infrared region. Infrared spectrum has a higher frequencyrange than microwave and lesser frequency than visible light. An infrared sensor is used for emitting and detecting IR radiation. By this principle, IR sensor can be used as Obstacle detector. There are two types of IR sensors as Active and Passive IR sensors.

Passive IR sensor: When sensor does not use any IR source to detect the emitted energy fromthe obstacles it acts as a Passive IR sensor. Examples like thermocouple, pyro electric detectorand bolometers comes under passive sensors.

Active IR sensor: When are there two components which acts as IR source and IR detector itis called as Active sensor. LED or laser diode act as IR source. Photodiode or phototransistorsacts as IR detector.

IR Sensor (Infrared Sensor)

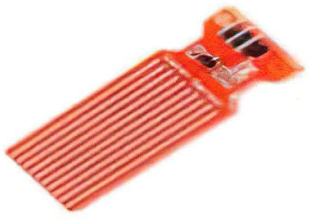
9. Water Level Sensor

The working of the water level sensor is pretty straight forward. The series of exposed parallel conductors, together acts as a variable resistor (just like a potentiometer) whose resistance varies according to the water level.

The change in resistance corresponds to the distance from the top of the sensor tothe surface of the water.

The resistance is inversely proportional to the height of the water.

The more water the sensor is immersed in, results in better conductivity and willresult in a lower resistance. less water the sensor is immersed in, results in poor conductivity and



will resultin higher resistance. The sensor produces an output voltage according to the resistance, which bymeasuring we can determine the water level.

3.3 Introduction to Actuators

Actuators are basically the muscle behind a mechatronics system that accepts a control command (mostly in the form of an electrical signal) and produces a change in the physical system by generating force, motion, heat, flow, etc.

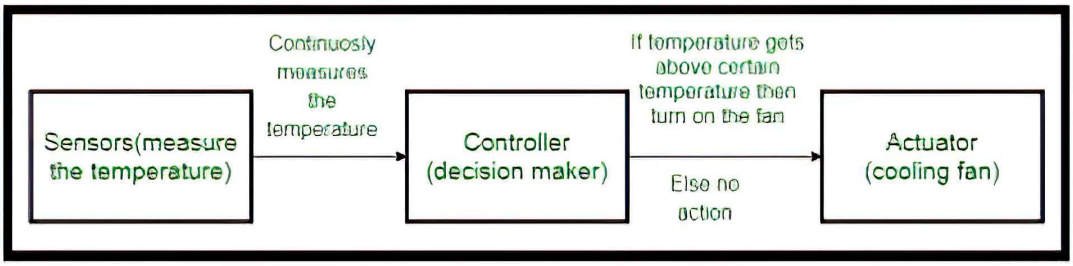
An actuator is a component of a machine that is responsible for moving or controlling a mechanism or system. Normally, the actuators are used in conjunction with the power supplyand a coupling mechanism.

An actuator requires a control signal and a source of energy. The control signal is relatively low energy: Electrical (voltage/current), Pneumatic Pressure, Hydraulic Pressure, Human power, etc. When the control signal is received, the actuator responds by converting the energy into mechanical motion. Typical mechanisms include rack and pinion, gear drive, beltdrive, lead screw and nut, piston, and linkages.

An IoT device is made up of a Physical object ("thing") + Controller ("brain") + Sensors + Actuators + Networks (Internet). An actuator is a machine component or system that moves or controls the mechanism or the system. Sensors in the device sense the environment, thencontrol signals are generated for the actuators according to the actions needed to perform.

A servo motor is an example of an actuator. They are linear or rotatory actuators, can move to a given specified angular or linear position. We can use servo motors for IoT applications and make the motor rotate to 90 degrees, 180 degrees, etc., as per our need.

The following diagram shows what actuators do, the controller directs the actuator based onthe sensor data to do the work.



The control system acts upon an environment through the actuator. It requires a source of energy and a control signal. When it receives a control signal, it converts the source of energyto a mechanical operation.

Functions of actuation:

1. Transformation of rotary motion into a translating motion as in the case of the cam and follower mechanism where the rotational motion of the cam is changed into the translationalmovement of the follower.

2. Transformation of rotary motion for a long distance which is not possible by using gears, asin the case of belt drives.

3. Transformation of rotary motion for a medium distance without slipping which is not possible by using belt drives, as in the case of belt drives.

4. Transformation of linear motion into rotational motion as in the case of rack and pinion mechanism.

5. Locking of rotating elements as in the case of ratchet and pawl mechanism.

3.4 Different Types of Actuators

1. **Pneumatic Actuators**: Pneumatic actuators convert energy in the form of compressed air into mechanical motion. Here pressurised gas or compressed air enters a chamber thus building up the pressure inside. Once this pressure goes above the required pressure levels in contrast to the atmospheric pressure outside the chamber, it makes the piston or gear move kinetically in a controlled manner, thus leading to a straight or circular mechanical motion. Examples include pneumatic cylinders, air cylinders, and air actuators. Cheaper and often more powerful than other actuators, they can quickly startor stop as no power source has to be stored in reserve for operation. Often used with valves to control the flow of air through the valve, these actuators generate considerableforce through relatively small pressure changes.

   Examples of maker projects using pneumatic actuators include lifting

devices andhumanoid robots with arms and limbs, typically used for lifting.

Advantages:

The simple design of the actuator makes it popular, and perfect for application wherecleanliness is a must.

- There is a minimal risk of contamination from the power supply because these actuators are gas-driven.
- These actuators feature no motors, which means no magnetic interference is createdat high temperatures. This makes the actuator ideal for applications involving high temperatures.
- These actuators require almost no maintenance, are lightweight, and equipped with durable components. All these help lower their costs of operation.
- Pneumatic actuators are suited for applications, where regular closing and the opening is required.

Disadvantages:

- Compressibility and pressure losses are two factors that make these actuators imperfect for various key linear motion applications
- At times, it is very difficult to achieve positional accuracy with these actuators, whichis one of the largest drawbacks.
- Noise generated by these actuators is large, which makes them incapable of applications where silence is required.

2. **Hydraulic Actuators**: Hydraulic actuators have a cylinder or fluid motor that uses hydraulic power to generate mechanical motion, which in turn leads to linear, rotatory oroscillatory motion. Given the fact that liquids are nearly impossible to compress, a hydraulic actuator can exert a large force. When the fluid enters the lower chamber of theactuator's hydraulic cylinder, pressure inside increases and exerts a force on the bottom of the piston, also inside the cylinder. The pressure causes the sliding piston to move in adirection opposite to the force caused by the spring in the upper chamber, making the piston move upward and opening the valve. The downside with these actuators is the need for many complementary parts and possibility of fluid leakage.

Advantages:

- These actuators offer high horsepower than the pneumatic actuators.
- The small and compact construction of these actuators makes them perfect for manyminiature devices of the day.

Disadvantages:

- In some cases, the fluid may leak that will lead to huge losses. More to this, these fluid leaks will also cause cleanliness problems, and damage their surrounding components.
- These actuators require too many companion parts, such as heat exchangers, motors, pump and more. This increases user maintenance throughout the lifetime of the actuator.
- Midstroke positioning is difficult to achieve with these actuators, and it requires lots of user support, as well as additional components.

3. **Electrical Actuators:** Electrical actuators are equipped with a motor. The rotational energy of the motor is converted into the linear movement of a device. This actuator possesses high positioning capabilities owing to electronic controllers fitted within. Thesecapabilities along with velocity control are brilliantly exploited by various industries today. These actuators are easy to set up, and can be reprogrammed quickly, and offer an immediate response. Electric actuators offer a wide range of motion profiles, owing to their versatile designs.

Advantages:

- These actuators require almost no maintenance, except for the replacement of wornparts.
- They do not leak fluids, so there are no cleanliness issues, also the environmentalhazards are eliminated.

Disadvantages:

- The purchasing cost of these actuators is considerably high than the other two types,but their operating and maintenance costs are low.
- They are not suitable for hazardous and flammable areas.

Other actuators are–Thermal Actuators-

A thermal actuator is a non-electric motor that generates linear motion in response to temperature changes. Its main components are a piston and a thermal sensitive material. When there is a rise in temperature, the thermal-sensitive materials begin to expand in response, driving the piston out of the actuator. Similarly, upon detecting a drop in the temperature, the thermal-sensitive materials inside contract, making the piston retract. Thus these actuators can be used for carrying out tasks such as releasing latches, working switches and opening or closing valves. They have many applications, particularly in the aerospace, automotive, agricultural and solar industries.

Magnetic Actuators –

Magnetic actuators are those that use magnetic effects to produce motion of a part in the actuator. They usually come in the following categories: moving coil actuator, moving magnetactuator, moving iron actuator and electromagnetic actuator.

In case of the first kind (moving coil actuator), a mobile coil driven by a current is placed in a static magnetic field, where it is subject to the Lorentz force. This force is proportional to theapplied current.

Moving magnet actuators work differently; here mobile permanent magnet is placed between two magnet poles and is switched from one pole to the other using coils. Such actuators can generate high forces but are not easily controlled.

In moving iron actuators, a soft magnetic part placed into a coil system moves in a fashion that keeps the system magnetic energy to a minimum.

Mechanical Actuators –

Mechanical actuators create movement by converting one kind of motion, such as rotarymotion, into another kind, such as linear motion. Say for instance, a rack and a pinion.

Another example is that of a chain block hoisting weight where the mechanical motion of the chain is used to lift a load. The functioning of mechanical actuators relies on the combinations of their structural components, such as gears and rails, or pulleys and chains. High reliability, simplicity of utilisation, easier maintenance and greater

precision of positioning are some of the advantages. They can be categorised into hydraulic, pneumaticand electric actuators.

Example – A crankshaft.

- Soft Actuators
- Shape Memory Polymers
- Light Activated Polymers
- With the expanding world of IoT, sensors and actuators will find more usage in commercial and domestic applications along with the pre-existing use in industry

3.5 Difference between Sensors & Actuators

Sensors	Actuators
It converts physical characteristics into Electrical signals.	It converts electrical signals into physical Characteristics.
It takes input from environment.	It takes input from output conditioning Unit of system.
It gives output to input conditioning unit of System.	It gives output to environment.
Sensor generated electrical signals.	Actuator generates heat or motion.
It is placed at input port of the system.	It is placed at output port of the system.
It is used to measure the physical quantity.	It is used to measure the continuous and Discrete process parameters.
It gives information to the system about Environment.	It accepts command to perform a function.
Examples: Magnetometer, Cameras, Accelerometer, microphones.	Examples: LED, Laser, Loudspeaker, Solenoid, motor controllers.

Short Questions:

1. What is Active IR Sensor?
2. What is Passive IR Sensor?
3. Definition of Sensor.
4. What is Actuator?
5. What is Thermal Actuator?
6. What is Ultrasonic Sensor?
7. Define: Light Sensor
8. Define: IR Sensor

Long Questions:

1. List out Types of Sensors. Explain in Detail.
2. Explain Types of Actuators in detail.
3. Difference between Sensors & Actuators.

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