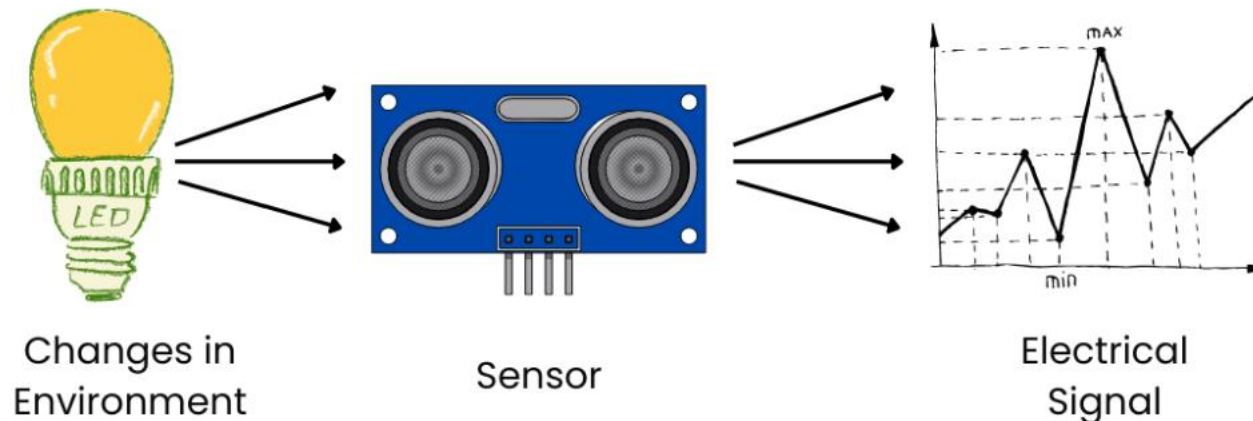


# Sensors

# What are Sensors?

- ❖ Sensor is a device that produces an output signal for the purpose of sensing of a physical phenomenon. This signal must be produced by some type of energy, such as heat, light, motion, or chemical reaction.
- ❖ One of the best-known sensors is the microphone, which converts sound energy to an electrical signal that can be amplified, transmitted, recorded, and reproduced.



## Cont...

- ❖ Mercury thermometer is a very old type of sensor used for measuring temperature.
- ❖ Touch sensor: Detecting and recording physical touch used in Mobile phones, monitor screens, control panels, etc.
- ❖ Sensors are widely used in various applications including automation, healthcare, and environmental monitoring.

A good sensor obeys the following rules

- It is sensitive to the measured property
- It is insensitive to any other property likely to be encountered in its application, and
- It does not influence the measured property.

# Basic Sensor Types

- Thermal Sensors
  - Motion Sensors
  - Gas Sensors
  - Smart Sensors
- 
- Each type detects specific phenomena using different principles and mechanisms.
  - Understanding their operation helps in selecting the right sensor for a given application

# Thermal Sensors

- ❖ Thermal sensors are devices that detect temperature changes in their environment. In a Temperature Sensor, the temperature changes correspond to changes in its physical properties, such as resistance or voltage.
- ❖ Thermal sensors detect temperature changes and heat flow.
- ❖ They are widely used in various industries including healthcare, automotive, and electronics.
- ❖ Also used in applications like climate control and industrial processes.
- ❖ These sensors operate based on the material's response to temperature variations.



# Working principle of Thermal Sensors

**Operating principle:** Based on the **Seebeck Effect** – a voltage is generated when two dissimilar metals are joined at two points with different temperatures.

- ❖ **Energy Conversion:** Thermal sensors convert thermal energy into a measurable electrical signal (voltage or resistance).
- ❖ **Signal Measurement:** A suitable electronic circuit or device then measures the generated electrical signal.
- ❖ **Data Interpretation:** The measured electrical signal is correlated with a temperature value, often through calibration or using a known relationship between the signal and temperature.

# Types of Thermal Sensors

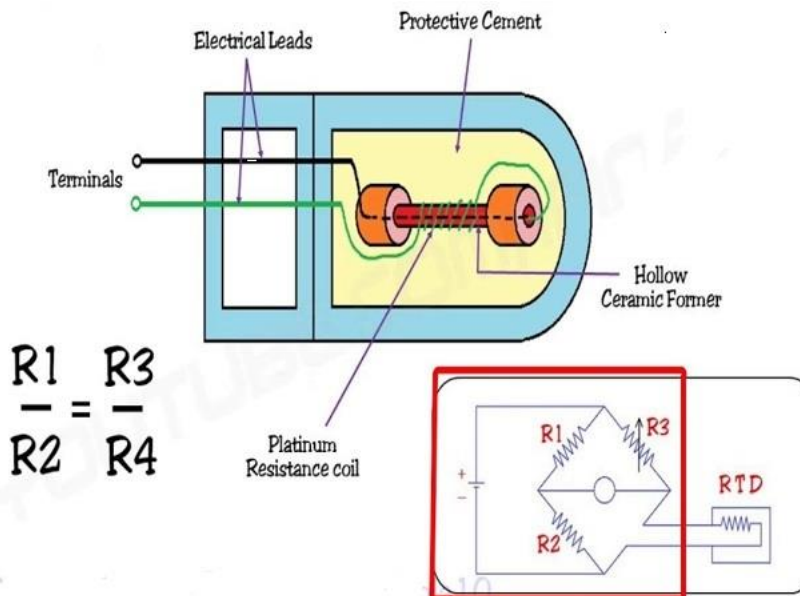
- **RTDs (Resistance Temperature Detectors):** Based on resistance changes in pure metals
- **Thermocouples:** Junction of two different metals
- **Thermistors:** Semiconductor-based temperature detection
- **Infrared sensors:** Non-contact temperature measurement

# Applications of Thermal Sensors

- HVAC Systems: Thermal sensors are crucial components in heating, ventilation, and air conditioning systems for maintaining comfortable indoor temperatures.
- Industrial Processes: They are used in industrial processes such as manufacturing, chemical processing, and food production to monitor and control temperature for quality control and process optimization.
- Medical Devices: Thermal sensors are employed in medical devices such as thermometers, incubators, and medical imaging equipment for patient monitoring and diagnosis.
- Automotive: In vehicles, temperature sensors are utilized for engine temperature monitoring, climate control systems, and cabin comfort control.

# RTDs (Resistance Temperature Detectors)

- An RTD is a temperature sensor that uses the principle of resistance change with temperature.
- It consists of a metal wire, usually platinum, whose resistance increases with increasing temperature and vice versa.
- RTDs are accurate and stable, and they have a wide temperature range.
- RTD devices commonly use metals like Copper, Nickel, and Platinum. Each metal has unique resistance changes that correspond to temperature variations, known as resistance-temperature characteristics.



# Working Principle of RTD

- RTD Sensor works on this basic principle that the resistance of a metal changes with changes in temperature.. The value of resistance measured in ohms and equivalent temperature can be converted based on this resistance value.
- The temperature coefficient of the RTD sensor is the average changes of resistance over the temperature range 0 °C to 100 °C and normally denoted by the  $\alpha_0$ .
- $\alpha_0 = (R_{100} - R_0) / (R_0 \times 100)$
- Where  $R_{100}$  = Resistance at 100 °C (ohm)
- $R_0$  = Resistance at 0 °C (ohm)
- As per the above equation relationship between temperature and resistance may be expressed as,
- $R_t = R_0 (1 + \alpha_0 t)$
- Where  $R_t$  = Resistance of RTD sensor at temperature  $t$  °C (ohm)
- $R_0$  = Resistance at 0 °C (ohm)
- $\alpha_0$  = Temperature coefficient of RTD sensor at 0 °C

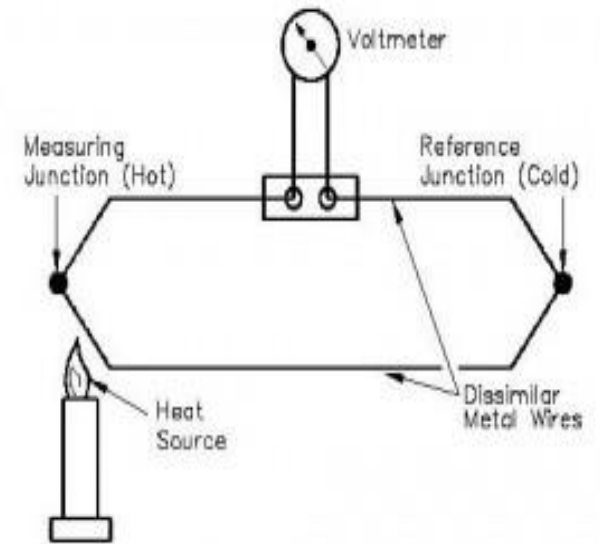
# Thermocouple Sensor

- Thermocouples are made of two dissimilar metals joined at one end. They generate a voltage proportional to the temperature difference between the ends. They are versatile and used in a wide temperature range.
- They are simple, durable, and suitable for high-temperature measurements.
- Commonly used in industrial processes and temperature monitoring systems.
- Thermocouples are known for their wide temperature range and durability.



# Thermocouple Sensors – Operation and Working Principle

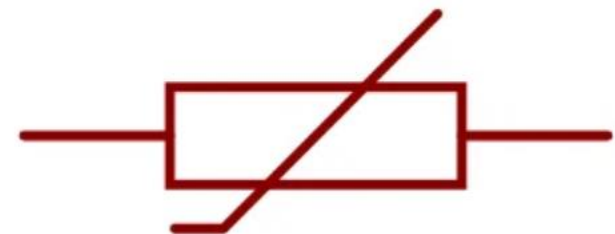
- ❖ The operation of thermocouples is based on the **Seebeck effect**: when two different conducting metals are in contact, an electric potential difference is generated, which is proportional to the temperature one between the two junction points.
- ❖ Specifically, a thermocouple consists of two metallic wires of different materials, soldered together at one end (known as the hot junction), while the other end (the cold junction) is maintained at a known reference temperature. The temperature difference between the junctions then generates a small current flow on the order of microvolts.
- ❖ This voltage is measured and correlated to the temperature using a voltmeter connected to the thermocouple circuit, providing a precise electromotive force reading.



# Thermistor Sensor

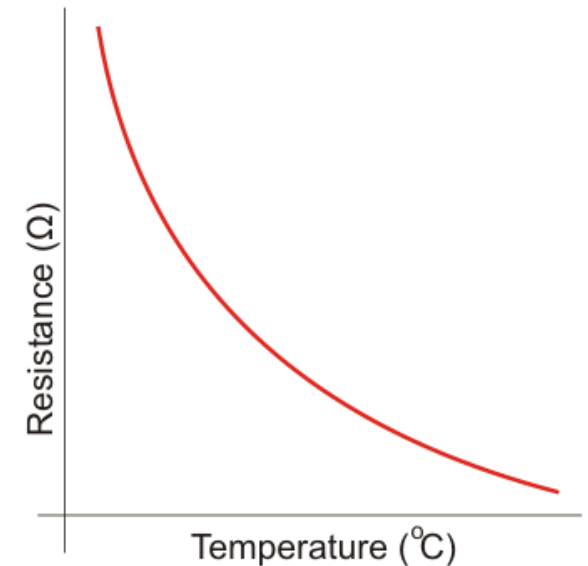
- A thermistor (or thermal resistor) is defined as a type of resistor whose electrical resistance varies with temperature changes. Although all resistors' resistance will fluctuate slightly with temperature, a thermistor is particularly sensitive to temperature changes.
- A thermistor is similar to an RTD, but a semiconductor material is used instead of a metal. A thermistor is a solid-state device and has a larger sensitivity than an RTD. Unlike RTDs, the temperature-resistance characteristic of a thermistor is non-linear and cannot be characterised by a single coefficient. Furthermore, unlike RTDs, the resistance of a thermistor decreases with increasing temperature.

Thermistor



# Thermistor Sensor- Working Principle

- The working principle of a thermistor is that its resistance is dependent on its temperature. The resistance of a thermistor can be measured using an ohmmeter.
- By understanding how temperature changes affect a thermistor's resistance, we can measure its resistance to determine the temperature. How much the resistance changes depends on the type of material used in the thermistor.
- The relationship between a thermistor's temperature and resistance is non-linear.



# Types of thermistor

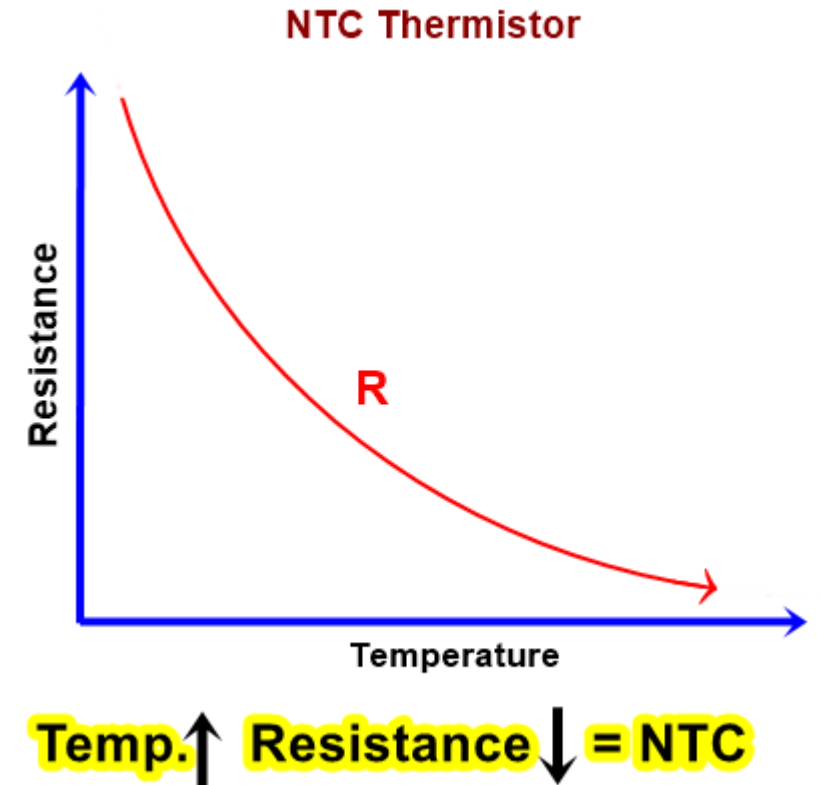
There are 2 types of thermistor

- NTC

- PTC

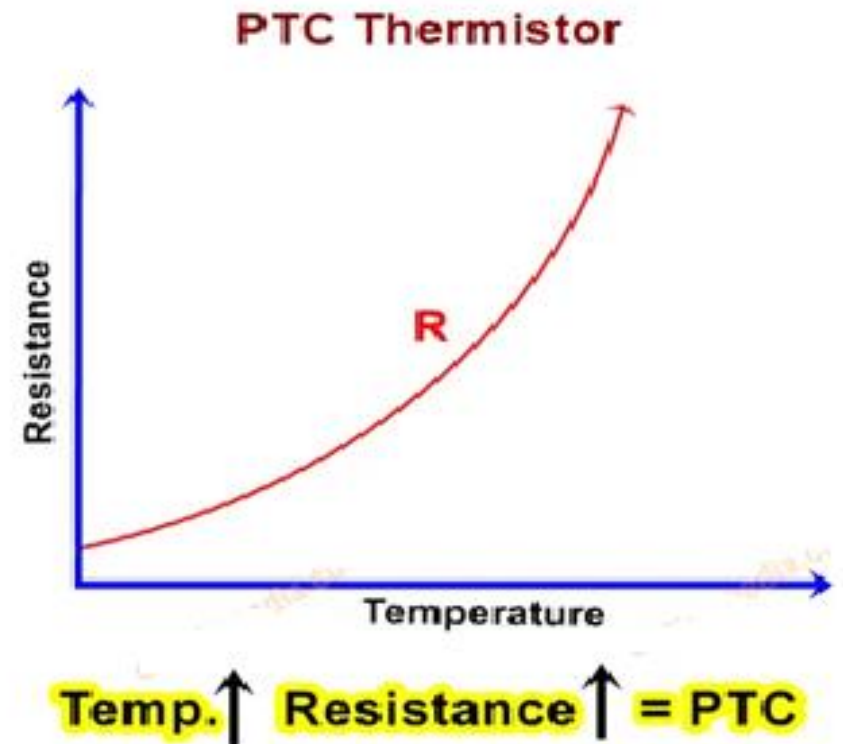
❖ **NTC- Negative temperature coefficient** –In an NTC thermistor, resistance decreases as temperature increases, and vice versa. This inverse relationship makes NTC thermistors the most common type.

The resistance of the NTC thermistor is inversely proportional to its temperature ( $T \propto 1/R$ ).



# PTC- Positive temperature coefficient

- A PTC thermistor has the reverse relationship between temperature and resistance. When temperature increases, the resistance increases.
- And when temperature decreases, resistance decreases. Hence in a PTC thermistor temperature and resistance are inversely proportional. ( $T \propto R$ )
- Although PTC thermistors are not as common as NTC thermistors, they are frequently used as a form of circuit protection. Similar to the function of fuses, PTC thermistors can act as current-limiting device



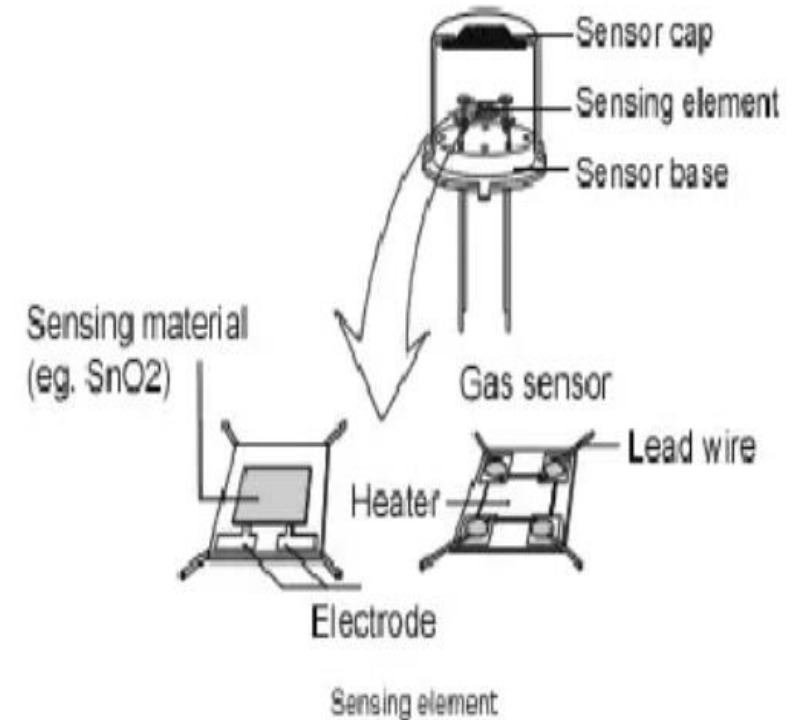
# Gas sensors

- Gas sensors are electronic devices that detect and identify different types of gases.
- They are commonly used to detect toxic or explosive gases and measure gas concentration.
- Gas sensors are employed in factories and manufacturing facilities to identify gas leaks and to detect smoke and carbon monoxide in homes.
- They are crucial in environmental monitoring, safety, and industrial processes.
- These sensors can detect gases like carbon monoxide, methane, and volatile organic compounds.
- They are widely used in applications ranging from leak detection to environmental monitoring.



# Gas sensors- Operation and Working principle

- **The** Gas sensor works on the principle of detecting changes in electrical conductivity or resistance in response to the presence of a specific gas.
- Gas sensors work by detecting the presence and concentration of specific gases, converting these interactions into measurable electrical signals. Common types include semiconductor sensors, electrochemical sensors, and catalytic sensors, each utilizing different principles to achieve gas detection.
- Gas sensors also require a sample and a receptor to acquire and analyse measurements; in semiconductor gas sensors, gas interacts with the metal oxide surface and the subsequent analysis is made on the basis of whether that gas is reduced or oxidised.



# Gas Sensors: Applications

- **Environmental Monitoring**

Gas sensors are vital for monitoring air quality in indoor and outdoor environments. They detect harmful gases such as carbon monoxide, nitrogen dioxide, ozone, and volatile organic compounds (VOCs), ensuring a safe and healthy living and working environment.

- **Industrial Safety**

Gas sensors are indispensable for worker safety in industries where hazardous gases are present. They detect toxic and combustible gases, providing early warnings to prevent accidents or exposure to harmful substances.

- **Automotive Industry**

Gas sensors are integrated into vehicles to monitor emissions and comply with environmental regulations. They measure gases like carbon monoxide, nitrogen oxides, and hydrocarbons, contributing to improved fuel efficiency and reduced pollution.

## Cont...

- **Leak Detection**

Gas sensors are extensively used to detect leaks in various systems, including natural gas pipelines, refrigeration systems, and chemical plants. They help identify leaks promptly, preventing potential hazards and minimizing environmental impact.

- **Industrial Processes**

Gas sensors play a crucial role in controlling and optimizing industrial processes. They are used for monitoring gas concentrations during production, detecting gas leaks, and ensuring process efficiency and safety.

# Motion sensor

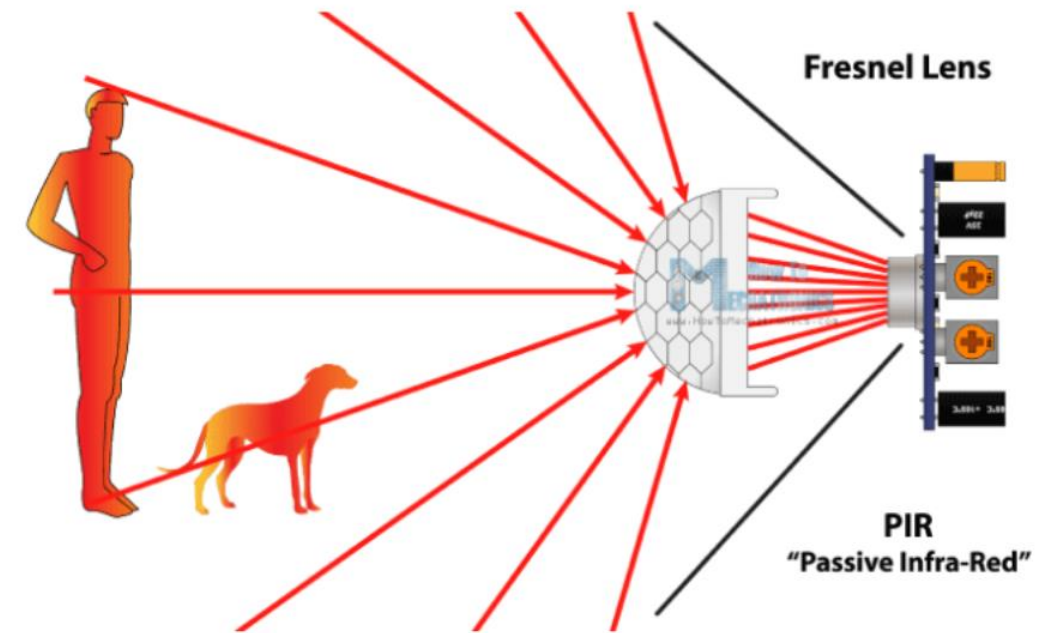
- A motion sensor is an electronic device that is designed to detect and measure movement within a specific area.
- They are commonly used in security systems, lighting automation, and occupancy detection
- These sensors can detect various types of motion, including body movement or object displacement.
- When a sensor detects motion, it will send an alert to your security system, and with newer systems, right to your mobile phone.
- Working Principle: Detect displacement, velocity, or acceleration using physical effects (piezoelectric, Doppler, capacitive sensing).
- .

# Motion sensors- Operation and Working principle

- ❖ Motion sensors typically detect movement using a pyroelectric sensor, a device that has two photoactive diode areas, to convert infrared light emanating from an object into an electrical charge. With a pair of pyroelectric sensors located next to each other, any changes in the signal differential between the two sensors (caused, for example, by a person entering a room) will cause the motion sensor itself to activate. This physical design, with a total of four photoactive diode areas, minimizes the number of possible false alarms that can be generated and improves both the accuracy and performance of the device.
- State-of-the-art motion sensors provide support for internet connectivity and can be flexibly integrated into the Internet of Things (IoT) software. This facilitates the integration of occupancy measurements with the output of other sensors (e.g., temperature sensors) and boosts building intelligence and management.
- ❖ The motion sensor works by detecting changes in infrared radiation or the presence of heat and movement within its coverage area. The most common type of motion sensor is a passive infrared (PIR) sensor, which detects changes in the infrared radiation emitted by objects in its field of view. When an object moves within the sensor's field of view and emits heat, the sensor registers the change and generates an electrical signal. This signal can then be used to trigger an alarm or activate other devices

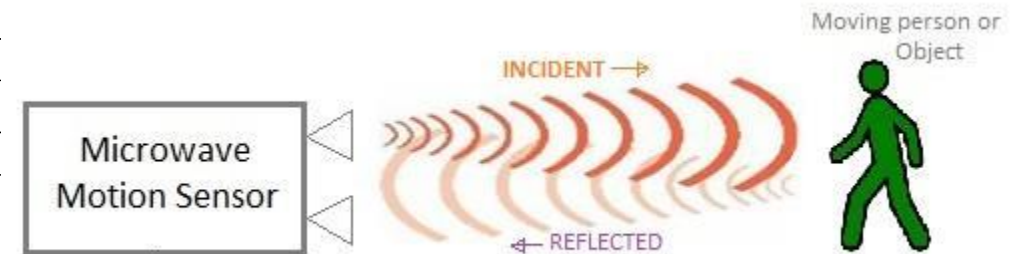
# Types of motion sensors

- ❖ **Passive Infrared (PIR) Sensor:** Detects body heat using infrared light.
- ❖ **Working Principle:** PIR sensors detect the infrared radiation emitted by humans or animals. They contain pyroelectric sensors that generate a voltage when exposed to IR radiation.
- Movement is sensed when a change in IR radiation levels occurs within the sensor's field of view.
- In the detection area, the PIR sensor's lens receives infrared radiation energy emitted by the human body, even through clothing. This energy is then focused on the pyroelectric sensor. When a human body moves within the sensor's field of view and subsequently exits, the pyroelectric sensor registers temperature changes, generating an alarm signal.



# Microwave Motion sensor

- Use the microwave Doppler effect for motion detection.
- Microwave sensors emit microwave signals and analyze reflections from objects. Movement causes a change in the reflected signal's frequency or phase. They can detect motion through walls and obstacles, making them highly versatile.
- This type of motion sensor transmits microwave frequencies and then receives the reflected signal. It detects motion by analyzing changes in the frequency or amplitude of the reflected microwave frequency.
- The coverage area of the motion sensor depends on the speed and size of the object or person, as well as the sensor's mounting height.
- Microwave motion sensors are known for their use in harsh environments. However, they can be prone to false alarms under certain conditions.

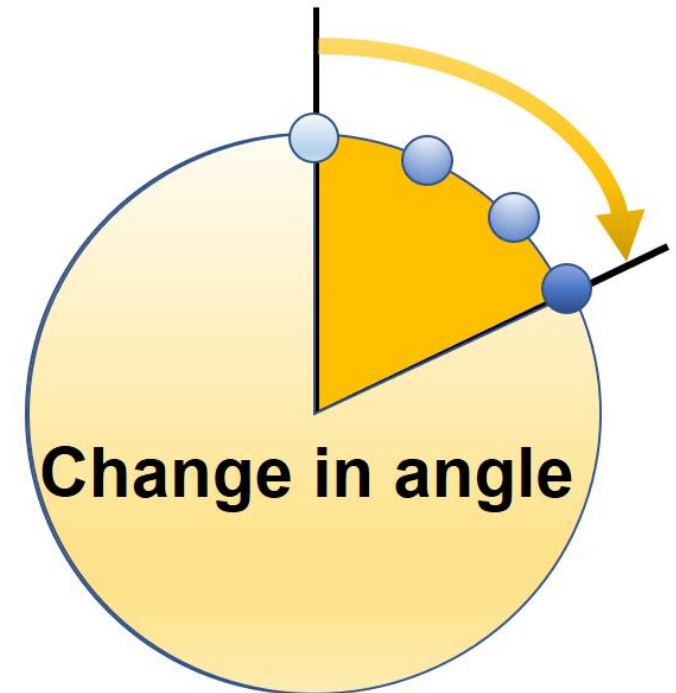


# Motion Sensors: Applications

- **Security** – In security systems, motion sensors are used to detect intruders and trigger alarms, helping to prevent theft or damage to property.
- **Automatic Doors** – In automatic doors, motion sensors are used to detect people approaching the door and opening it automatically, providing a convenient and accessible entrance.
- **Lighting Controls** – In lighting controls, motion sensors are used to turn on lights when someone enters a room and turn them off when the room is vacant, saving energy and reducing costs.
- **HVAC Systems** – In HVAC systems, motion sensors are used to detect occupancy and adjust temperature or ventilation accordingly, improving energy efficiency and reducing costs.

# Gyroscope Sensor

- A **Gyroscope Sensor** is a device that measures and maintains the orientation and angular velocity of an object.
- It is a more advanced sensor than the accelerometers and is used to measure the tilt and lateral orientation of the object, whereas the accelerometer can only measure linear motion. Moreover, this sensor measures the degree per second and is installed in the application where the orientation of the object is difficult to sense by humans.
- Gyro sensors are found in smartphones, digital cameras, game consoles, car navigation systems, robots, industrial equipment, and wherever else features such as vibration detection, camera shake correction, and attitude control are needed.



# Gyroscope Sensor-Working Principle

- A gyroscope sensor works on the principle of conservation of angular momentum.
- The working principle of a gyroscope is based on gravity. It is explained as the product of angular momentum, which is experienced by the torque on a disc to produce a gyroscopic precession in the spinning wheel.
- This process is termed gyroscopic motion or gyroscopic force and is defined as a rotating object's tendency to maintain its orientation.
- We know that the rotating object possesses angular momentum, which needs to be conserved. This is done because when there is any change in the axis of rotation, there will be a change in the orientation, which changes the angular momentum.

# Smart Sensors

- A smart sensor is a device that takes input from the physical environment and uses built-in compute resources to perform predefined functions upon detection of specific input and then processes data before passing it on.
- They offer improved accuracy and reliability.
- They often include microprocessors, memory, and connectivity modules.
- Smart sensors enable real-time decision-making and integration in IoT systems.

# Smart sensor: Operation and Working Principle

- A smart sensor detects a physical parameter (like temperature, motion, or gas) and converts it into an electrical signal. The built-in microcontroller processes this signal to extract meaningful information or make decisions. The processed data is then communicated wirelessly or through wired systems to other devices or control units.
- These sensors have 4 main functions: measurement, configuration, verification & communication.
- **Measurements** are simply taken through detecting physical signals & changing them into electrical signals. So this will help in monitoring and measuring things like temperature, traffic, & industrial applications.
- **Configuration function** is a significant feature as it allows the smart sensor to detect position, otherwise installation errors
- **The verification** function has different uses, like nonstop supervision of sensor behavior, using a set of supervisory circuits or equipment executed within the sensor.
- Lastly, **the communication** feature allows the sensor to converse to the main microcontroller/ microprocessor.

# Types of smart sensors

- **Temperature sensors.** These monitor a component's temperature so a corrective action can be taken if the temperature gets too high or low. For example, in an industrial setting, a temperature sensor is used to ensure machinery doesn't overheat.
- These sensors are mainly used in medical devices, computers, automobiles, cooking appliances & other types of machinery.
- **Pressure sensors.** These are used to monitor the pressure of gases or fluids in a pipeline. A sudden drop in pressure might indicate a leak or a flow control system issue.



*Temperature Sensor*



*Pressure Sensor*

## Cont...

- **Infrared sensors.** These are used in thermal imaging cameras, and noncontact infrared thermometers are used for temperature monitoring. Other infrared sensors are optical sensors tuned to a frequency that helps them see light in the infrared spectrum. These sensors are used in medical equipment, such as pulse oximetry devices, and electronic devices designed for remote control operation.
- **Proximity sensors.** These are used to detect the location of a person or object in relation to the sensor. In retail environments, proximity sensors can track customer movements throughout the store.



*Infrared Sensor*



*Proximity Sensor*

# Smart Sensors: Applications

- Industrial applications
- Automotive
- Aerospace
- Defense
- Industrial
- Intelligent house
- Medical
- Environmental monitoring
- Flood and water level monitoring system
- Transport
- Traffic monitoring and controlling
- Precision agriculture and animal tracking

# Emerging Trends in Electronics

- **Miniaturization**

Through improvements in nanotechnology, the size of the sensors has been minimised and made to provide sophisticated results for devices such as wearable devices and smartphones.

- **Wireless Sensor Networks (WSN)**

Wireless connectivity is transforming sensors, enabling seamless integration into IoT systems for remote monitoring and data collection.

- **AI-Driven Sensors**

AI improves sensors' reliability and optimizes their performance since AI can predict and adjust the operation of a sensor.

- **Energy Harvesting Sensors**

These sensors obtain their power from light, heat, mechanical movement, etc, making it possible for deployment in remote and long-term use.

- **Multi-Sensor Integration**

This increases the functionality and reliability of multiple sensors as seen in automobiles and robotics.

THANK YOU