Microcontrollers and Embedded Systems

Unit IV: **SENSORS**

Symbiosis Institute of Technology, Nagpur

Sensors:

Introduction to Sensors, Temperature Sensor (LM35), Light/LDR Sensor, Level Sensor, IR Sensor, Ultrasonic Sensor, Motion Detection Sensors/PIR, Gas sensors, Humidity Sensors (DHT 11), Case studies using sensors

Introduction to Sensors

A **sensor** is a device that detects and responds to physical, chemical, or biological conditions in its environment. It converts these changes into signals that can be measured, recorded, or analyzed. Sensors are widely used in various applications, including industrial automation, healthcare, consumer electronics, and environmental monitoring.

Types of Sensors

Sensors can be categorized based on the type of physical quantity they measure:

Temperature Sensors – Measure temperature changes (e.g., thermocouples, thermistors, infrared sensors).

Pressure Sensors – Detect pressure variations (e.g., barometers, piezoelectric sensors).

Motion Sensors – Identify movement (e.g., accelerometers, gyroscopes, PIR sensors).

Proximity Sensors – Sense the presence of objects without direct contact (e.g., ultrasonic, capacitive, inductive sensors).

Light Sensors – Measure light intensity (e.g., photodiodes, LDRs, infrared sensors).

Gas Sensors – Detect gases in the environment (e.g., CO2 sensors, methane sensors).

Biosensors – Monitor biological parameters (e.g., glucose sensors, heart rate sensors).

Working Principle of Sensors

Most sensors operate by detecting a change in an external stimulus (temperature, pressure, motion, etc.) and converting it into an electrical signal. This signal can then be processed, displayed, or used for automation and control.

For example:

A **thermistor** changes its resistance based on temperature.

A **photodiode** produces an electrical current when exposed to light.

A **pressure sensor** deforms under force, altering electrical properties.

Applications of Sensors

Automotive Industry – Sensors monitor fuel levels, speed, and engine temperature.
Healthcare – Wearable sensors track heart rate, blood pressure, and oxygen levels.
Consumer Electronics – Smartphones use sensors for screen brightness, touch recognition, and orientation.
Industrial Automation – Factories use sensors for robotics, safety, and process control.
Environmental Monitoring – Sensors detect air quality, humidity, and pollution levels.

Temperature Sensor (LM35)

The **LM35** is a widely used **temperature sensor** that provides an analog output directly proportional to the temperature in **Celsius (°C)**. It is known for its high accuracy, low power consumption, and easy interfacing with microcontrollers like **Arduino, Raspberry Pi, and PIC**.

Features of LM35

Direct Temperature Output: The LM35 provides an output voltage in **mV** that corresponds directly to temperature in **°C**.

High Accuracy: Typically ±0.5°C at room temperature.

Linear Output: The output voltage increases by **10mV per °C**.

Low Power Consumption: Requires very little current to operate.

Wide Temperature Range:

- **LM35**: −55°C to +150°C
- **LM35C**: −40°C to +110°C
- **LM35D**: 0°C to +100°C

Operates from 4V to 30V power supply.

Pin	Name	Description
1	VCC	Power supply (4V – 30V)
2	VOUT	Analog output voltage (10mV/°C)
3	GND	Ground

Working Principle

The **LM35** sensor works by generating a voltage output **proportional to temperature**. The formula to convert the voltage into temperature is:

T(°C)=VOUT/10mV

If **VOUT = 250mV**, the temperature is **25°C**.

If **VOUT = 750mV**, the temperature is **75°C**.

Applications of LM35

Weather Monitoring Systems

Industrial Temperature Monitoring

Medical Equipment

Home Automation (Smart Thermostats)

Overheating Protection for Electronics

Light Dependent Resistor (LDR) Sensor

A **Light Dependent Resistor (LDR)**, also known as a **photoresistor**, is a type of sensor that detects light intensity. It changes its resistance based on the amount of light falling on it. LDRs are widely used in **automatic lighting systems, light meters, and security applications**.

Features of LDR

✅ **Variable Resistance**: Resistance decreases with increasing light intensity.
✅ **Low Cost**: Affordable and easy to use in electronic projects.
✅ **No Polarity**: Can be connected in any direction.
✅ **Sensitive to Visible Light**: Mostly responsive to ambient light and artificial lighting.
✅ **Slow Response Time**: It takes some time to adjust to changing light levels.

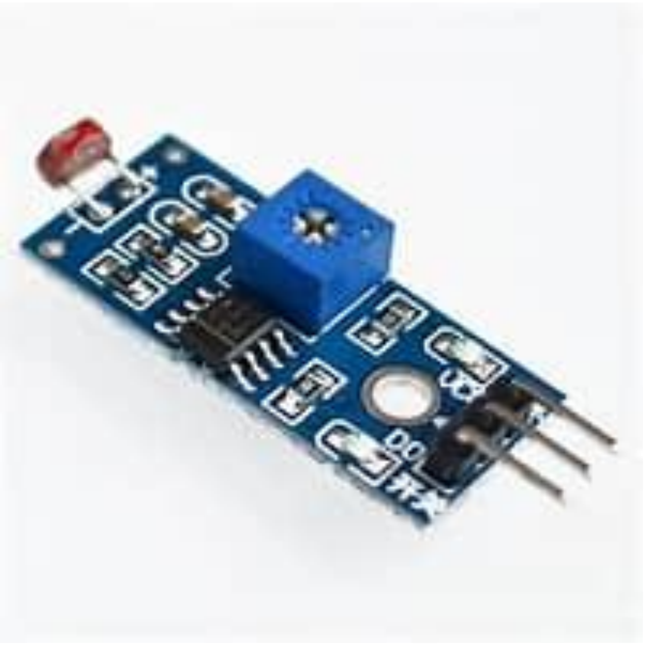
Working Principle of LDR

An **LDR works on the principle of photoconductivity**. When light falls on the **semiconductor material** of the LDR, it absorbs photons, exciting electrons and **reducing resistance**.

In darkness → High resistance (in the range of mega-ohms).

In bright light → Low resistance (a few hundred ohms).

This property makes it ideal for **automatic light control systems**.



Advantages of LDR Sensors

- ✅ Simple and easy to use
- ✅ Cost-effective for light detection applications
- ✅ Low power consumption
- ✅ No need for a separate power supply

Applications of LDR Sensors

✓ **Automatic Street Lights** – Lights turn ON in the dark and OFF in daylight.

✓ **Solar Tracking Systems** – Adjust solar panels based on sunlight.

✓ **Security Alarms** – Detect changes in light (e.g., laser tripwires).

✓ **Smart Homes** – Control indoor lighting based on ambient light.

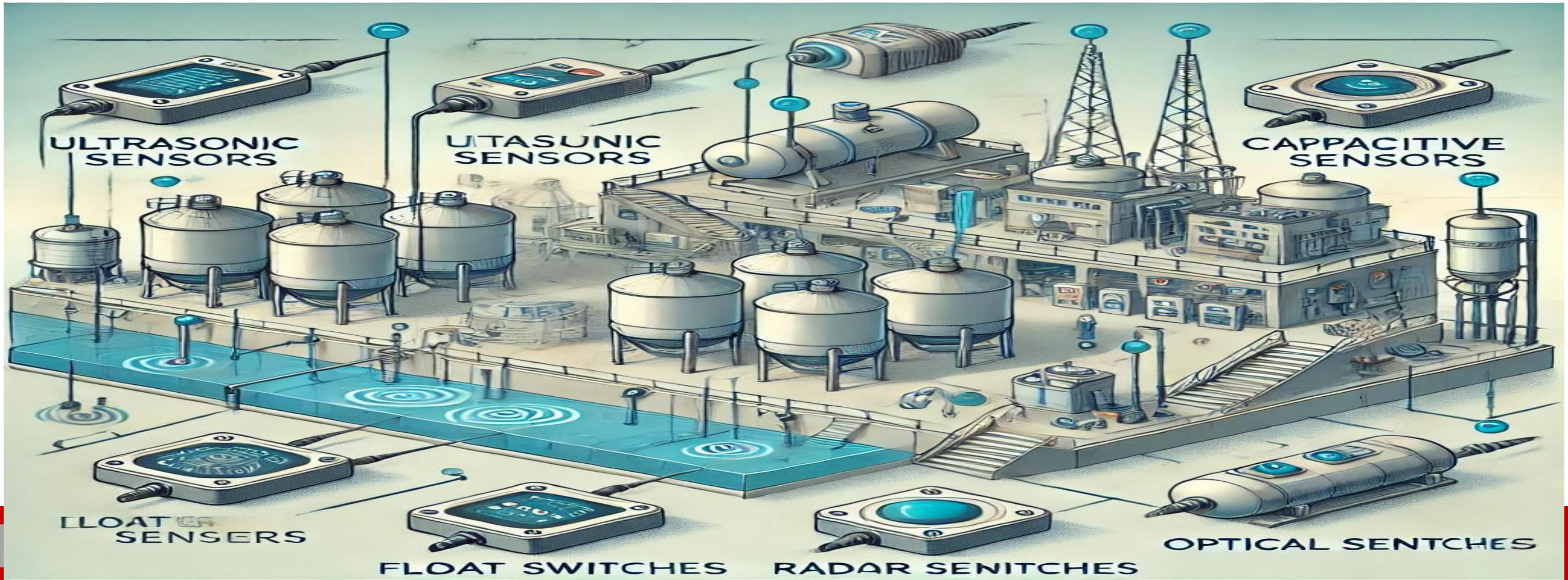
✓ **Photography** – Used in cameras for automatic exposure control

LDR Pin	Connection
One Side	**5V** (Arduino)
Other Side	**A0** (Analog Pin on Arduino) and **10kΩ Resistor to GND**

Level Sensors

Introduction to Level Sensor:

A **level sensor** is a device used to detect and measure the level of liquids, solids, or granular materials inside a container, tank, or open space. These sensors are commonly used in industries like manufacturing, oil and gas, water treatment, food and beverage, and pharmaceuticals.



Types of Level Sensors

Level sensors are broadly classified into two categories:

Contact Sensors (Directly touch the material being measured)

- **Float Switch** – Uses a floating mechanism to detect liquid levels.
- **Capacitive Sensor** – Measures changes in capacitance due to varying levels of material.
- **Resistive Tape** – Detects level changes through resistance variation.
- **Conductive Sensor** – Uses electrical conductivity to determine liquid levels.
- **Hydrostatic Sensor** – Measures pressure to infer liquid level.

Non-Contact Sensors (Measure level without direct contact)

- **Ultrasonic Sensor** – Uses sound waves to measure distance from the sensor to the material.
- **Radar Sensor** – Utilizes radio waves for highly accurate level measurement.
- **Laser Sensor** – Employs laser beams to detect the level of liquid or solid surfaces.
- **Optical Sensor** – Uses light reflection or absorption to detect levels.

Working Principle of Level Sensor

A **Level Sensor** detects the level of a substance (liquid or solid) in a container. This can be done via various methods like float-based sensors, capacitive sensors, ultrasonic sensors, or conductive sensors.

Applications of Level Sensor

- Water tanks for water level monitoring.
- Chemical storage to prevent overflow.
- Fuel management in gas stations.

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IR Sensor

Introduction to IR Sensor:

An **Infrared (IR) Sensor** is an electronic device that uses infrared radiation (IR) to detect objects, measure distances, or monitor temperature changes. These sensors can either detect the presence of objects or measure how far away they are, depending on the type and setup. IR sensors operate based on the principle of emitting and detecting infrared light, which is invisible to the human eye but detectable by specific sensors.

IR sensors are widely used in a variety of applications, from object detection and proximity sensing to communication and temperature monitoring. Their versatility and ability to function in both active (emitting and detecting) and passive (detecting only) modes make them essential components in many systems.

Working Principle of IR Sensor (Infrared Sensor)

An **Infrared (IR) Sensor** is an electronic device that detects infrared radiation (IR) emitted or reflected by an object. It consists of an **IR transmitter (emitter)** and an **IR receiver (detector)**. The working principle of an IR sensor depends on the type of IR sensing method used—**active** or **passive**.

Active IR Sensor (Reflective/Transmissive)

Active IR sensors use both an **IR emitter (LED or laser diode)** and a **receiver (photodiode or phototransistor)**. They work by emitting infrared light and detecting its reflection from an object.

Working Steps:

The IR **transmitter** emits infrared radiation.

If an object is present, it reflects some of the IR radiation.

The **receiver** detects the reflected IR signal.

The sensor processes the detected signal and determines the presence, distance, or motion of the object.

📌 **Examples:** Proximity sensors, line-following robots, obstacle detection in automation.

Passive IR Sensor (PIR Sensor)

Passive IR sensors detect **infrared radiation emitted by objects**, usually human bodies, without emitting any IR rays themselves.

Working Steps:

Every object emits **infrared radiation** based on its temperature.

The PIR sensor consists of **pyroelectric materials** that generate electrical signals when exposed to infrared changes.

When a warm object (e.g., a human body) moves across the sensor's detection area, it **alters the IR levels**.

The sensor detects this change and triggers an output signal.

📌 **Examples:** Motion detectors for security systems, automatic lighting systems.

Applications of IR Sensor

Obstacle detection in robots
✅ Motion sensing in security alarms
✅ Night vision cameras
✅ Temperature measurement (IR thermometers)
✅ Industrial automation

Ultrasonic Sensor

Introduction to Ultrasonic Sensor:

An **Ultrasonic Sensor** is an electronic device that uses high-frequency sound waves (ultrasound) to measure distance, detect objects, or monitor the level of materials. These sensors are non-invasive and work by emitting ultrasonic waves, which bounce off surfaces and return to the sensor. The time it takes for the sound waves to return is measured and converted into distance or level data.

Ultrasonic sensors are widely used in various applications, including robotics, industrial automation, distance measurement, and level detection in tanks or bins. They are highly valued for their accuracy, reliability, and ability to operate in various environments, including those where optical sensors might fail (e.g., in dusty or dark conditions).

Working Principle Ultrasonic Sensor

An **Ultrasonic Sensor** emits high-frequency sound waves and measures the time taken for the sound waves to reflect back from the surface of the material. The distance to the material is calculated using the time delay and the speed of sound.

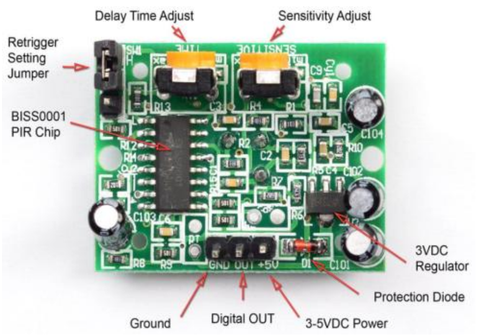
Applications of Ultrasonic Sensor

- **Distance measurement** in robotic navigation and autonomous vehicles.
- **Level measurement** for liquids or solids.
- **Object detection** in industrial environments.

Motion Detection Sensors/PIR

Introduction to Motion Detection Sensors/PIR:

A Motion Detection Sensor, commonly known as a PIR (Passive Infrared) Sensor, is an electronic device used to detect motion by measuring the infrared radiation (heat) emitted by objects in its field of view. PIR sensors are widely used in security systems, lighting control, and automated systems to detect the presence of humans or animals within a specified area. The term "passive" refers to the fact that these sensors do not emit any energy themselves. Instead, they passively detect infrared radiation emitted by warm bodies, typically humans or animals, within the sensor's detection range.



Working Principle of Motion Detection Sensors/PIR

A **PIR sensor** detects infrared radiation emitted by warm objects (e.g., humans or animals). The sensor consists of a pyroelectric sensor that detects changes in infrared light levels. When a moving body enters the detection area, the sensor detects the change and triggers an output.

Applications of Motion Detection Sensors/PIR

- **Security systems** for detecting motion in buildings.
- **Level measurement** for liquids or solids.
- **Home automation** for triggering alarms or events based on motion.

Gas sensors

Introduction to Gas sensors:

A Gas Sensor is a device designed to detect and measure the concentration of gases in the environment, particularly those that may pose a risk to health, safety, or the environment. These sensors are widely used in various applications, including industrial safety, environmental monitoring, home safety, and medical fields. Gas sensors work by detecting specific gases in the air, such as carbon dioxide (CO_2), carbon monoxide (CO), methane (CH_4), oxygen (O_2), and various volatile organic compounds (VOCs). Once the target gas is detected, the sensor typically outputs a corresponding electrical signal that can be interpreted by a microcontroller or monitoring system, triggering alarms or initiating corrective actions.

Working Principle of Gas sensors

A **Gas Sensor** detects the presence and concentration of gases in the environment. It works by sensing changes in the electrical conductivity of a material that reacts with specific gases (e.g., CO_2, CO, NH_3). This reaction leads to a change in the sensor's output signal.

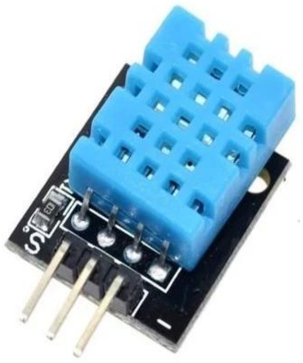
Applications of Gas sensors

- **Detecting hazardous gases** in industrial plants, mines, and labs.
- **Home safety** for detecting gas leaks (e.g., methane, propane).

Humidity Sensors (DHT 11)

Introduction to Humidity Sensors (DHT 11):

The **DHT11** is a popular and affordable humidity and temperature sensor often used in hobbyist projects, DIY electronics, and even professional applications where basic environmental data is needed. It's part of the DHT series of sensors, which also includes the DHT22, another widely used sensor that provides more accuracy and a wider range of measurements.



Working Principle of Humidity Sensors (DHT 11)

The **DHT11** is a digital humidity and temperature sensor. It works by measuring the change in the resistance of a sensing material as the humidity level changes. The sensor outputs a digital signal containing both the temperature and humidity data.

Applications of Humidity Sensors (DHT 11)

- **Weather stations** for monitoring environmental conditions.
- **Greenhouses** for controlling climate conditions.
- HVAC systems for humidity control.

Case studies using sensors

Here are some brief case studies where sensors were used effectively:

Smart Water Management:
In a city's water distribution system, **level sensors** and **ultrasonic sensors** are used to monitor tank levels and flow rates. Data collected is sent to a central system to automate water pumping and ensure optimal water levels, saving energy and preventing overflow.

Industrial Safety:
Gas sensors in a chemical factory detect dangerous gas concentrations, such as **ammonia** or **methane**, and immediately trigger alarms or activate ventilation systems to prevent explosions or toxic exposure.

Case studies using sensors

Smart Home Automation:
A home automation system uses **PIR sensors** for motion detection. When the system detects movement in a room, it triggers the lighting system to turn on automatically. Additionally, **humidity sensors** in the bathroom prevent mold growth by controlling ventilation based on humidity levels.