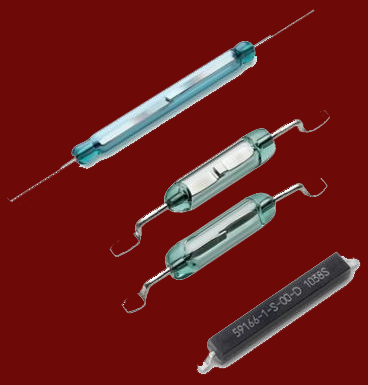
SENSORS FOR ENGINEERING APPLICATIONS



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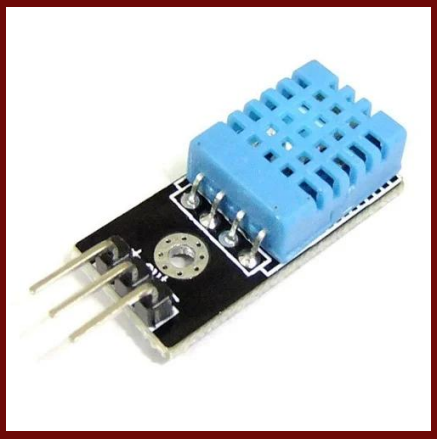
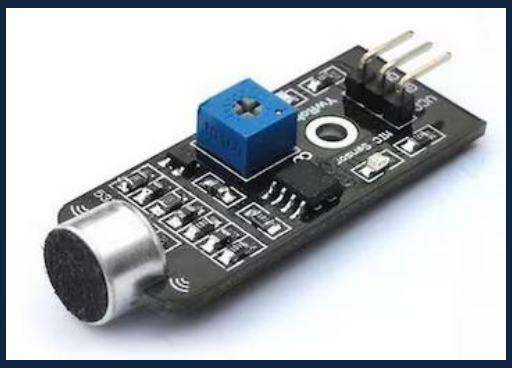
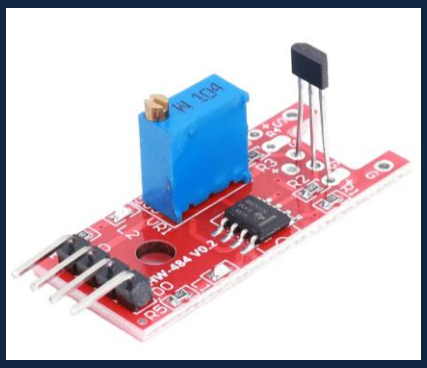
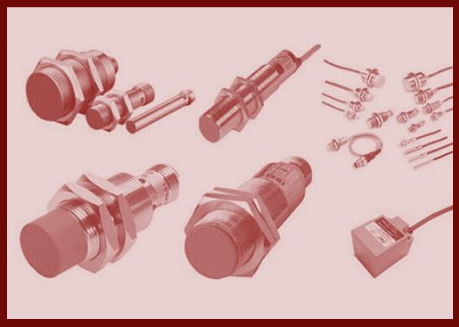


UNIT II
ELECTRONIC SENSORS







UNIT –II
ELECTRONIC SENSORS

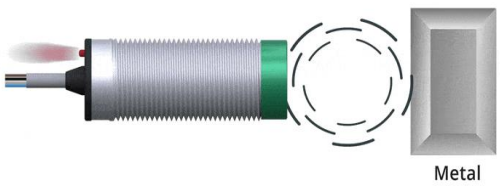
CONTENTS

1. Inductive, Capacitive and Ultrasonic based proximity sensors
2. Reed switch
3. Hall-effect switching sensors
4. Capacitive based humidity sensor
5. Liquid level detectors
6. Flow sensors
7. Smoke sensors

PROXIMITY SENSORS

A **Proximity sensors** detect objects without physical contact.
• Important in automation, robotics, and security systems.

A proximity sensor is device that detect the presence or absence of an object or its distance from the sensor—without making any physical contact.



- Detects the presence of an object without touching or contact
- No damage caused to the sensing object
- Does not use any type of Physical moving parts

Working Principle

Proximity sensors emit a signal—be it electromagnetic, optical, or acoustic—and monitor the changes in that signal when an object comes into its detection zone. The nature of the emitted signal depends on the sensor type:

Sensor Types

- Inductive
- Capacitive
- Ultrasonic

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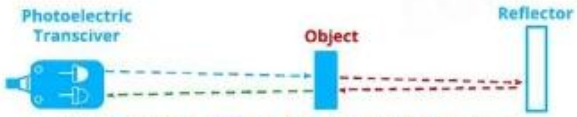
PROXIMITY SENSORS

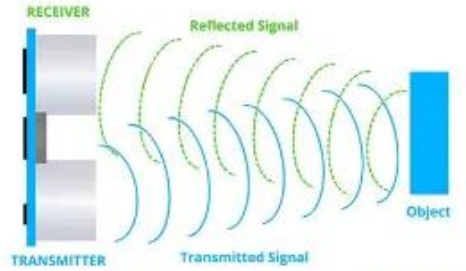
Types of Proximity Sensor

CAPACITIVE PROXIMITY SENSOR

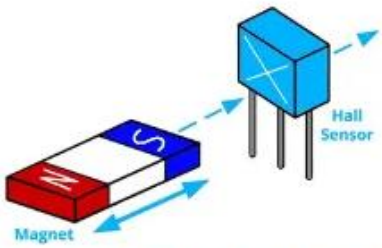
INDUCTIVE PROXIMITY SENSOR



PHOTOELECTIRC PROXIMITY SENSOR



ULTRASONIC PROXIMITY SENSOR



MAGNETIC PROXIMITY SENSOR

Proximity sensor comparison

Technology	Sensing range	Applications	Target materials
Inductive 	<4-40 mm	Any close-range detection of ferrous material	Iron Steel Aluminum Copper etc. 
Capacitative 	<3-60 mm	Close-range detection of non-ferrous material	Liquids Wood Granulates Plastic Glass etc. 
Photoelectric 	<1mm- 60 mm	Long-range, smalll or large target detection	Silicon Plastic Paper Metal etc. 
Ultrasonic 	<30 mm- 3 mm	Long-range detection of targets with difficult surface properites. Color/reflectivity insensitive.	Cellophane Foam Glass Liquid Powder etc. 

Inductive Proximity Sensors

Ultrasonic Proximity Sensor

Capacitive Proximity Sensor

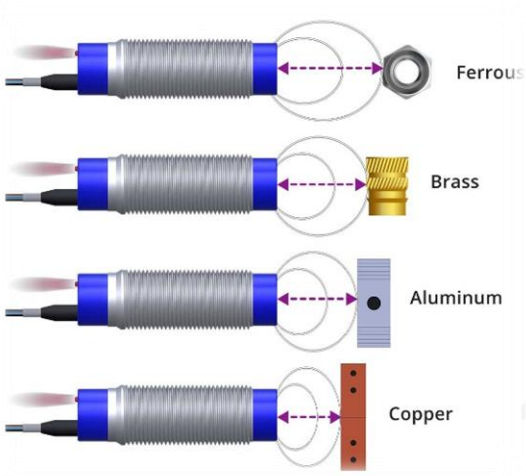
PROXIMITY SENSORS

Inductive Proximity Sensor

- The Inductive type of Proximity sensors are used to detect metallic or ferrous objects by using the inductive properties of a material.
- Their range is limited by the magnetic field generated by the sensor

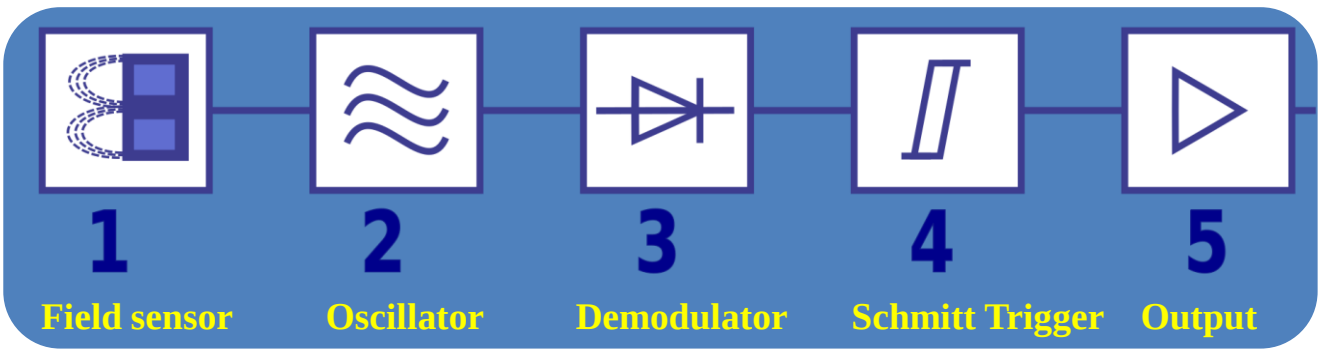
An Inductive sensors have a narrow sensing range and are widely used in industrial automation applications for collision detection or to detect a part position.

The inductive sensor is based on Faraday's law of induction.



Working of an Inductive Proximity Sensor

- An inductive proximity sensor is a device that uses the principle of electromagnetic induction to detect or measure objects.
- An inductor develops a magnetic field when an electric current flows through it; alternatively, a current will flow through a circuit containing an inductor when the magnetic field through it changes.
- This effect can be used to detect metallic objects that interact with a magnetic field.

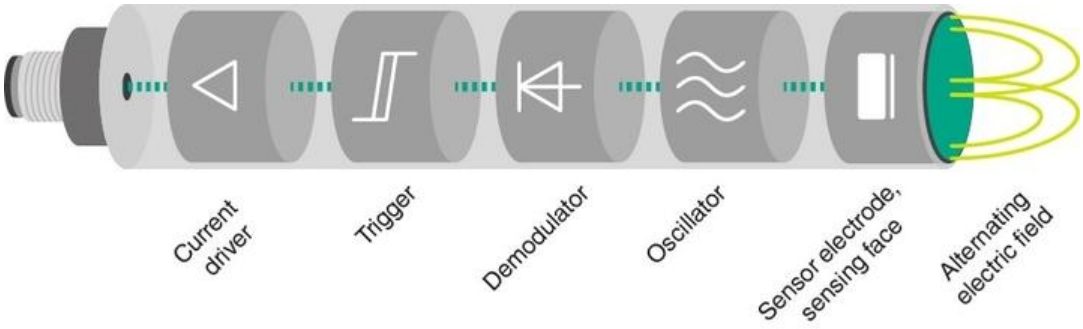


PROXIMITY SENSORS

Inductive Proximity Sensor

Main Components

- ✅ **Oscillator – Generates the alternating electromagnetic field.**
- ✅ **Coil & Ferrite Core – Produces and focuses the magnetic field.**
- ✅ **Detector Circuit – Monitors changes in the oscillation caused by metal objects.**
- ✅ **Output Circuit – Converts detection signals into electrical output (e.g., ON/OFF signal).**
- ✅ **Housing – Protects internal components (usually made of stainless steel or plastic)**

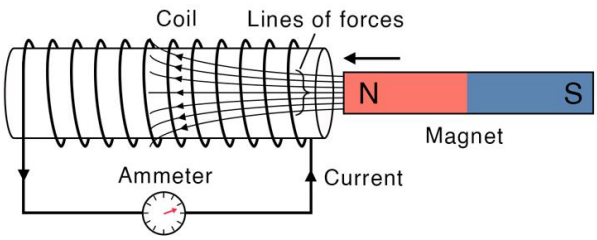


Working principle

Inductive Proximity Sensors operate on the basis of Faraday's Law of inductance

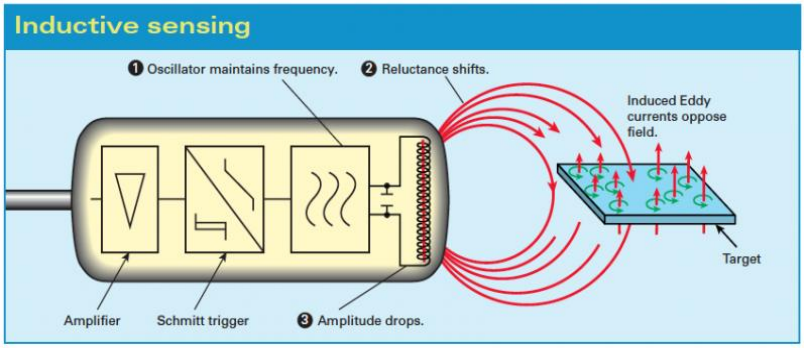
According to Faraday's Law of induction when an electrically conducting object is placed in a magnetic field then an electric current called Eddy current will be generated in the object

According to Lenz Law the Eddy current creates a magnetic field in a conductor and this magnetic field opposed the magnetic field which created it



$$\varepsilon = -N\frac{d\phi}{dt}$$

ε : Electromotive force (EMF)
N : Number of turns of the coil
$\frac{d\phi}{dt}$: Instaneous change of magnetic flux with time



Ferrous targets change the reluctance of the magnetic circuit; system oscillation frequency, which gets left behind when the natural frequency shifts, then loses amplitude.

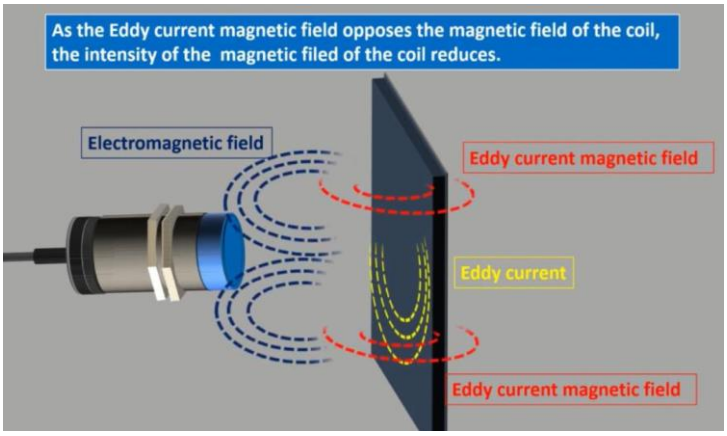
PROXIMITY SENSORS

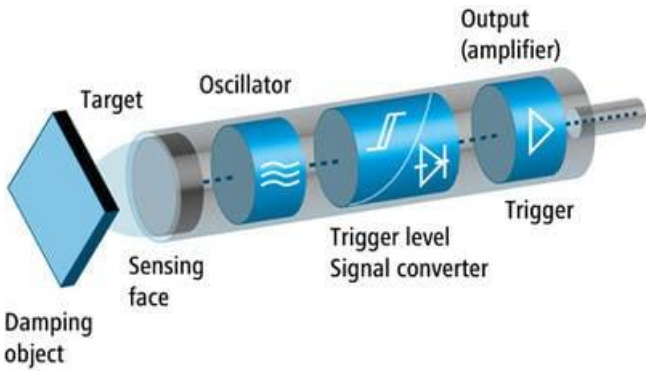
1. **Oscillator Circuit – The circuit generates a high-frequency electromagnetic field using a coil.**

2. **Eddy Currents Formation – When a metal object enters the field, eddy currents are induced in the object.**

3. **Energy Loss Detection – The eddy currents absorb energy, causing a change in the sensor's oscillator circuit.**

4. **Trigger Output Signal – The sensor detects this change and activates an output signal to indicate the presence of metal.**



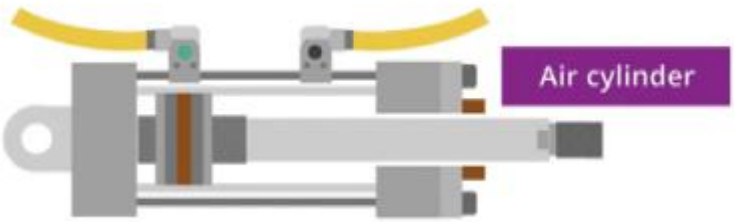


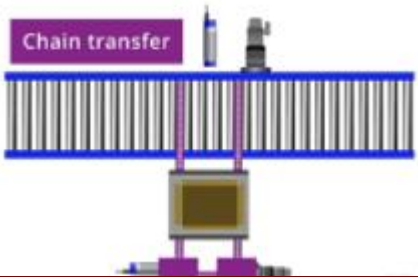
Advantages of Inductive Proximity Sensors

✓ **Non-Contact Detection – No physical wear & tear.**
✓ **High Durability – Works in harsh environments (dust, dirt, moisture).**
✓ **Fast Response Time – Suitable for high-speed automation.**
✓ **Reliable & Precise – Not affected by light or environmental factors.**

Applications

Industrial Automation – Detecting metal parts on conveyor belts.
Robotics – Position detection in robotic arms.
Automotive – Used in gear detection, speed sensing, and safety systems.
Construction Equipment – Detecting metal in machinery.





PROXIMITY SENSORS

Types of Inductive Proximity Sensors

Inductive sensors can be classified based on **design, range, and output type**:

Based on Shielding

- **Shielded (Flush Type)**
  - •Magnetic field is **concentrated in front** of the sensor.
  - •Works best when mounted **flush with metal surfaces**.
  - •Offers **higher precision** but shorter detection range.

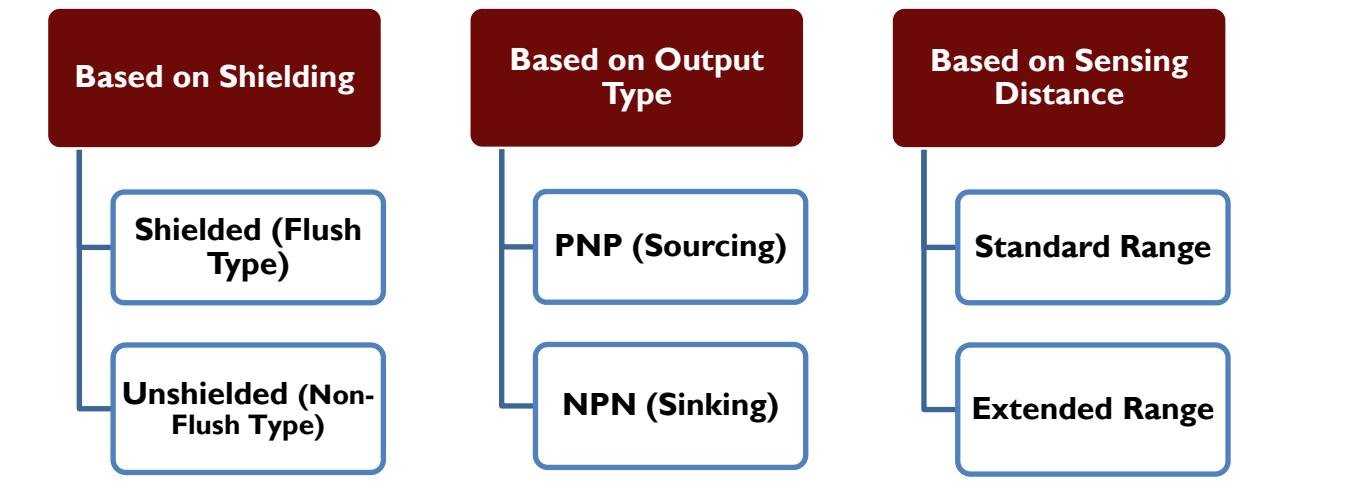
- **Unshielded (Non-Flush Type)**
  - •Magnetic field spreads **wider** for greater detection distance.
  - •Cannot be mounted flush with metal surfaces.
  - •Suitable for applications where **longer sensing distance** is needed.

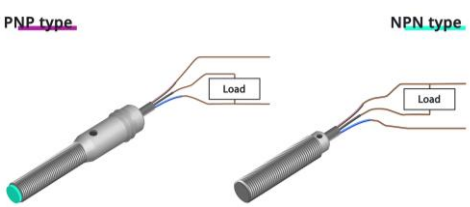
Based on Output Type

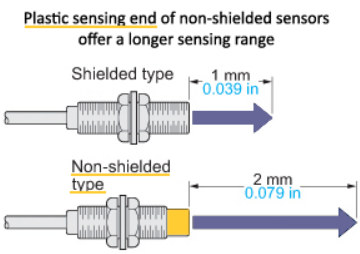
- **PNP (Sourcing) Sensors** – Provide a **positive (high) output** when detecting metal.
- **NPN (Sinking) Sensors** – Provide a **negative (low) output** when detecting metal.

Based on Sensing Distance

- **Standard Range Sensors** – Typically **1mm to 15mm** sensing distance.
- **Extended Range Sensors** – Can detect metals from **15mm to 50mm** away.





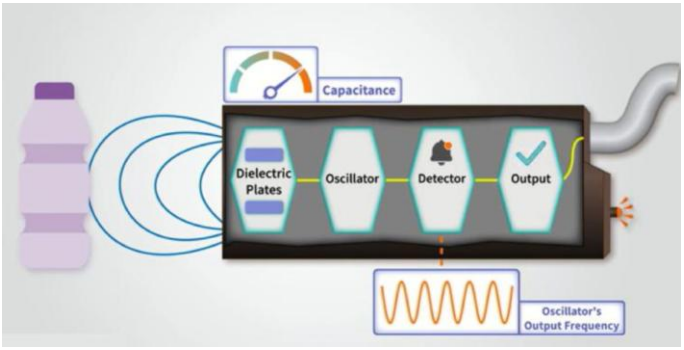


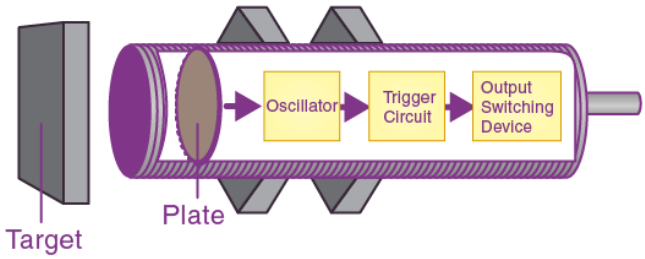
PROXIMITY SENSORS

Capacitive Proximity Sensor

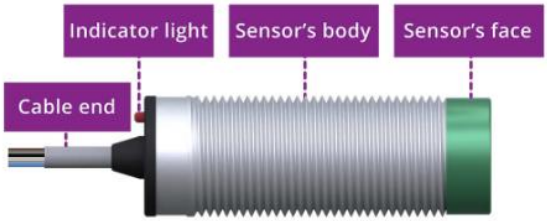
Capacitive proximity sensors are non-contact sensors used to detect both metallic and non-metallic objects such as plastics, liquids, wood, and powders.

They work based on changes in capacitance, making them useful in material handling, packaging, and liquid level sensing applications.





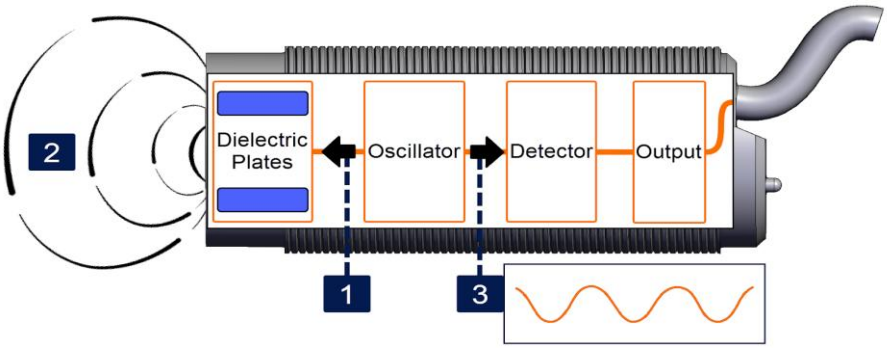
Capacitive Sensor



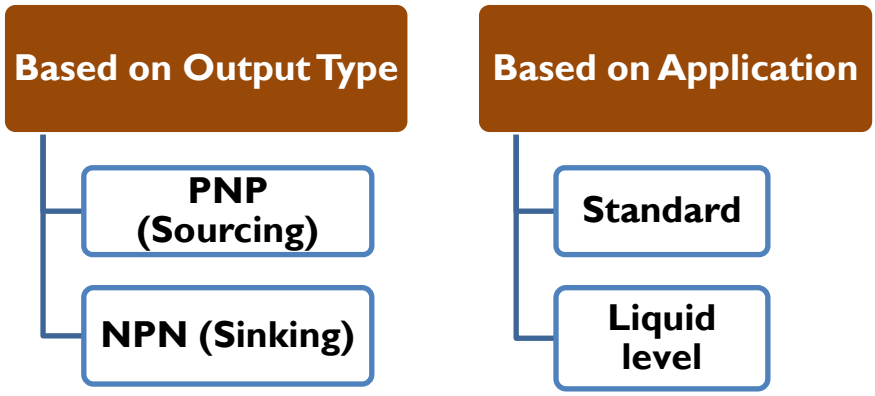
Basic Working Principle

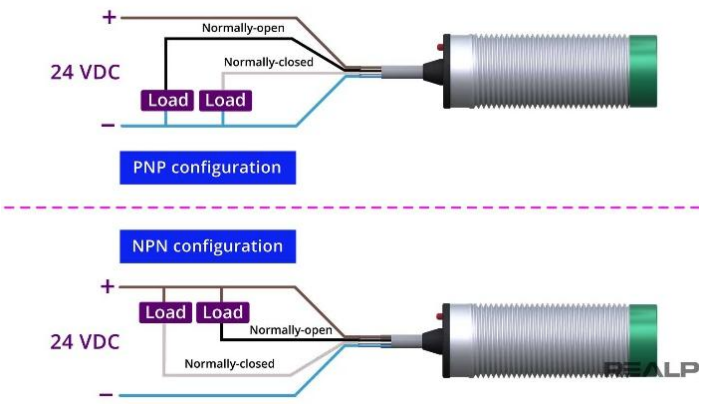
Capacitive sensors detect objects by measuring changes in the electrical field between two conductive plates.

1. **Electrode Plates Form a Capacitor – The sensor has two plates: one inside the sensor and one formed by the target object.**
2. **Capacitance Changes – When an object enters the sensor's detection field, the capacitance changes.**
3. **Threshold Detection – The circuit detects this change in capacitance.**
4. **Trigger Output Signal – Once the capacitance exceeds a set threshold, the sensor outputs a signal**



PROXIMITY SENSORS





Capacitive sensors are classified based on design, output, and application:

Based on Output Type

- **PNP (Sourcing) – Provide a positive (high) output when detecting an object.**
- **NPN (Sinking) – Provide a negative (low) output when detecting an object.**

Based on Application

- **Standard Capacitive Sensors – Used for detecting solid objects like plastic, wood, and metal.**
- **Liquid-Level Capacitive Sensors – Designed to detect fluids through non-metallic containers (e.g., water in plastic tanks).**

Based on Mounting Type

- **Shielded (Flush Type) – Limited sensing range, more precise detection.**
- **Unshielded (Non-Flush Type) – Wider sensing range but needs more space.**

PROXIMITY SENSORS

Advantages:

✓ Detects metals and non-metals

✓ Can work through thin non-metal barriers

✓ Non-Contact Detection – No wear & tear, increasing lifespan.

✓ Adjustable Sensitivity – Can be fine-tuned for different materials.

Disadvantages:

✕ Sensitive to environmental conditions

✕ Limited sensing range

Applications:

- Liquid level monitoring
- Object detection in packaging
- Touch-sensitive interfaces

🏭 Industrial Automation – Detects presence of plastic, paper, or liquids.

📦 Packaging Industry – Detects contents inside sealed containers.

🚜 Agriculture – Measures grain levels in storage silos.

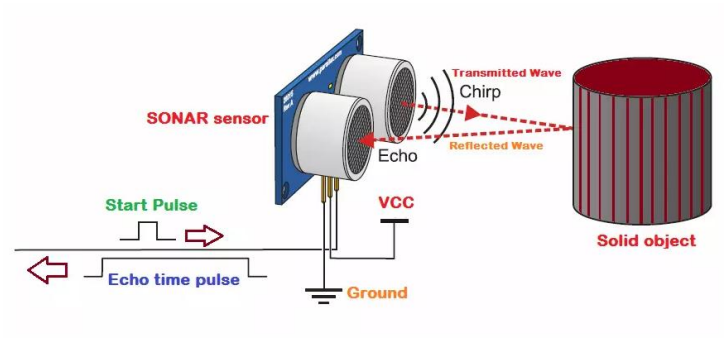
💧 Liquid Level Detection – Monitors tank levels through plastic walls.

🏗️ Material Handling – Detects powders, wood, and other non-metallic objects.

PROXIMITY SENSORS

Ultrasonic Proximity Sensor

Ultrasonic sensors utilize sound waves higher than the human audible limit~ 25 to 50 kHz to detect objects.
Therefore, object color and transparency do not impact the sensor's ability to detect an object

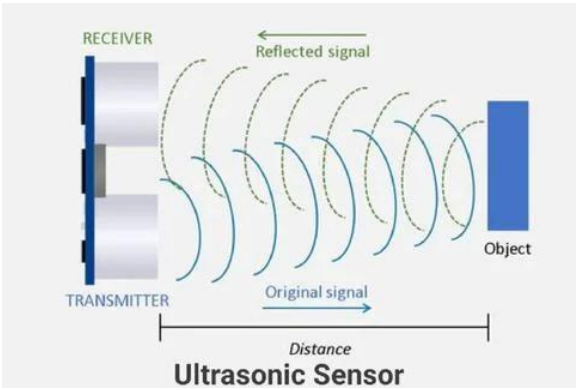


Ultrasonic sensors sends an ultrasonic pulse and the object reflects it to the sensor. The time difference between send and received signals is used to calculate the distance between the objects.

Working Principle

Ultrasonic sensors work by emitting high-frequency sound waves and measuring their reflection from an object.
The working process includes:
1.Sound Wave Emission – The sensor sends out an ultrasonic pulse (typically 20 kHz to 200 kHz).
2.Reflection from Object – When an object is present, the pulse bounces back to the sensor.
3.Time-of-Flight Calculation – The sensor calculates the time delay between transmission and reception.
4.Distance Measurement –

$$\text{Distance} = \frac{\text{Speed of Sound} \times \text{Time Delay}}{2}$$

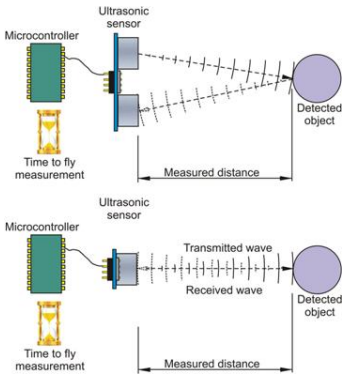


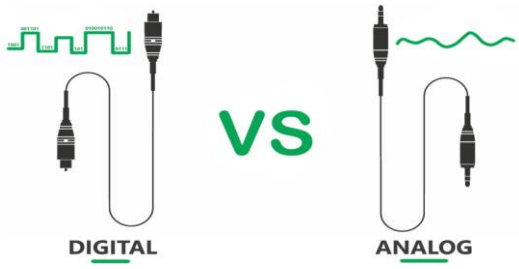
Types of Ultrasonic Proximity Sensor

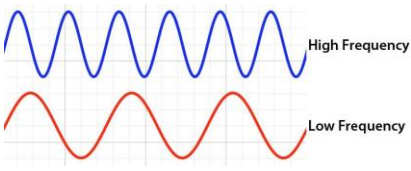
Based on Detection type
- Through Beam type
- Reflective sensor

Based on Output Type
- Digital
- Analog

Based on Frequency Range
- Low-Frequency Sensors (20-100 kHz)
- High-Frequency Sensors (100-200 kHz)







Advantages of Ultrasonic Proximity Sensors

✓ **Works with all Materials – Detects metal, plastic, glass, liquid, wood, etc.**

✓ **Non-Contact Detection – No physical wear and tear.**

✓ **Accurate Distance Measurement – Provides precise readings.**

✓ **Insensitive to Light & Dust – Works in challenging environments.**

Limitations of Ultrasonic Proximity Sensors

☒ **Susceptibility to environmental factors**

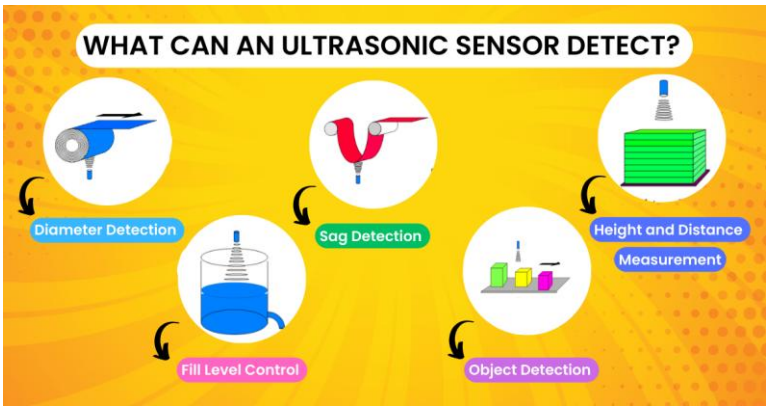
☒ **Interference with other sensors**

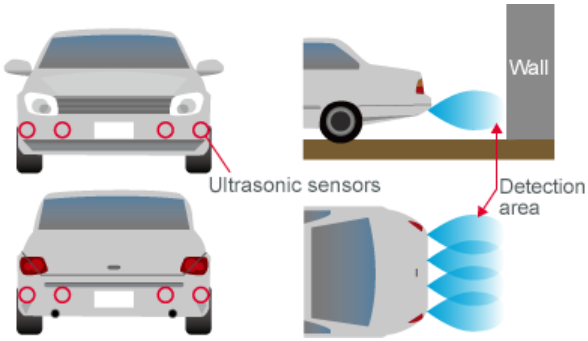
☒ **Limits Spatial resolution**

☒ **Angle dependency issues**

☒ **Limited Range**

PROXIMITY SENSORS





Applications

- 🚙 **Automotive – Parking sensors for obstacle detection.**
- 🏭 **Industrial Automation – Object positioning on conveyor belts.**
- 🌱 **Agriculture – Liquid level monitoring in tanks and silos.**
- 🤖 **Robotics – Object avoidance in autonomous robots.**
- 📦 **Logistics & Warehousing – Distance measurement for stacking and sorting.**

Comparison of Proximity Sensors

Feature	Inductive	Capacitive	Ultrasonic
Detectable Materials	Metals only	Metals & Non-metals	All materials
Detection Range	Short (mm to cm)	Short to medium (cm)	Long (cm to meters)
Environmental Resistance	High	Moderate	Affected by temperature, humidity
Applications	Industrial, automotive	Packaging, liquid level sensing	Robotics, automotive, level sensing

Summary

- ❑ Each sensor type has specific applications.
- ❑ Inductive sensors are best for detecting metals.
- ❑ Capacitive sensors work for non-metal objects.
- ❑ Ultrasonic sensors are ideal for long-range detection.
- ❑ Selection depends on material type, sensing range, and environmental factors.