University of Dhaka
Department of Computer Science and Engineering
CSE-2205: Introduction to Mechatronics

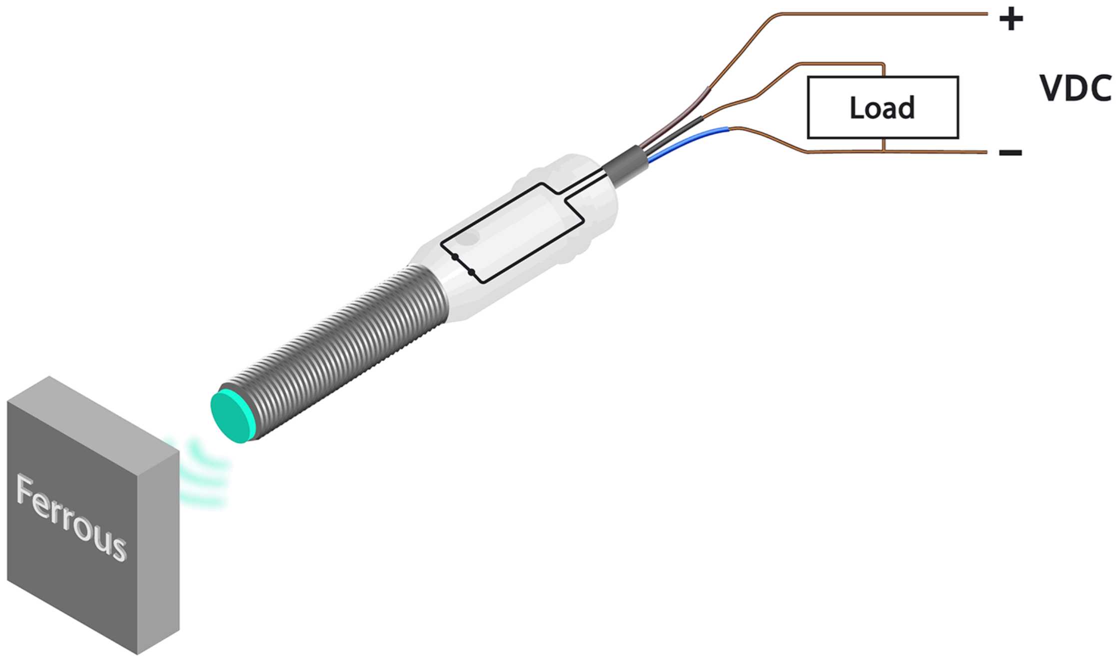
Lec-5: Proximity Sensors

Mechatronics: Electronic Control Systems in Mechanical Engineering by W. Bolton

Md. Ariful Islam
Assistant Professor
Dept. of Robotics and Mechatronics Engineering
University of Dhaka

1. Proximity Sensor

A proximity sensor is a type of sensor that is designed to *detect the presence or proximity of an object* without the *need for physical contact*.

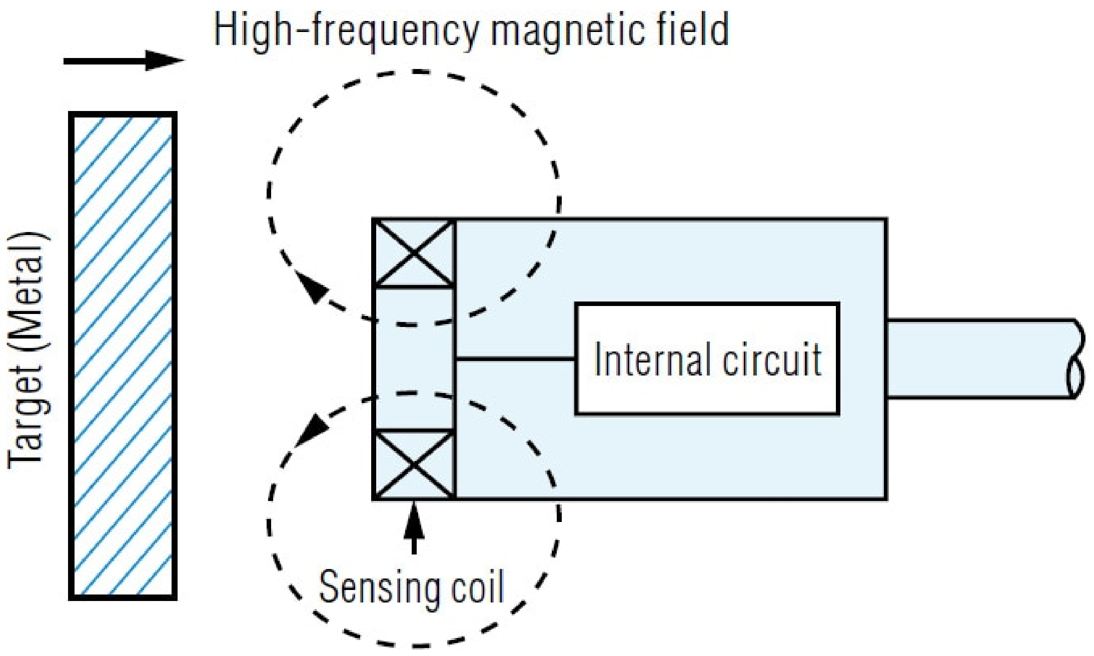


1.1 Types of Proximity Sensor

Inductive Proximity Sensors:

These sensors work *based on electromagnetic induction*. They *generate eddy currents in metallic objects placed in their proximity*.

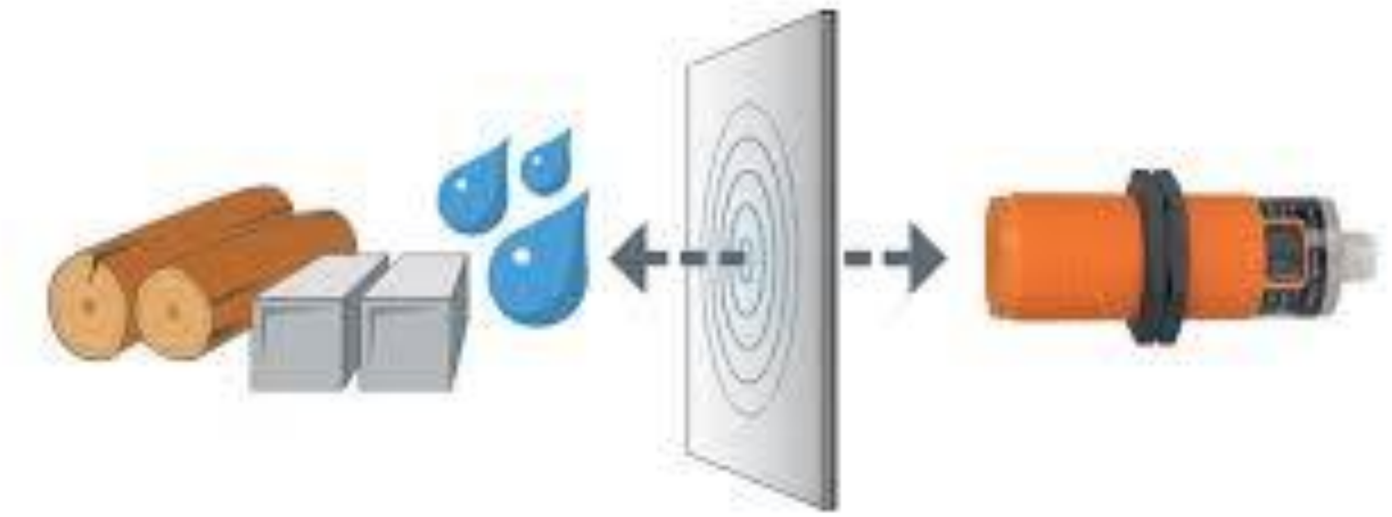
By detecting changes in these eddy currents, inductive proximity sensors can determine the presence or absence of metallic objects. These sensors are commonly used for *detecting metal objects* such as machine parts, tools, or components.



Capacitive Proximity Sensors:

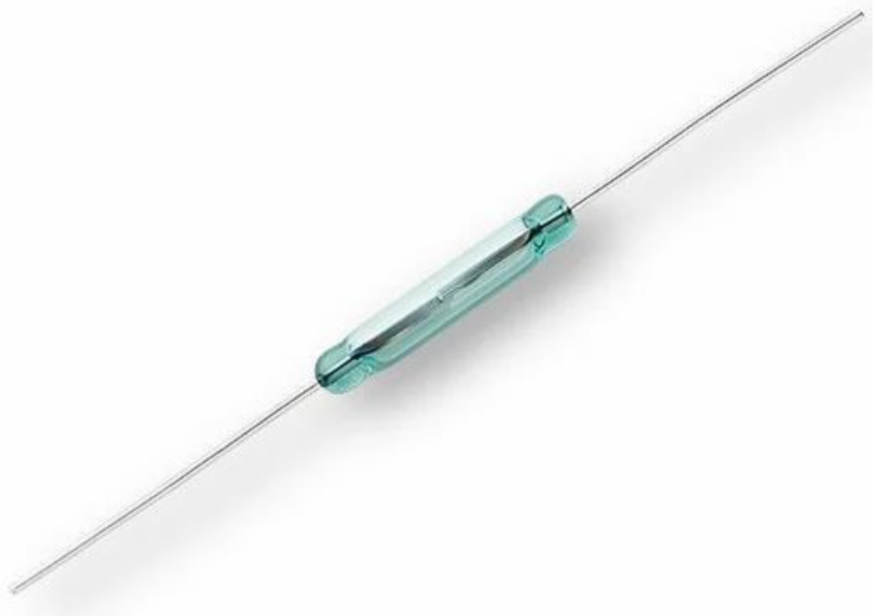
Capacitive sensors *detect changes in electrical capacitance* when an *object approaches the sensor*.

They can be used to *detect both metallic and non-metallic objects*, as capacitance changes with the dielectric properties of the material.



Magnetic Proximity Sensors:

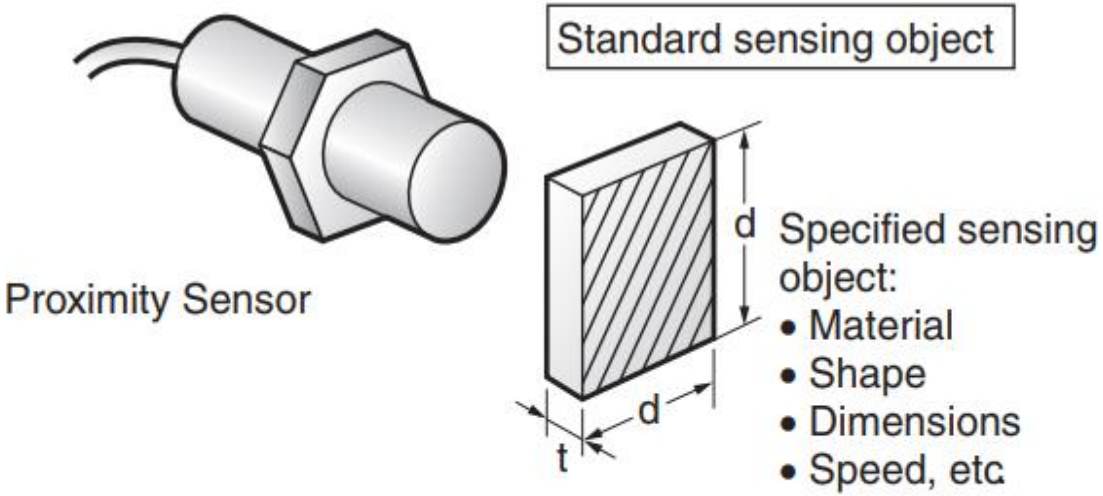
Magnetic proximity sensors *use magnets and reed switches or other magnetic field-based technologies* to detect the *presence of objects*.



1.2 Explanation of Terms

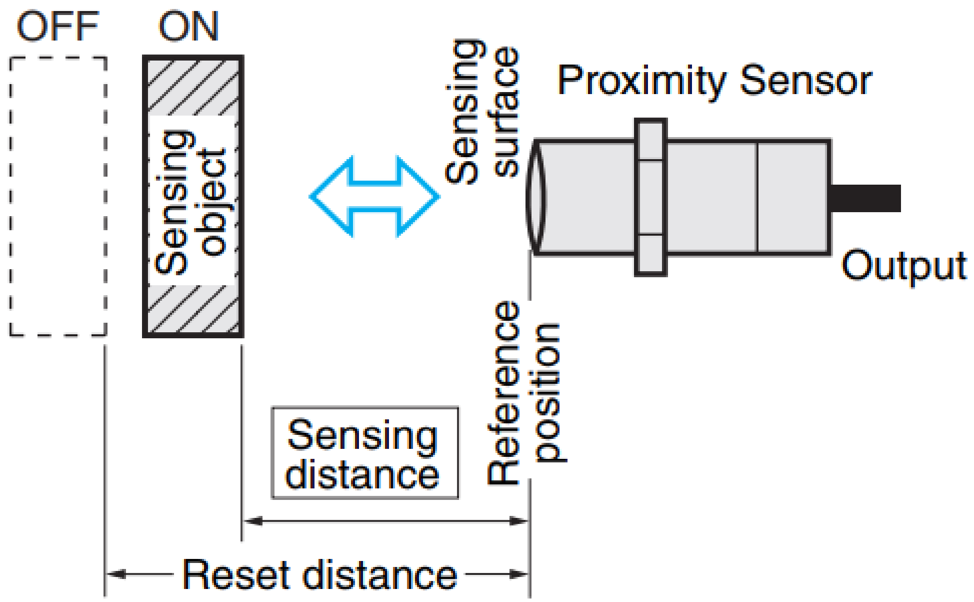
Standard Sensing Object:

Imagine we have a proximity sensor designed to detect metallic objects. In this case, the standard sensing object would be a *specific metal object with known properties*, such as a steel rod, that *serves as a reference for measuring the sensor's basic performance*. This object has specified materials, a *specified shape, and known dimensions*.



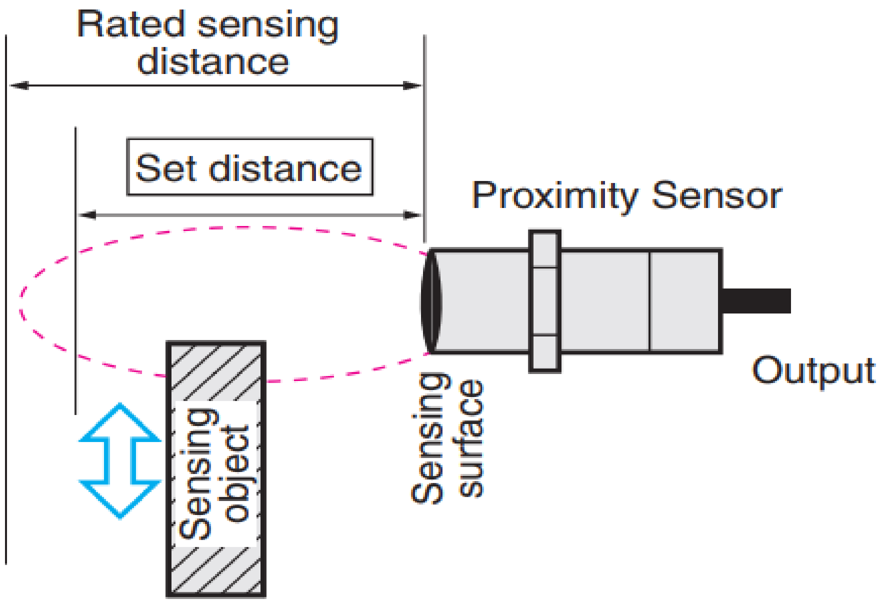
Sensing Distance:

The sensing distance refers to the *distance from the reference position* (the reference surface) to the point *where the proximity sensor activates* when the standard sensing object is moved towards it using a specified method. For example, if the sensor is rated to *have a sensing distance of 10 centimeters*, this means *it will detect* the standard sensing object when it is *10 centimeters away from the sensor*.



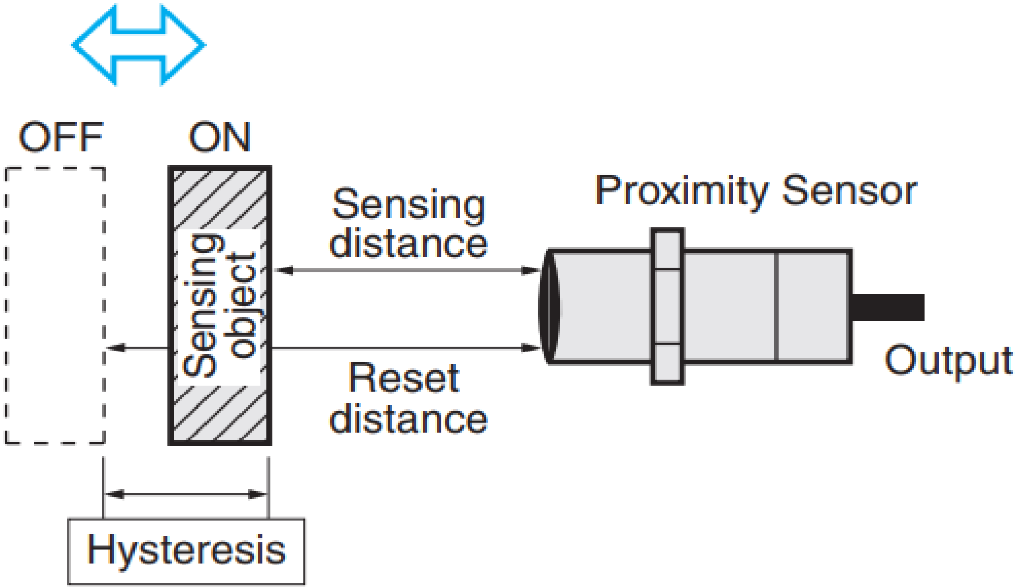
Set Distance:

The set distance is a *slightly shorter distance than the rated sensing distance*, typically *around 70% to 80% of the rated distance*. It accounts for factors like *temperature and voltage variations*, ensuring stable sensor performance. So, if your sensor has a *rated sensing distance of 10 centimeters*, the set distance might be around *7 to 8 centimeters*.



Hysteresis (Differential Travel):

Hysteresis is the difference between the distance at which the sensor activates (turns ON) and the distance at which it deactivates (resets or turns OFF). For instance, *if the sensor activates at 9 centimeters* when the standard sensing object approaches and *deactivates at 11 centimeters* when the object moves away, the *hysteresis is 2 centimeters*.

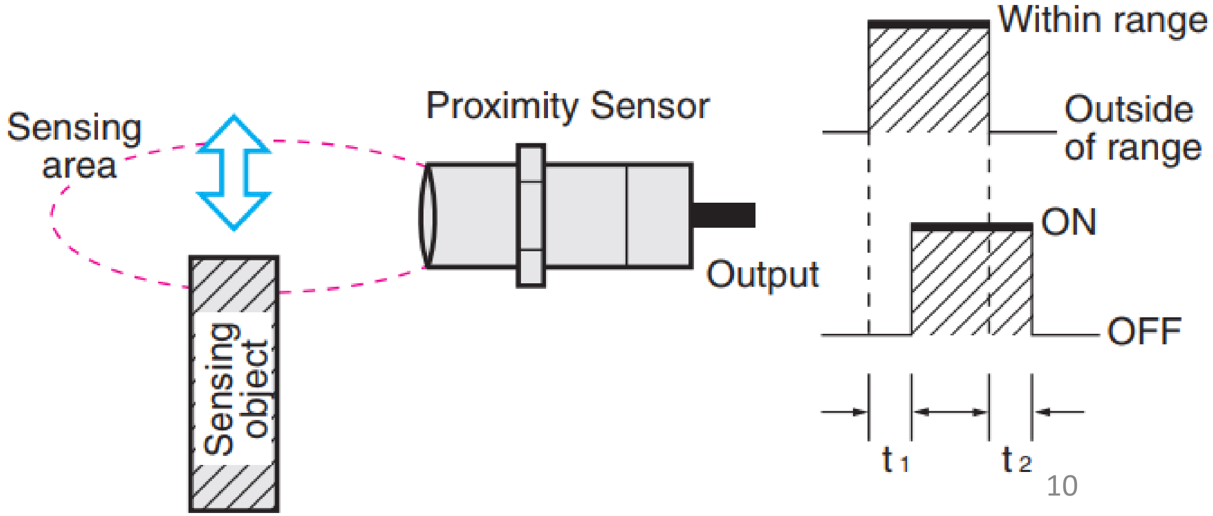


Response Time:

The response time of the sensor refers to *how quickly it reacts to the presence or absence* of the standard sensing object. There are two components:

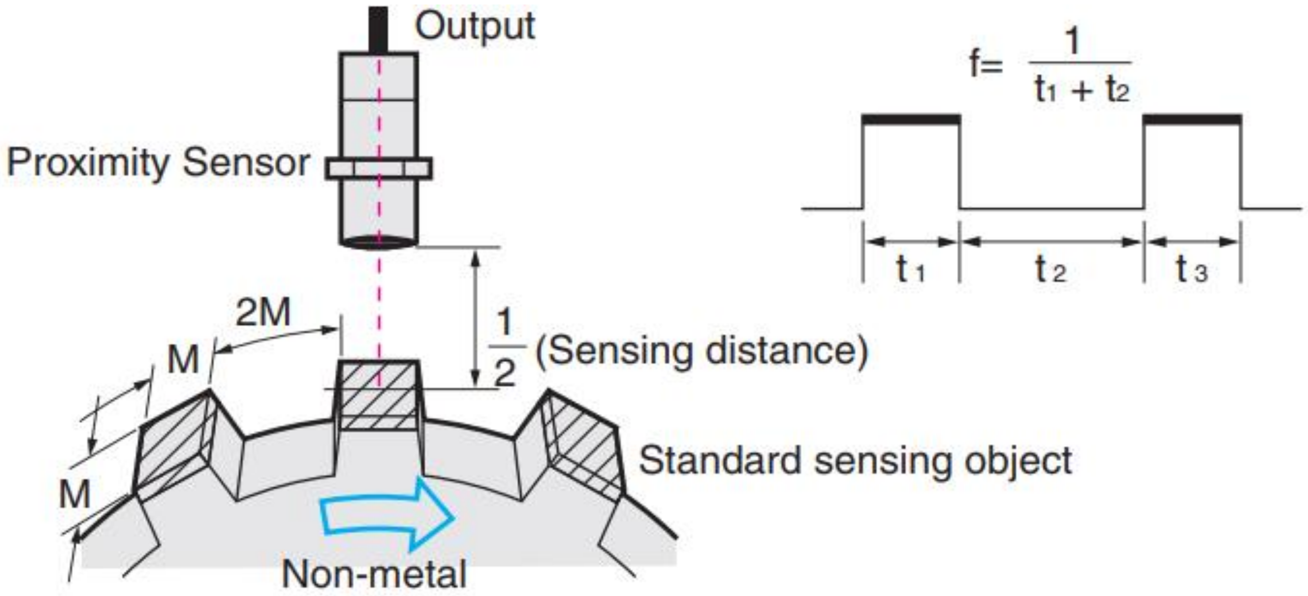
- t1: The *time it takes for the sensor to detect* the object when it enters the sensing area and activate (*output turns ON*).

- t2: The time it takes for the sensor to detect the object leaving the sensing area and deactivate (*output turns OFF*).



Response Frequency:

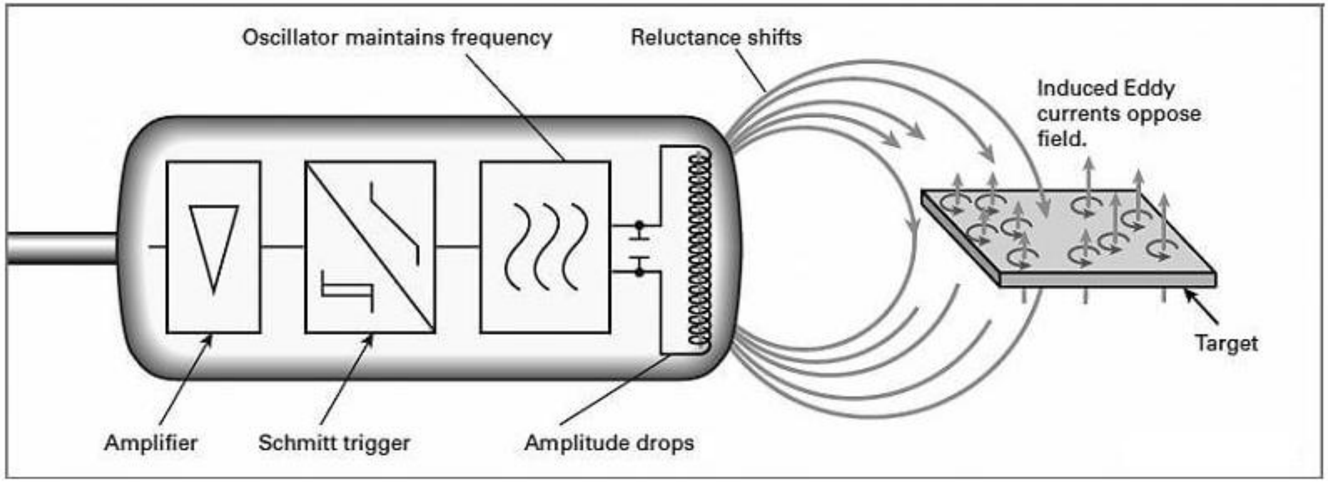
Response frequency is the number of detection repetitions the sensor can output per second when the standard sensing object is repeatedly brought into proximity. It indicates *how quickly the sensor can respond to changes in the object's position*.



1. Inductive Proximity Sensor

An inductive proximity sensor is a type of sensor that *detects the presence of metallic objects* within its detection range *without physical contact*. It achieves this through the *use of electromagnetic fields*.

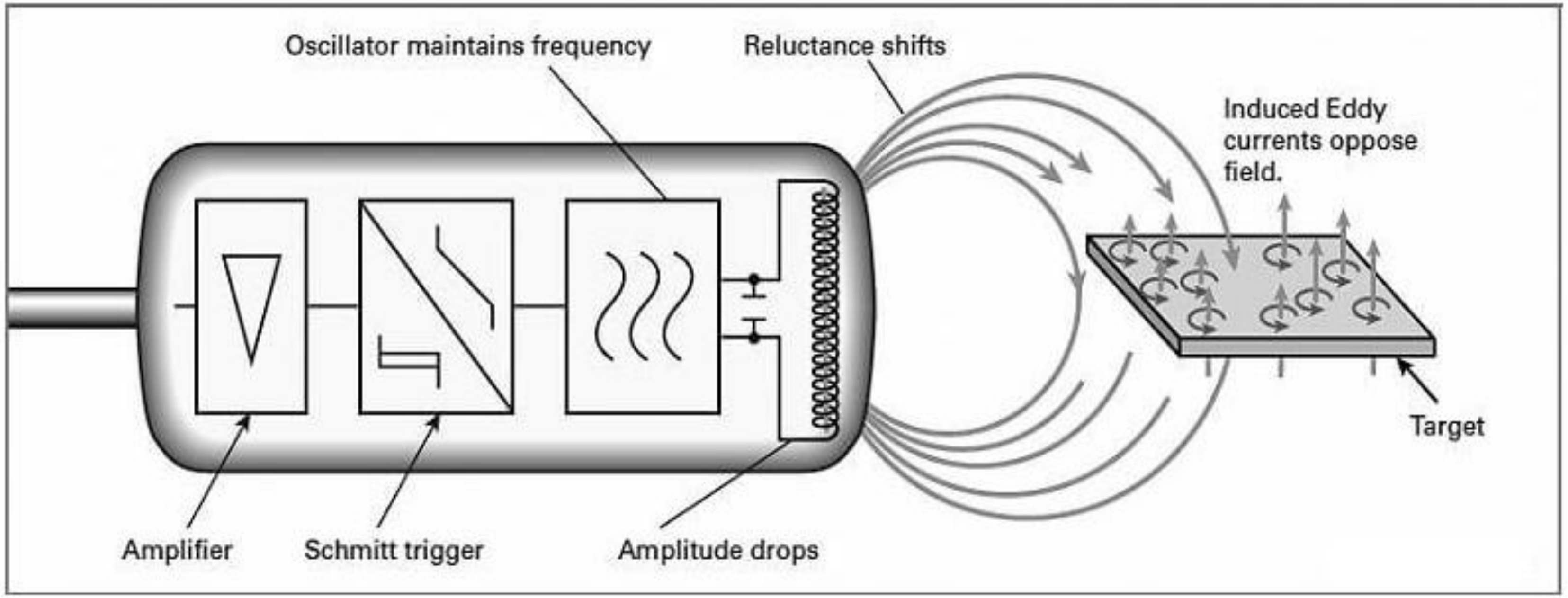
LC Oscillator: The sensor circuit contains an LC oscillator, consisting of a *capacitor (C) and a coil (L).* This oscillator *generates an oscillating magnetic field* when the *sensor is activated*.



Special Circuit for Frequency Control: A special circuit within the sensor is responsible for *maintaining the oscillation frequency at a constant value*.

The frequency is typically around *10 to 20 Hz for AC sensors* and *500 Hz to 5 kHz for DC sensors*.

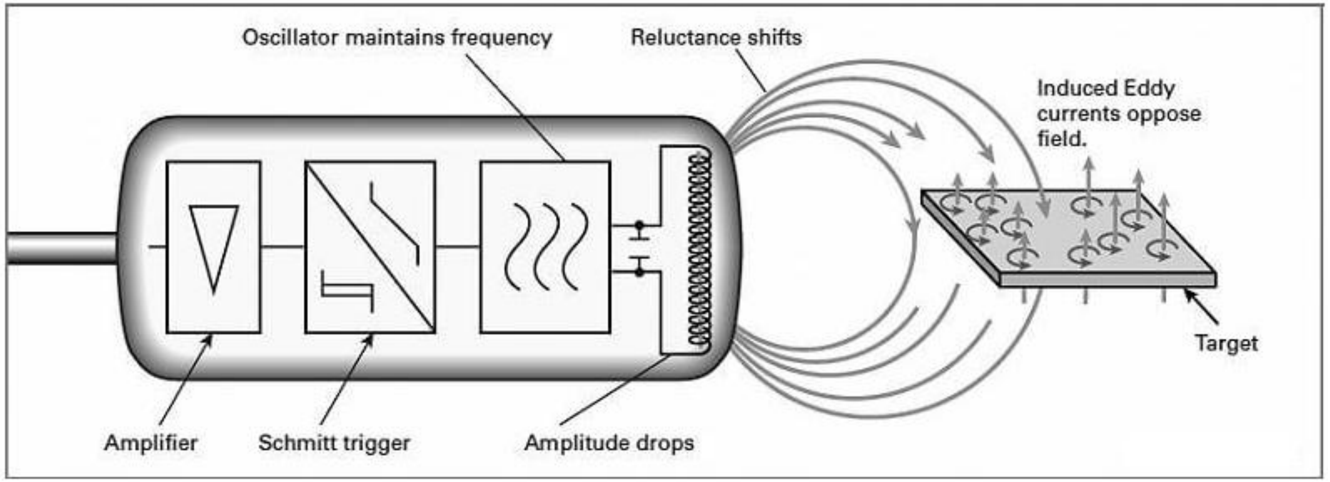
$$f = \frac{1}{2\pi\sqrt{LC}}$$



1.1 Detection Process

Oscillating Magnetic Field Generation:

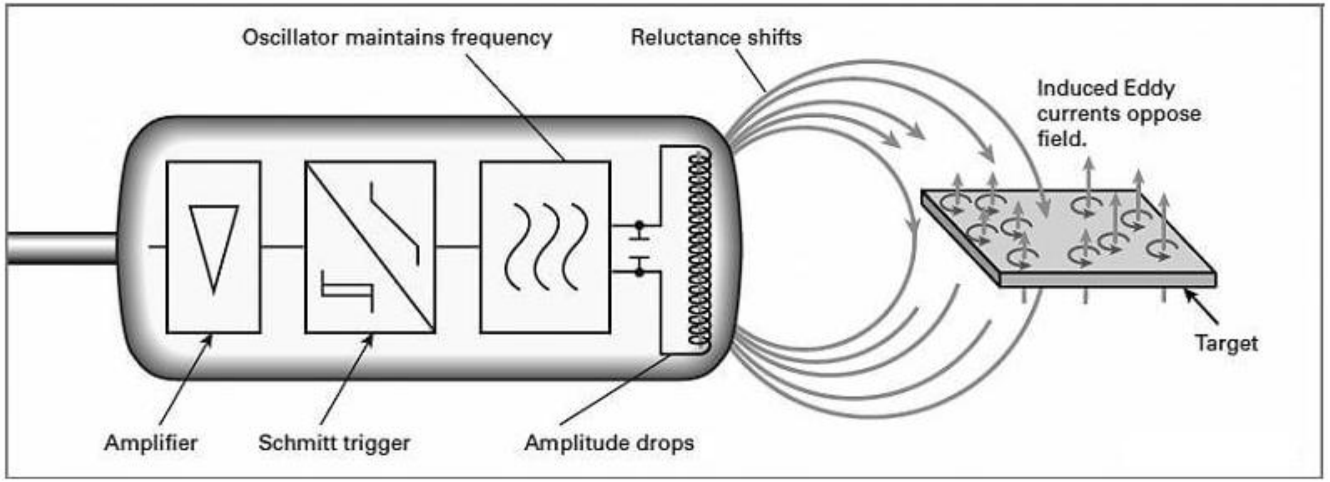
When the inductive proximity sensor is powered or activated, the ***LC oscillator generates an oscillating magnetic field*** at the sensor's sensing face.



Metallic Object Interaction:

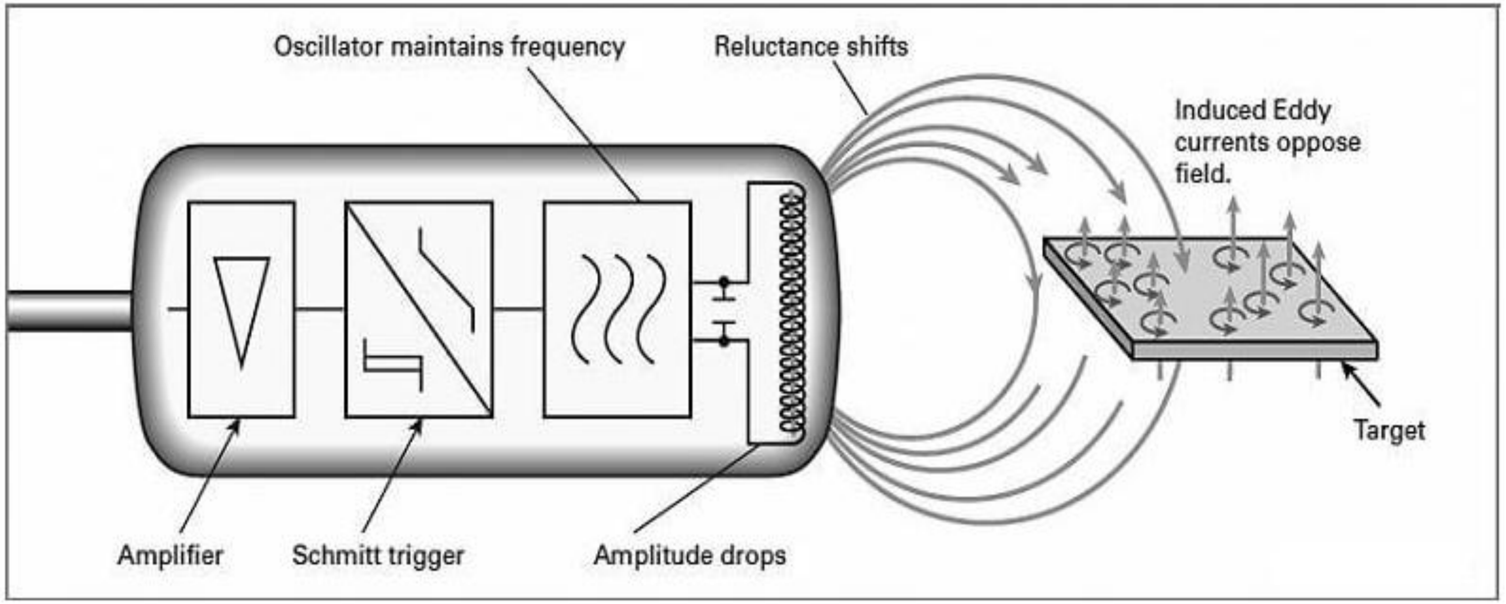
When a *metallic object enters the vicinity of the sensor* and comes into *contact with the generated magnetic field*, several processes occur:

a. Eddy Current Induction: The presence of the metallic object within the magnetic field *induces electrical currents inside the object*. These are known as *eddy currents*. Eddy currents *circulate within the object due to the changing magnetic field*.



b. Disruption of Magnetic Field: Eddy currents in the metallic object *disrupt the magnetic field generated by the sensor*. This disruption is often referred to as "*magnetic damping*.“

c. Impact on Oscillator: The disruption caused by eddy currents *affects the natural oscillation of the LC oscillator circuit*. It *reduces the amplitude (strength) of the oscillating signal*.



1.2 Output Signal Generation

Comparator Circuit: The sensor contains a *separate comparator circuit* that *continuously monitors the amplitude of the oscillating signal* generated by the LC oscillator.

Threshold Detection: When the *amplitude of the signal falls below or rises above a certain threshold*, the *comparator circuit is triggered*.

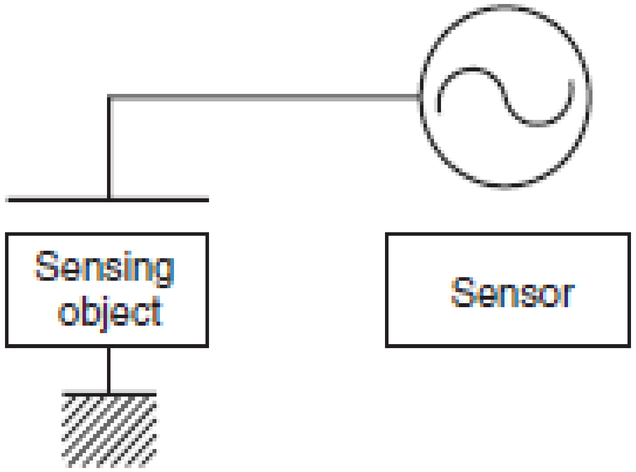
Output Signal: The *output signal generated by the comparator* can take different forms:

For *digital sensors*, it can be a logic HIGH or LOW signal.
For *analog sensors*, it can be a current or voltage signal that varies with the proximity of the metallic object.

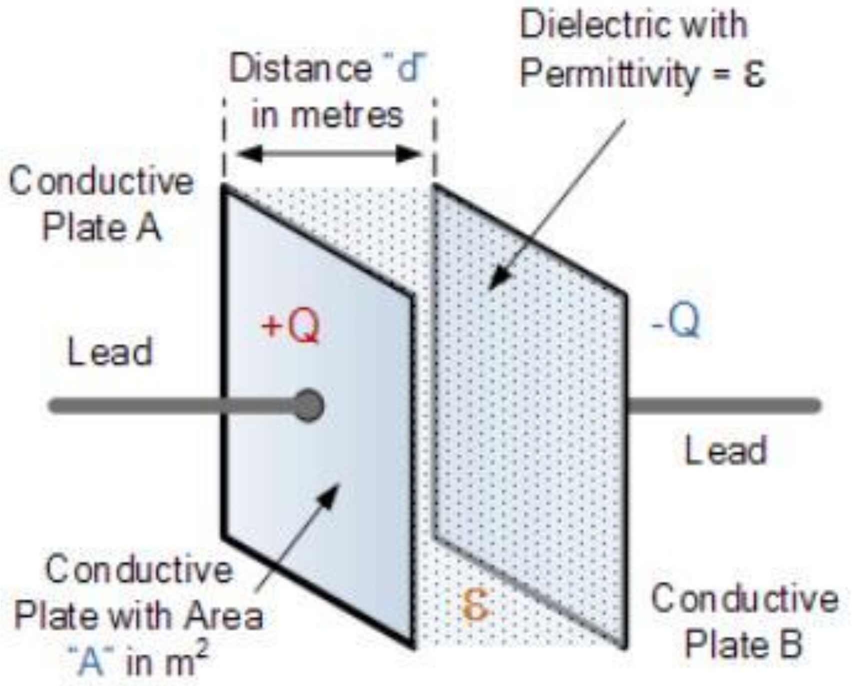
2. Capacitive Proximity Sensor

A capacitive proximity sensor is a sensor that can detect an object *using the electrical property, capacitance*.

They are widely used to *detect and measure objects/fluids* that *have a higher dielectric constant (such as metal, water, or other dense materials) than air*. This includes anything that is conductive or non-conductive.



A capacitor is a device that can hold an electric charge like a battery. They are made of two conductive plates with a dielectric material filling the gap. Depending on the dielectric width, their capacitance (capacity to store electric charge) changes.

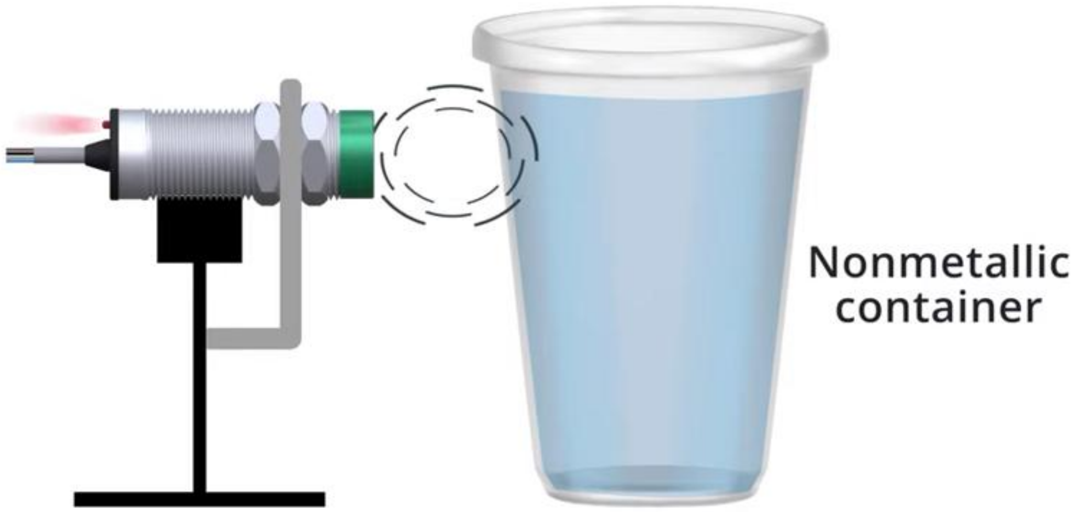


$$C = \frac{\kappa \cdot \varepsilon_0 \cdot A}{d}$$

A dielectric material is an insulating (non-conductive) material that can be *polarized when placed in an electric field*. This means that while it *doesn't allow electric current to flow through it*, it can *store and separate electric charges*, enhancing the capacitance of a capacitor.

Common dielectric materials include glass, plastic, rubber, ceramic, and certain liquids.

Any material, whether conductive or non-conductive, that *enters this electric field can affect the field's distribution* and *increase the sensor's capacitance* if it has a dielectric constant higher than air.



The *sensor circuit detects this change in capacitance*. If the change *reaches a specific threshold*, the *sensor triggers a signal, indicating the presence of an object*.

3. Magnetic Proximity Sensor

In other words, magnetic proximity sensors are ***<u>specifically designed to work with magnets</u>***.