Proximity sensors detect the presence of an object (usually called the target) without physical contact. Detection of the presence of solids such as metal, glass, and plastics, as well as most liquids, is achieved by means of a sensing magnetic or electrostatic field. These electronic sensors are completely encapsulated to protect against excessive vibration, liquids, chemicals, and corrosive agents found in the industrial environment. Proximity sensors are available in various sizes and configurations to meet different application requirements. One of the most common configurations is the barrel type, which houses the sensor in a metal or polymer barrel with threads on the outside of the housing.
INDUCTIVE PROXIMITY SENSORS Proximity sensors operate on different principles, depending on the type of matter being detected. When an application calls for noncontact metallic target sensing, an inductive-type proximity sensor is used. Inductive proximity sensors are used to detect both ferrous metals (containing iron) and nonferrous metals (such as copper, aluminum, and brass). Inductive proximity sensors operate under the electrical principle of inductance, where a fluctuating current induces an electromotive force (emf) in a target object.

Set Distance
The distance from the reference surface that allows stable use, including the effects of temperature and voltage, to the (standard) sensing object transit position. This is approximately 70% to 80% of the normal (rated) sensing distance.

### Selection by Detection Method

<table>
<thead>
<tr>
<th>Items requiring confirmation</th>
<th>Inductive Proximity Sensors</th>
<th>Capacitive Proximity Sensors</th>
<th>Magnetic Proximity Sensors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensing object</td>
<td>Metallic objects (iron, aluminum, brass, copper, etc.)</td>
<td>Metallic objects, resins, liquids, powders, etc.</td>
<td>Magnets</td>
</tr>
<tr>
<td>Electrical noise</td>
<td>Affected by positional relationship of power lines and signal lines, grounding of cabinet, etc.</td>
<td>CE Marking (EC Directive compliance) Sensor covering material (metal, resin). Easily affected by noise when the cable is long.</td>
<td>Almost no effect.</td>
</tr>
<tr>
<td>Power supply</td>
<td>DC, AC, AC/DC, DC with no polarity, etc.</td>
<td>Connection method, power supply voltage.</td>
<td></td>
</tr>
<tr>
<td>Current consumption</td>
<td>Depends on the power supply, i.e., DC 2-wire models, DC 3-wire models, AC, etc.</td>
<td>DC 2-wire models are effective for suppressing current consumption.</td>
<td></td>
</tr>
<tr>
<td>Sensing distance</td>
<td>The sensing distance must be selected by considering the efforts of factors such as the temperature, the sensing object, surrounding objects, and the mounting distance between Sensors. Refer to the set distance in the catalog specifications to determine the proper distance. When high precision sensing is required, use a Separable Amplifier model.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ambient environment</td>
<td>Temperature or humidity, or existence of water, oil, chemicals etc.</td>
<td>Confirm that the degree of protection (refer to the Degree of Protection) matches the ambient environment.</td>
<td></td>
</tr>
<tr>
<td>Physical vibration, shock</td>
<td>An extra margin must be provided in the sensing distance when selecting Sensors for use in environments subject to vibration and shock. To prevent Sensors from vibrating loose, refer to the catalog values for tightening torque during assembly.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Assembly</td>
<td>Effects of tightening torque, Sensor size, number of wiring steps, cable length, distance between Sensors, surrounding objects. Check the effects of surrounding metallic and other objects, and the specifications for the mutual interference between Sensors.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Sensing Distance
The distance from the reference position (reference surface) to the measured operation (reset) when the standard sensing object is moved by the specified method.

Hysteresis (Differential Travel)
With respect to the distance between the standard sensing object and the Sensor, the difference between the distance at which the Sensor operates and the distance at which the Sensor resets.

Leakage current - In the off state, enough current must flow through the circuit to keep the sensor active. This off state current is called leakage current.
The oscillator circuit generates a high-frequency electromagnetic field that radiates from the end of the sensor. When a metal object enters the field, eddy currents are induced in the surface of the object. The eddy currents on the object absorb some of the radiated energy from the sensor, resulting in a loss of energy and change of strength of the oscillator. The sensor’s detection circuit monitors the oscillator’s strength and triggers a solid-state output at a specific level. Once the metal object leaves the sensing area, the oscillator returns to its initial value.

<table>
<thead>
<tr>
<th>Output configuration</th>
<th>NPN transistor output</th>
<th>PNP transistor output</th>
<th>Non-polarity/non-contact output</th>
</tr>
</thead>
<tbody>
<tr>
<td>A general-use transistor can be directly connected to a Programmable Controller or Counter.</td>
<td>Primarily built into machines exported to Europe and other overseas destinations.</td>
<td>A 2-wire AC output that can be used for both AC and DC Sensors. Eliminates the need to be concerned about reversing the polarity.</td>
<td></td>
</tr>
</tbody>
</table>

Take the following points into account when selecting a DC 2-wire model (polarity/no-polarity). (For details, refer to the Precautions for Correct Use in the Safety Precautions for All Proximity Sensors.)

- Leakage current: A maximum current of 0.8 mA flows to the load current even when the output is OFF. Check that the load will not operate with this current.
- Output residual voltage: When the output is ON, voltage remains in the Sensor, and the voltage applied to the load decreases. Check that the load will operate with this load voltage.

<table>
<thead>
<tr>
<th>Output configuration</th>
<th>NO (normally open)</th>
<th>NC (normally closed)</th>
<th>NO/NC switchable</th>
</tr>
</thead>
<tbody>
<tr>
<td>When there is an object in the sensing area, the output switching element is turned ON.</td>
<td>When there is no object in the sensing area, the output switching element is turned ON.</td>
<td>NO or NC operation can be selected for the output switching element by a switch or other means.</td>
<td></td>
</tr>
</tbody>
</table>

Response Time
- t1: The interval from the point when the standard sensing object moves into the sensing area and the Sensor activates, to the point when the output turns ON.
- t2: The interval from the point when the standard sensing object moves out of the Sensor sensing area to the point when the Sensor output turns OFF.

Response Frequency
- The number of detection repetitions that can be output per second when the standard sensing object is repeatedly brought into proximity.
- See the accompanying diagram for the measuring method.
Capacitive proximity sensors are similar to inductive proximity sensors. The main differences between the two types are that capacitive proximity sensors produce an electrostatic field instead of an electromagnetic field and are actuated by both conductive and nonconductive materials. Capacitive sensors contain a high-frequency oscillator along with a sensing surface formed by two metal electrodes. When the target nears the sensing surface, it enters the electrostatic field of the electrodes and changes the capacitance of the oscillator. As a result, the oscillator circuit begins oscillating and changes the output state of the sensor when it reaches certain amplitude. As the target moves away from the sensor, the oscillator's amplitude decreases, switching the sensor back to its original state. Capacitive proximity sensors will sense metal objects as well as nonmetallic materials such as paper, glass, liquids, and cloth. They typically have a short sensing range of about 1 inch, regardless of the type of material being sensed. The larger the dielectric constant of a target, the easier it is for the capacitive sensor to detect. This makes possible the detection of materials inside nonmetallic containers.

An ordinary Capacitive Proximity Sensor is similar to a capacitor with two parallel plates, where the capacity of the two plates is detected. One of the plates is the object being measured (with an imaginary ground), and the other is the Sensor's sensing surface.
Detection Principle of Magnetic Proximity Sensors

The reed end of the switch is operated by a magnet. When the reed switch is turned ON, the Sensor is turned ON. Magnetic proximity switches detect magnetic fields at greater distances of up to 60 mm, even through non-ferromagnetic materials like stainless steel. Depending on the permanent magnets used, different sensing distances can be implemented. The permanent magnet can be installed independent of polarity and with large tolerances, which allows many different installation options, even in cramped spaces. Precise switching is thus guaranteed even when used in dirty or damp environments. This means that applications in cranes or heavy vehicles are also easy to implement.

A photoelectric sensor is an optical control device that operates by detecting a visible or invisible beam of light, and responding to a change in the received light intensity. Photoelectric sensors are composed of two basic components: a transmitter (light source) and a receiver (sensor). These two components may or may not be housed in separate units. The basic operation of a photoelectric sensor can be summarized as follows:

- The transmitter contains a light source, usually an LED along with an oscillator.
- The oscillator modulates or turns the LED on and off at a high rate of speed.
- The transmitter sends this modulated light beam to the receiver.
- The receiver decodes the light beam and switches the output device, which interfaces with the load.
- The receiver is tuned to its emitter’s modulation frequency, and will only amplify the light signal that pulses at the specific frequency.
- Most sensors allow adjustment of how much light will cause the output of the sensor to change state.
- Response time is related to the frequency of the light pulses. Response times may become important when an application calls for the detection of very small objects, objects moving at a high rate of speed,
The scan technique refers to the method used by photoelectric sensors to detect an object. Common scan techniques include through-beam, retro reflective, and diffuse scan. Understanding the differences among the available photoelectric sensing techniques is important in determining which sensor will work best in a specific application.

The through-beam scan technique (also called direct scan) places the transmitter and receiver in direct line with each other. The operation of the system can be summarized as follows:

- The receiver is aligned with the transmitter beam to capture the maximum amount of light emitted from the transmitter.
• The object to be detected placed in the path of the light beam blocks the light to the receiver and causes the receiver’s output to change state.

• Because the light beam travels in only one direction, through-beam scanning provides long-range sensing. The maximum sensing range is about 300 feet.

• This scan technique is a more reliable method in areas of heavy dust, mist, and other types of airborne contaminants that may disperse the beam and for monitoring large areas.

• Quite often, a garage door opener has a through beam photoelectric sensor mounted near the floor, across the width of the door. For this application the sensor senses that nothing is in the path of the door when it is closing.

RETROREFLECTIVE SCANNING In a retro reflective scan, the transmitter and receiver are housed in the same enclosure. This arrangement requires the use of a separate reflector or reflective tape mounted across from the sensor to return light back to the receiver. This sensor is designed to respond to objects that interrupt the beam normally maintained between the transmitter and receiver. In contrast to a through-beam application, retroreflective sensors are used for medium-range applications.

Retroreflective scan sensors may not be able to detect shiny targets because they tend to reflect light back to the sensor. In this case the sensor is unable to differentiate between light reflected from the target and that from the reflector. A variation of retroreflective scan, the polarized retroreflective scan sensor is designed to overcome this problem. Polarizing filters are placed in front of the emitter and receiver lenses. The polarizing filter projects the emitter’s beam in one plane only. As a result, this light is considered to be polarized. A corner-cube reflector must be used to rotate the light reflected back to the receiver. The polarizing filter on the receiver allows rotated light to pass through to the receiver.

DIFFUSE SCANNING In a diffuse scan sensor (also called proximity scan), the transmitter and receiver are housed in the same enclosure, but unlike similar retroreflective devices, they do not rely on any type
of reflector to return the light signal to the receiver. Instead, light from the transmitter strikes the target and the receiver picks up some of the diffused (scattered) light.

When the receiver receives enough reflected light the output will switch states. Because only a small amount of light will reach the receiver, its operating range is limited to a maximum of about 40 inches. The sensitivity of the sensor may be set to simply detect an object or to detect a certain point on an object that may be more reflective. Often this is accomplished using various colors with different reflective properties.

**FIBER OPTICS** Fiber optics is not a scan technique, but another method for transmitting light. Fiber optic sensors use a flexible cable containing tiny fibers that channel light from emitter to receiver. Fiber optics can be used with throughbeam, retroreflective scan, or diffuse scan sensors. In through-beam scan, light is emitted and received with individual cables. In retroreflective and diffuse scan, light is emitted and received with the same cable. Fiber optic sensors systems are completely immune to all forms of electrical interference. The fact that an optical fiber does not contain any moving parts and carries only light means that there is no possibility of a spark. This means that it can be safely used even in the most hazardous sensing environments such as a refinery for producing gases, grain bins, mining, pharmaceutical manufacturing, and chemical processing. Another advantage of using optical fibers is the luxury it affords users to route them through extremely tight areas to the sensing location. Certain fiber optics materials, particularly the glass fibers, have very high operating temperatures (450°F and higher).
**Hall effect sensors** are used to detect the proximity and strength of a magnetic field. When a current-carrying conductor is placed into a magnetic field, a voltage will be generated perpendicular to both the current and the field. This principle is known as the Hall effect. A Hall effect sensor switch is constructed from a small integrated circuit (IC) chip. A permanent magnet or electromagnet is used to trigger the sensor on and off. The sensor is off with no magnetic field and triggered on in the presence of a magnetic field. Hall effect sensors are designed in a variety of body styles. Selection of a sensor based on body style will vary by application. Analog-type Hall effect sensors put out a continuous signal proportional to the sensed magnetic field. An analog linear Hall effect sensor may be used in conjunction with a split ferrite core for current measurement. The magnetic field across the gap in the ferrite core is proportional to the current through the wire, and therefore the voltage reported by the Hall effect sensor will be proportional to the current. Clamp on ammeters that can measure both AC and DC current use a Hall effect sensor to detect the DC magnetic field induced into the clamp. The signal from the Hall effect device is then amplified and displayed. Digital-type Hall effect devices are used in magnetically operated proximity sensors. In industrial applications they may serve to determine shaft or gear speed or direction by detecting fluctuations in the magnetic field.

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One such application, which involves the monitoring of speed of a motor. The operation of the device can be summarized as follows:
When the sensor is aligned with the rotating ferrous gear tooth, the magnetic field will be at its maximum strength.

When the sensor is aligned with the gap between the teeth, the strength of the magnetic field is weakened.

Each time the tooth of the target passes the sensor, the digital Hall switch activates, and a digital pulse is generated.

By measuring the frequency of the pulses, the shaft speed can be determined.

The Hall effect sensor is sensitive to the magnitude of flux, not its rate of change, and as a result the digital output pulse produced is of constant amplitude regardless of speed variations.

This feature of Hall effect technology allows you to make speed sensors that can detect targets moving at arbitrarily slow speeds, or even the presence or absence of nonmoving targets.

An ultrasonic sensor operates by sending high-frequency sound waves toward the target and measuring the time it takes for the pulses to bounce back. The time taken for this echo to return to the sensor is directly proportional to the distance or height of the object because sound has a constant velocity. The 4-20 mA represents the sensor’s measurement span. The 4-mA set point is typically placed near the bottom of the empty tank, or the greatest