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Introduction

Welcome to another course in the STEP 2000 series, **S**iemens **T**echnical **E**ducation **P**rogram, designed to prepare our distributors to sell Siemens Energy & Automation products more effectively. This course covers **Sensors** and related products.

Upon completion of **Sensors** you should be able to:

- Describe advantages, disadvantages, and applications of limit switches, photoelectric sensors, inductive sensors, capacitive sensors, and ultrasonic sensors
- Describe design and operating principles of mechanical limit switches
- Identify components of International and North American mechanical limit switches
- Describe design and operating principles of inductive, capacitive, ultrasonic, and photoelectric sensors and describe differences and similarities
- Apply correction factors where appropriate to proximity sensors
- Identify the various scan techniques of photoelectric sensors
- Identify ten categories of inductive sensors and sensors in each category
- Describe the effects of dielectric constant on capacitive proximity sensors
- Identify environmental influences on ultrasonic sensors
- Identify types of ultrasonic sensors that require manual adjustment, can be used with SONPROG, and require the use of a signal evaluator

- Describe the difference between light operate and dark operate modes of a photoelectric sensor
- Describe the use of fiber optics and laser technology used in Siemens photoelectric sensors
- Select the type of sensor best suited for a particular application based on material, sensing distance, and sensor load requirements

This knowledge will help you better understand customer applications. In addition, you will be better able to describe products to customers and determine important differences between products. You should complete **Basics of Electricity** and **Basics of Control Components** before attempting **Sensors**. An understanding of many of the concepts covered in **Basics of Electricity** and **Basics of Control Components** is required for **Sensors**.

If you are an employee of a Siemens Energy & Automation authorized distributor, fill out the final exam tear-out card and mail in the card. We will mail you a certificate of completion if you score a passing grade. Good luck with your efforts.

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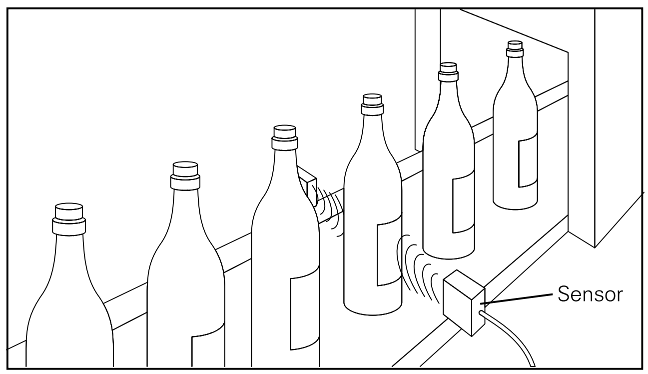
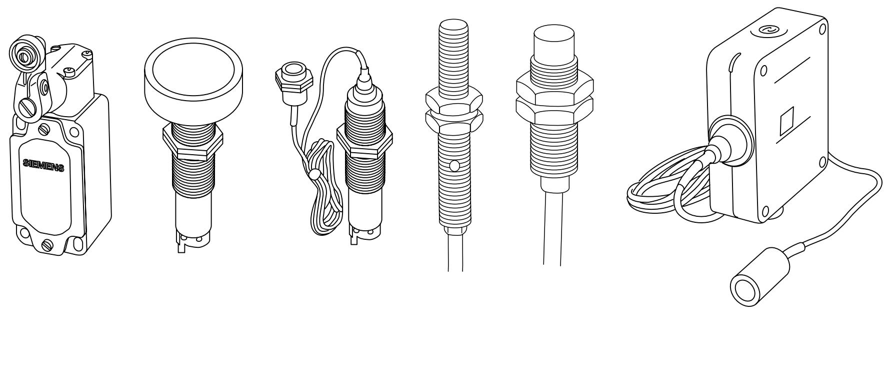
Sensors

One type of feedback frequently needed by industrial-control systems is the position of one or more components of the operation being controlled. Sensors are devices used to provide information on the presence or absence of an object.



Siemens Sensors

Siemens sensors include limit switches, photoelectric , inductive, capacitive, and ultrasonic sensors. These products are packaged in various configurations to meet virtually any requirement found in commercial and industrial applications. Each type of sensor will be discussed in detail. At the end of the course an application guide is provided to help determine the right sensor for a given application.



Technologies

Limit switches use a mechanical actuator input, requiring the sensor to change its output when an object is physically touching the switch. Sensors, such as photoelectric, inductive, capacitive, and ultrasonic, change their output when an object is present, but not touching the sensor.

In addition to the advantages and disadvantages of each of these sensor types, different sensor technologies are better suited for certain applications. The following table lists the sensor technologies that will be discussed in this course.

Sensor	Advantages	Disadvantages	Applications
Limit Switch	•High Current Capability •Low Cost •Familiar "Low-Tech" Sensing	•Requires Physical Contact with Target •Very Slow Response •Contact Bounce	•Interlocking •Basic End-of-Travel Sensing
Photoelectric	•Senses all Kinds of Materials •Long Life •Longest Sensing Range •Very Fast Response Time	•Lens Subject to Contamination •Sensing Range Affected by Color and Reflectivity of Target	•Packaging •Material Handling •Parts Detection
Inductive	•Resistant to Harsh Environments •Very Predictable •Long Life •Easy to Install	•Distance Limitations	•Industrial and Machines •Machine Tool •Senses Metal-Only Targets
Capacitive	•Detects Through Some Containers •Can Detect Non-Metallic Targets	•Very Sensitive to Extreme Environmental Changes	•Level Sensing
Ultrasonic	•Senses all Materials	•Resolution •Repeatability •Sensitive to Temperature Changes	•Anti-Collision •Doors •Web Brake •Level Control

Contact Arrangement

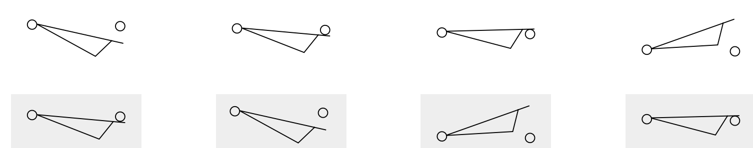
Contacts are available in several configurations. They may be normally open (NO), normally closed (NC), or a combination of normally open and normally closed contacts.

Circuit symbols are used to indicate an open or closed path of current flow. Contacts are shown as normally open (NO) or normally closed (NC). The standard method of showing a contact is by indicating the circuit condition it produces when the contact actuating device is in the deenergized or nonoperated state. For the purpose of explanation in this text a contact or device shown in a state opposite of its normal state will be highlighted. Highlighted symbols used to indicate the opposite state of a contact or device are not legitimate symbols. They are used here for illustrative purposes only.

Normally Open Deenergized State | Normally Open Energized State | Normally Closed Deenergized State | Normally Closed Energized State

Mechanical limit switches, which will be covered in the next section, use a different set of symbols. Highlighted symbols are used for illustrative purposes only.

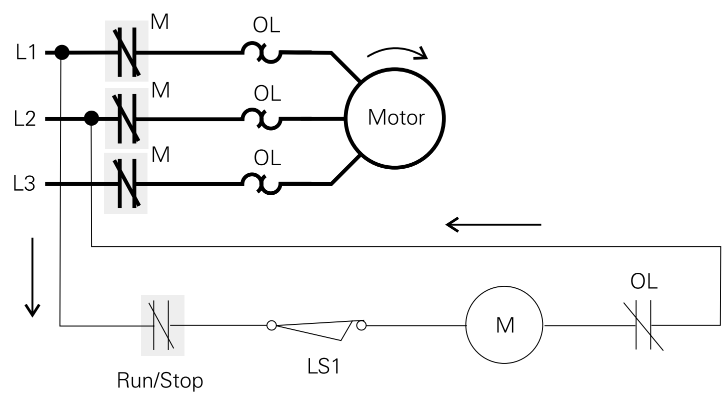
Normally Open | Normally Open Held Closed | Normally Closed | Normally Closed Held Open



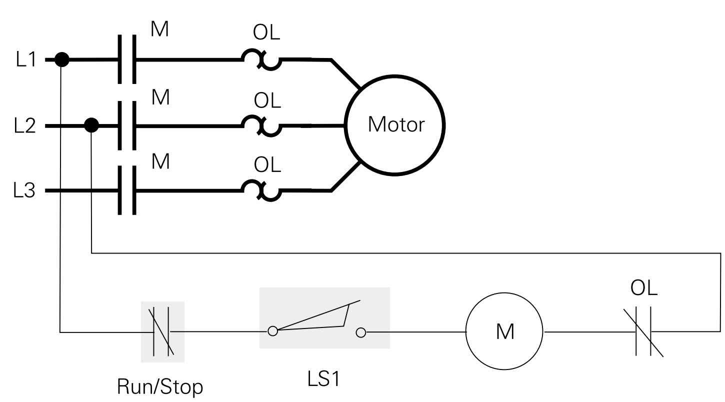
Normally Open in Closed Position | Normally Open Held Closed in Open Position | Normally Closed in Open Position | Normally Closed Held Open in Closed Position

Circuit Example

In the following diagram a mechanical limit switch (LS1) has been placed in series with a Run/Stop contact and the "M" contactor coil. The Run/Stop contact is in the Run condition and the motor is running a process. This could be a conveyor or some other device. Note that the "M" contacts and the "Run/Stop" are shown highlighted, indicating they are normally open contacts in the closed position. LS1 is a normally closed contact of the mechanical limit switch.



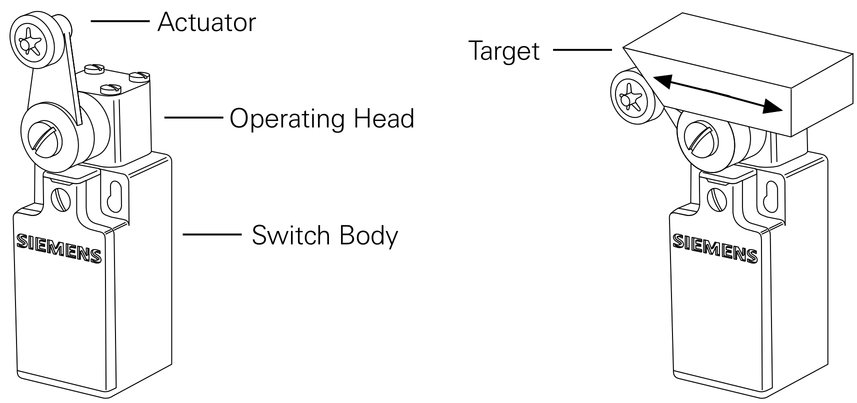
When an object makes contact with the mechanical limit switch the LS1 contacts will change state. In this example the normally closed contacts of LS1 open. The mechanical limit switch symbol is highlighted. The "M" contactor coil is deenergized, returning the normally open contacts of the "M" contactor to their normal position, stopping the motor and the process.



Limit Switches

A typical limit switch consists of a switch body and an operating head. The switch body includes electrical contacts to energize and deenergize a circuit. The operating head incorporates some type of lever arm or plunger, referred to as an actuator.

The standard limit switch is a mechanical device that uses physical contact to detect the presence of an object (target). When the target comes in contact with the actuator, the actuator is rotated from its normal position to the operating position. This mechanical operation activates contacts within the switch body.



Principle of Operation

A number of terms must be understood to understand how a mechanical limit switch operates.

The free position is the position of the actuator when no external force is applied.

Pretravel is the distance or angle traveled in moving the actuator from the free position to the operating position.

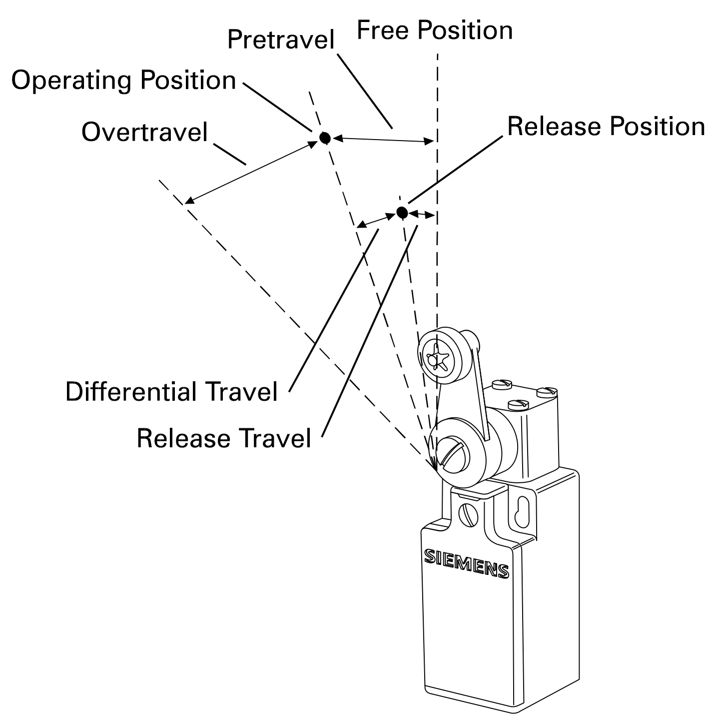
The operating position is where contacts in the limit switch change from their normal state (NO or NC) to their operated state.

Overtravel is the distance the actuator can travel safely beyond the operating point.

Differential travel is the distance traveled between the operating position and the release position.

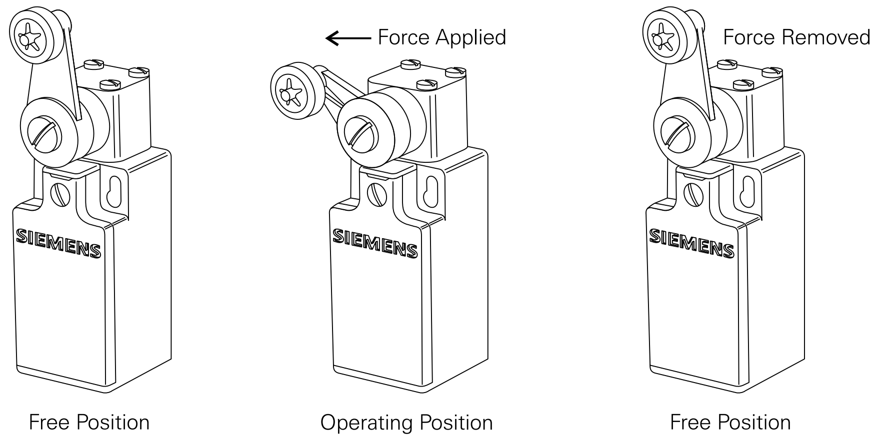
The release position is where the contacts change from their operated state to their normal state.

Release travel is the distance traveled from the release position to the free position.



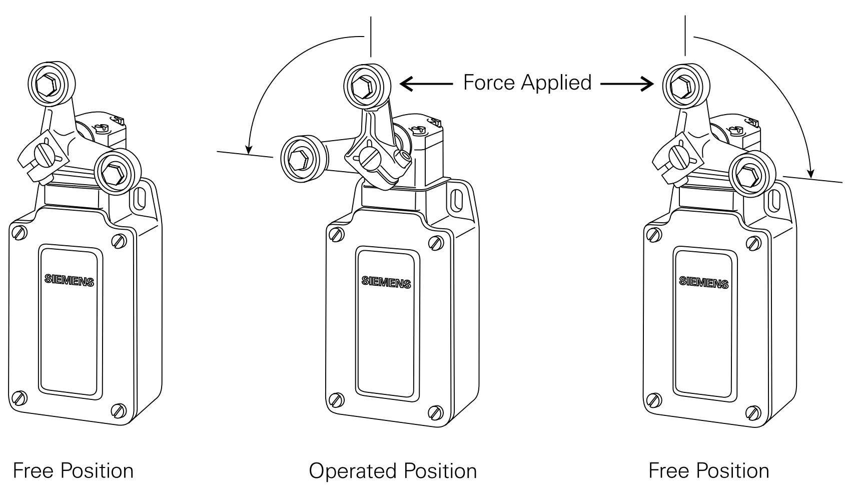
Momentary Operation

One type of actuator operation is momentary. When the target comes in contact with the actuator, it rotates the actuator from the free position, through the pretravel area, to the operating position. At this point the electrical contacts in the switch body change state. A spring returns the actuator lever and electrical contacts to their free position when the actuator is no longer in contact with the target.



Maintained Operation

In many applications it is desirable to have the actuator lever and electrical contacts remain in their operated state after the actuator is no longer in contact with the target. This is referred to as maintained operation. With maintained operation the actuator lever and contacts return to their free position when a force is applied to the actuator in the opposite direction. A fork-style actuator is typically used for this application.

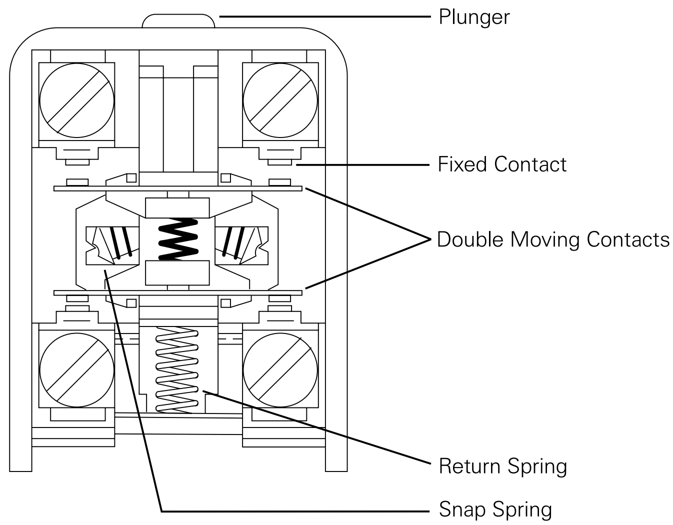


Snap-Action Contacts

There are two types of contacts, snap-action and slow-break. Snap-action contacts open or close by a snap action regardless of the actuator speed. When force is applied to the actuator in the direction of travel, pressure builds up in the snap spring. When the actuator reaches the operating position of travel, a set of moveable contacts accelerates from its normal position towards a set of fixed contacts.

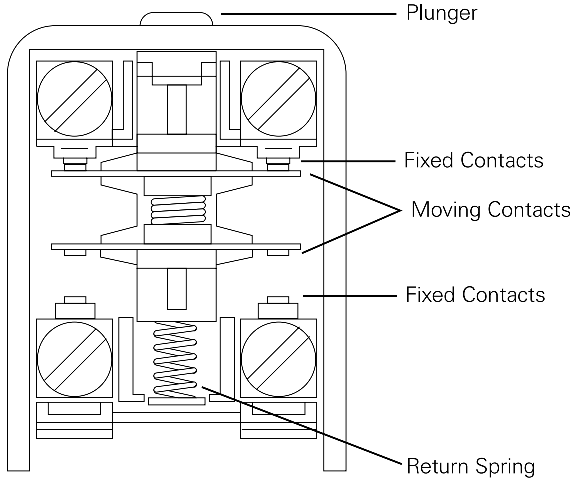
As force is removed from the actuator it returns to its free position. When the actuator reaches the release position the spring mechanism accelerates the moveable contact back to its original state.

Since the opening or closing of the contacts is not dependent on the speed of the actuator, snap-action contacts are particularly suited for low actuator speed applications. Snap-action contacts are the most commonly used type of contact.



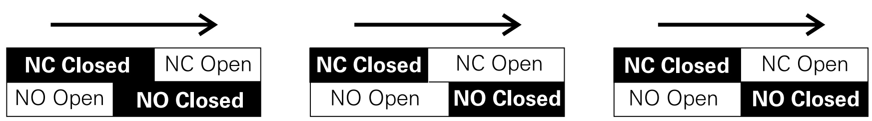
Slow-Break Contacts

Switches with slow-break contacts have moveable contacts that are located in a slide and move directly with the actuator. This ensures the moveable contacts are forced directly by the actuator. Slow-break contacts can either be break-before-make or make-before-break.



In slow-break switches with break-before-make contacts, the normally closed contact opens before the normally open contact closes. This allows the interruption of one function before continuation of another function in a control sequence.

In slow-break switches with make-before-break contacts, the normally open contact closes before the normally closed contact opens. This allows the initiation of one function before the interruption of another function.

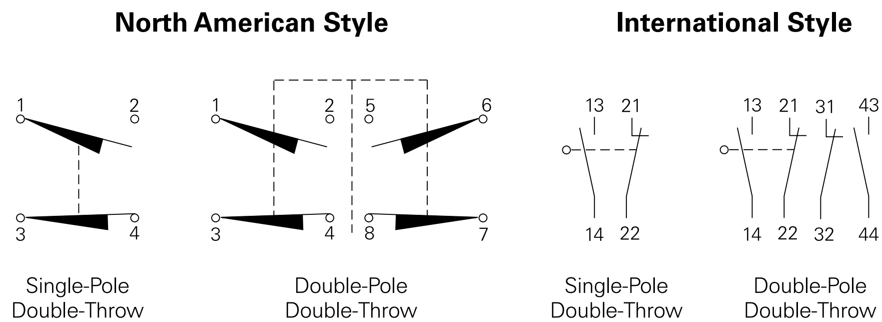


Make-Before-Break   Break-Before-Make   Snap-Action

Contact State	Break-Before-Make		Make-Before-Break	
	NO	**NC**	**NO**	**NC**
Free Position	Open	Closed	Open	Closed
Transition	Open	Open	Closed	Closed
Operated State	Closed	Open	Closed	Open

Contact Arrangements

There are two basic contact configurations used in limit switches: single-pole, double-throw (SPDT) and double-pole, double-throw (DPDT). This terminology may be confusing if compared to similar terminology for other switch or relay contacts, so it is best just to remember the following points. The single-pole, double-throw contact arrangement consists of one normally open (NO) and one normally closed (NC) contact. The double-pole, double-throw (DPDT) contact arrangement consists of two normally open (NO) and two normally closed (NC) contacts. There are some differences in the symbology used in the North American and International style limit switches. These are illustrated below.



Electrical Ratings

Contacts are rated according to voltage and current. Ratings are generally described as inductive ratings. A typical inductive load is a relay or contactor coil. There are three components to inductive ratings:

Make The load a switch can handle when the mechanical contacts close. This is associated with inrush currents. This is typically two cycles or less.

Break The load a switch can handle when the mechanical contacts are opened. This is the maximum continuous switch current.

Continuous The load that a switch can handle without making or breaking a load.

The following ratings are typical of Siemens International and North American style limit switches.

Inductive AC Contact Ratings

AC Volts	International and North American Style			
	Make		Break	
	Amp	VA	Amp	VA
120	60	7200	6	720
240	30	7200	3	720

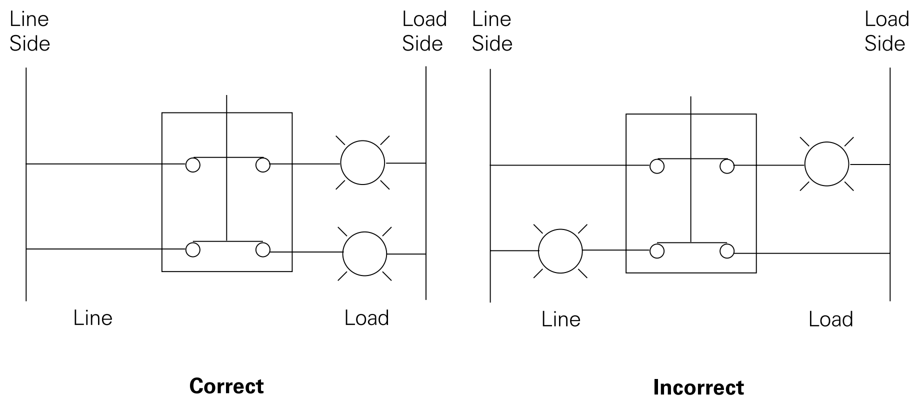
Inductive DC Contact Ratings

DC Volts	International Style			
	Make		Break	
	Amp	VA	Amp	VA
120	0.55	69	0.55	69
240	0.27	69	0.55	69

DC Volts	North American Style			
	Make		Break	
	Amp	VA	Amp	VA
120	0.22	-	0.22	-
240	0.11	-	0.11	-

Load Connection

Care must be made to ensure that multiple loads on one switch are properly connected. The correct way to wire a switch is so that the loads are connected to the load side of the switch. Loads should never be connected to the line side of the switch.

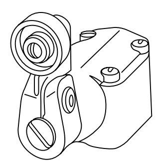


Actuators

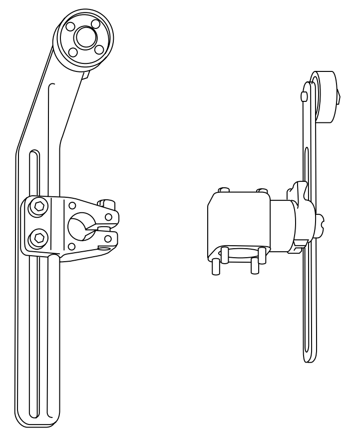
Several types of actuators are available for limit switches, some of which are shown below. There are also variations of actuator types. Actuators shown here are to provide you with a basic knowledge of various types available. The type of actuator selected depends on the application.

Roller Lever

The standard roller is used for most rotary lever applications. It is available in various lengths. When the length of the roller lever is unknown, adjustable length levers are available.



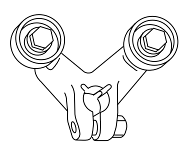
Standard Roller Lever



Adjustable Length Roller Crank Levers

Fork

The fork style actuator must be physically reset after each operation and is ideally suited for transverse movement control.



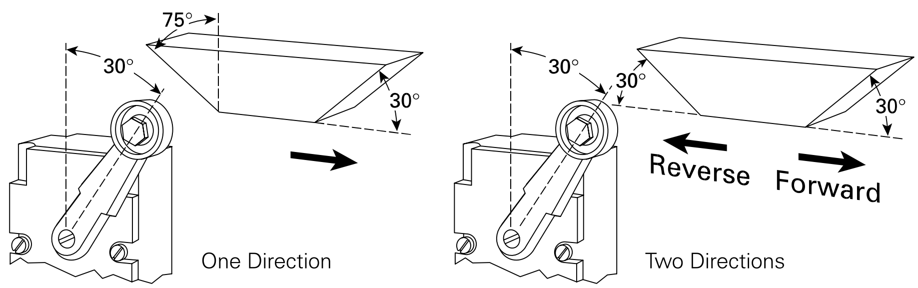
Mounting Considerations

Limit switches should be mounted in locations which will prevent false operations by normal movements of machine components and machine operators. An important aspect of limit switch mounting is cam design. Improper cam design can lead to premature switch failure.

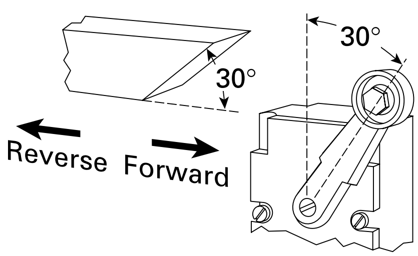
For lever arm actuators it is always desirable to have the cam force perpendicular to the lever arm. For applications in which the cam is traveling at speeds less than 100 feet per minute a cam lever angle of 30 degrees is recommended.

Overriding and Non-Overriding Cams

In overriding cam applications it is necessary to angle the trailing edge of the cam in order to prevent the lever arm from snapping back. Snapping back of the lever arm can cause shock loads on the switch which will reduce the life of the switch.

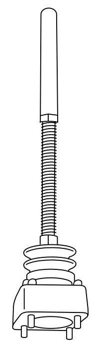


Non-Overriding cams are cams which will not overtravel the actuating mechanism.

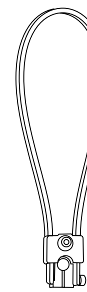


Flexible Loop and Spring Rod

Flexible loop and spring rod actuators can be actuated from all directions, making them suitable for applications in which the direction of approach is constantly changing.



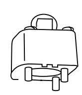
Spring Rod

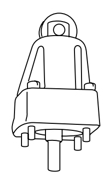


Flexible Loop

Plungers

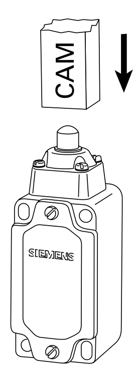
Plunger type actuators are a good choice where short, controlled machine movements are present or where space or mounting does not permit a lever type actuator. The plunger can be activated in the direction of plunger stroke, or at a right angle to its axis.





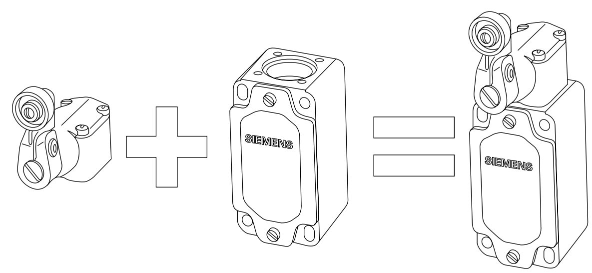
Mounting Considerations

When using plain and side plunger actuators the cam should be operated in line with the push rod axis. Consideration should be given so as not to exceed the overtravel specifications. In addition, the limit switch should not be used as a mechanical stop for the cam. When using roller top plunger the same considerations should be given as with lever arm actuators.



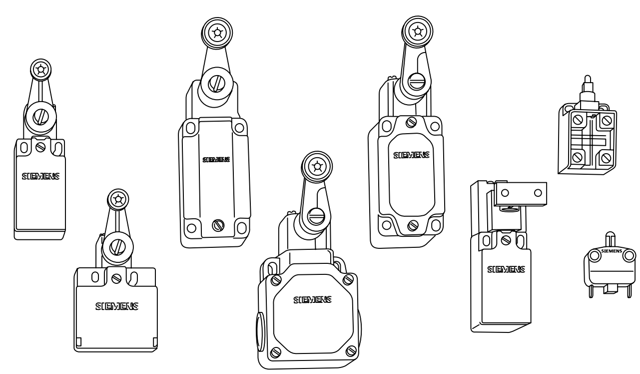
International Limit Switches

International mechanical limit switches are widely used in many countries, including North America. The International Electrotechnical Commission (IEC) and the National Electrical Manufacturers Association (NEMA) develop standards for electrical equipment. Siemens international mechanical switches are built to IEC and NEMA standards. In addition, they are UL listed and CSA certified. International style switches consist of two major components, the operating head and switch body.



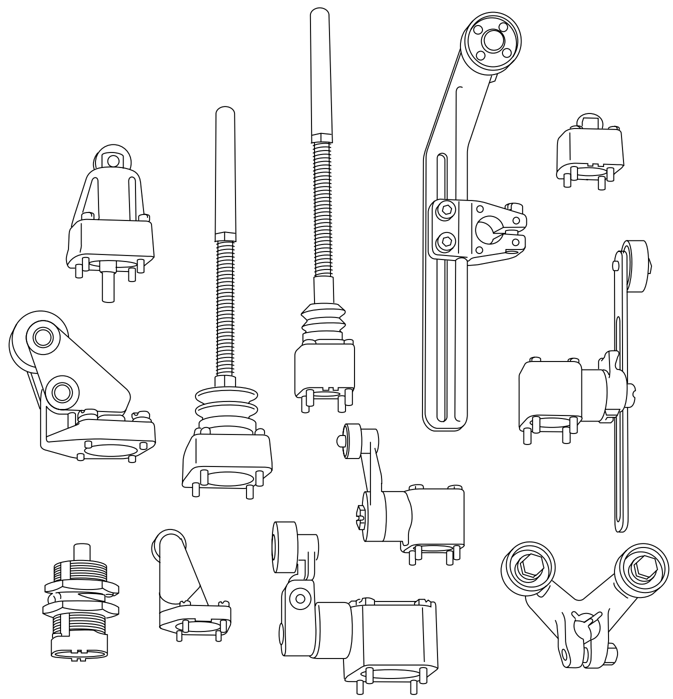
International Limit Switch Family

A large family of mechanical limit switches is available in the international style to meet virtually any mechanical limit switch application.

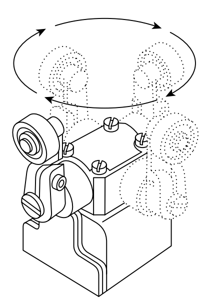


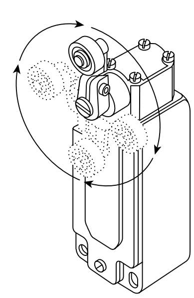
Operating Heads

Depending on the switch, Siemens international style limit switches can be fitted with any of several interchangeable operating heads and actuators. Overtravel plunger, roller plunger, roller or angular roller lever, plain or adjustable length roller lever, plain or spring rod, fork lever, or coded sensing heads are available.



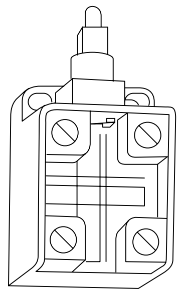
The actuator head can be rotated so that the switching direction of limit switches with roller crank, adjustable-length roller crank or rod actuators can operate from any side of the switch body. In addition, roller cranks can be repositioned to the left or right around the operating shaft.



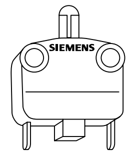


Open-Type Limit Switches

Open-type limit switches are intended for use as auxiliary switches in cabinets, large enclosures, or locations where they are not exposed to dust and moisture. A miniature version is available for limited space applications such as automatic door interlocking. Open-type switches use a plunger actuator.



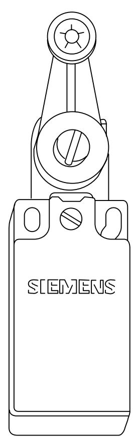
Open Type



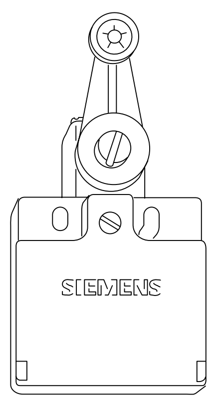
Miniature Open Type

Miniature Formed Housing Limit Switches

Miniature formed housing limit switches are used in applications where space is restricted. The glass-reinforced fiber, flame-retardant molded plastic enclosure resists most shocks, impacts, cutting oils, and penetration from dust and water.



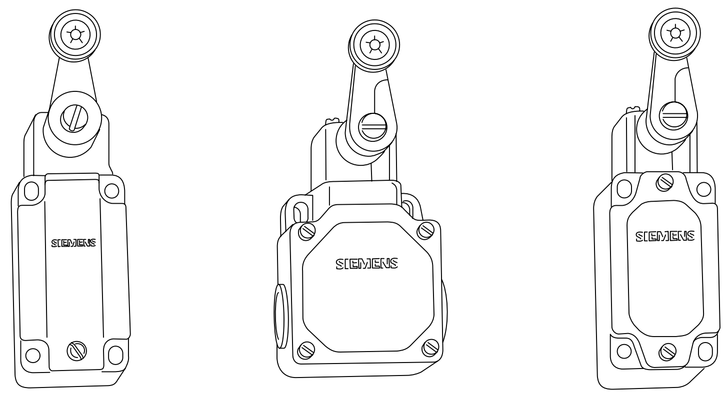
Miniature Formed Housing



Wide Miniature Formed Housing

Replaceable Contact Block Limit Switches

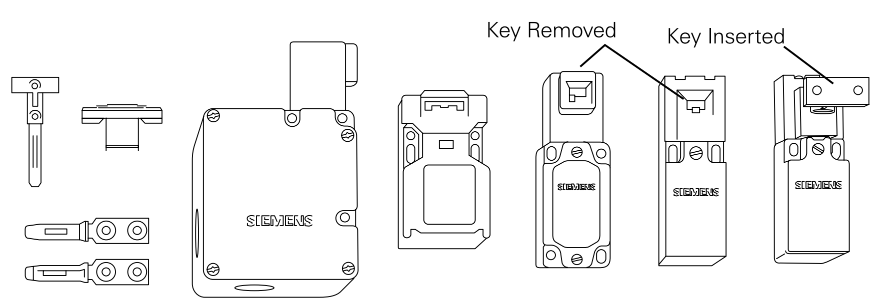
Siemens has developed two limit switch models with replaceable contact blocks, one with a formed plastic enclosure and one with a metal enclosure. The formed plastic version is in an enclosure similar to the miniature limit switches discussed previously. The metal version is enclosed in die-cast aluminum. It is impervious to most mechanical shocks.



Formed Housing Replaceable Contact Block | Wide Metal Housing Replaceable Contact Block | Metal Housing Replaceable Contact Block

SIGUARD Mechanical Interlock Switches

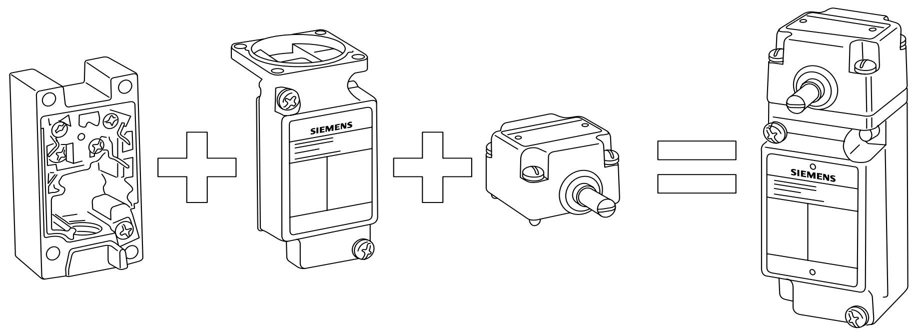
Sensitivity to safety is an increasing priority for the workplace. Most sensors cannot be used in safety circuits, including proximity sensors and photoelectric sensors which will be covered in later sections. Sensors used in safety circuits must meet stricter design and test standards specified by DIN and IEC. The SIGUARD line of International style switches is designed for safety circuits. SIGUARD mechanical interlock switches have triple coded actuators that act as a key. These devices can be used to control the position of doors, machine guards, gates, and enclosure covers. They can also be used to interrupt operation for user safety. They are available in miniature formed housing and metal housing models.



Interlock Keys | Interlock Switches

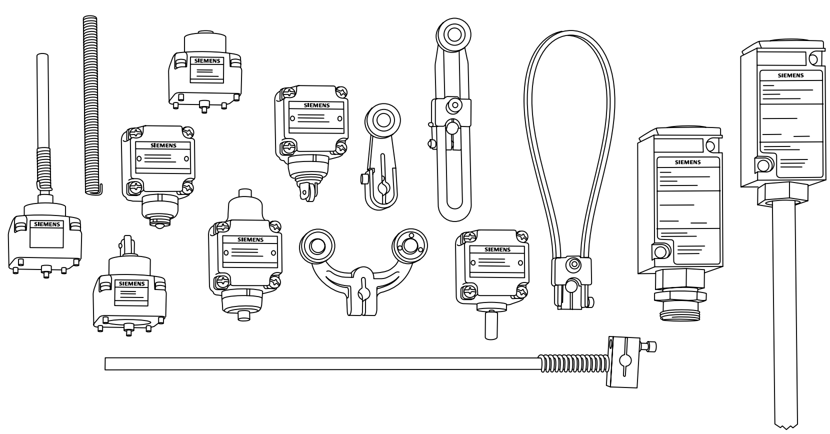
North American Limit Switches

North American mechanical limit switches are specifically designed to meet unique requirements of the North American market. These switches are comprised of three interchangeable components; contact block, switch body, and sensing head. North American limit switches meet UL (Underwriters Laboratory) and CSA (Canadian Standards Association).



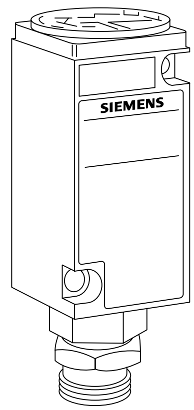
Actuators

Like the International limit switches, Siemens North American limit switches also accept a variety of operating heads and actuators.



NEMA Type 6P Submersible

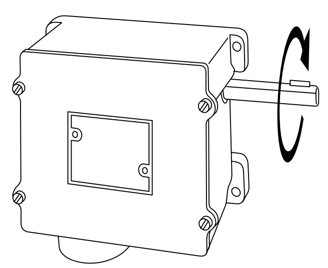
The housing for North American NEMA Type 6P submersible limit switch is die-cast metal with an epoxy finish for harsh industrial environments. In addition, the Siemens 6P submersible switch can be used for watertight applications.



NEMA Type 6P Submersible
Without Acuator Head

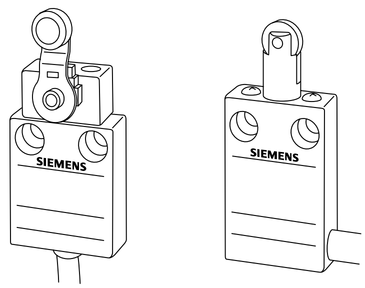
Class 54, Rotating Type

Class 54 rotating limit switches are used to limit the travel of electrically operated doors, conveyors, hoists, and similar applications. The contacts are operated when the external shaft is rotated sufficiently. Siemens rotating switches employ a simple reduction worm and gear(s) to provide shaft-to-cam ratios of 18 to 1, 36 to 1, 72 to 1, or 108 to 1. In addition, long dwell cams are available which keeps contacts closed for longer periods of time. This may be necessary in hoist or similar applications. A fine adjustment cam is also available to increase the accuracy of the number of shaft turns required to cause the contacts to operate.



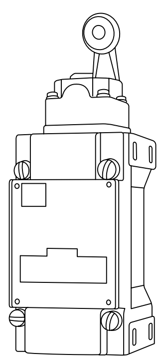
Miniature, Prewired, Sealed Switches

Miniature, prewired, sealed switches allow for miniaturization of the electrical connection. The switch is prewired and the terminals and connection are encapsulated in epoxy. The switch uses a single-pole, double-throw contact. The contact can be wired either normally open (NO) or normally closed (NC). Depending on the load voltage, the contact can make up to 7.5 amps and break up to 5 amps.



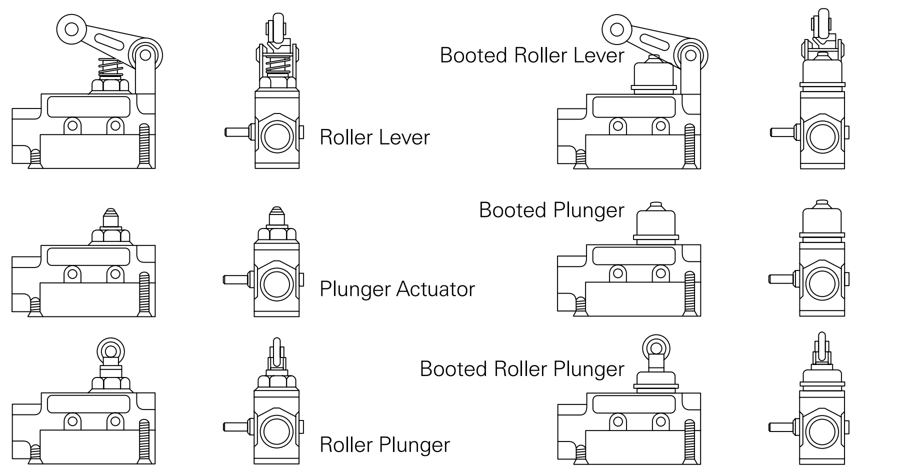
3SE03 Hazardous Locations, Type EX

Type EX limit switches are designed for extreme environmental service in locations where there exists a danger of an internal or external explosion of flammable gasses, vapors, metal alloy, or grain dust. EX switches are designated by the catalog number 3SE03-EX.



Enclosed Basic Switches

North American limit switches are also available in an enclosed basic version. These switches are designated by the catalog number 3SE03-EB. Enclosed basic switches are preconfigured with a plunger actuator, booted plunger, roller lever, booted roller lever, roller plunger, or a booted roller plunger.



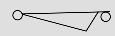
Review 1

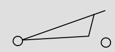
1) A ___________ ___________ is a type of sensor that requires physical contact with the target.

2) Which of the following symbols identifies a Normally Closed, Held Open limit switch?

a. 

b. 

c. 

d. 

3. ___________ is the distance or angle traveled in moving the actuator from the free position to the operating position.

4. The ___________ ___________ is where contacts in the limit switch change from their normal state to their operated state.

5. In slow-break switches with ___________ - ___________ - ___________ contacts, the normally closed contact opens before the normally open contact closes.

6. ___________ defines the load a switch can handle when the mechanical contacts are opened. This is the maximum continuous switch current.

7. For applications in which the cam is travelling at speeds less than 100 feet per minute a cam lever angle of ___________ degrees is recommended.

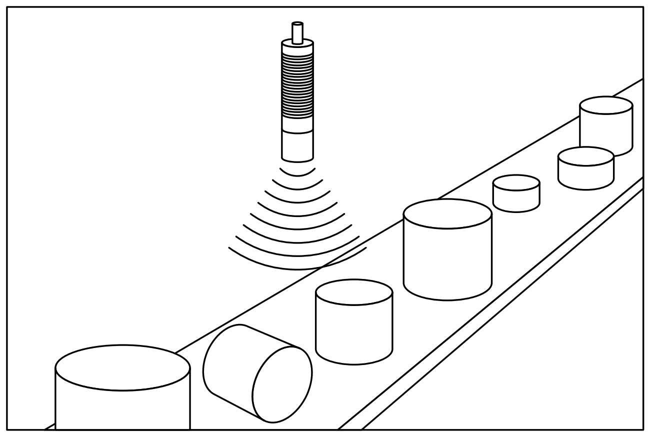
8. An International switch consists of an ___________ ___________ and switch body.

9. ___________ is the trade name for a type of International switch suitable for safety circuits.

10. The Siemens ___________ submersible switch can be used for watertight applications.

BERO Sensors

BERO is the trade name used by Siemens to identify its line of "no-touch" sensors. Siemens BERO sensors operate with no mechanical contact or wear. In the following application, for example, a BERO sensor is used to determine if cans are in the right position on a conveyor.



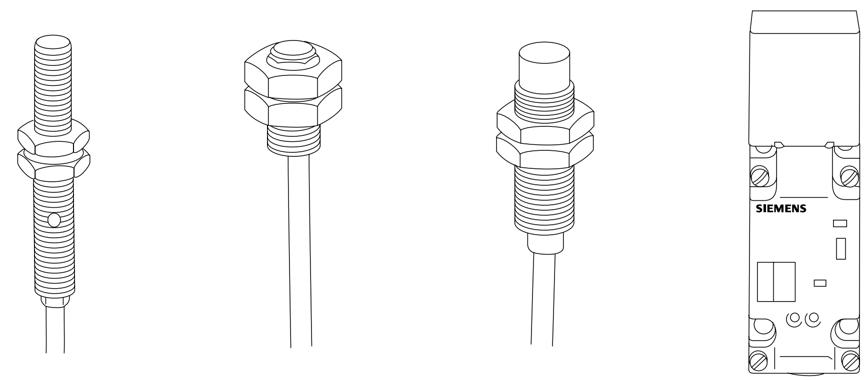
Types of BERO Sensors

There are four types of BERO sensors: inductive, capacitive, ultrasonic, and photoelectric. Inductive proximity sensors use an electromagnetic field to detect the presence of metal objects. Capacitive proximity sensors use an electrostatic field to detect the presence of any object. Ultrasonic proximity sensors use sound waves to detect the presence of objects. Photoelectric sensors react on changes in the received quantity of light. Some photoelectric sensors can even detect a specific color.

Sensor	Objects Detected	Technology
Inductive	Metal	Electromagnetic Field
Capacitive	Any	Electrostatic Field
Ultrasonic	Any	Sound Waves
Photoelectric	Any	Light

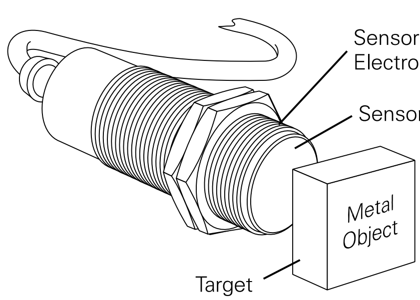
Inductive Proximity Sensors
Theory of Operation

In this section we will look at BERO inductive proximity sensors, and how they detect the presence of an object without coming into physical contact with it. Inductive proximity sensors are available in a variety of sizes and configurations to meet varying applications. Specific sensors will be covered in more detailed in the following section.



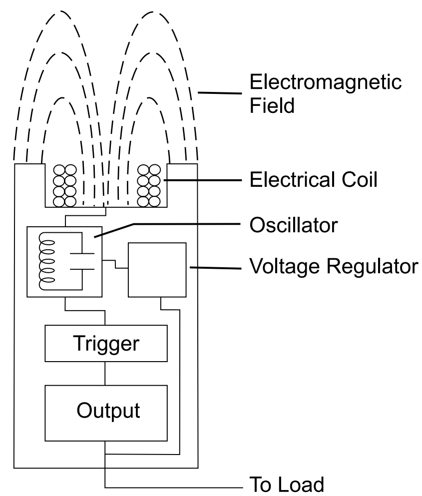
Electromagnetic Coil and Metal Target

The sensor incorporates an electromagnetic coil which is used to detect the presence of a conductive metal object. The sensor will ignore the presence of an object if it is not metal.

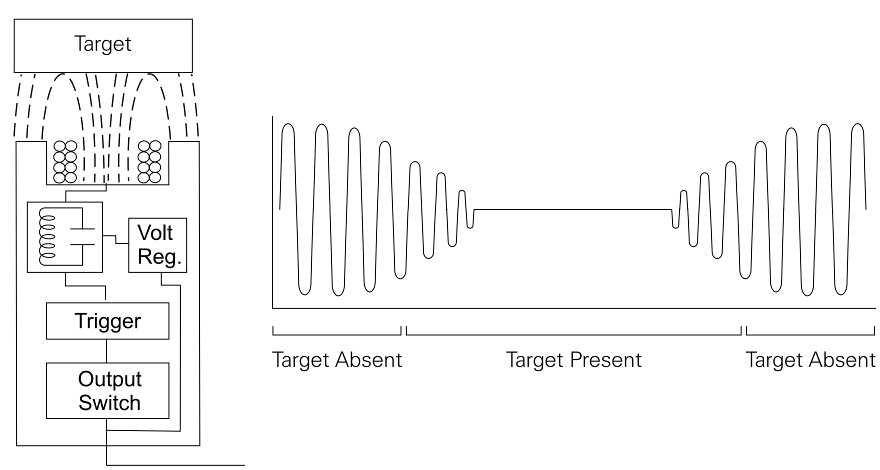


ECKO

Siemens BERO inductive proximity sensors are operated using an Eddy Current Killed Oscillator (ECKO) principle. This type of sensor consists of four elements: coil, oscillator, trigger circuit, and an output. The oscillator is an inductive capacitive tuned circuit that creates a radio frequency. The electromagnetic field produced by the oscillator is emitted from the coil away from the face of the sensor. The circuit has just enough feedback from the field to keep the oscillator going.



When a metal target enters the field, eddy currents circulate within the target. This causes a load on the sensor, decreasing the amplitude of the electromagnetic field. As the target approaches the sensor the eddy currents increase, increasing the load on the oscillator and further decreasing the amplitude of the field. The trigger circuit monitors the oscillator's amplitude and at a predetermined level switches the output state of the sensor from its normal condition (on or off). As the target moves away from the sensor, the oscillator's amplitude increases. At a predetermined level the trigger switches the output state of the sensor back to its normal condition (on or off).

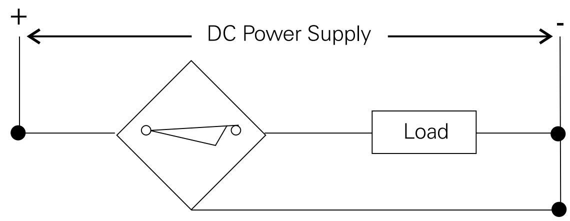


Operating Voltages

Siemens inductive proximity sensors include AC, DC, and AC/DC (universal voltage) models. The basic operating voltage ranges are from 10 to 30 VDC, 15 to 34 VDC, 10 to 65 VDC, 20 to 320 VDC, and 20 to 265 VAC.

Direct Current Devices

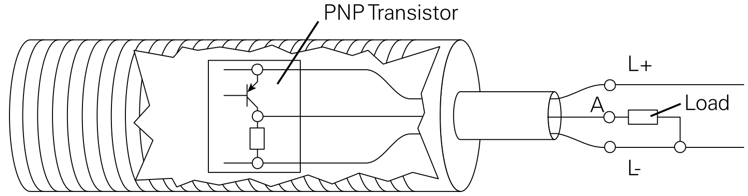
Direct current models are typically three-wire devices (two-wire also available) requiring a separate power supply. The sensor is connected between the positive and negative sides of the power supply. The load is connected between the sensor and one side of the power supply. The specific polarity of the connection depends on the sensor model. In the following example the load is connected between the negative side of the power supply and the sensor.



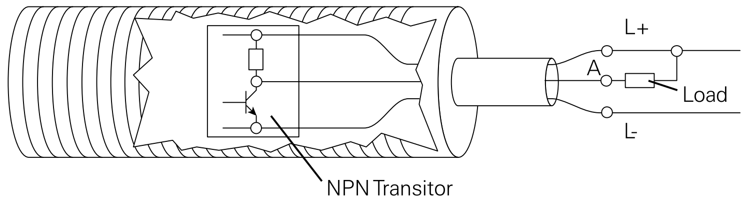
Output Configurations

Three-wire, DC proximity sensor can either be PNP (sourcing) or NPN (sinking). This refers to the type of transistor used in the output switching of the transistor.

The following drawing illustrates the output stage of a PNP sensor. The load is connected between the output (A) and the negative side of the power supply (L-). A PNP transistor switches the load to the positive side of the power supply (L+). When the transistor switches on, a complete path of current flow exists from L- through the load to L+. This is also referred to as current sourcing since in this configuration conventional current is (+ to -) sourced to the load. This terminology is often confusing to new users of sensors since electron current flow (- to +) is from the load into the sensor when the PNP transistor turns on.



The following drawing illustrates the output of an NPN sensor. The load is connected between the output (A) and the positive side of the power supply (L+). An NPN transistor switches the load to the negative side of the power supply (L-). This is also referred to as current sinking since the direction of conventional current is into the sensor when the transistor turns on. Again, the flow of electron current is in the opposite direction.

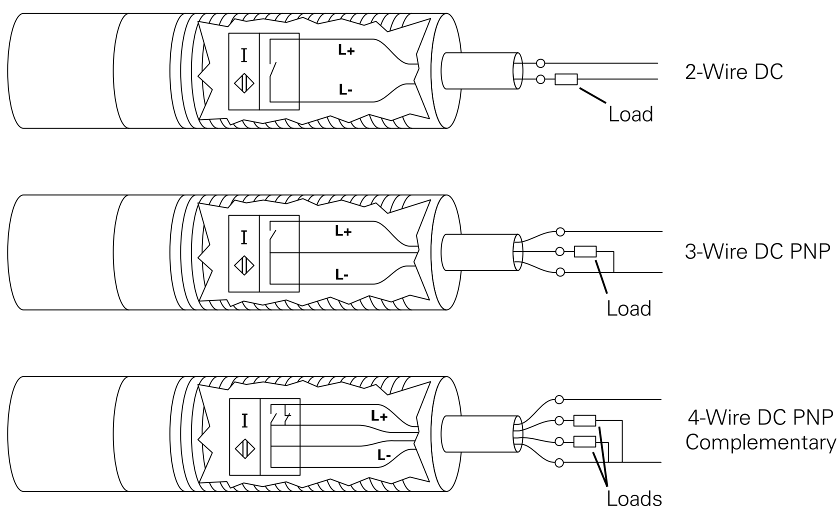


Normally Open (NO)
Normally Closed (NC)

Outputs are considered normally open (NO) or normally closed (NC) based on the condition of the transistor when a target is absent. If, for example, the PNP output is off when the target is absent then it is a normally open device. If the PNP output is on when the target is absent it is a normally closed device.

Complementary

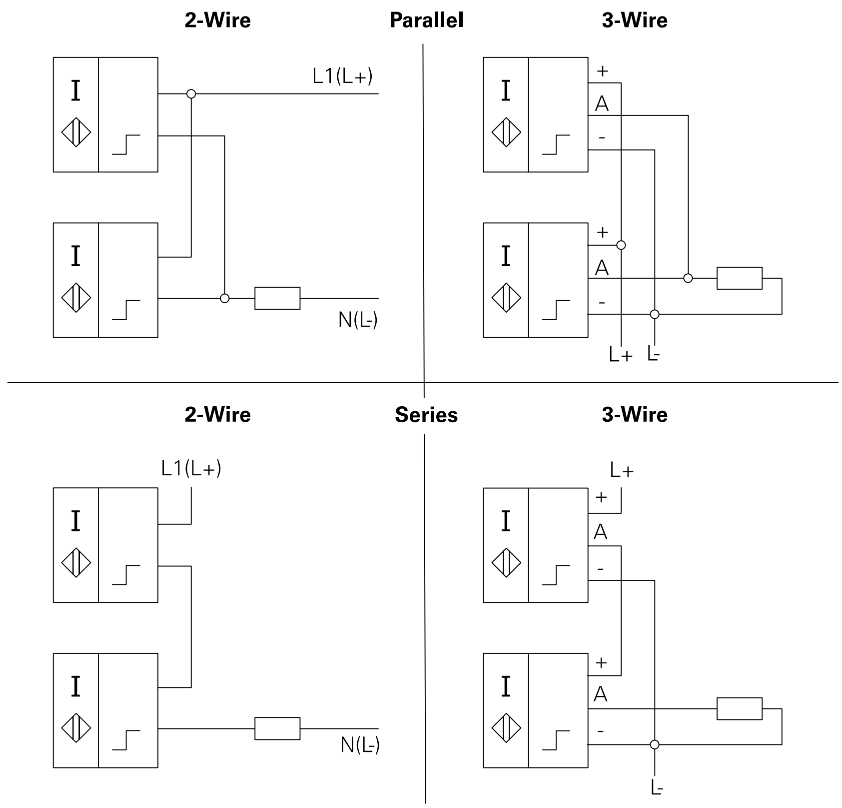
Transistor devices can also be complementary (four-wire). A complementary output is defined as having both normally open and normally closed contacts in the same sensor.



Series and Parallel Connections

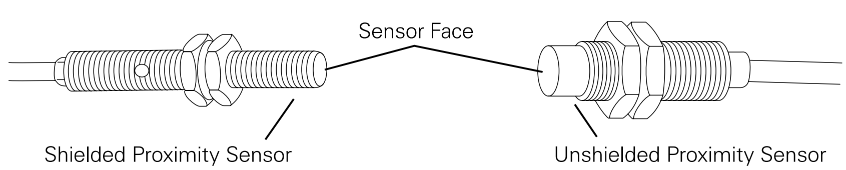
In some applications it may be desirable to use more than one sensor to control a process. Sensors can be connected in series or in parallel. When sensors are connected in series all the sensors must be on to turn on the output. When sensors are connected in parallel either sensor will turn the output on.

There are some limitations that must be considered when connecting sensors in series. In particular, the required supply voltage increases with the number of devices placed in series.



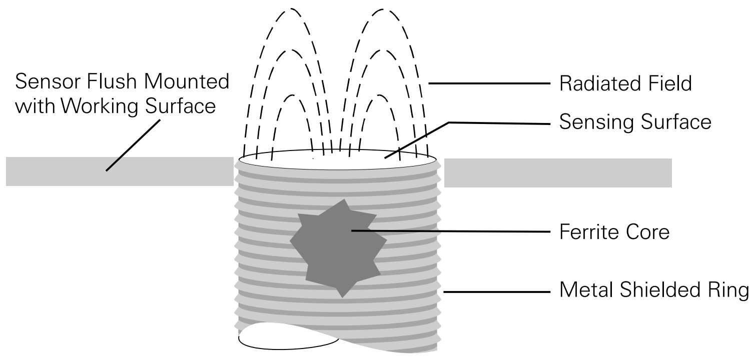
Shielding

Proximity sensors contain coils that are wound in ferrite cores. They can be shielded or unshielded. Unshielded sensors usually have a greater sensing distance than shielded sensors.



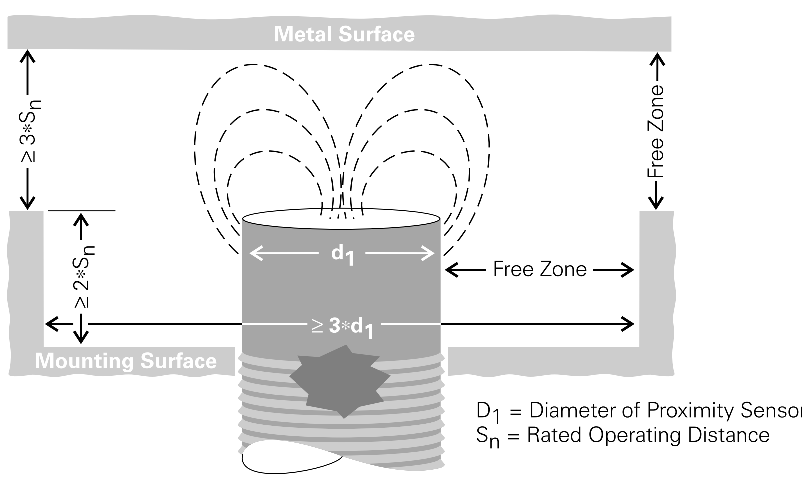
Shielded Proximity Sensors

The ferrite core concentrates the radiated field in the direction of use. A shielded proximity sensor has a metal ring placed around the core to restrict the lateral radiation of the field. Shielded proximity sensors can be flush mounted in metal. A metal-free space is recommended above and around the sensor's sensing surface. Refer to the sensor catalog for this specification. If there is a metal surface opposite the proximity sensor it must be at least three times the rated sensing distance of the sensor from the sensing surface.



Unshielded Proximity Sensors

An unshielded proximity sensor does not have a metal ring around the core to restrict lateral radiation of the field. Unshielded sensors cannot be flush mounted in metal. There must be an area around the sensing surface that is metal free. An area of at least three times the diameter of the sensing surface must be cleared around the sensing surface of the sensor. In addition, the sensor must be mounted so that the metal surface of the mounting area is at least two times the sensing distance from the sensing face. If there is a metal surface opposite of the proximity sensor it must be at least three times the rated sensing distance of the sensor from the sensing surface.

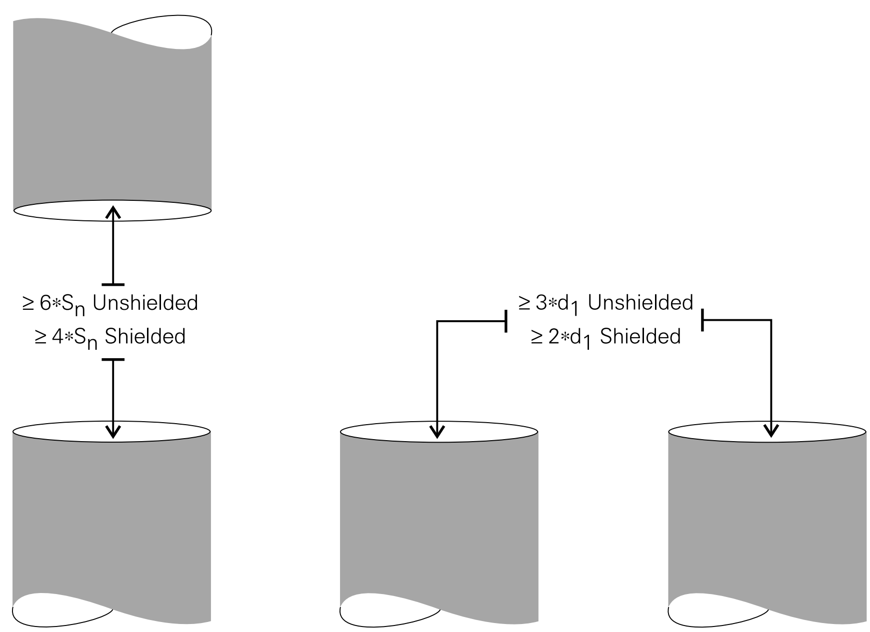


Mounting Multiple Sensors

Care must be taken when using multiple sensors. When two or more sensors are mounted adjacent to or opposite one another, interference or cross-talk can occur producing false outputs. The following guidelines can generally be used to minimize interference.

- Opposite shielded sensors should be separated by at least four times the rated sensing range
- Opposite unshielded sensors should be separated by at least six times the rated sensing range
- Adjacent shielded sensors should be separated by at least two times the diameter of the sensor face
- Adjacent unshielded sensors should be separated by at least three times the diameter of the sensor face

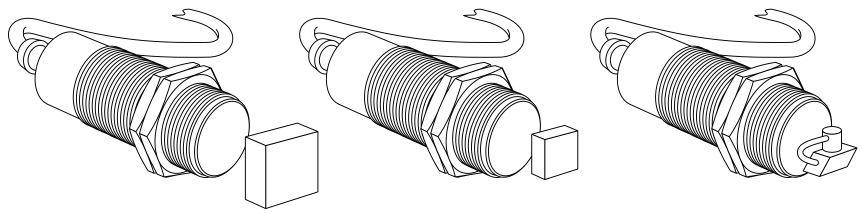
These are general guidelines. BERO proximity sensors have individual specifications which should be followed. For instance, some devices are rated as suitable for side-by-side mounting.



Standard Target

A standard target is defined as having a flat, smooth surface, made of mild steel that is 1 mm (0.04") thick. Steel is available in various grades. Mild steel is composed of a higher content of iron and carbon. The standard target used with shielded sensors has sides equal to the diameter of the sensing face. The standard target used with unshielded sensors has sides equal to the diameter of the sensing face or three times the rated operating range, whichever is greater.

If the target is larger than the standard target, the sensing range does not change. However, if the target is smaller or irregular shaped the sensing distance (S_n) decreases. The smaller the area of the target the closer it must be to the sensing face to be detected.



Target Size Correction Factor

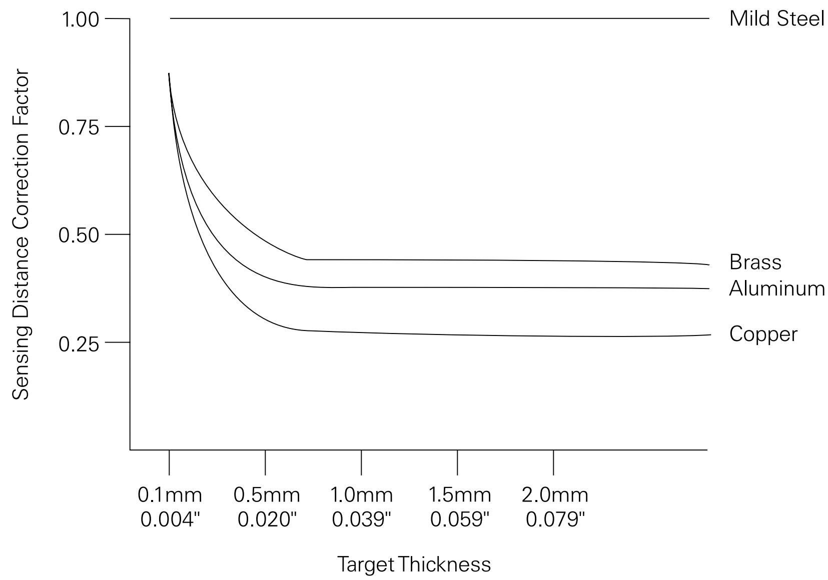
A correction factor can be applied when targets are smaller than the standard target. To determine the sensing distance for a target that is smaller than the standard target (S_{new}), multiply the rated sensing distance (S_{rated}) times the correction factor (T). If, for example, a shielded sensor has a rated sensing distance of 1 mm and the target is half the size of the standard target, the new sensing distance is 0.83 mm (1 mm x 0.83).

$S_{new} = S_{rated} \times T$
$S_{new} = 1 \text{ mm} \times 0.83$
$S_{new} = 0.83 \text{ mm}$

Size of Target Compared to Standard Target	Correction Factor	
	Shielded	Unshielded
25%	0.56	0.50
50%	0.83	0.73
75%	0.92	0.90
100%	1.00	1.00

Target Thickness

Thickness of the target is another factor that should be considered. The sensing distance is constant for the standard target. However, for nonferrous targets such as brass, aluminum, and copper a phenomenon known as “skin effect” occurs. Sensing distance decreases as the target thickness increases. If the target is other than the standard target a correction factor must be applied for the thickness of the target.



Target Material

The target material also has an effect on the sensing distance. When the material is other than mild steel correction factors need to be applied.

Material	Correction Factor	
	Shielded	Unshielded
Mild Steel, Carbon	1.00	1.00
Aluminum Foil	0.90	1.00
300 Series Stainless Steel	0.70	0.08
Brass	0.40	0.50
Aluminum	0.35	0.45
Copper	0.30	0.40

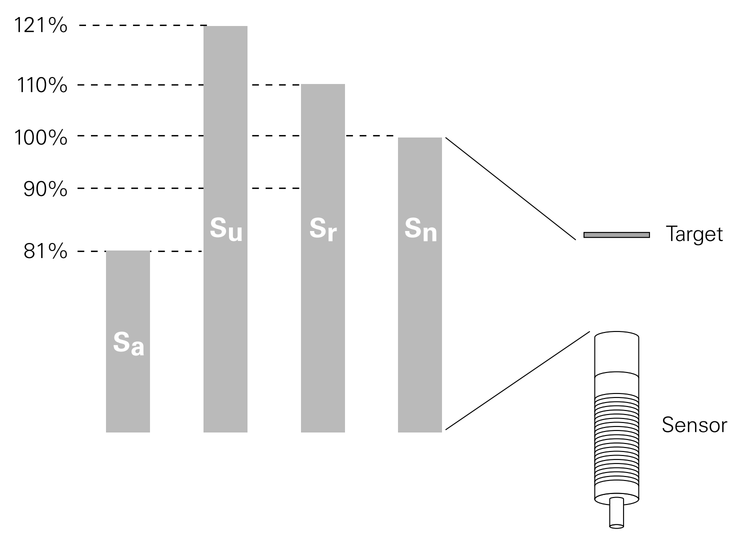
Rated Operating Distances

The rated sensing distance (S_n) is a theoretical value which does not take into account such things as manufacturing tolerances, operating temperature, and supply voltage. In some applications the sensor may recognize a target that is outside of the rated sensing distance. In other applications the target may not be recognized until it is closer than the rated sensing distance. Several other terms must be considered when evaluating an application.

The effective operating distance (S_r) is measured at nominal supply voltage at an ambient temperature of 23°C ± 0.5°. It takes into account manufacturing tolerances. The effective operating distance is ±10% of the rated operating distance. This means the target will be sensed between 0 and 90% of the rated sensing distance. Depending on the device, however, the effective sensing distance can be as far out as 110% of the rated sensing distance.

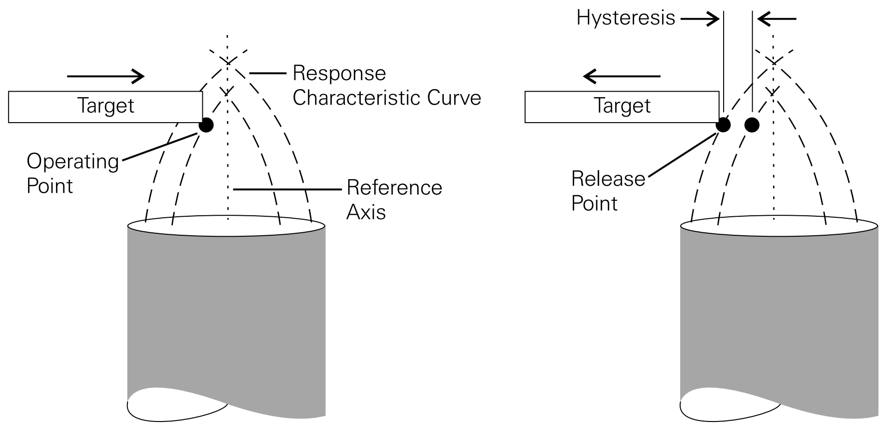
The useful switching distance (S_u) is the switching distance measured under specified temperature and voltage conditions. The useful switching distance is ±10% of the effective operating distance.

The guaranteed operating distance (S_a) is any switching distance for which an operation of the proximity switch within specific permissible operating conditions is guaranteed. The guaranteed operating distance is between 0 and 81% of the rated operating distance.



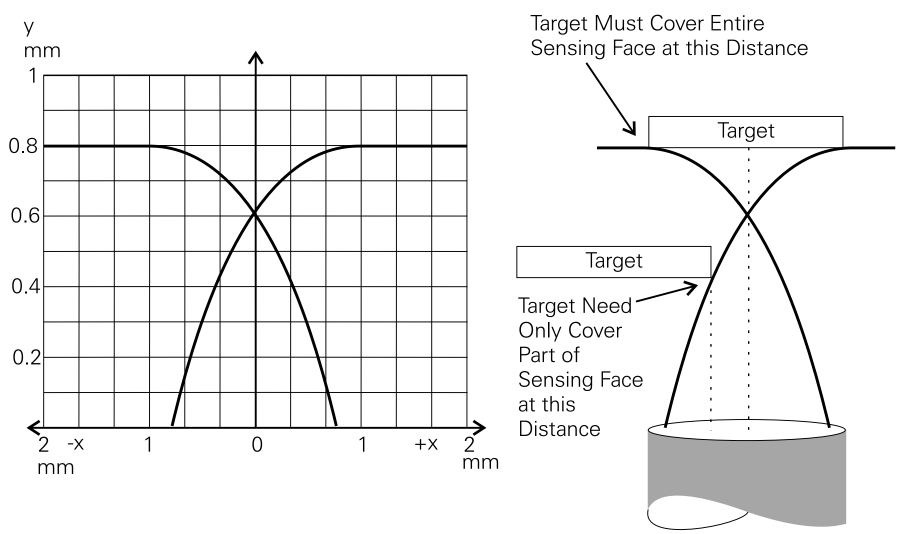
Response Characteristic

Proximity switches respond to an object only when it is in a defined area in front of the switch's sensing face. The point at which the proximity switch recognizes an incoming target is the operating point. The point at which an outgoing target causes the device to switch back to its normal state is called the release point. The area between these two points is called the hysteresis zone.



Response Curve

The size and shape of the response curve depends on the specific proximity switch. The following curve represents one type of proximity switch.



Review 2

1) An ___________ sensor uses an electromagnetic field and can only detect metal objects.

2) Which of the following is not an element of an inductive proximity sensor.

   a. Target
   b. Electrical Coil
   c. Oscillator
   d. Trigger Circuit
   e. Output

3) An area surrounding an unshielded inductive proximity sensor of at least ___________ times the area of the sensing face must be metal free.

4) Shielded inductive proximity sensors mounted opposite each other should be mounted at least ___________ times the rated sensing area from each other.

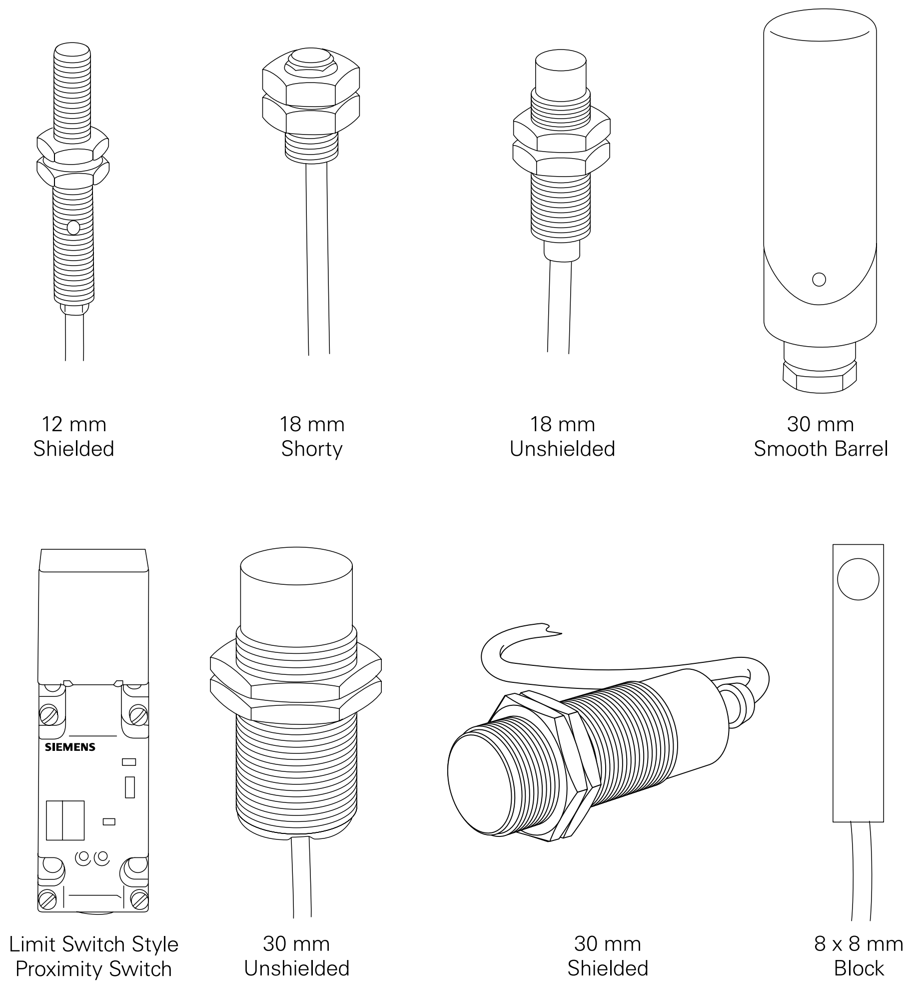
5) A standard target for an inductive proximity sensor is made of mild ___________ and is 1 mm thick.

6) A correction factor of ___________ should be applied to a shielded inductive proximity sensor when the target is made of brass.

7) The guaranteed operating distance of an inductive proximity switch is between 0 and ___________ % of the rated operating distance.

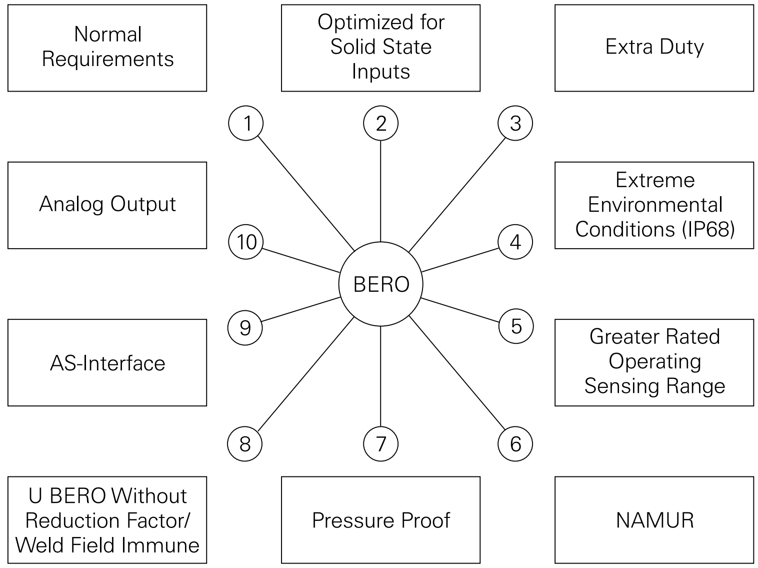
Inductive Proximity Sensor Family

In this section we will look at the 3RG4 and 3RG04 families of inductive proximity sensors. 3RG4 refers to the first part of the part number that is used to identify this line of sensors.



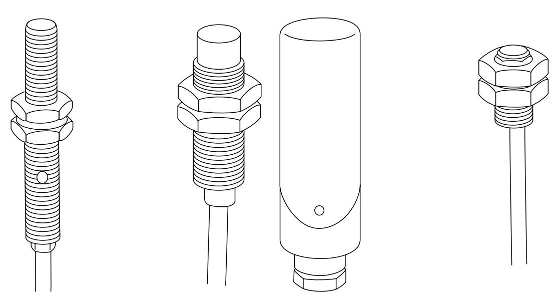
Categories

Inductive proximity sensors are available in ten categories. Each category will be briefly discussed and followed by a selection guide.



Normal Requirements Cylindrical

Inductive proximity sensors designed for normal requirements are also referred to as the standard series. These sensors will meet the needs of normal or standard applications. Standard series sensors used for normal requirements are available in several sizes, including the shorty version which is used where mounting space is limited. The diameter sensing face ranges from 3 mm to 34 mm. In addition, standard series sensors come with PNP or NPN outputs in 2, 3, or 4 wires. Standard series sensors can handle loads up to 200 mA.



Shielded   Unshielded   Shorty

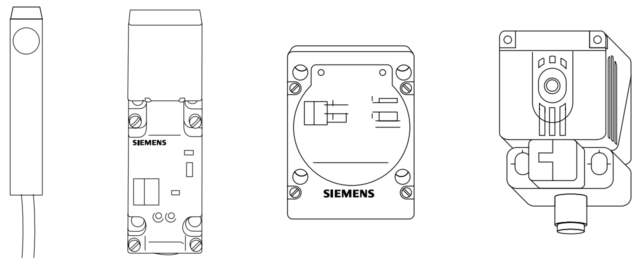
Normal Requirements Cylindrical Selection Guide

The following Inductive Proximity Selection Guide will help you find the right sensor for a given application. The housing dimension column refers to the diameter of the sensing face. The material column identifies if the sensor body is made of stainless steel (SST), brass, or a molded plastic.

Housing Dimension (mm)	Material	Shielded Unshielded	Sn (mm)	Operating Voltage	Wires
3, 4	SST	Shielded	0.6-0.8	10-30 VDC	3
5	Brass	Shielded	0.8	10-30 VDC	3
6.5	SST	Shielded	1.5	15-34 VDC	3
	SST	Shielded	1.5	10-30 VDC	3
	SST	Unshielded	2.5	15-34 VDC	3
8	SST	Shielded	1	15-34 VDC	3
	SST	Shielded	1	10-30 VDC	4
	Brass	Shielded	1.5	10-30 VDC	3
	SST	Shielded	1.5	15-34 VDC	3
	SST	Shielded	1.5	10-30 VDC	3, 4
	SST	Unshielded	2.5	15-34 VDC	3
12	Brass	Shielded	2	15-34 VDC	3, 4
	SST	Shielded	2	10-55 VDC	2
	SST	Shielded	2	20-250 VAC	2
	Brass	Shielded	2	20-250 VAC	2
	Brass	Unshielded	4	15-34 VDC	3, 4
	SST	Unshielded	4	10-55 VDC	2
	SST	Unshielded	4	20-250 VAC	2
	Brass	Unshielded	4	20-250 VAC	2
18	Brass	Shielded	5	15-34 VDC	3, 4
	SST	Shielded	5	10-30 VDC	4
	SST	Shielded	5	10-55 VDC	2
	SST	Shielded	5	20-250 VAC	2
	Brass	Shielded	5	20-250 VAC	2
	Brass	Unshielded	8	15-34 VDC	3,4
	SST	Unshielded	8	10-55 VDC	2
	SST	Unshielded	8	20-250 VAC	2
	Brass	Unshielded	8	20-250 VAC	2
20	Plastic	Unshielded	10	10-36 VDC	3
30	Brass	Shielded	10	15-34 VDC	3, 4
	Brass	Shielded	10	10-30 VDC	4
	SST	Shielded	10	10-55 VDC	2
	SST	Shielded	10	20-250 VAC	2
	Brass	Shielded	10	20-250 VAC	2
	Brass	Unshielded	15	15-34 VDC	3, 4
	SST	Unshielded	15	10-55 VDC	2
	SST	Unshielded	15	20-250 VAC	2
	Brass	Unshielded	15	20-250 VAC	2
34	Plastic	Unshielded	20	10-36 VDC	3

Normal Requirements Cubic Shape

Inductive proximity sensors designed for normal requirements are also available in a block or cubic shape.

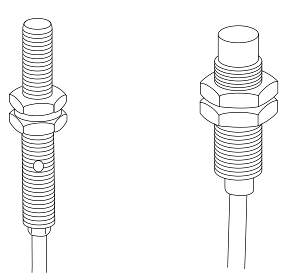


Normal Requirements Cubic Shape Selection Guide

Housing Dimension (mm)	Material	Shielded Unshielded	Sn (mm)	Operating Voltage	Wires
5x5 8x8	Brass Brass	Shielded Shielded	0.8 1.5	10-30 VDC 10-30 VDC	3 3
18 Tubular (Flat Pack)	Plastic	Shielded	4	10-30 VDC	3
40x26x12	Plastic	Shielded	2	15-34 VDC	3, 4
26x40x12	Plastic	Shielded Unshielded	2 4	15-34 VDC 15-34 VDC	3 3
40x32x12.5	Plastic	Shielded	2	15-34 VDC	4
Block with M14	Plastic Plastic	Shielded Unshielded	2.5 5	15-34 VDC 15-34 VDC	3, 4 3, 4
40x40 (Limit Switch Style)	Plastic Plastic	Shielded Unshielded	15 20	15-34 VDC 15-34 VDC	4 4
40x40x40	Plastic	Shielded Unshielded	35 35	15-34 VDC 15-34 VDC	4 4
40x40x40	Plastic	Shielded Unshielded	35 35	20-265 VAC 20-265 VAC	2 2
40x60 (Flat Pack)	Plastic Plastic	Shielded Unshielded	25 30	15-34 VDC 15-34 VDC	4 4
40x80 (Flat Pack)	Plastic	Unshielded	40	15-34 VDC	4

Optimized for Solid State Inputs

These two-wire devices are optimized for use with solid state inputs such as PLCs and solid state timing relays. Optimized for solid state input sensors are available in tubular (shown) and block packs (not shown).

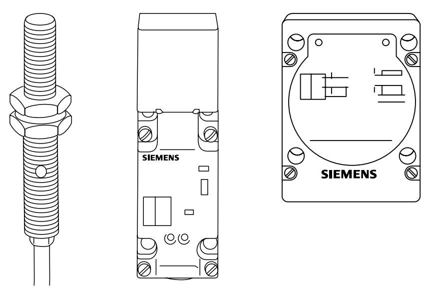


Optimized for Solid State Inputs Selection Guide

Housing Dimension (mm)	Material	Shielded Unshielded	Sn (mm)	Operating Voltage	Wires
8	SST	Shielded	1	15-34 VDC	2
12	Brass	Shielded	2	15-34 VDC	2
	Brass	Unshielded	4	15-34 VDC	2
18	Brass	Shielded	5	15-34 VDC	2
	Brass	Unshielded	8	15-34 VDC	2
30	Brass	Shielded	10	15-34 VDC	2
	Brass	Unshielded	15	15-34 VDC	2
Block with M14	Plastic	Shielded	2.5	15-34 VDC	2
40x40 (Limit Switch Style)	Plastic	Shielded	15	15-34 VDC	2
	Plastic	Unshielded	20	15-34 VDC	2

Extra Duty

Some applications require a higher operating voltage, or a faster switching frequency than is found with standard series sensors. This group of inductive proximity sensors provides a higher operating range and can handle loads up to 300 mA. These are two-wire and three-wire devices available in either normally open (NO) or normally closed (NC) configurations. They are available in cylindrical or cubic shape.

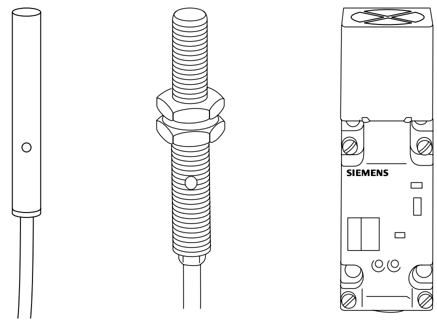


Extra Duty Selection Guide

Housing Dimension (mm)	Material	Shielded Unshielded	Sn (mm)	Operating Voltage	Wires
8	SST	Shielded	1	10-65 VDC	3
12	Brass	Shielded	2	20-265 VAC/ 20-320 VDC	2
	Brass	Shielded	2	10-65 VDC	3
	Brass	Unshielded	4	20-265 VAC/ 20-320 VDC	2
	Brass	Unshielded	4	10-65VDC	3
18	Brass	Shielded	10	20-265 VAC/ 20-320 VDC	2
	Brass	Shielded		10-65 VDC	3
	Brass	Unshielded		20-265 VAC/ 20-320 VDC	2
	Brass	Unshielded		10-65VDC	3
20	Plastic	Unshielded	10	20-265 VAC/ 20-320 VDC	2
30	Brass	Shielded	10	20-265 VAC/ 20-320 VDC	2
	Brass	Shielded	10	10-65 VDC	3
	Brass	Unshielded	15	20-265 VAC/ 20-320 VDC	2
	Brass	Unshielded	15	10-65VDC	3
34	Plastic	Unshielded	20	20-265 VAC/ 20-320 VDC	2
Block with M14	Plastic	Shielded	2.5	20-265 VAC/ 20-320 VDC	2
	Plastic	Shielded	2.5	10-65VDC	3
	Plastic	Unshielded	5	10-65 VDC	3
40x40 (Limit Switch Style)	Plastic	Shielded	15	20-265 VAC/ 20-320 VDC	2
	Plastic	Shielded	15	10-65 VDC	3
	Plastic	Unshielded	20	20-265 VAC/ 20-320 VDC	
	Plastic	Unshielded	20	10-65 VDC	
40x60 (Flat Pack)	Plastic	Unshielded	30	20-265 VAC/ 20-320 VDC	2
	Plastic	Unshielded	30	10-65 VDC	3
40x80 (Flat Pack)	Plastic	Shielded	30	20-265 VAC/ 20-320 VDC	2
	Plastic	Unshielded	40	20-265 VAC/ 20-320 VDC	2
	Plastic	Unshielded	40	20-265 VAC/ 20-320 VDC	2
	Plastic	Unshielded	40	10-65 VDC	3

Extreme Environmental Conditions (IP68)

IP protection is a European system of classification which indicates the degree of protection an enclosure provides against dust, liquids, solid objects, and personnel contact. The IP system of classification is accepted internationally. Proximity switches classified IP68 provide protection against the penetration of dust, complete protection against electrical shock, and protection against ingress of water on continuous submersion. These are three- and four-wire devices configured for NPN or PNP, normally closed (NC) or normally open (NO) outputs.

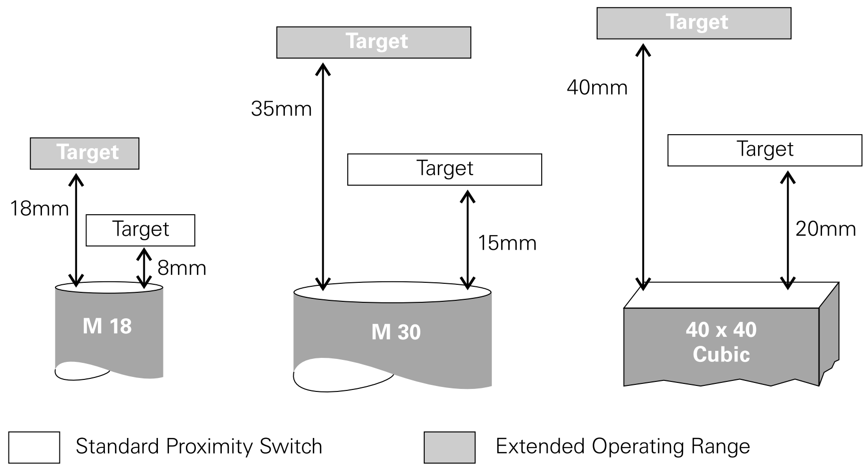


Extreme Environmental Conditions (IP68) Selection Guide

Housing Dimension (mm)	Material	Shielded Unshielded	Sn (mm)	Operating Voltage	Wires
4.5	SST	Shielded	0.6	10-30 VDC	3
6.5	Brass	Unshielded	2.5	10-30 VDC	3
8	Brass	Unshielded	2.5	10-30 VDC	3
12	Plastic	Shielded	2	15-34 VDC	3
	Brass	Shielded	2	15-34 VDC	3
	Plastic	Unshielded	4	15-34 VDC	3
	Brass	Unshielded	4	15-34 VDC	3
18	Plastic	Shielded	5	15-34 VDC	3
	Brass	Shielded	5	15-34 VDC	3
	Plastic	Unshielded	8	15-34 VDC	3
	Brass	Unshielded	8	15-34 VDC	3
	Plastic	Unshielded	8	20-265 VAC 20-250 VDC	2
	Plastic	Unshielded	8	10-65 VDC	3
30	Plastic	Shielded	10	15-34 VDC	3
	Brass	Shielded	10	15-34 VDC	3
	Plastic	Unshielded	15	15-34 VDC	3
	Brass	Unshielded	15	15-34 VDC	3
	Plastic	Unshielded	15	20-265 VAC 20-250 VDC	2
	Plastic	Unshielded	15	10-65 VDC	3
40x40 (Limit Switch Style)	Plastic	Shielded	15	15-34 VDC	4

Greater Rated Operating Sensing Range

These devices provide a greater operating distance in comparison with standard proximity switches. Devices are three-wire DC with PNP or NPN or AC and normally open (NO) or normally closed (NC) output configurations.



Greater Rated Operating Sensing Range Selection Guide

Housing Dimension (mm)	Material	Shielded Unshielded	Sn (mm)	Operating Voltage	Wires
6.5	Brass	Unshielded	3	10-30 VDC	3
8	SST	Shielded	2	15-34 VDC	3
	Brass	Unshielded	3	10-30 VDC	3
	Brass	Unshielded	6	10-30 VDC	3
12	Brass	Shielded	4	15-34 VDC	3
	Brass	Shielded	6	10-30 VDC	3
	Brass	Unshielded	10	10-30 VDC	3
18	Plastic	Shielded	8	15-34 VDC	3
	Brass	Unshielded	12	10-30 VDC	3
	Brass	Unshielded	20	10-30 VDC	3
30	Brass	Shielded	15	15-34 VDC	3
	Brass	Shielded	22	10-30 VDC	3
	Brass	Unshielded	40	10-30 VDC	3
8x8	Brass	Unshielded	3	10-30 VDC	3
40x40 (Limit Switch Style)	Plastic	Shielded	20	15-34 VDC	3
	Plastic	Unshielded	25	10-65 VDC	3
	Plastic	Unshielded	40/25(adj)	10-65 VDC	3
	Plastic	Unshielded	40	10-65 VDC	3
40x40 (Mini Base)	Plastic	Shielded	20	10-30 VDC	3
40x60 (Flat Pack)	Plastic	Unshielded	50	10-65 VDC	3
40x80 (Flat Pack)	Plastic	Unshielded	65	10-65 VDC	3

NAMUR

NAMUR is a standard issued by the Standards Committee of Measurement and Control of the chemical industry in Europe. Deutsche Industrie Normenausschuss (DIN) refers to a set of German standards now used in many countries. Like NAMUR, DIN 19234 is a set of standards for equipment used in hazardous locations.

Intrinsically Safe

NAMUR sensors are intrinsically safe only when used with an approved barrier power supply/output device and approved cabling.

It is beyond the scope of this course to offer a complete explanation on this subject. You are encouraged to become familiar with Articles 500 through 504 of the National Electrical Code® which cover the use of electrical equipment in locations where fire or explosions due to gas, flammable liquids, combustible dust, or ignitable fibers may be possible.

Hazardous Environments

Although you should never specify or suggest the type of location, it is important to understand regulations that apply to hazardous locations. It is the user’s responsibility to contact local regulatory agencies to define the location as Division I or II and to comply with all applicable codes.

Divisions

Division I identifies a condition where hazardous materials are normally present in the atmosphere. Division II identifies conditions where an atmosphere may become hazardous as result of abnormal conditions. This may occur if, for example, a pipe containing a hazardous chemical begins to leak.

Classes and Groups

Hazardous locations are further defined by class and group. Class I, Groups A through D are chemical gases or liquids. Class II, Groups E, F, and G include flammable dust. Class III is not divided into groups. It includes all ignitable fibers and lints such as clothing fiber in textile mills.

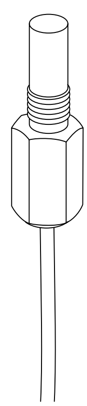
Group	Class I Groups A-D Gases and Liquids	Group	Class II Groups E-G Flammable Dust	Group	Class III Ignitable Fibers
A	Acetylene	E	Metallic Dust		Rayon
B	Hydrogen	F	Carbon Dust		Jute
C	Acetaldehyde Ethylene Methyl Ether	G	Grain Dust		
D	Acetone Gasoline Methanol Propane				

NAMUR Selection Guide

Housing Dimension (mm)	Material	Shielded Unshielded	Sn (mm)	Operating Voltage	Wires
4.5	SST	Shielded	0.8	5-25 VDC	2
8	SST	Shielded	1.5	5-25 VDC	2
12	SST	Shielded	2	5-25 VDC	2
	SST	Unshielded	4	5-25 VDC	2
18	SST	Shielded	5	5-25 VDC	2
	SST	Unshielded	8	5-25 VDC	2
30	SST	Shielded	10	5-25 VDC	2
	SST	Unshielded	15	5-25 VDC	2
40x40 (Limit Switch Style)	Plastic	Shielded	15	5-25 VDC	2

Pressure Proof

These devices are used in extremely dynamic pressure stressing such as the monitoring of piston or valve limit positions, speed monitoring and measurement of hydraulic motors, and vacuum applications. The operating voltage is 10 to 30 VDC, with loads up to 200 mA. The operating distance of devices rated up to 7253 psi is 3 mm. These are three-wire devices with a PNP or NPN, normally open (NO) or normally closed (NC) output.

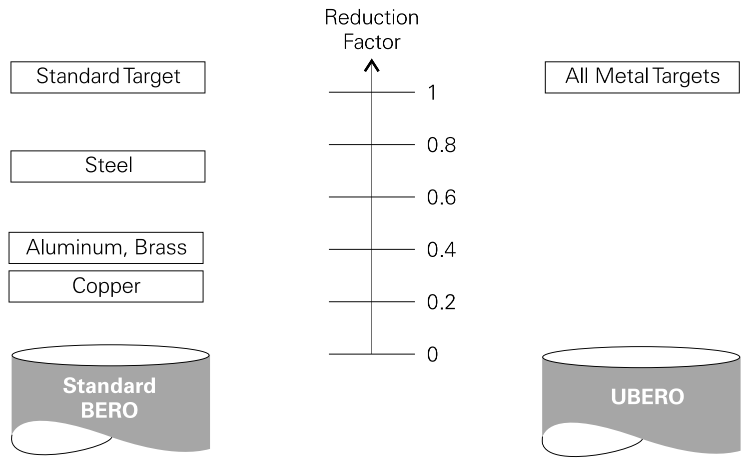


Pressure Proof Selection Guide

Housing Dimension (mm)	Material	Shielded Unshielded	Sn (mm)	Operating Voltage	Wires
12	SST	Unshielded	3	10-30 VDC	3

UBERO Without Reduction Factor/Weld Field Immune

Standard BERO proximity switches require a reduction factor for metals other than the standard target. UBERO products sense all metals without a reduction factor. They can also be used in applications near a strong magnetic fields.

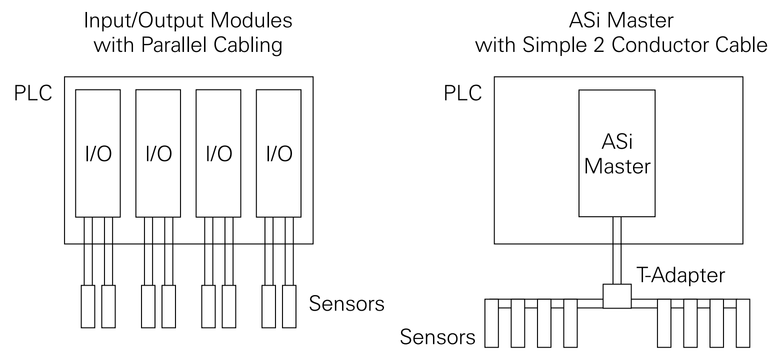


UBERO Without Reduction Factor/Weld Field Immune Selection Guide

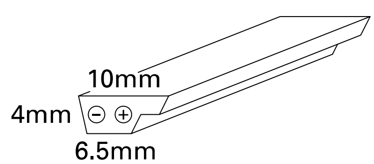
Housing Dimension (mm)	Material	Shielded Unshielded	Sn (mm)	Operating Voltage	Wires
8	SST	Shielded Unshielded	1.5 4	10-30 VDC 10-30 VDC	3 3
12	Brass or SST	Shielded Unshielded	2 8	10-30 VDC 10-30 VDC	3 3
18	Brass or SST	Shielded Unshielded	5 12	10-30 VDC 10-30 VDC	3 3
30	Brass or SST	Shielded Unshielded	10 20	10-30 VDC 10-30 VDC	3 3
40x40 (Limit Switch Style)	Plastic Plastic Plastic	Shielded Unshielded Unshielded	15 25 40	10-30 VDC 10-30 VDC 10-30 VDC	4 3 4
40x40 (Mini Base)	Plastic Plastic Plastic	Shielded Unshielded Unshielded	15 25 35	10-30 VDC 10-30 VDC 10-30 VDC	3 3 3
80x80	Plastic	Unshielded	75	10-30 VDC	4

AS-i

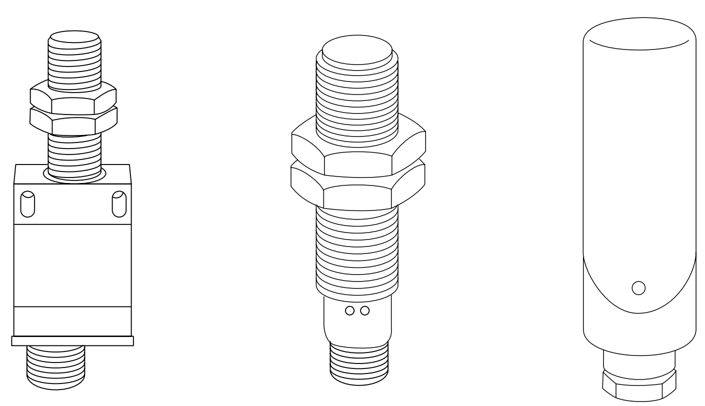
Actuator Sensor Interface (AS-i or AS-Interface) is a system for networking binary devices such as sensors. Until recently, extensive parallel control wiring was needed to connect sensors to the controlling device. PLCs, for example, use I/O modules to receive inputs from binary devices such as sensors. Binary outputs are used to turn on or off a process as the result of an input. Using conventional wiring it would take a cable harness of several parallel inputs to accomplish complex tasks.



AS-i replaces the complex cable harness with a simple 2-core cable. The cable is designed so that devices can only be connected correctly.



Inductive proximity sensors developed for use on AS-i have the AS-i chip and intelligence built into the device

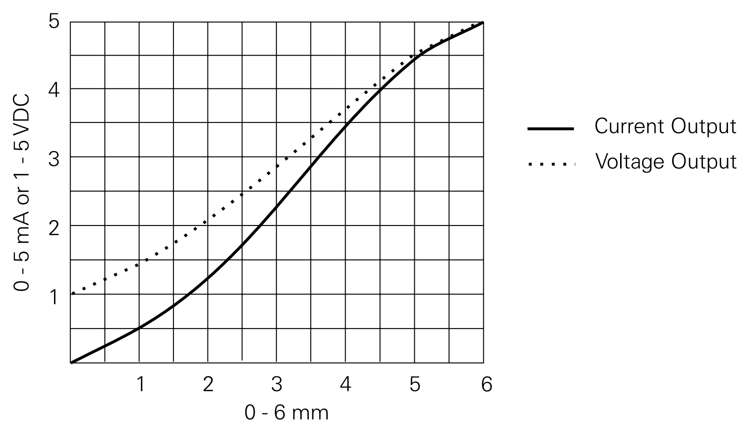


AS-i Selection Guide

Housing Dimension (mm)	Material	Shielded Unshielded	Sn (mm)	Operating Voltage
12	Brass	Shielded	2	20-32 VDC
18	Brass	Shielded	5	20-32 VDC
20	Plastic	Unshielded	10	20-32 VDC
30	Brass	Shielded	10	20-32 VDC
34	Plastic	Unshielded	20	20-32 VDC
40x40	Plastic	Shielded	15	20-32 VDC

Analog Output

These devices are used when an analog value is required. In some applications it may be desireable to know the distance a target is from the sensor. The rated sensing range of an inductive analog sensor is 0 to 6 mm. The output of the sensor increases from 1 to 5 VDC or 0 to 5 mA as the target is moved away from the sensor.



Analog Selection Guide

Housing Dimension (mm)	Material	Shielded Unshielded	Sn (mm)	Operating Voltage	Wires
12	Brass	Unshielded	0-6	10-30 VDC	4

Review 3

1) Inductive proximity sensors are divided into ___________ categories.

2) The maximum sensing range of an inductive proximity sensor with a cylindrical style housing in the standard series (normal requirements) is ___________ mm.

3) The maximum operating voltage that can be used on an inductive proximity sensor for increased electric requirements is ___________ VAC or ___________ VDC.

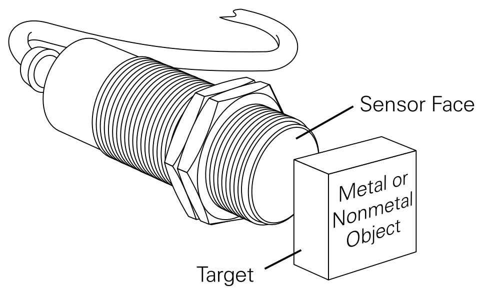
4) ___________ is a European system of classification which indicates the degree of protection an enclosure provides against dust, liquids, solid objects, and personnel contact.

5) The maximum sensing range of an inductive proximity sensor designated for greater rated distance is ___________ mm.

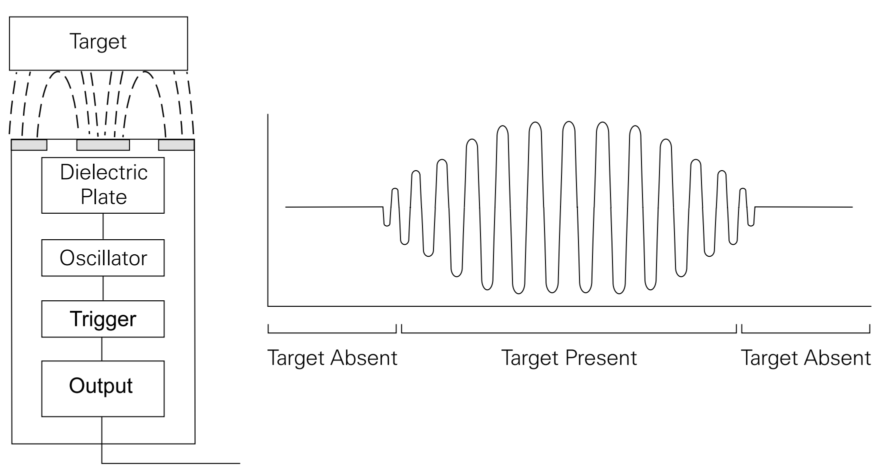
6) ___________ inductive proximity sensors detect all metals without a reduction factor.

Capacitive Proximity Sensors Theory of Operation

Capacitive proximity sensors are similar to inductive proximity sensors. The main difference between the two types is that capacitive proximity sensors produce an electrostatic field instead of an electromagnetic field. Capacitive proximity switches will sense metal as well as nonmetallic materials such as paper, glass, liquids, and cloth.

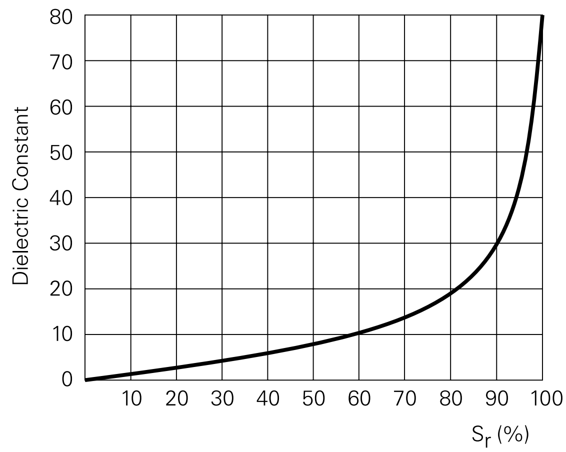


The sensing surface of a capacitive sensor is formed by two concentrically shaped metal electrodes of an unwound capacitor. When an object nears the sensing surface it enters the electrostatic field of the electrodes and changes the capacitance in an oscillator circuit. As a result, the oscillator begins oscillating. The trigger circuit reads the oscillator's amplitude and when it reaches a specific level the output state of the sensor changes. As the target moves away from the sensor the oscillator's amplitude decreases, switching the sensor output back to its original state.



Standard Target and Dielectric Constant

Standard targets are specified for each capacitive sensor. The standard target is usually defined as metal and/or water. Capacitive sensors depend on the dielectric constant of the target. The larger the dielectric number of a material the easier it is to detect. The following graph shows the relationship of the dielectric constant of a target and the sensor's ability to detect the material based on the rated sensing distance (Sr).

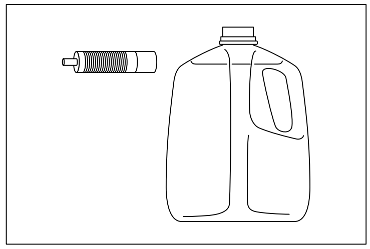


The following table shows the dielectric constants of some materials. If, for example, a capacitive sensor has a rated sensing distance of 10 mm and the target is alcohol, the effective sensing distance (Sr) is approximately 85% of the rated distance, or 8.5 mm.

Material	Dielectric Constant	Material	Dielectric Constant
Alcohol	25.8	Polyamide	5
Araldite	3.6	Polyethylene	2.3
Bakelite	3.6	Polyproplene	2.3
Glass	5	Polystyrene	3
Mica	6	Polyvinyl Chloride	2.9
Hard Rubber	4	Porcelain	4.4
Paper-Based Laminate	4.5	Pressboard	4
Wood	2.7	Silica Glass	3.7
Cable Casting Compound	2.5	Silica Sand	4.5
Air, Vacuum	1	Silicone Rubber	2.8
Marble	8	Teflon	2
Oil-Impregnated Paper	4	Turpentine Oil	2.2
Paper	2.3	Transformer Oil	2.2
Paraffin	2.2	Water	80
Petroleum	2.2	Soft Rubber	2.5
Plexiglas	3.2	Celluloid	3

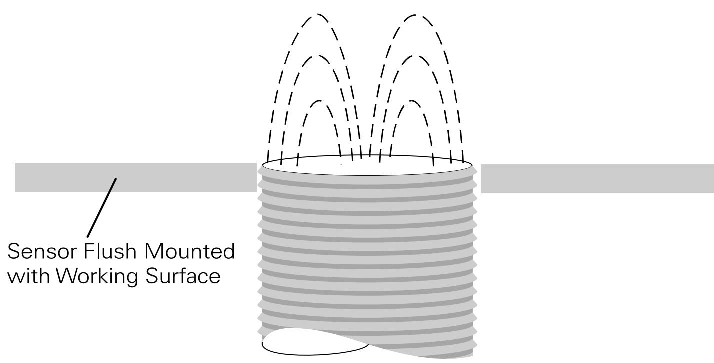
Detection Through Barriers

One application for capacitive proximity sensors is level detection through a barrier. For example, water has a much higher dielectric than plastic. This gives the sensor the ability to "see through" the plastic and detect the water.



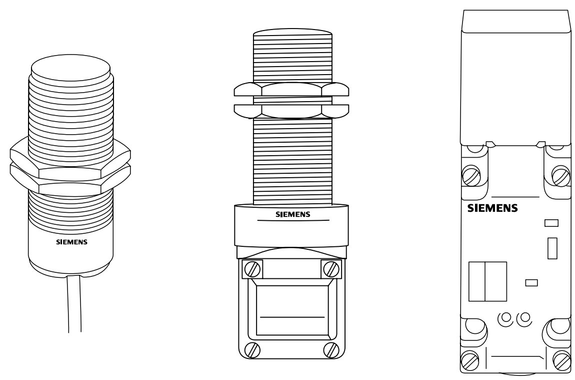
Shielding

All Siemens capacitive sensors are shielded. These sensors will detect conductive material such as copper, aluminum, or conductive fluids, and nonconductive material such as glass, plastic, cloth, and paper. Shielded sensors can be flush mounted without adversely affecting their sensing characteristics. Care must be taken to ensure that this type of sensor is used in a dry environment. Liquid on the sensing surface could cause the sensor to operate.



Capacitive Proximity Sensor Family

The 3RG16 product family identifies the Siemens capacitive proximity sensor. Units are available in DC or AC versions. Electronic controls such as SIMATIC® PLCs or relays can be controlled directly with the DC voltage version. In the case of the AC voltage version the load (contactor relay, solenoid valve) is connected with the sensor in series directly to the AC voltage. Sensors are available with two-, three-, and four-wire outputs.



Capacitive Sensor Selection Guide

Housing Dimension (mm)	Material	Shielded Unshielded	Sn (mm)	Operating Voltage	Wires
18	Plastic	Shielded	5	10-65 VDC	3
30	Metal	Shielded	10	20-250 VAC	3
	Plastic	Shielded	10	20-250 VAC	2
	Metal	Shielded	10	10-65 VDC	4
	Plastic	Shielded	10	10-65 VDC	4
40	Plastic	Shielded	20	20-250 VAC	2
	Plastic	Shielded	20	10-65 VDC	4
40x40 (Limit Switch Style)	Plastic	Shielded	20	20-250 VAC	2
	Plastic	Shielded	20	10-65 VDC	4
20x20 (Flat Pack)	Metal	Shielded	5	10-30 VDC	3

Review 4

1) A main difference between an inductive proximity sensor and a capacitive proximity sensor is that a capacitive proximity sensor produces an ____________ field.

2) Capacitive proximity sensors will sense ____________ material.

3) The larger the ____________ constant of a material the easier it is for a capacitive proximity sense to detect.

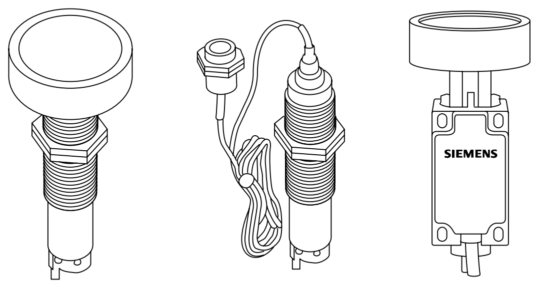
4) It is easier for a capacitive proximity sensor to detect ____________ than porcelain.

   a. teflon
   b. marble
   c. petroleum
   d. paper

5) The maximum rated sensing distance of a capacitive proximity sensor is ____________ mm.

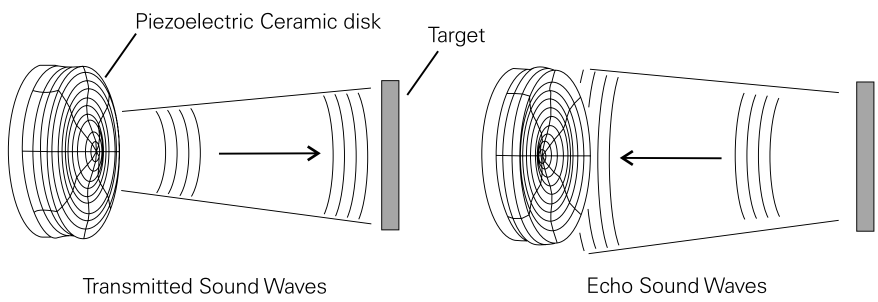
Ultrasonic Proximity Sensors Theory of Operation

Ultrasonic proximity sensors use a transducer to send and receive high frequency sound signals. When a target enters the beam the sound is reflected back to the switch, causing it to energize or deenergize the output circuit.

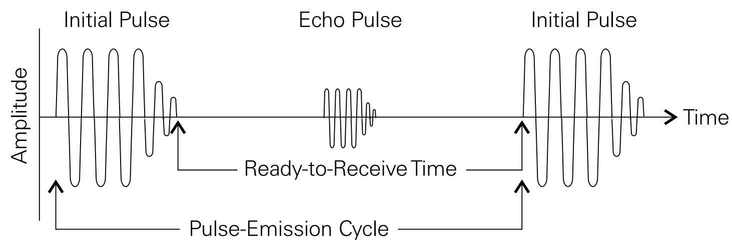


Piezoelectric Disk

A piezoelectric ceramic disk is mounted in the sensor surface. It can transmit and receive high-frequency pulses. A high-frequency voltage is applied to the disk, causing it to vibrate at the same frequency. The vibrating disk produces high-frequency sound waves. When transmitted pulses strike a sound-reflecting object, echoes are produced. The duration of the reflected pulse is evaluated at the transducer. When the target enters the preset operating range, the output of the switch changes state. When the target leaves the preset operating range, the output returns to its original state.

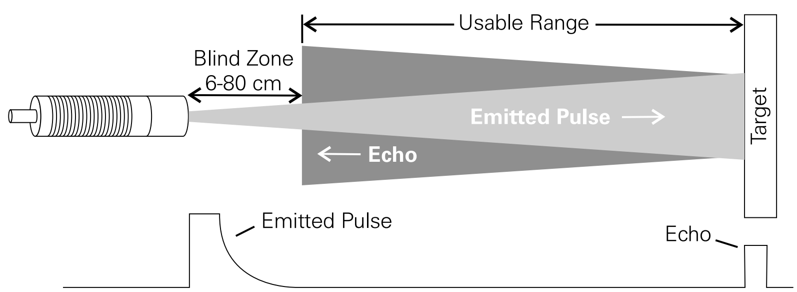


The emitted pulse is actually a set of 30 pulses at an amplitude of 200 Kvolts. The echo can be in microvolts.



Blind Zone

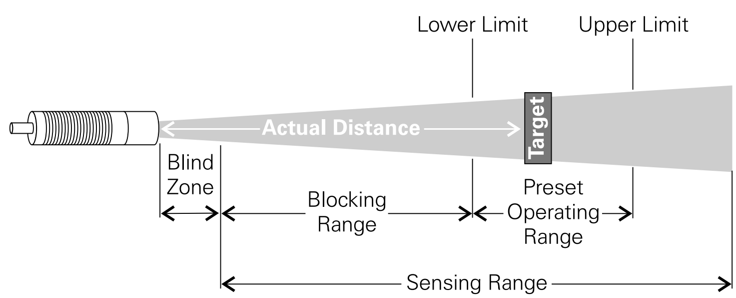
A blind zone exists directly in front of the sensor. Depending on the sensor the blind zone is from 6 to 80 cm. An object placed in the blind zone will produce an unstable output.



Range Definition

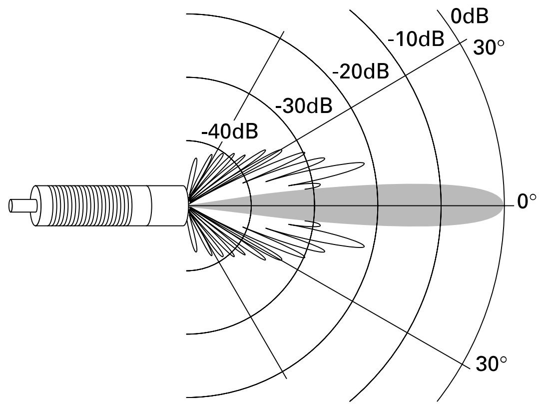
The time interval between the transmitted signal and the echo is directly proportional to the distance between the object and sensor. The operating range can be adjusted in terms of its width and position within the sensing range. The upper limit can be adjusted on all sensors. The lower limit can be adjusted only with certain versions. Objects beyond the upper limit do not produce a change at the output of the sensor. This is known as "blanking out the background".

On some sensors, a blocking range also exists. This is between the lower limit and the blind zone. An object in the blocking range prevents identification of a target in the operating range. There is a signal output assigned to both the operating range and the output range.



Radiation Pattern

The radiation pattern of an ultrasonic sensor consists of a main cone and several neighboring cones. The approximate angle of the main cone is 5°.

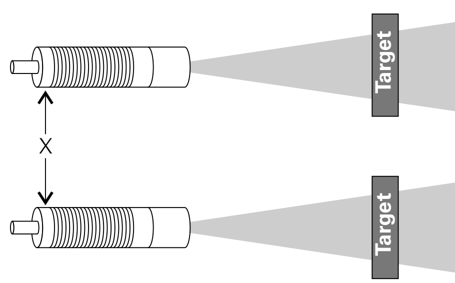


Free Zones

Free zones must be maintained around the sensor to allow for neighboring cones. The following examples show the free area required for different situations.

Parallel Sensors

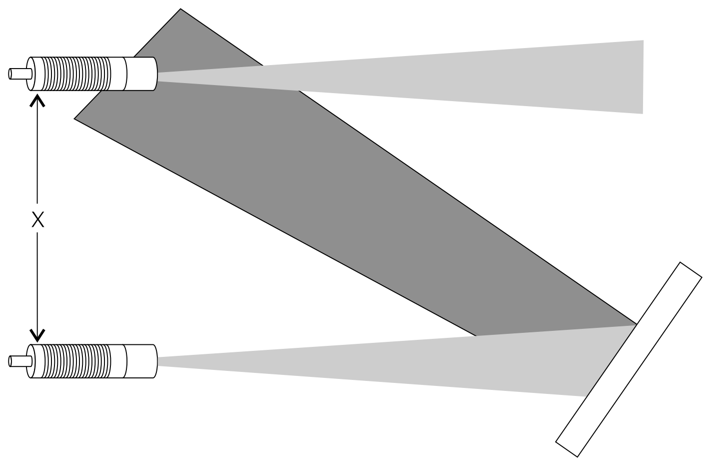
In the first example, two sonar sensors with the same sensing range have been mounted parallel to each other. The targets are vertical to the sound cone. The distance between the sensors is determined by the sensing range. For example, if the sensing range of the sensors is 6 cm, they must be located at least 15 cm apart.



Sensing Range (CM)	X (CM)
6-30	>15
20-130	>60
40-300	>150
60-600	>250
80-1000	>350

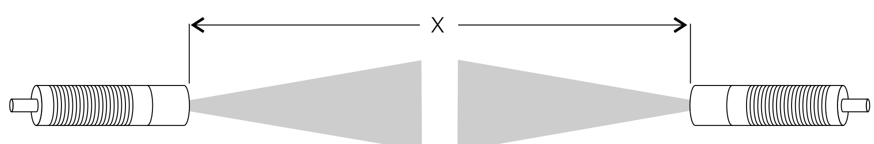
Mutual Interference

Mutual interference occurs when sonar devices are mounted in close proximity to each other and the target is in a position to reflect echoes back to a sensor in the proximity of the transmitting sensor. In this case, the distance between sensors (X) can be determined through experimentation.



Opposing Sensors

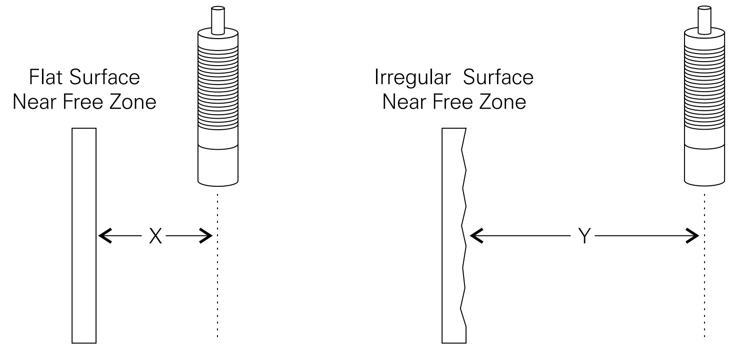
In the following example, two sonar sensors with the same sensing range have been positioned opposite of each other. A minimum distance (X) is required between opposing sensors so that mutual interferance does not occur.



Sensing Range (CM)	X (CM)
6-30	>120
20-130	>400
40-300	>1200
60-600	>2500
80-1000	>4000

Flat and Irregular Shaped Surfaces

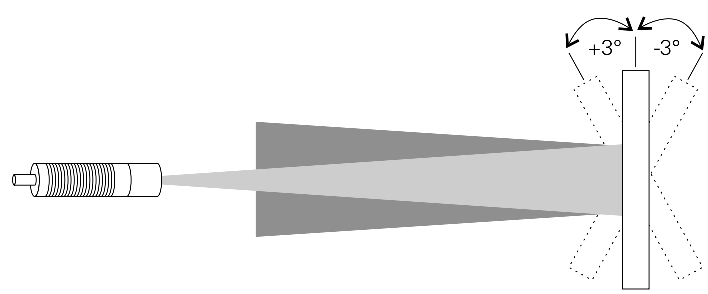
Sonar sensors mounted next to a flat surface, such as a wall or smooth machine face, require less free area than sensors mounted next to an irregular shaped surface.



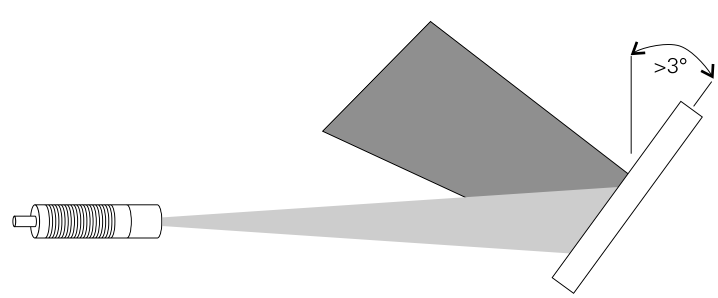
Sensing Range (CM)	X (CM)	Y (CM)
6-130	>3	>6
20-130	>15	>30
40-300	>30	>60
60-600	>40	>80
80-1000	>70	>150

Angular Alignment

The angle of the target entering the sound cone must also be considered. The maximum deviation from the send direction to a flat surface is ±3°.

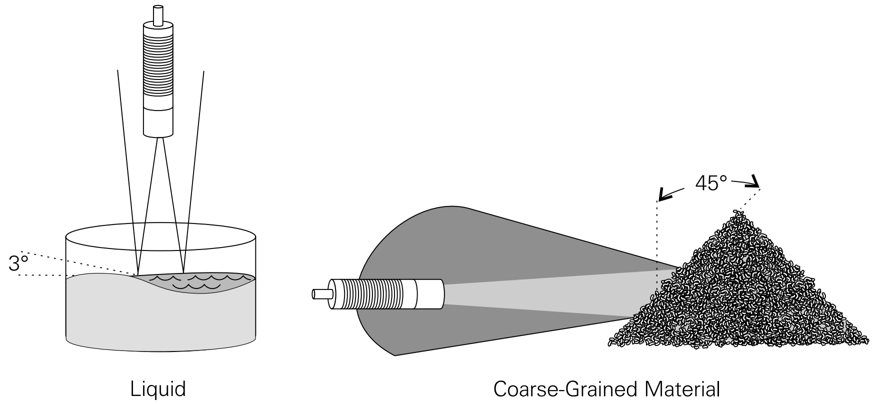


If the angle were greater than 3° the sonic pulses would be reflected away and the sensor would not receive an echo.



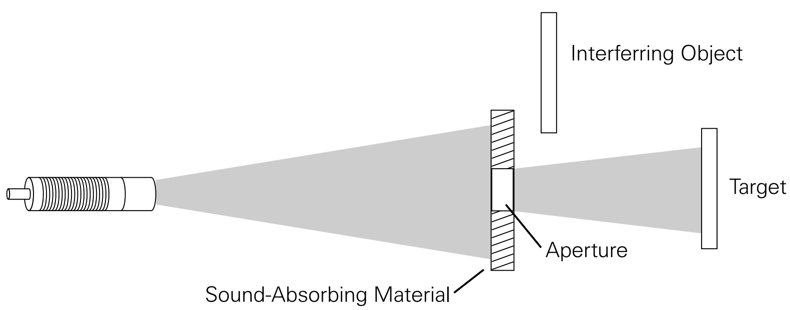
Liquids and Coarse-Grained Materials

Liquids, such as water, are also limited to an angular alignment of 3°. Coarse-grained materials, such as sand, can have an angular deviation as much as 45°. This is because the sound is reflected over a larger angle by coarse-grained materials.



Blanking Out Objects

An object may be located in the vicinity of the sound cone that causes improper operating of the sensor. These objects can be blanked out by using an aperture made of a sound absorbing material such as rock wool. This narrows the sound cone and prevents pulses from reaching the interfering object.

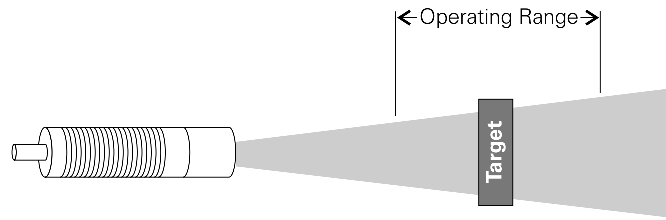


Operating Modes

Sonar sensors can be setup to operate in several different modes: diffuse, reflex, and thru-beam.

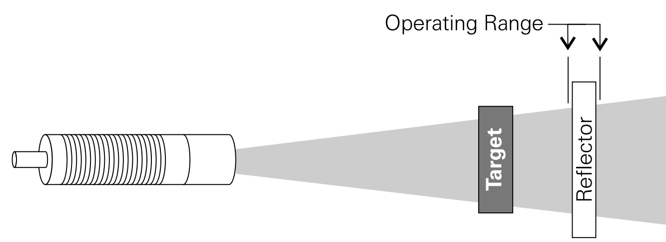
Diffuse Mode

This is the standard mode of operation. Objects, traveling in any direction into the operating range of the sound cone, will cause the sensor output to switch states. This mode of operation is similar to a proximity sensor.



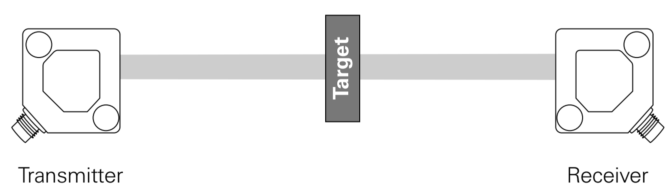
Reflex Mode

The reflex mode uses a reflector located in the preset operating range. The operating range is adjusted for the reflector. The pulses are bounced off the reflector and the echo pulses are returned to the sensor. When a target blocks the echo pulses the output is activated. Typically used in applications where the target is not a good sound absorber.



Thru-Beam Mode

Thru-beam sensors consist of a transmitter, which emits ultrasonic pulses, and a receiver. If the beam between the transmitter and the receiver is interrupted the output of the receiver switches state.



Environmental Influences

Sound travel time can be affected by physical properties of the air. This, in turn, can affect the preset operating distance of the sensor.

Condition	Effect
Temperature	Sonic wave speed changes by 0.17%/°K. Most sensors have a compensation adjustment.
Pressure	With normal atmospheric variation of ±5%, sound velocity varies approximately ±0.6%. Sound velocity decreases 3.6% between sea level and 3 km above sea level. Adjust sensor for appropriate operating range.
Vacuum	Sensors will not operate in a vacuum.
Humidity	Sound velocity increases as humidity increases. This leads to the impression of a shorter distance to the target. The increase of velocity from dry to moisture-saturated air is up to 2%.
Air Currents	Wind Speed <50 km/h - No Effect 50 - 100 km/h - Unpredictable Results >100 km/h - No Echo Received by Sensor
Gas	Sensors are designed for operation in normal atmospheric conditions. If sensors are operated in other types of atmospheres, such as carbon dioxide, measuring errors will occur.
Precipitation	Rain or snow of normal density does not impair the operation of a sensor. The transducer surface should be kept dry.
Paint Mist	Paint mist in the air will have no effect, however, paint mist should not be allowed to settle on transducer surface.
Dust	Dusty environments can lower sensing range 25-33%.

Review 5

1) Ultrasonic proximity sensors use high frequency ___________ signals to detect the presence of a target.

2) The blind zone of an ultrasonic proximity sensor can be from ___________ - ___________ cm, depending on the sensor.

3) The approximate angle of the main sound cone of an ultrasonic proximity sensor is ___________ degrees.

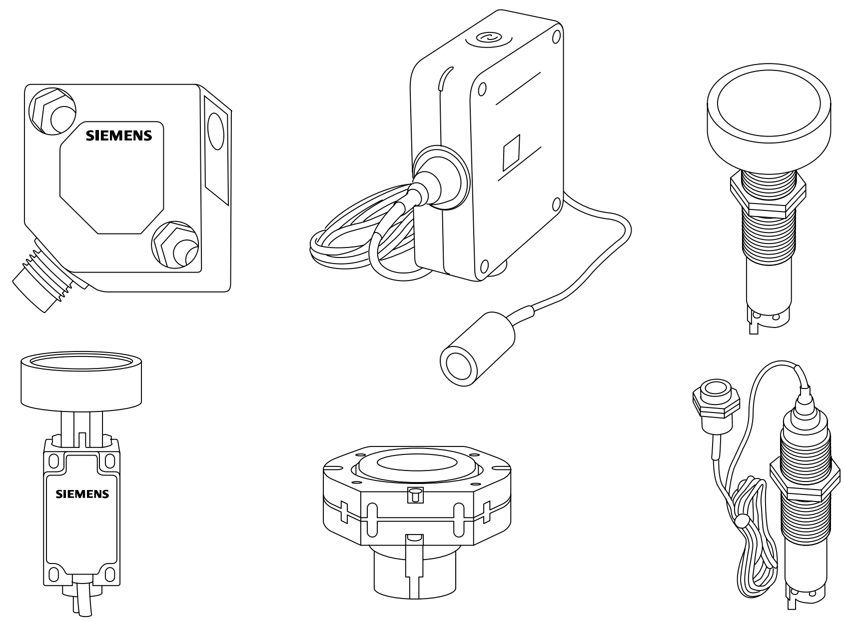
4) The free zone between two parallel ultrasonic sensors with a rated sensing range of 20-130 cm must be greater than ___________ cm.

5) The maximum angle of deviation from the send direction of an ultrasonic sensor to a flat surface is ___________ degrees.

6) ___________ mode is the standard mode of operation for an ultrasonic sensor.

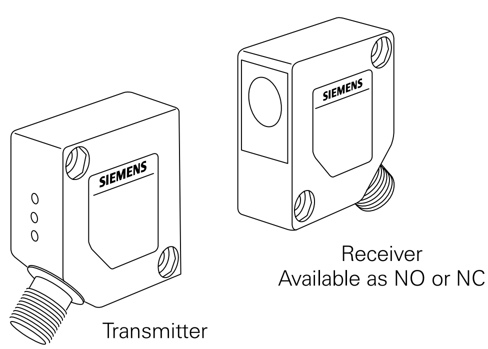
Ultrasonic Proximity Sensor Family

The ultrasonic proximity sensor family consists of a Thru-Beam sensor, compact range (M18, Compact Range 0, I, II, and III), and modular (Modular Range II) sensors.



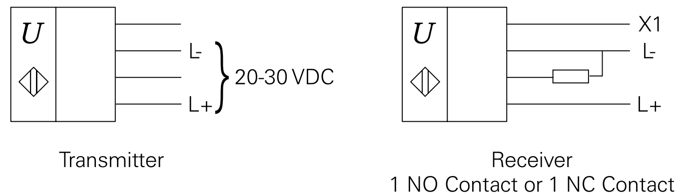
Thru-Beam

Thru-Beam sensors consist of a transmitter and a receiver. The transmitter sends a narrow continuous tone. When a target is positioned between the transmitter and the receiver the tone is interrupted, which causes the output of the receiver to change state. The operating voltage is 20-30 VDC. The switching frequency is 200 Hz at 40 cm sensing distance.



Thru-Beam Receivers

There are two receivers available for the Thru-Beam sensors. Both use a PNP transistor. One receiver provides a normally open (NO) contact and the other provides a normally closed (NC) contact.



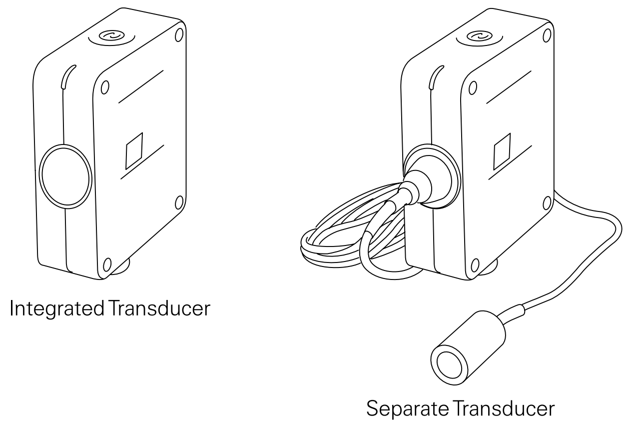
The sensitivity and frequency setting of the Thru-Beam sensors is a function of the X1 connection on the receiver.

Receiver	Distance (cm)	Switching Frequency (Hz)
X1 Open	5-150	100
X1 to L-	5-80	150
X1 to L+	5-40	200

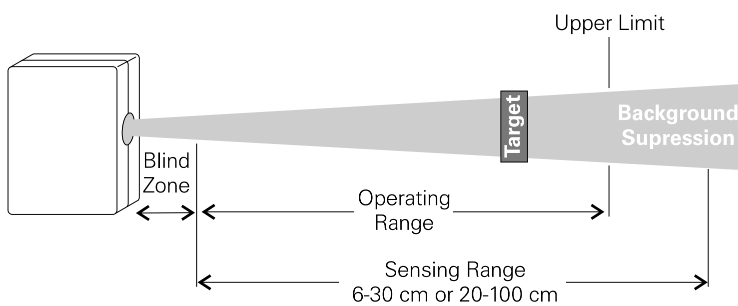
The minimum size of a detectable object is a function of the distance between the transmitter and the receiver. If the distance between the transmitter and the receiver is less than 40 cm and the minimum gap width between two objects is at least 3 cm, objects of 2 cm or larger will be detected. If the distance between the sensors is less, even gaps of less than 1 mm can be detected. At maximum sensing distance, objects greater than 4 cm will be detected, provided the gap between objects is greater than 1 cm.

Compact Range 0

Compact Range 0 sensors are available with an integrated or an separate transducer. They are configured with a normally open (NO), normally closed (NC) or analog output. These sensors have a cubic shape (88 x 65 x 30 mm). The sensors operate on 18 - 35 VDC and can handle a load up to 100 mA.

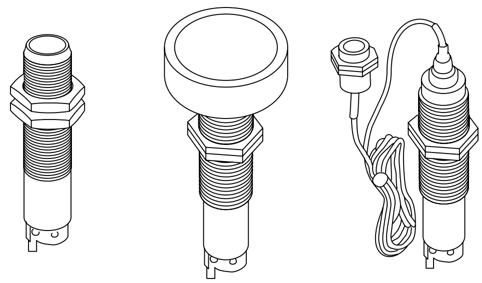


Depending on the sensor, the sensing range is either 6 - 30 cm (separate transducer) or 20 - 100 cm (integrated transducer). Switching frequencies vary from 5 Hz to 8 Hz. Compact Range 0 sensors have background suppression. This means the upper limit of the sensing range is adjustable with a potentiometer. Targets within the sensing range but beyond the switching range of the upper limit will not be detected.

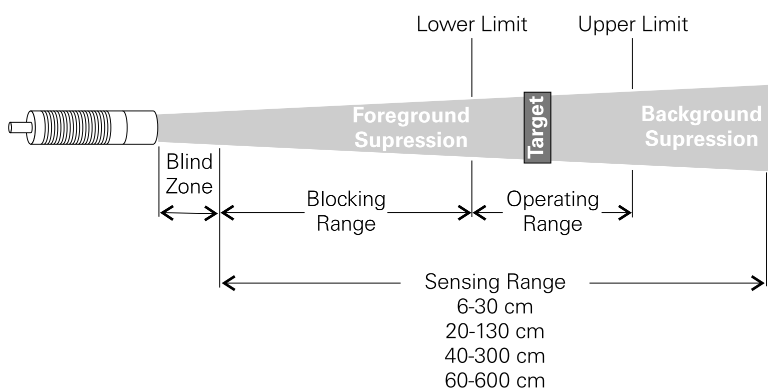


Compact Range I

Compact Range I sensors are available with a normally open (NO) or a normally closed (NC) contact. They are also available with two outputs, one normally open (NO) and one normally closed (NC). These sensors have a cylindrical shape (M30 x 150 mm). Several versions are available, including a separate transducer (shown) and a tilting head (not shown). The sensors operate on 20 - 30 VDC and can handle a load up to 200 mA.



Depending on the sensor the sensing range is either 6 - 30 cm, 20 - 130 cm, 40 - 300 cm, or 60 - 600 cm. Switching frequencies vary from 1 Hz to 8 Hz. Compact Range I sensors have background and foreground suppression. This means the upper and lower limits of the sensing range are adjustable with separate potentiometer. Targets within the sensing range but beyond the switching range of the upper and lower limits will not be detected.



SONPROG

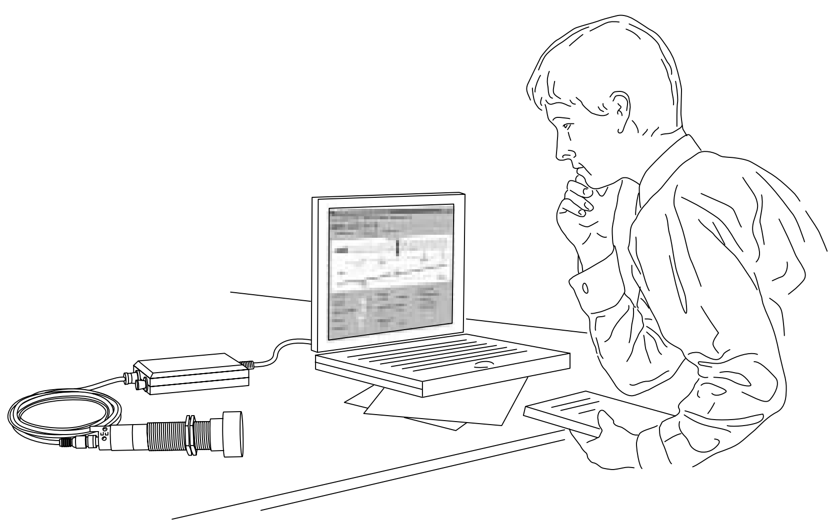
The ultrasonic sensors discussed so far (Thru-Beam, Compact Range 0, and Compact Range I) are either nonadjustable or can be adjusted manually with potentiometers. SONPROG is a computer program, unique to Siemens, that is used to adjust Compact Range II, Compact Range III, and Compact Range M18 sensors.

Sensor	Adjustment
Thru-Beam	None
Compact Range 0	1 Potentiometer
Compact Range I	2 Potentiometers
Compact Range II	SONPROG
Compact Range III	SONPROG
Compact Range M18	SONPROG

With SONPROG sonar sensors can be matched individually to the requirements of a particular application. An interface is connected between the sensor and an RS232 port of a computer. SONPROG can be used to set the following parameters:

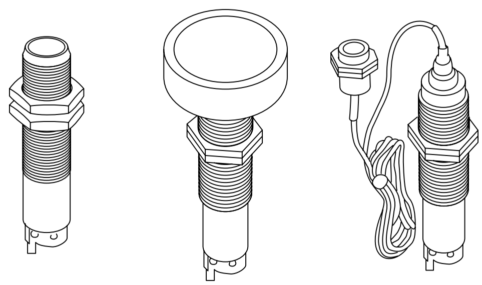
- Beginning and end of switching range
- Switching hysteresis
- Beginning and end of analog characteristic
- End of blind zone
- End of sensing range
- NO/NC contacts
- Potentiometer adjustments on sensors on/off

These values can be printed out and stored in a file. They are immediately available when needed. When replacing a sensor, for example, the stored parameters can be easily applied to the new sensor.

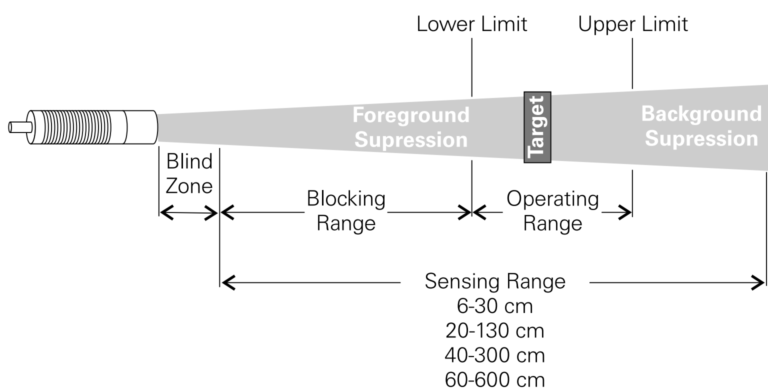


Compact Range II

Compact Range II sensors are similar in appearance to Compact Range I sensors. A major difference is that Compact Range II sensors can be adjusted manually or with SONPROG. They are available with a normally open (NO) or a normally closed (NC) contact. They are also available with two outputs, one normally open (NO) and one normally closed (NC). These sensors have a cylindrical shape (M30 x 150 mm). Several versions are available, including a separate transducer. The sensors operate on 20 - 30 VDC and can handle a load up to 300 mA. Compact Range II sensors can be synchronized to prevent mutual interference when using multiple sensors in close proximity to each other.

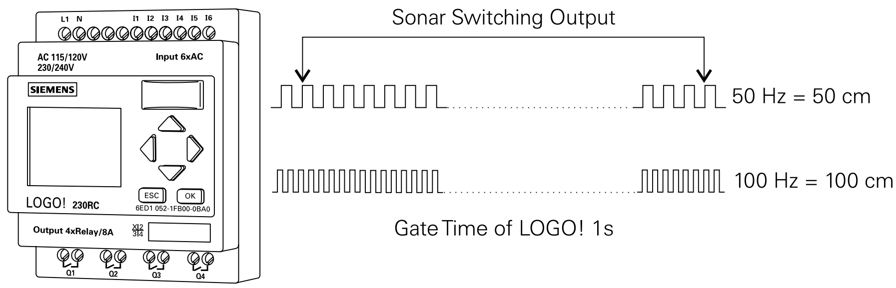


Depending on the sensor the sensing range is either 6 - 30 cm, 20 - 130 cm, 40 - 300 cm, or 60 - 600 cm. Switching frequencies vary from 1 Hz to 8 Hz. Compact Range II sensors have background and foreground suppression.



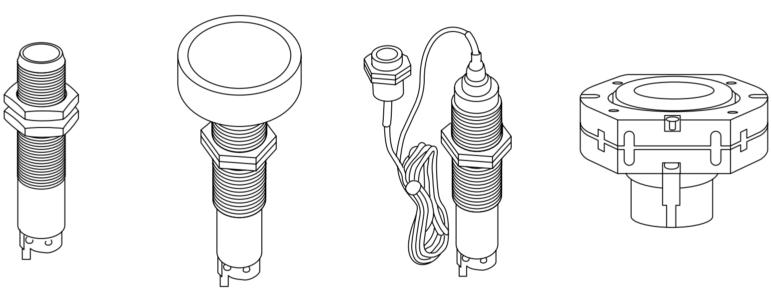
Compact Range II Analog Version

An analog version of the Compact Range II sensor is available. The analog measurement is converted by the sensor to digital pulses. A counter in LOGO! or a PLC counts the pulses and makes the measurement conversion. If, for example, the switching output of the sensor were set such that 50 Hz was equivalent to 50 cm and the gate time of LOGO! was set for 1 second, LOGO! would be able to accurately convert any frequency to its corresponding distance.

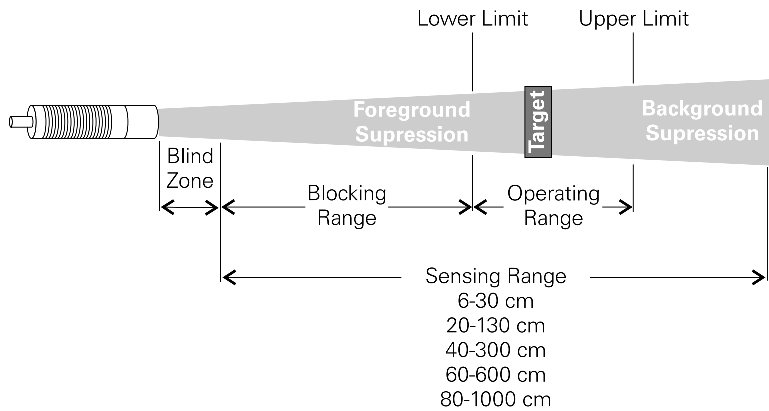


Compact Range III

Like the Compact Range II sensors, Compact Range III sensors can be adjusted manually or with SONPROG. They are available with a normally open (NO) or a normally closed (NC) contact. They are also available with two analog outputs, 0 - 20 mA or 0 - 10 VDC. The sensors operate on 20 - 30 VDC and can handle a load up to 300 mA. Compact Range III sensors can be synchronized to prevent mutual interference when using multiple sensors in close proximity to each other. In addition, they offer an arithmetic mean feature. This is useful for liquid level sensing or other applications where reflection variations can occur. The arithmetic mean feature helps compensate for these variations.

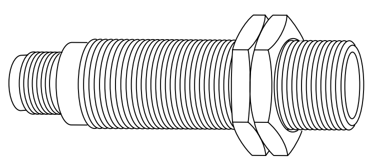


Depending on the sensor, the sensing range is either 6 - 30 cm, 20 - 130 cm, 40 - 300 cm, 60 - 600 cm, or 80 - 1000 cm. Switching frequencies vary from 0.5 Hz to 5 Hz. Compact Range III sensors have background and foreground suppression.

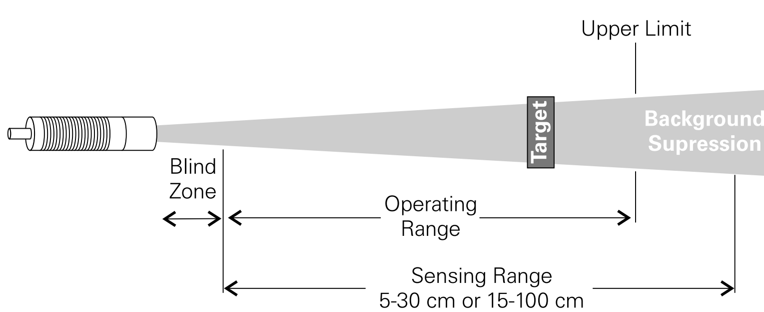


Compact Range M18

The small size (M18 x 101 mm) of the Compact Range M18 sensor makes it suited for applications where space is limited. Compact Range M18 sensors are available with a normally open (NO) or a normally closed (NC) contact. They are also available with an analog output (4 - 20 mA, 0 - 20 mA, or 0 - 10 VDC). The sensors operate on 20 - 30 VDC and can handle a load up to 100 mA.

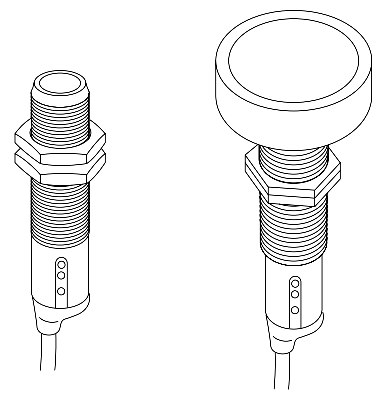


Depending on the sensor the sensing range is either 5 - 30 cm or 15 - 100 cm and the switching frequency is either 4 or 5 Hz. Compact Range M18 sensors have background suppression.



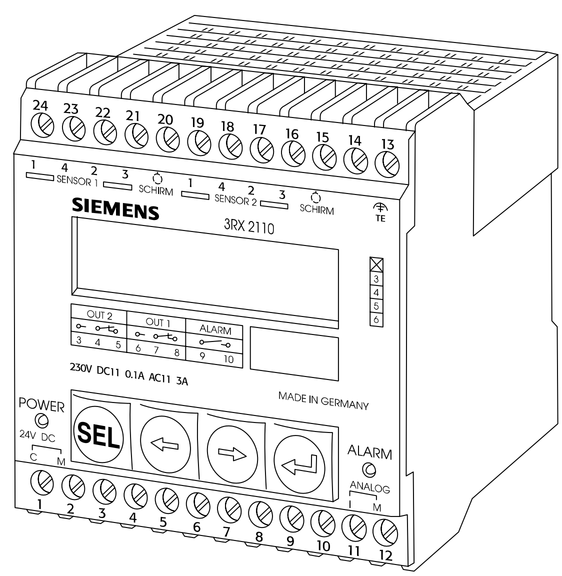
Compact Range with for use with AS-i

Siemens also manufactures ultrasonic sensors for use with AS-i. Four sensing ranges are available: 6 - 30 cm, 20 - 130 cm, 40 - 300 cm, and 60 - 600 cm. The switching frequency varies from 1 to 8 Hz.

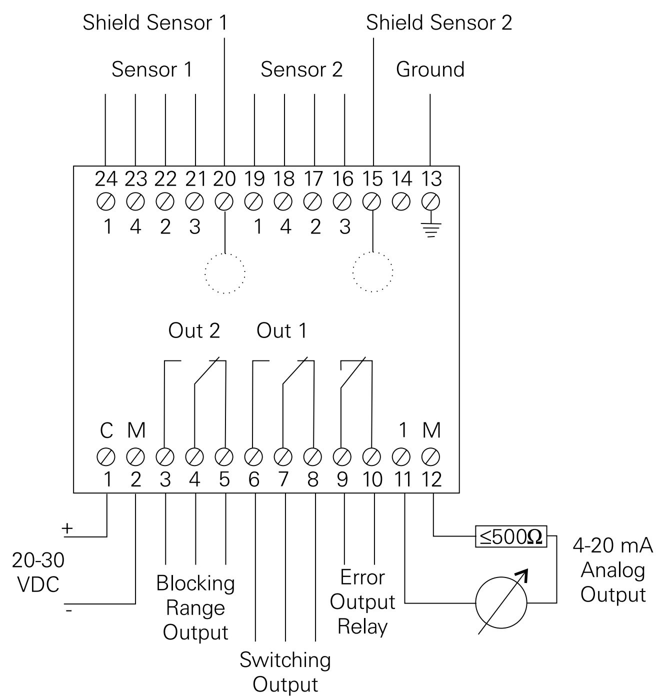


Modular Range II and the Signal Evaluator

The next group of ultrasonic sensors is Modular Range II. The Modular Range II consists of sensors and their corresponding signal evaluator. The signal evaluator is required for Modular Range II sensors. Sensor values are set using buttons on the evaluator. A two-line LCD displays the set values.

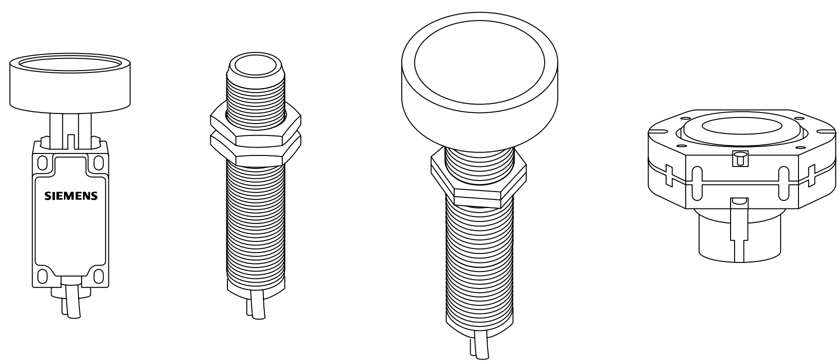


The signal evaluator can operate a maximum of two Modular Range II sensors. It is supplied with a 20 - 30 VDC power supply. It has two switching outputs, one error output, and one analog output.



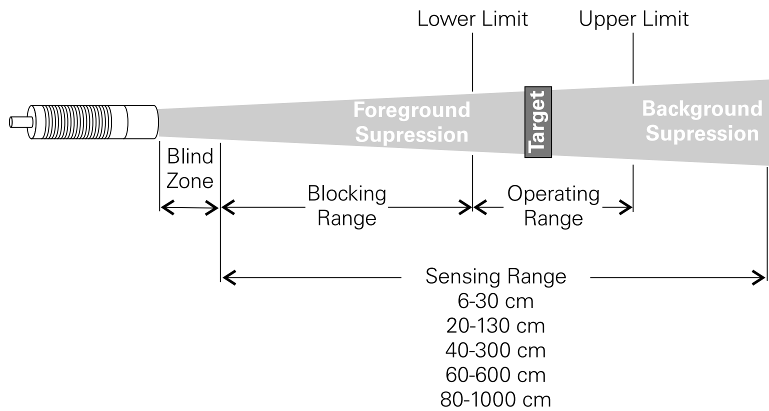
Modular Range II Sensors

Module Range II sensors are available in three versions: cubic sensors, cylindrical sensors, and spherical sensors. They have analog and normally open (NO) or normally closed (NC) outputs. As mentioned earlier, all settings and operations are done with a signal evaluator.



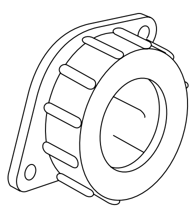
Cubic Sensors Cylindrical Sensors Spherical Sensors

Depending on the sensor the sensing range is either 6 - 30 cm, 20 - 130 cm, 40 - 300 cm, 60 - 600 cm, or 80 - 1000 cm. Switching frequencies vary from 1 Hz to 20 Hz. Modular Range II sensors have background and foreground suppression.

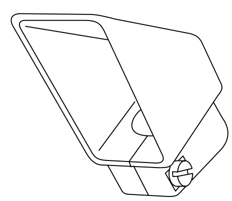


Accessories

An adjusting device with a mounting flange (shown) or bracket (not shown) and a 90° diverting reflector are available for M30 spherical sensors. The adjusting device allows the sensor to be positioned in hard-to-mount areas.



Adjusting Device
Flange Model



90° Diverting Reflector

Review 6

1) Ultrasonic ___________-___________ proximity sensors require a separate transmitter and receiver.

2) If X1 is connected to L+ of a Thru-Beam ultrasonic proximity sensor, the sensing range is ___________ to ___________ cm.

3) The maximum sensing range of a Compact Range 0 ultrasonic sensor with a ___________ transducer is 6 - 30 cm.

4) Compact Range ___________ does not offer foreground suppression.

   a. 0
   b. I
   c. II
   d. III

5) ___________ is a computer program used to adjust Compact Range II, Compact Range III, and Compact Range M18 ultrasonic sensors.

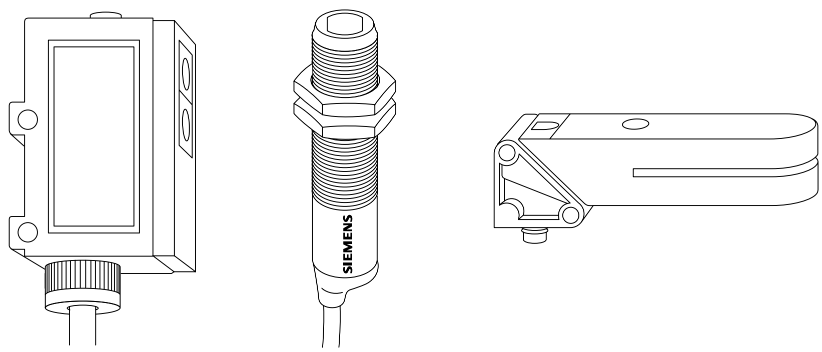
6) ___________ Range II require a signal evaluator.

7) A signal evaluator can operate a maximum of ___________ sensors.

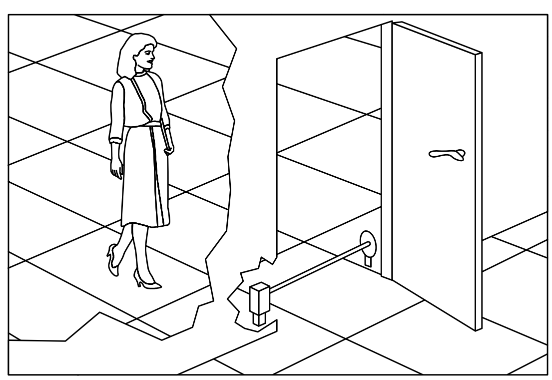
   a. 1
   b. 2
   c. 3
   d. 4

Photoelectric Sensors Theory of Operation

A photoelectric sensor is another type of position sensing device. Photoelectric sensors, similar to the ones shown below, use a modulated light beam that is either broken or reflected by the target.

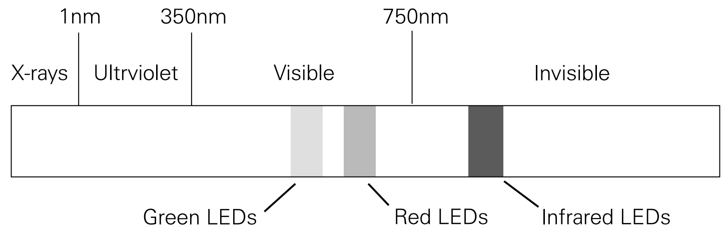


The control consists of an emitter (light source), a receiver to detect the emitted light, and associated electronics that evaluate and amplify the detected signal causing the photoelectric's output switch to change state. We are all familiar with the simple application of a photoelectric sensor placed in the entrance of a store to alert the presence of a customer. This, of course, is only one possible application.



Modulated Light

Modulated light increases the sensing range while reducing the effect of ambient light. Modulated light is pulsed at a specific frequency between 5 and 30 KHz. The photoelectric sensor is able to distinguish the modulated light from ambient light. Light sources used by these sensors range in the light spectrum from visible green to invisible infrared. Light-emitting diode (LED) sources are typically used.



Clearance

It is possible that two photoelectric devices operating in close proximity to each other can cause interference. The problem may be rectified with alignment or covers. The following clearances between sensors are given as a starting point. In some cases it may be necessary to increase the distance between sensors.

Sensor Model	Distance
D4 mm / M5	50 mm
M12	250 mm
M18	250 mm
K31	250 mm
K30	500 mm
K40	750 mm
K80	500 mm
L18	150 mm
L50 (Diffuse)	30 mm
L50 (Thru-Beam)	80 mm

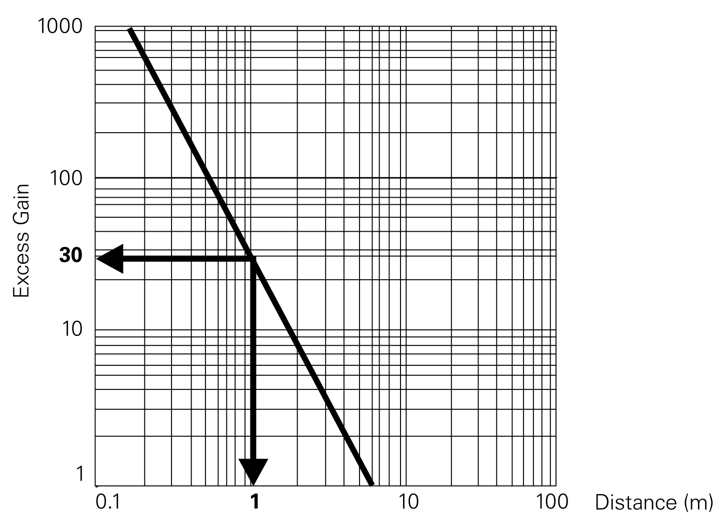
Excess Gain

Many environments, particularly industrial applications, include dust, dirt, smoke, moisture, or other airborne contaminants. A sensor operating in an environment that contains these contaminants requires more light to operate properly. There are six grades of contamination:

1. Clean Air (Ideal condition, climate controlled or sterile)
2. Slight Contamination (Indoor, nonindustrial areas, office buildings)
3. Low Contamination (Warehouse, light industry, material handling operations)
4. Moderate Contamination (Milling operations, high humidity, steam)
5. High Contamination (Heavy particle laden air, extreme wash down environments, grain elevators)
6. Extreme/Severe Contamination (Coal bins, residue on lens)

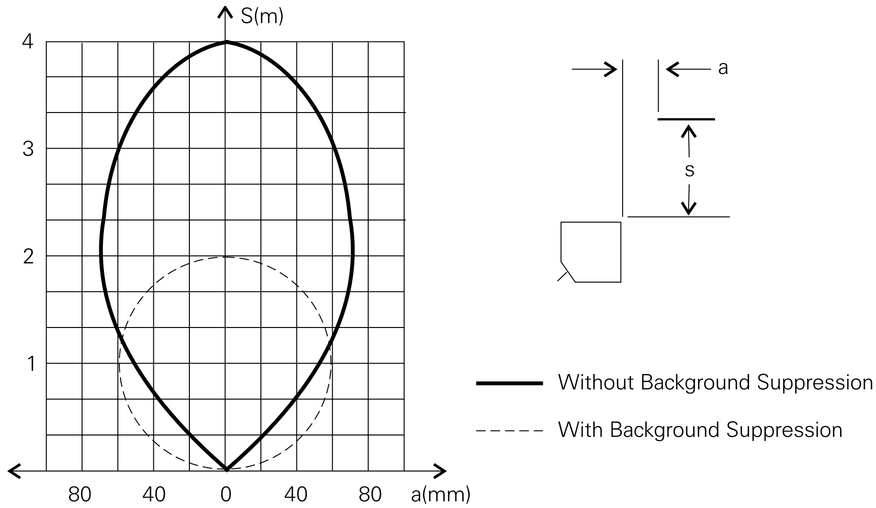
Excess gain represents the amount of light emitted by the transmitter in excess of the amount required to operate the receiver. In clean environments an excess gain equal to or greater than 1 is usually sufficient to operate the sensor's receiver. If, for example, an environment contained enough airborne contaminants to absorb 50% of the light emitted by the transmitter, a minimum excess gain of 2 would be required to operate the sensor's receiver.

Excess gain is plotted on a logarithmic chart. The example shown below is an excess gain chart for an M12 thru-beam sensor. If the required sensing distance is 1 m there is an excess gain of 30. This means there is 30 times more light than required in clean air hitting the receiver. Excess gain decreases as sensing distance increases. Keep in mind that the sensing distance for thru-beam sensors is from the transmitter to the receiver and the sensing distance for reflective sensors is from the transmitter to the target.



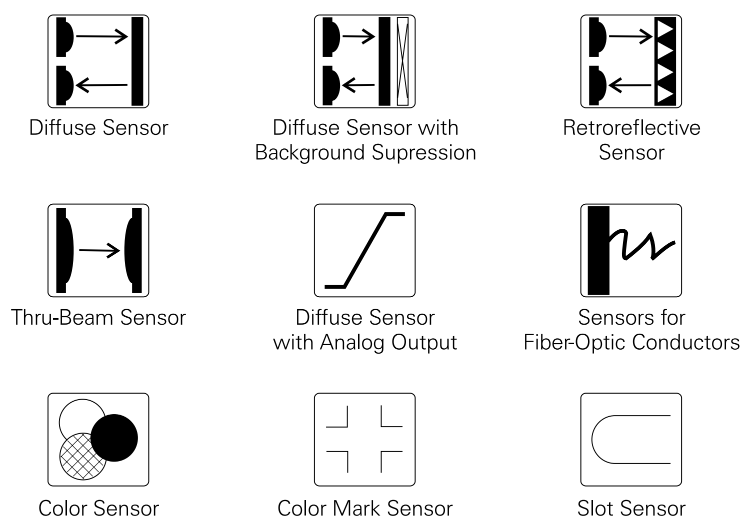
Switching Zones

Photoelectric sensors have a switching zone. The switching zone is based on the beam pattern and diameter of the light from the sensor's emitter. The receiver will operate when a target enters this area.



Symbols

Various symbols are used in the Sensor catalog (SFPC-08000) to help identify the type of photoelectric sensor. Some symbols are used to indicate a sensor's scan technique, such as diffuse, retroreflective, or thru beam. Other symbols identify a specific feature of the sensor, such as fiber-optics, slot, or color sensor.



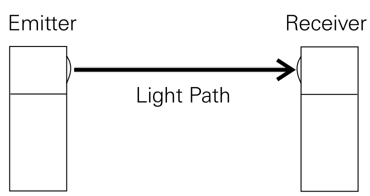
Scan Techniques

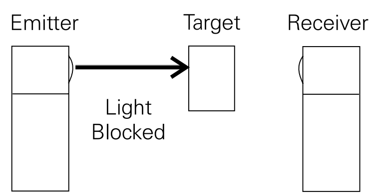
A scan technique is a method used by photoelectric sensors to detect an object (target). In part, the best technique to use depends on the target. Some targets are opaque and others are highly reflective. In some cases it is necessary to detect a change in color. Scanning distance is also a factor in selecting a scan technique. Some techniques work well at greater distances while others work better when the target is closer to the sensor.

Thru-Beam

Separate emitter and receiver units are required for a thru-beam sensor. The units are aligned in a way that the greatest possible amount of pulsed light from the transmitter reaches the receiver. An object (target) placed in the path of the light beam blocks the light to the receiver, causing the receiver's output to change state. When the target no longer blocks the light path the receiver's output returns to its normal state.

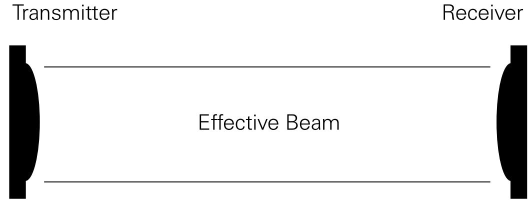
Thru-beam is suitable for detection of opaque or reflective objects. It cannot be used to detect transparent objects. In addition, vibration can cause alignment problems. The high excess gain of thru-beam sensors make them suitable for environments with airborne contaminants. The maximum sensing range is 300 feet.





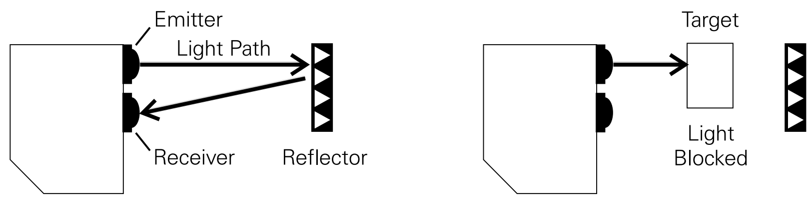
Thru-Beam Effective Beam

The effective beam of a photoelectric sensor is the region of the beam's diameter where a target is detected. The effective beam on a thru-beam sensor is the diameter of the emitter and receiver lens. The effective beam extends from the emitter lens to the receiver lens. The minimum size of the target should equal the diameter of the lens.



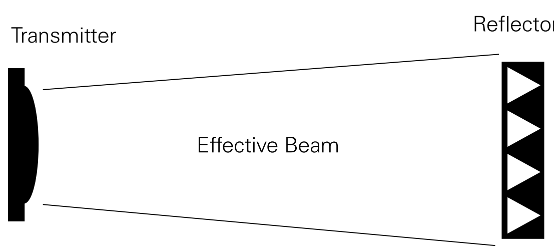
Reflective or Retroreflective Scan

Reflective and retroreflective scan are two names for the same technique. The emitter and receiver are in one unit. Light from the emitter is transmitted in a straight line to a reflector and returns to the receiver. A normal or a corner-cube reflector can be used. When a target blocks the light path the output of the sensor changes state. When the target no longer blocks the light path the sensor returns to its normal state. The maximum sensing range is 35 feet.



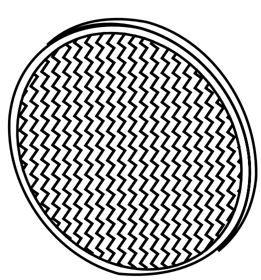
Retroreflective Scan Effective Beam

The effective beam is tapered from the sensor's lens to the edges of the reflector. The minimum size of the target should equal the size of the reflector.



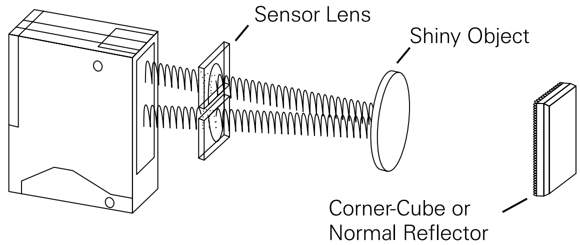
Reflectors

Reflectors are ordered separately from sensors. Reflectors come in various sizes and can be round or rectangular in shape or reflective tape. The sensing distance is specified with a particular reflector. Reflective tape should not be used with polarized retroreflective sensors.



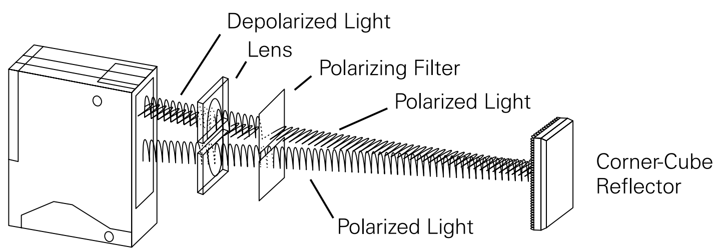
Retroreflective Scan and Shiny Objects

Retroreflective scan sensors may not be able to detect shiny objects. Shiny objects reflect light back to the sensor. The sensor is unable to differentiate between light reflected from a shiny object and light reflected from a reflector.



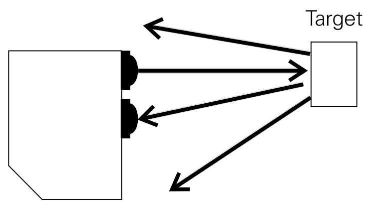
Polarized Retroreflective Scan

A variation of retroreflective scan is polarized retroreflective scan. Polarizing filters are placed in front of the emitter and receiver lenses. The polarizing filter projects the emitter's beam in one plane only. This light is said 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. In comparison to retroreflective scan, polarized retroreflective scan works well when trying to detect shiny objects.



Diffuse Scan

The emitter and receiver are in one unit. Light from the emitter strikes the target and the reflected light is diffused from the surface at all angles. If the receiver receives enough reflected light the output will switch states. When no light is reflected back to the receiver the output returns to its original state. In diffuse scanning the emitter is placed perpendicular to the target. The receiver will be at some angle in order to receive some of the scattered (diffuse) reflection. Only a small amount of light will reach the receiver, therefore, this technique has an effective range of about 40."



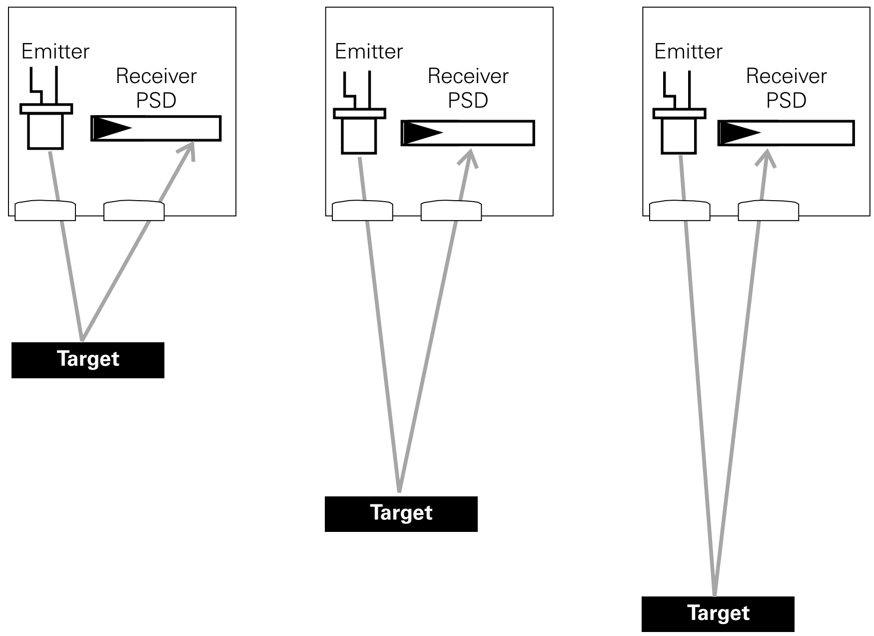
Diffuse Scan Correction Factors

The specified sensing range of diffuse sensors is achieved by using a matte white paper. The following correction values may be applied to other surfaces. These values are guidelines only and some trial and error may be necessary to get correct operation.

Test Card (Matte White)	100%
White Paper	80%
Gray PVC	57%
Printed Newspaper	60%
Lightly Colored Wood	73%
Cork	65%
White Plastic	70%
Black Plastic	22%
Neoprene, Black	20%
Automobile Tires	15%
Aluminum, Untreated	200%
Aluminum, Black Anodized	150%
Aluminum, Matte (Brushed Finish)	120%
Stainless Steel, Polished	230%

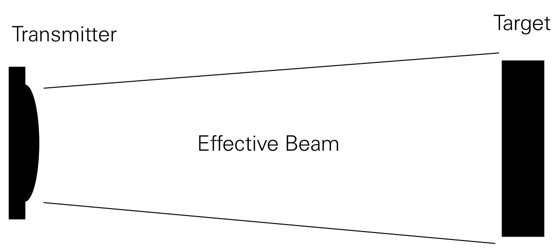
Diffuse Scan with Background Suppression

Diffuse scan with background suppression is used to detect objects up to a certain distance. Objects beyond the specified distance are ignored. Background suppression is accomplished with a position sensor detector (PSD). Reflected light from the target hits the PSD at different angles, depending on the distance of the target. The greater the distance the narrower the angle of the reflected light.



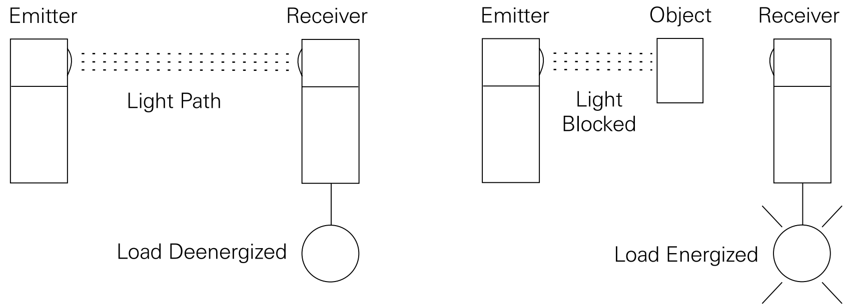
Diffuse Scan Effective Beam

The effective beam is equal to the size of the target when located in the beam pattern.

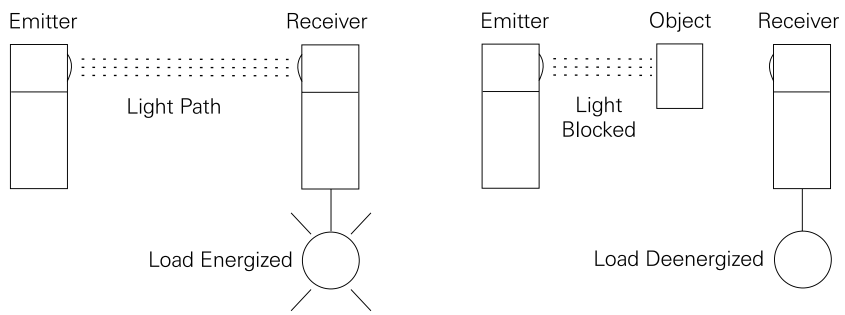


Operating Modes

There are two operating modes: dark operate (DO) and light operate (LO). Dark operate is an operating mode in which the load is energized when light from the emitter is absent from the receiver.



Light operate is an operating mode in which the load is energized when light from the emitter reaches the receiver.

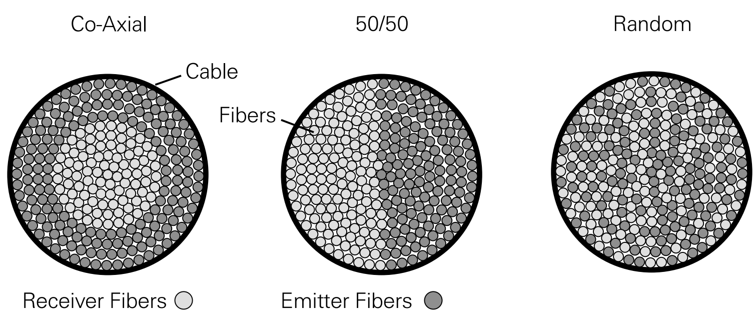


The following table shows the relationship between operating mode and load status for thru, retroreflective, and diffuse scan.

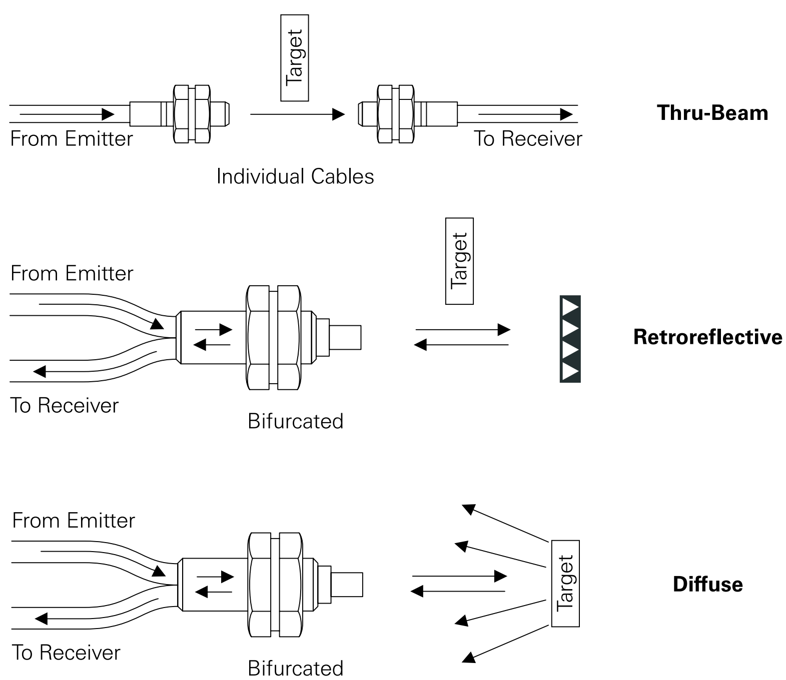
Operating Mode	Light Path	Load Status	
		Thru San and Retroreflective	Diffuse
Light Operate (LO)	Not Blocked	Energized	Deenergized
	Blocked	Deenergized	Energized
Dark Operate (DO)	Not Blocked	Deenergized	Energized
	Blocked	Energized	Deenergized

Fiber Optics

Fiber optics is not a scan technique, but another method for transmitting light. Fiber optic sensors use an emitter, receiver, and a flexible cable packed with tiny fibers that transmit light. Depending on the sensor there may be a separate cable for the emitter and receiver, or it may use a single cable. When a single cable is used, the emitter and receiver use various methods to distribute emitter and transmitter fibers within a cable. Glass fibers are used when the emitter source is infrared light. Plastic fibers are used when the emitter source is visible light.



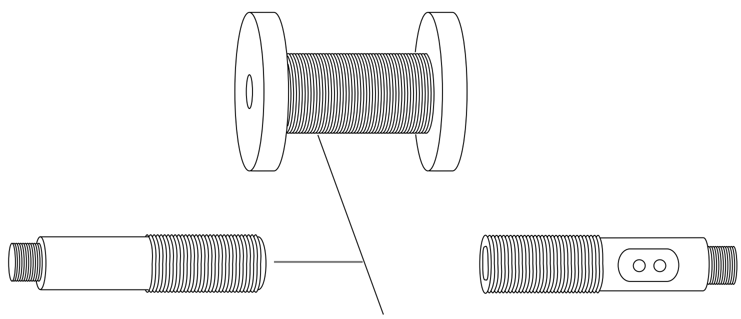
Fiber optics can be used with thru-beam, retroreflective scan, or diffuse scan sensors. In thru beam light is emitted and received with individual cables. In retroreflective and diffuse scan light is emitted and received with the same cable (bifurcated). Fiber optics is ideal for small sensing areas or small objects. Fiber optics have a shorter sensing range due to light losses in the fiber optic cables.



Lasers

Lasers are sometimes used as sensor light sources. Siemens uses Class 2 lasers which have a maximum radiant power of 1 mW. Class 2 lasers require no protective measures and a laser protection officer is not required. However, a warning notice must be displayed when laser sensors are used.

Laser sensors are available in thru-beam, diffuse scan, and diffuse scan with background suppression versions. Lasers have a high intensity visible light, which makes setup and adjustment easy. Laser technology allows for detection of extremely small objects at a distance. The Siemens L18 sensor, for example, will detect an object of 0.03 mm at a distance of 80 cm. Examples of laser sensor applications include exact positioning, speed detection, or checking thread thickness of 0.1 mm and over.



Review 7

1) Modulated light of a Siemens photoelectric sensor is pulsed at a frequency between ___________ and _________ KHz.

2) Excess ___________ is a measurement of the amount of light falling on the receiver in excess of the minimum light required to operate the sensor.

3) ___________ is a scan technique in which the emitter and receiver are in one unit. Light from the emitter is transmitted in a straight line to a reflector and returned to the receiver.

4) Polarizing filters on a retroreflective scan sensor orientate planes of light ___________ degrees to one another.

5) The correction factor for diffuse scan of cork with a photoelectric sensor is ___________ %.

6) ___________ operate is an operating mode in which the load is energized when light from the emitter of a photoelectric sensor is absent from the receiver.

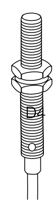
7) Fiber optics is a scan technique.

   a. true
   b. false

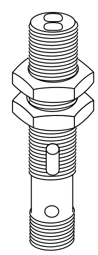
8) Siemens laser photoelectric sensors use Class ___________ lasers.

Photoelectric Family of Sensors

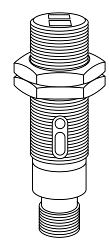
Siemens offers a wide variety of photoelectric sensors, including thru-beam, retroreflective scan, and diffuse scan sensors. There are many photoelectric sensors to choose from. Choice depends on many factors such as scan mode, operating voltage, environment, and output configurations. Most of these sensors can be used with some or all scan techniques. In addition, specialized sensors such as fiber optic, laser, and color sensors are available. To help simplify the process of determining the right sensor selection guides are provided. These guides do not list all the features of a given sensor. For a more detailed description refer to the appropriate catalog.



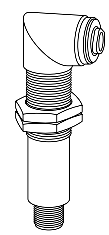
D4



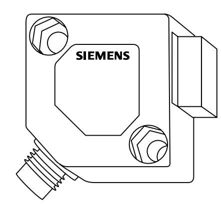
M12



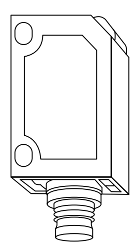
M18



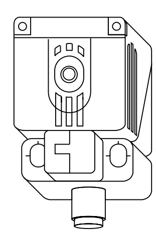
L18



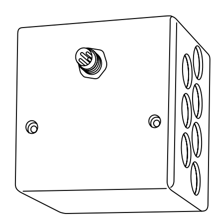
K40



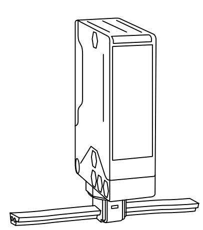
K20



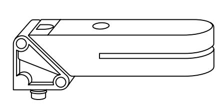
C40



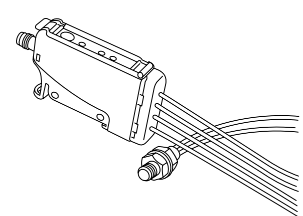
Light Array



K80 with AS-i Cable



G20



CL40

Thru-Beam Sensors

Sensor	Range	Voltage	Output			Mode		Connection					Housing
			PNP	NPN	Relay	DO	LO	AS-i	M8	M12	Cable	Terminals	
D4/M5	250 mm	10-30 VDC	X	X			X		X		X		Metal
M12	4 m	10-30 VDC	X	X		X	X			X	X		Metal
M18	6 m	10-36 VDC	X	X		X	X			X	X		Metal
M18M	12 m	10-30 VDC	X	X		X	X			X	X		Metal
M18P	12 m	10-30 VDC	X	X		X	X			X	X		Plastic
K30	12 m	10-36 VDC	X	X		X	X		X		X		Plastic
K35	5 m	10-30 VDC	X	X		X	X		X		X		Plastic
K40	15 m	10-36 VDC	X	X		X	X		X	X	X		Plastic
K50	5 m	10-30 VDC 15-264 VAC	X	X	X	X	X	X		X	X		Plastic
K65	50 m	10-30 VDC	X	X		X	X			X	X		Plastic
K80	50 m	10-36 VDC 20-320 VAC	X	X	X	X	X	X		X		X	Plastic
L18 (Laser)	50 m	10-30 VDC	X			X	X			X	X		Metal

Retroreflective Sensors

Sensor	Range	Voltage	Output			Mode		Connection					Housing
			PNP	NPN	Relay	DO	LO	AS-i	M8	M12	Cable	Terminals	
M12	1.5 m	10-30 VDC	X	X		X	X			X	X		Metal
M18	2 m	10-36 VDC	X	X		X	X			X	X		Metal
M18M	2 m	10-30 VDC	X	X		X	X			X	X		Metal
M18P	2 m	10-30 VDC	X	X		X	X			X	X		Plastic
K20	2.5 m	10-30 VDC	X	X		X	X		X		X		Plastic
K30	4 m	10-36 VDC	X	X		X	X		X		X		Plastic
K35	2.5 m	10-30 VDC	X	X		X	X		X		X		Plastic
K40	6 m	10-36 VDC	X	X		X	X		X	X	X		Plastic
K50	4 m	10-30 VDC 15-264 VAC	X	X	X	X	X	X		X	X		Plastic
K65	8 m	10-30 VDC	X	X		X	X			X	X		Plastic
K80	6 m	10-36 VDC 20-320 VAC	X	X	X	X	X	X		X		X	Plastic
L50 (Laser)	12 m	10-30 VDC	X	X		X	X			X	X		Metal
Light Array	1.4 m	12-36 VDC	X			X			X				Plastic
C40	6 m	10-36 VDC	X	X		X	X			X			Plastic

Diffuse Sensors

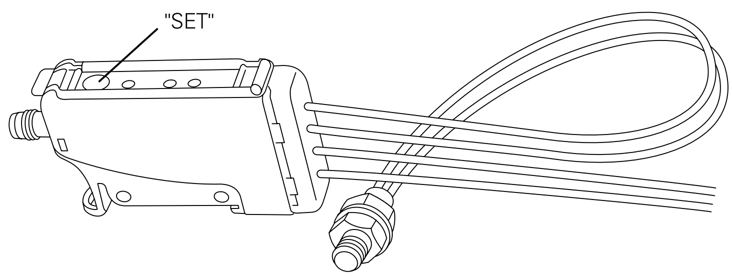
Sensor	Range	Voltage	Output			Mode		Connection					Housing
			PNP	NPN	Relay	DO	LO	AS-i	M8	M12	Cable	Terminals	
D4/M5	50 mm	10-30 VDC	X	X			X		X		X		Metal
M12	30 cm	10-30 VDC	X	X		X	X			X	X		Metal
M18	60 cm	10-36 VDC	X	X		X	X			X	X		Metal
M18M	30 cm	10-30 VDC	X	X		X	X			X	X		Metal
M18P	30 cm	10-30 VDC	X	X		X	X			X	X		Plastic
K20	30 cm	10-30 VDC	X	X		X	X		X		X		Plastic
K30	1.2 m	10-36 VDC	X	X		X	X		X		X		Plastic
K35	50 cm	10-30 VDC	X	X		X	X		X		X		Plastic
K40	2 m	10-36 VDC	X	X		X	X		X	X	X		Plastic
K50	90 cm	10-30 VDC 15-264 VAC	X	X	X	X	X	X		X	X		Plastic
K65	2 m	10-30 VDC	X	X		X	X			X	X		Plastic
K80	2 m	10-36 VDC 20-320 VAC	X	X	X	X	X	X		X		X	Plastic
C40	2.5 cm	10-30 VDC	X	X		X	X			X			Plastic

Diffuse Sensors with Background Suppression

Sensor	Range	Voltage	Output			Mode		Connection					Housing
			PNP	NPN	Relay	DO	LO	AS-i	M8	M12	Cable	Terminals	
M18	120 mm	10-36 VDC	X	X		X	X			X	X		Metal
M18P	100 mm	10-30 VDC	X	X		X	X			X	X		Plastic
K20	100 mm	10-30 VDC	X	X		X	X		X		X		Plastic
K50	25 cm	10-30 VDC 15-264 VAC	X	X	X	X	X	X		X	X		Plastic
K65	50 cm	10-30 VDC	X	X		X	X			X	X		Plastic
K80	1 m	10-36 VDC 20-320 VAC	X	X	X	X	X	X		X		X	Plastic
L50 (Laser)	150 mm	10-30 VDC	X	X		X	X			X	X		Metal
C40	2.5 cm	10-30 VDC	X	X		X	X			X			Plastic

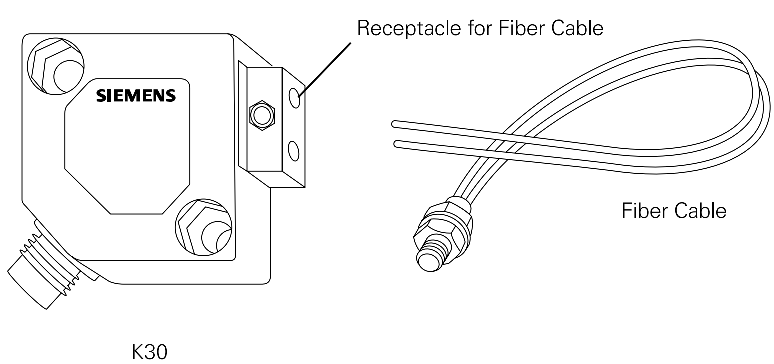
Teach In

Some of the following sensors, such as the CL40, have a feature known as Teach In. This feature allows the user to teach the sensor what it should detect. An object to be detected is placed in front of the sensor so that it knows what the accepted reflected light is. The sensor is then programmed to respond only to this light. The CL40 uses a "SET" button to Teach In. Other sensors have different methods to Teach In. Teach In can be used to detect a specific color, for example. Teach In also works to detect transparent objects.



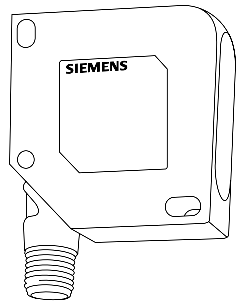
Fiber Optic Sensors

The basic operation is the same for optical fibers made of glass or plastics. Optical fibers are fitted in front of the transmitter and receiver and extend the "eye" of the sensor. Fiber optic cables are small and flexible and can be used for sensing in hard to access places.



Laser Diffuse Sensor with Analog Output

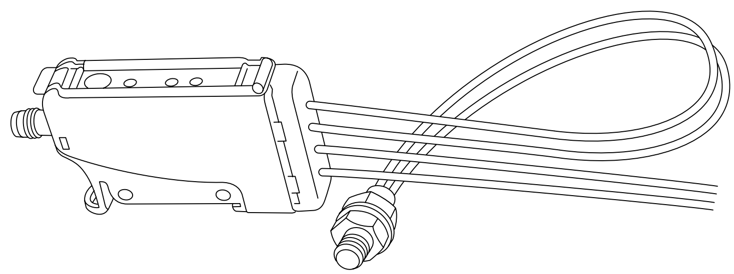
The analog laser sensor is able to measure the exact distance of an object within its sensing range. This sensor uses a visible laser light with a highly accurate and linear output.



L50

Color BERO

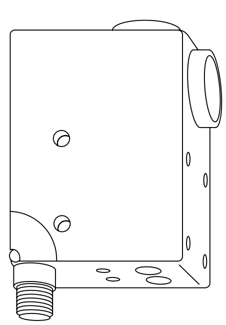
The color BERO uses 3 LEDs with the colors red, green, and blue. Light is emitted to the target and can detect a specific color of reflected light. This sensor uses Teach In to set the color to be detected. The CL40 is also a fiber optic device.



CL40

Color Mark BERO

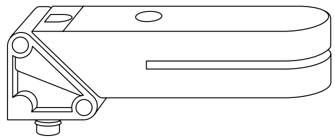
The color mark BERO is also used to detect specific colors. This sensor works differently from the CL40. The color mark BERO uses green or red light for the emitter. The color is selected dependent on the contrast of the target. The target and background color can be set separately.



C80

Slot BERO

The target is placed inside the slot of the sensor. Emitted light passes through the object. Different contrast, tears, or holes in the target will vary the quantity of light reaching the receiver. This sensor uses Teach In. It is available with infrared or visible red/green light



G20

Selection Guide

Sensor Type	Sensor	Range	Voltage	Teach In	Output		Mode		Connection			Housing
					PNP	NPN	DO	LO	M8	M12	Cable	
Fiber Optic	K35	75 mm	10-30 VDC		X	X	X	X	X		X	Plastic
	KL40	280 mm	10-30 VDC	X	X	X	X	X	X		X	Plastic
	K30	120 mm	10-36 VDC		X	X	X	X	X		X	Plastic
	K40	150 cm	10-36 VDC		X	X	X	X	X	X	X	Plastic
Laser Diffuse Analog Output	L50	45-85 mm	18-28 VDC								X	Plastic
Color BERO	CL40	15 mm	10-30 VDC	X	X	X	X	X	X		X	Plastic
Color Mark BERO	C80	18 mm	10-30 VDC	X	X		X	X		X	X	Metal
Slot BERO	G20	2 mm	10-30 VDC	X	X	X	X	X	X			Metal

Review 8

1) The maximum sensing range of a K80, thru scan, photoelectric sensor is ___________ m.

2) ___________ is an example of a photoelectric sensor with Teach In.

   a. D4
   b. K50
   c. CL40
   d. K30

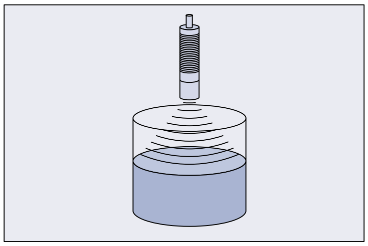
3) A ___________ is a photoelectric sensor that has a slot where the target is placed.

4) The maximum sensing range of a Color Mark BERO C80 is ___________ mm.

Sensor Applications

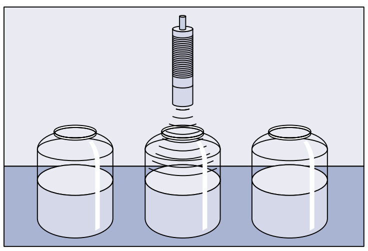
There are any number of applications where sensors can be utilized, and as you have seen throughout this book there are a number of sensors to chose from. Choosing the right sensor can be confusing and takes careful thought and planning. Often, more than one sensor will do the job. As the application becomes more complex the more difficult it is to choose the right sensor for a given application.The following application guide will help you find the right sensor for the right application.

Ultrasonic Sensors



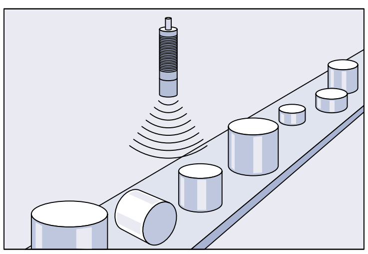
Application
Level Measurement in Large Vessels (Tanks, Silos)

Sensor
3RG61 13
Compact Range III



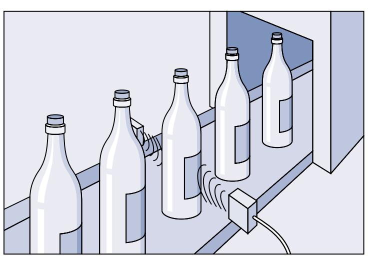
Application
Level Measurement in Small Bottles

Sensor
3RG61 12
Compact Range III



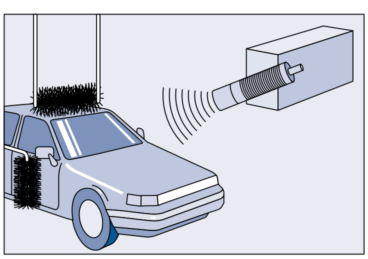
Application
Quality Control

Sensor
3RG61 12
Compact Range III



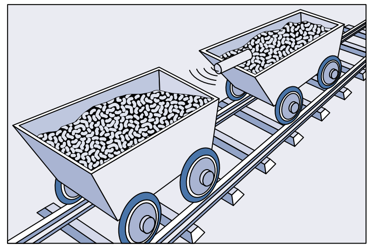
Application
Bottle Counting

Sensor
3RG62 43
Thru Beam



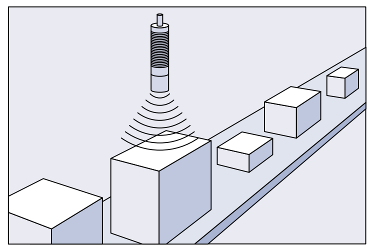
Application
Vehicle Sensing and Positioning

Sensor
3RG60 14
Compact Range III



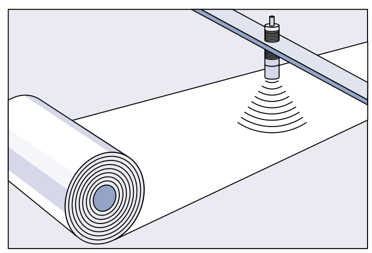
Application
Anti-Collision

Sensor
3RG60 14
Compact Range I



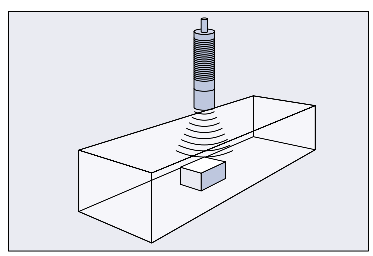
Application
Height Sensing

Sensor
3RG60 13
Compact Range II



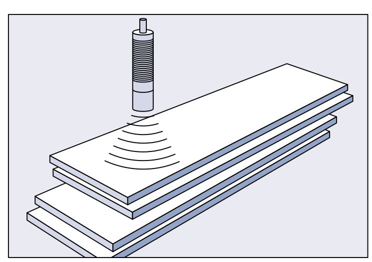
Application
Breakage Sensing

Sensor
3RG61 12
Compact Range I



Application
Object Sensing

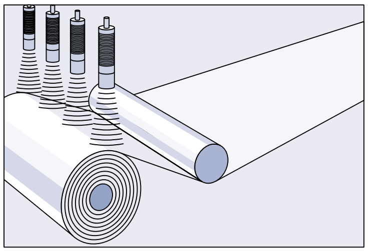
Sensor
3RG60 12
Compact Range II



Application
Stack Height Sensing

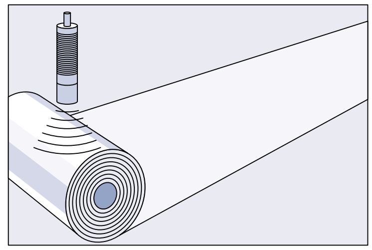
Sensor
3RG60 13
Compact Range II

Ultrasonic Sensors



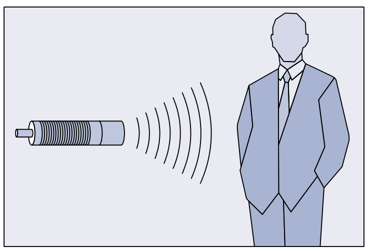
Application
Contour Recognition

Sensor
3RG61 13
Compact Range III



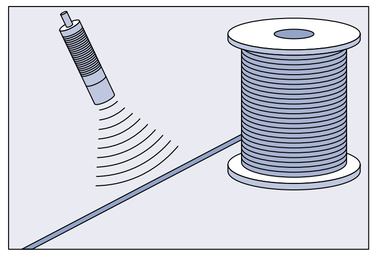
Application
Diameter Sensing and
Strip Speed Control

Sensor
3RG61 12
Compact Range III



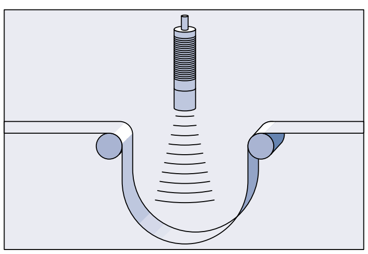
Application
People Sensing

Sensor
3RG60 12
Compact Range II



Application
Wire and Rope
Breakage Monitoring

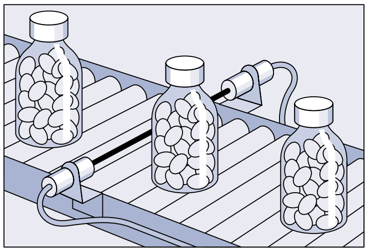
Sensor
3RG60 12
Compact Range I



Application
Loop Control

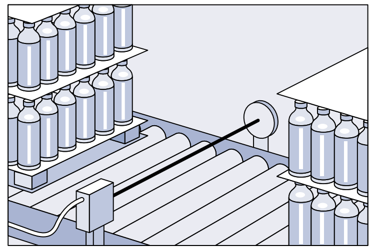
Sensor
3RG60 15
Compact Range II

Photoelectric Sensors



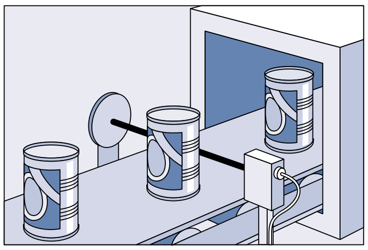
Application
Verifying Objects in Clear Bottles

Sensor
M12 Thru Beam



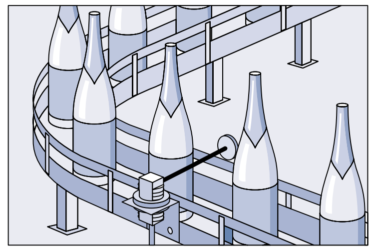
Application
Flow of Pallets Carrying Bottles

Sensor
K40 Retroreflective



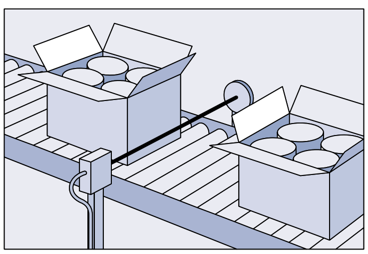
Application
Counting Cans

Sensor
K50 Polarized Retroreflective



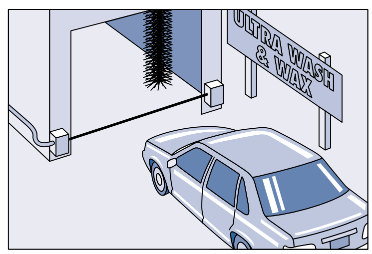
Application
Counting Bottles

Sensor
SL18 Retroreflective



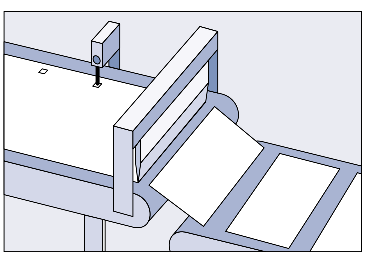
Application
Counting Cartons

Sensor
K65 Retroreflective



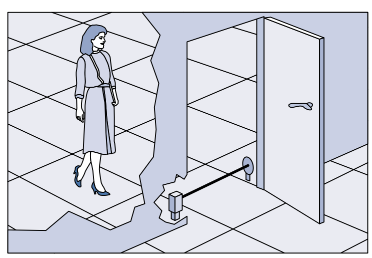
Application
Car Wash

Sensor
SL Thru Beam



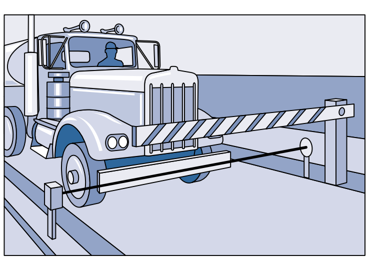
Application
Reading Reference Marks for Trimming

Sensor
C80 Mark Sensor



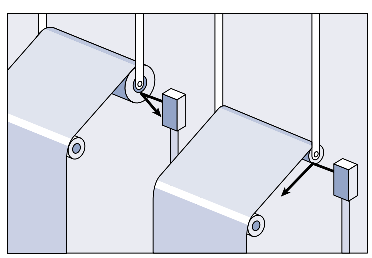
Application
Detecting Persons

Sensor
K50 Retroreflective



Application
Controlling Parking Gate

Sensor
SL Retroreflective

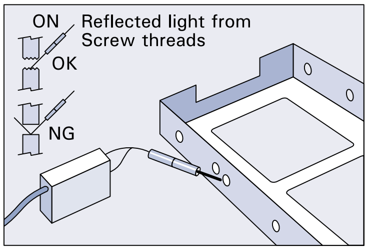


Application
End of Roll Detection

Sensor
K31 Diffuse

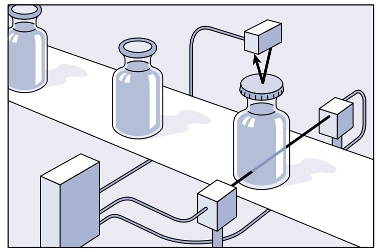
For further application assistance contact your local sales office. Call (800) 964-4414 for nearest office.

Photoelectric Sensors



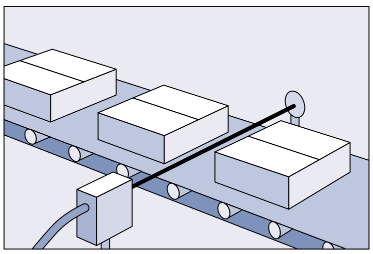
Application
Detecting Tab Threads

Sensor
KL40 Fiber Optic



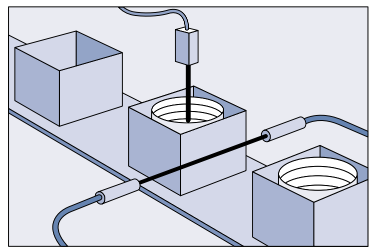
Application
Detecting Caps on Bottles

Sensor
K20 Diffuse with Background Suppression and K31 Thru Beam



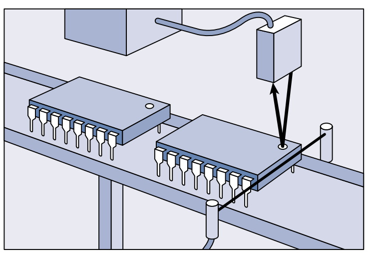
Application
Counting Packages

Sensor
K80 Retroreflective



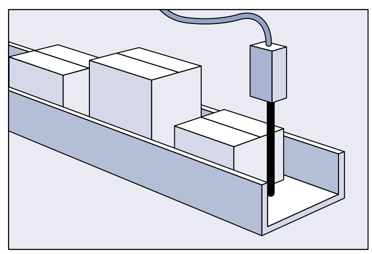
Application
Detecting Components Inside Metal Can

Sensor
K50 Background Suppression



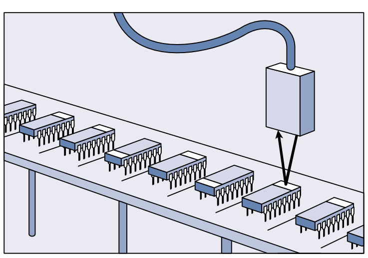
Application
Determining Orientation of IC Chip

Sensor
L50 Laser with Background Suppression



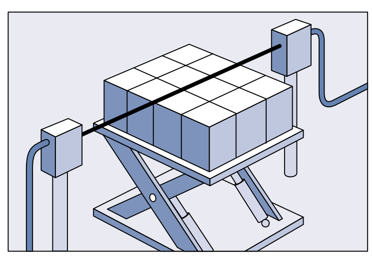
Application
Detecting Items of Varying Heights

Sensor
K80 Background Suppression



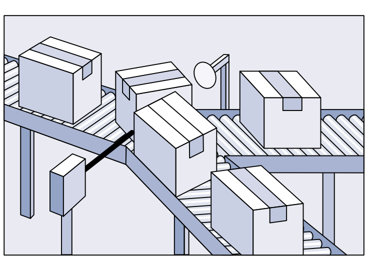
Application
Detecting Orientation of IC Chip

Sensor
Color Mark or Fiber Optic



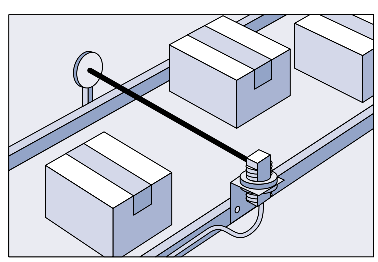
Application
Controlling Height of a Stack

Sensor
SL Thru Beam



Application
Detecting Jams on a Conveyor

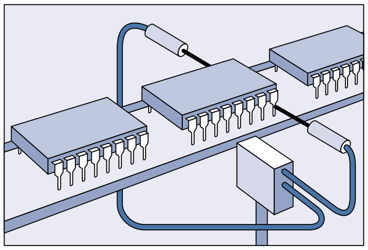
Sensor
K50 Retroreflective



Application
Counting Boxes Anywhere on a Conveyor

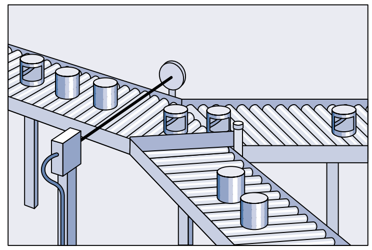
Sensor
SL18 Right Angle Retroreflective

Photoelectric Sensors



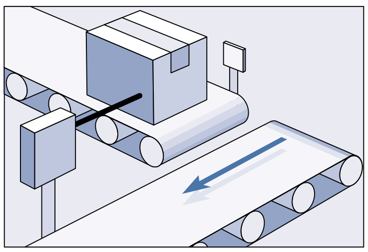
Application
Counting IC Chip Pins

Sensor
KL40 Fiber Optic



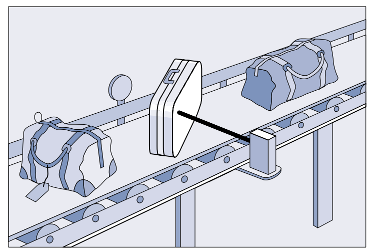
Application
Batch counting and Diverting Cans Without Labels

Sensor
K40 Polarized



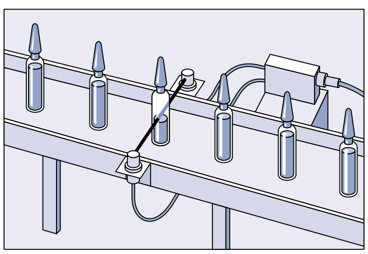
Application
Detecting Presence of Object to Start a Conveyor

Sensor
K35 Retroreflective



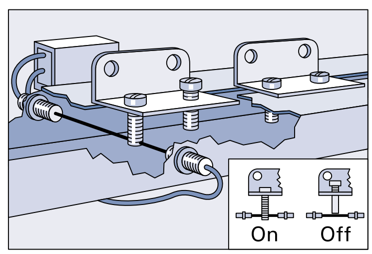
Application
Detecting Reflective Objects

Sensor
K80 Polarized Retroreflective



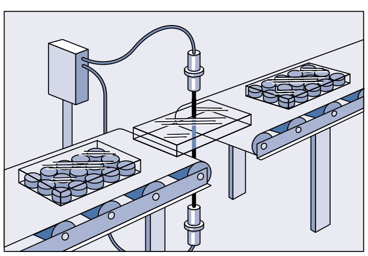
Application
Verifying Liquid in Vials

Sensor
K35 Fiber Optic



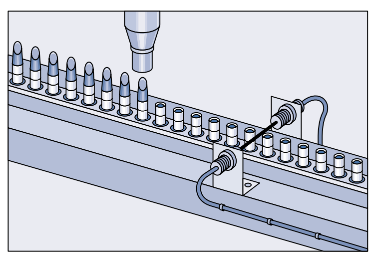
Application
Verifying Screws are Correctly Seated

Sensor
KL40 Fiber Optic



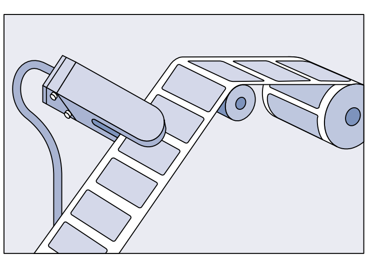
Application
Verifying Cakes are Present in Transparent Package

Sensor
KL40 Fiber Optic



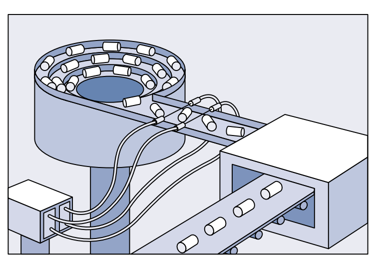
Application
Verifying Lipstick Height Before Capping

Sensor
M5 or M12 Thru Beam



Application
Detecting Labels with Transparent Background

Sensor
G20 Slot Sensor

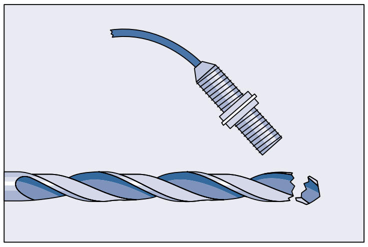


Application
Monitoring Objects as they Exit Vibration Bowl

Sensor
K35 Fiber Optic

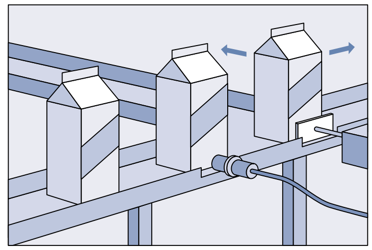
For further application assistance contact your local sales office. Call (800) 964-4414 for nearest office.

Proximity Switches



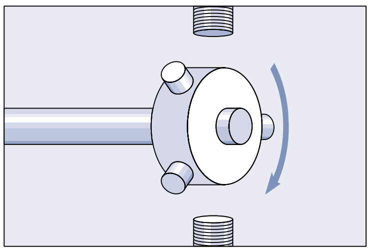
Application
Detecting the Presence of a Broken Drill Bit

Sensor
12 mm Normal Requirements



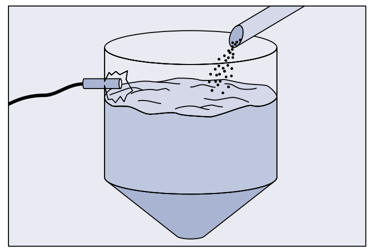
Application
Detecting Milk in Cartons

Sensor
Capacitive



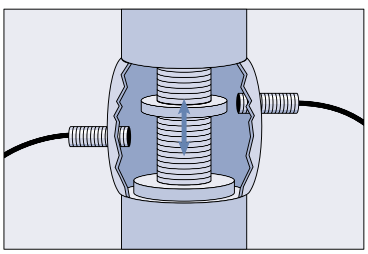
Application
Detecting Presence of Set Screws on Hub for Speed or Direction Control

Sensor
30mm Shorty



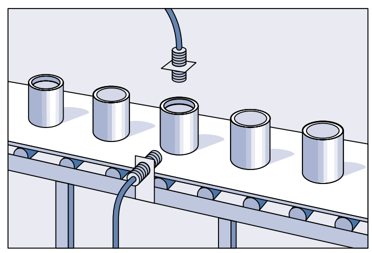
Application
Controlling Fill level of solids in a bin

Sensor
Capacitive



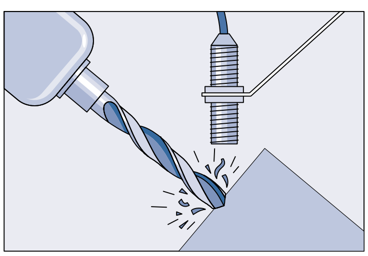
Application
Detecting Full Open or Closed Valve Postition

Sensor
12mm or 18mm Extra Duty



Application
Detecting Presence of Can and Lid

Sensor
30mm Normal Requirements or UBERO, 18mm Normal Requirements Gating Sensor



Application
Detecting Broken Bit on Milling Machine

Sensor
18 mm

Application Inquiry

Providing a sensing device solution requires both knowledge of the application and answers to specific questions to obtain key additional facts. This page is intended to be photocopied and used as a self-help guide in assessing the scope of sensor applications. The information recorded on this form may then be cross-checked with the product specifications found in our "BERO - Sensing Solutions" catalog to obtain a potential solution to your application. If your application involves machine guard safety interlocking, the use of standard position sensors could result in serious injury or death. Please contact SE&A Sensor Marketing for assistance at (630) 879-6000.

1. **Target Material**
   ___ Metal ___ Non-Metal
   ___ Ferrous ___ Non-Ferrous
   ___ Transparent ___ Translucent
   ___ Opaque

2. **Target Description and Dimensions**
   Target Finish
   (shiny/dull/matte, etc.) __________
   Target Color __________
   Target Texture __________

3. **Target Orientation/Spacing**
   Describe position of target when sensed relative to immediate environment.

   Number of Multiple Targets ____
   Number of Targets Nested Together ___
   Spacing Between Targets _______
   Size of Target __________

4. **Target Movement/Speed/Velocity**
   Describe how the target approaches the sensing area (Axial/Lateral).

   Target Speed __________
   Cycles per Second/Minute/etc ______
   Hours machine is run? ________

5. **Sensing Distance**
   From Target to Sensor __________
   From Target to Background __________

6. **Background Description**
   Describe the background conditions.

7. **Physical/Mounting Criteria**
   Is target accessible from more than one side?

   Space available to install sensor _____

   Sensor Orientation Possibilities _____

   ____

8. **Environment**
   ___ Clean ___ Oily ___ Dusty
   ___ Humid ___ Outdoor ___ Indoor
   ___ Submersion ___ Wash down
   Temperature ________
   Temperature Variation ________

9. **Load Requirements**
   Describe the Load ________________
   Inductive: Inrush _____ Sealed _____

10. **Control Voltage Supply**
    __________ VAC __________ VDC

11. **Output Requirements**
    ___ NPN ___ PNP ___ SCR ___ FET
    ___ Relay
    ___ Normally Open ___ Normally Closed
    ___ Complimentary _____ LO/DO

12. **Connection Preference**
    ___ Connector/Matching Cordset

    Length of Sensor Prewired Cable
    (2 Meters Standard) ________

    ___ AS-i Interface

For further application assistance contact your local sales office. Call (800) 964-4414 for nearest office.

Review Answers

Review 1	1) Limit switch; 2) d; 3) Pretravel; 4) operating position; 5) break-before-make; 6) Break; 7) 30; 8) operating head; 9) SIGUARD; 10) 6P
Review 2	1) inductive; 2) a; 3) 3; 4) 4; 5) steel; 6) 0.40; 7) 81%
Review 3	1) 10; 2) 20; 3) 265, 320; 4) IP; 5) 65; 6) UBERO
Review 4	1) electrostatic; 2) any; 3) dielectric; 4) b; 5) 20
Review 5	1) sound; 2) 6-80; 3) 5; 4) 60; 5) 3; 6) Diffuse
Review 6	1) Thru-Beam; 2) 5 to 40; 3) separate; 4) a; 5) SONPROG; 6) Modular; 7) b
Review 7	1) 5 and 30; 2) gain; 3) Retroreflective; 4) 90 degrees; 5) 65; 6) Dark; 7) b; 8) 2
Review 8	1) 50; 2) c; 3) G20; 4) 18

Final Exam

The final exam is intended to be a learning tool. The book may be used during the exam. A tear-out answer card is provided. After completing the final exam, mail in the answer card for grading. A grade of 70% or better is passing. Upon successful completion of the test a certificate will be issued.

Questions

1. The distance an actuator arm travels on a mechanical limit switch from the release position to the free position is known as ___________ .

   a. Overtravel
   b. Differential Travel
   c. Pretravel
   d. Release Travel

2. ___________ is a term that describes the load a mechanical limit switch can handle when the mechanical contacts close.

   a. Make
   b. Break
   c. Continuous
   d. Inductive

3. ___________ are the two product lines for Siemens mechanical limit switches.

   a. International and IEC
   b. International and North American
   c. North American and BERO
   d. International and BERO

4. ___________ is a type of sensor that can only detect metal.

   a. Photoelectric
   b. Ultrasonic
   c. Inductive
   d. Capacitive

5. When two or more shielded inductive proximity sensors are mounted opposite one another, they should be placed a distance of at least ___________ times the rated sensing range from each other.

   a. two
   b. three
   c. four
   d. six

6. A correction factor of ___________ is applied to an unshielded inductive proximity switch when the target is 50% smaller than the standard target.

a. 0.50 b. 0.73
c. 0.83 d. 0.92

7. ___________ is a type of Siemens inductive proximity switch that can detect all metal targets without a reduction factor.

a. NAMUR
b. UBERO
c. Increased Operating Distance
d. AS-i

8. When using a capacitive proximity sensor with a rated sensing distance of 10 mm to detect polyamide, the effective sensing distance is approximately ___________ mm.

a. 4 b. 6
c. 8 d. 10

9. ___________ proximity sensors develop an electrostatic field to detect the target.

a. Inductive b. Ultrasonic
c. Photoelectric d. Capacitive

10. The approximate angle of the main cone of an ultrasonic sensor is ___________ degrees.

a. 5 b. 10
c. 30 d. 45

11. A distance greater than ___________ cm should be left between two ultrasonic sensors mounted opposite each other with a rated sensing range of 20 - 130 cm.

a. 4000 b. 2500
c. 1200 d. 400

12. Coarse-grained materials can have as much as ___________ degrees angular deviation from the send direction of an ultrasonic sensor.

a.	3	b.	5
c.	45	d.	90

13. Sound velocity decreases ___________ % between sea level and 3000 m above sea level.

a.	0.17	b.	3.6
c.	5	d.	25 - 33

14. A signal evaluator is required for use with ___________ ultrasonic sensors.

a. Compact Range 0
b. Compact Range I
c. Compact Range III
d. Modular Range II

15. The maximum sensing distance of a Thru Beam ultrasonic sensor is 80 cm when ___________ .

a. X1 is open
b. X1 is connected to L+
c. X1 is connected to L-
d. X1 is closed

16. SONPROG can be used to adjust ___________ ultrasonic sensors.

a. Thru Beam
b. Compact Range 0 and Compact Range I
c. Compact Range I and Compact Range II
d. Compact Range II and Compact Range III

17. A 90° diverting reflector is available for use with ___________ ultrasonic sensors.

a. M30 spherical
b. Compact Range M18 spherical
c. Compact Range 0 with Integrated Transducer
d. Thru Beam

18. ___________ scan is a photoelectric scan technique in which the planes of emitter light and reflected light are orientated 90° to one another.

a. Polarized Retroreflective
b. Retroreflective
c. Diffuse
d. Thru

19. ___________ is a photoelectric sensor that use three LEDs with colors red, green, and blue and is can be used to detect a specific color of reflected light.

a. G20
b. K30
c. CL40
d. C80

20. The maximum sensing range of the L18 laser photoelectric sensor is ___________ .

a. 12 m
b. 50 m
c. 100 mm
d. 150 mm

Notes