

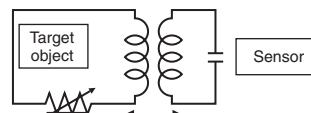
# TECHNICAL GUIDE FOR PROXIMITY SENSORS

## DEFINITIONS

"Proximity sensor" includes all sensors that detect the presence of a metallic object approaching the sensing face or near the sensing face without mechanical contact.

There are detection systems that use the eddy currents that are generated in metallic target objects by electromagnetic induction (most Yamatake proximity sensors), systems that detect changes in electrical capacity when approaching the target object, etc. The Japanese Industrial Standards (JIS) define them as inductive and capacitive proximity sensors respectively.

The target object and sensor form what appears to be a transformer-like relationship.



The transformer-like coupling condition is replaced by impedance changes due to eddy-current losses. The impedance changes can be viewed as changes in the resistance that is inserted in series with the target object.

### Detection principle of high-frequency oscillation proximity sensors

High-frequency oscillation proximity sensors detect magnetic loss due to eddy currents that are generated on a conductive surface by an external magnetic field. An AC magnetic field is generated on the detection coil, and changes in the impedance due to eddy currents generated on a metallic object are detected. Other systems include aluminum-detecting sensors, which detect the phase component of the frequency, etc.

## YAMATAKE PROXIMITY SENSOR CATEGORIES

The following table summarizes Yamatake proximity sensors by actuation method, structure (built-in or separate amplifier), sensing head shape and shielding:

Series name	DC2-wire FL7M	DC3-wire FL7M	DC2-wire FL7M-A	AC/DC2-wire FL7M	DC2/3-wire APM	DC2-wire FL2F	DC2-wire FL2R/S	DC3-wire FL2	DC2/3-wire FL2R-V	DC2-wire APT
Categorization by actuation method	High-frequency oscillation									
Categorization by structure	Built-in amplifier									Amplifier-Relayed
Categorization by sensing head shape	Cylindrical				Square					Cyl./Sq
Shielded	○		○				—			○
Unshielded	○		—				○			—

### High-frequency oscillation

The sensor is turned ON and OFF when a metal object approaches the sensing face (coil).

Most Yamatake proximity sensors are this type.

### Built-in amplifier

Resists influence from electrical noise because the sensing coil is integrated with the oscillation circuit.

### Amplifier-Relayed

The sensing coil and the oscillation circuit are separate. This allows the sensing face to be smaller.

### Cylindrical

Round sensing face

### Square

Square-shaped sensing face

### Shielded

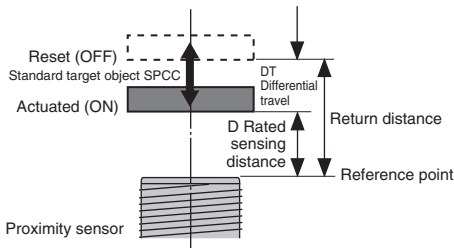
The sides of the sensing coil are covered with metal. This structure is robust and less likely to be affected by surrounding metal.

### Unshielded

The sides of the sensing coil are not covered with metal. This allows the sensing distance to be made longer.

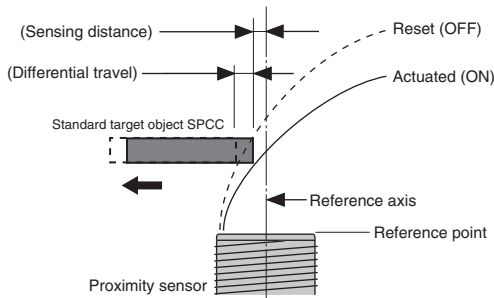
## GLOSSARY

### Perpendicular operation



Generally, the sensing distance of a proximity sensor is measured by this perpendicular actuation method.

### Parallel operation



Expressed as the measured distance from the reference point when the standard target objects moved parallel to the sensing face. This distance depends on the moving path (distance from the reference point), so it can be expressed as an operating point locus (sensing area diagram).

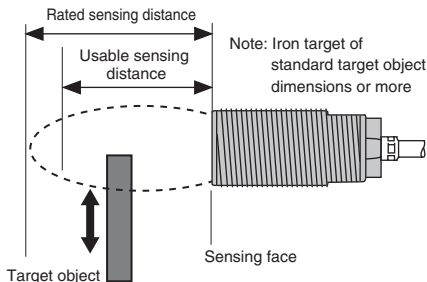
### Rated sensing distance

This is the distance to the target object from the sensing face at which the proximity sensor is actuated when a standard target object approaches in a direction that is perpendicular to the sensing face.

### Usable sensing distance

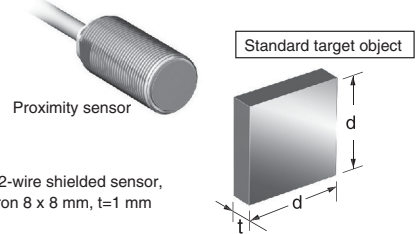
This is the distance to the target object from the sensing face at which the target object can be stably detected when it approaches from a direction that is parallel to the sensing face.

Normally, this is 70 to 80 % of the rated sensing distance.



### Standard target object

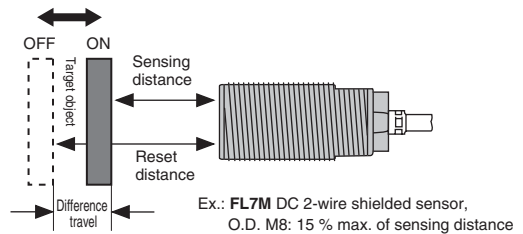
A target object that is used for measuring the sensing distance. Normally, this is a square iron plate (cold-rolled steel sheet, SPCC) of standard size. Generally, the size of the standard target object is the minimum target object size so that a fixed sensing distance can be achieved. Accordingly, the proximity sensor is actuated at approximately the rated sensing distance if the target object is larger than the standard target object and of the same material and thickness.



Ex.: **FL7M** DC 2-wire shielded sensor,  
O.D. M8: Iron 8 x 8 mm, t=1 mm

### Differential travel

This is the difference between the distance (sensing distance) at which a standard target object approaching perpendicular to the sensing face actuates the proximity sensor and the distance (reset distance) which the standard target object must move away for the sensor to return to OFF. This is expressed as a percentage of the sensing distance.



### Mutual interference

This refers to the state in which performance and characteristics (e.g. sensing distance) are influenced when two or more sensors are positioned close to each other.

### Off-state current

In the case of 2-wire proximity sensors, a slight current flows to activate internal circuits even when output is OFF. This is referred to as off-state current. Since off-state current is present, a voltage equivalent to load resistance x off-state current is exerted on the load even when the proximity sensor is OFF. Note that this will cause reset failure of the load if the off-state current exceeds the load reset voltage.

Ex.: **FL7M** DC 2-wire shielded sensor,  
O.D. M8: 0.55 mA max.

### Switching current

This refers to the minimum current required by the proximity sensor and the maximum current that the proximity sensor can switch.

#### ● Maximum switching current

The maximum current that is allowed to flow to the output circuit when the proximity sensor is ON. If the current is greater, the load short-circuit protection circuit will be activated, or the proximity sensor will be damaged.

### ● Minimum switching current

The minimum required current that flows to the internal circuits when the proximity sensor is ON. At a lower current, the sensor will not operate. If the load resistance is too large and results in the load current not satisfying this minimum switching current, connect a bleeder resistor in parallel to the load to lower the total load resistance.

Ex.: **FL7M** DC 2-wire shielded sensor, O.D. M8: 3 to 100 mA

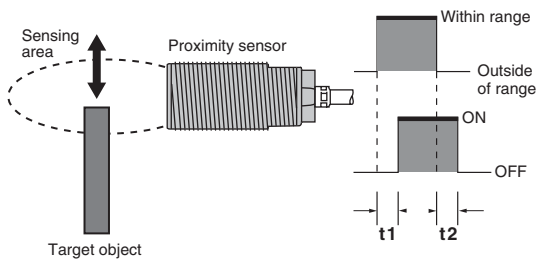
### ● Voltage drop

This is the voltage that is generated across the output and 0 V terminals (DC 3-wire proximity sensor) or the sensor output terminals (DC 2-wire proximity sensor). Note that the load sometimes cannot be actuated when output is ON as this voltage drop occurs.

Ex.: **FL7M** DC 2-wire shielded sensor, O.D. M8: 3.0 V max.

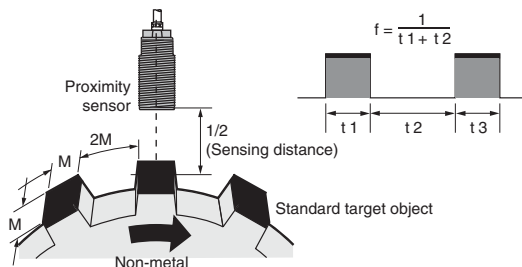
### Response time

- **t1**: The interval from the point when the standard target object moves into the sensing area and the sensor activates, to the point when the output turns ON
- **t2**: The interval from the point when the standard target object moves out of the sensor sensing area to the point when the sensor output turns OFF



### Operating frequency

This is the maximum number of sensing per second in which output can be made proportional to repeated approaches of the target object to the sensing face. Operating frequency expresses response speed.



### Temperature drift

This indicates how much (in %) the sensing distance changes when the operating temperature differs from the standard 25 °C.

Ex.: **FL7M** DC 2-wire shielded sensor, O.D.

M8:  $\pm 10\%$  max. of sensing distance for the -25 to +70°C range

### Power voltage drift

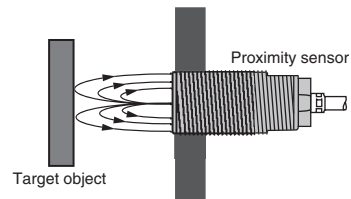
This indicates how much (in %) the sensing distance changes when the power voltage differs from the rated power voltage.

Ex.: **FL7M** DC 2-wire shielded sensor,

O.D. M8:  $\pm 10\%$  max. of sensing distance with a  $\pm 15\%$  voltage fluctuation.

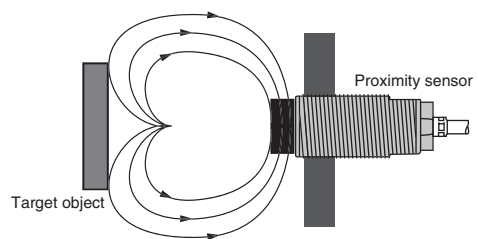
### Shielded

- With a shielded sensor, magnetic flux is concentrated in front of the sensor and the sides of the sensor coil are covered with metal.
- The sensor can be mounted by embedding it into metal.



### Unshielded

- With an unshielded sensor, magnetic flux is spread widely in front of the sensor and the sides of the sensor coil are not covered with metal.
- This model is easily affected by surrounding metal objects (magnetic objects), so care must be taken in selecting the mounting location.

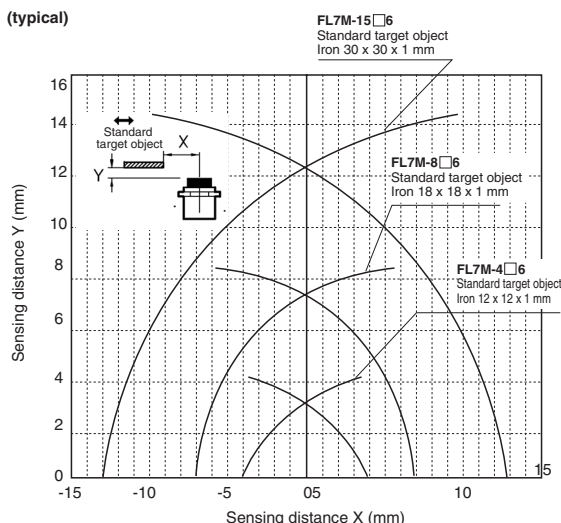


## GENERAL CHARACTERISTICS

### 1. Sensing area diagram

This is a plot of points at which the proximity sensor is actuated (measured from the edge of the standard target object) when a standard target object approaches parallel to the sensing face.

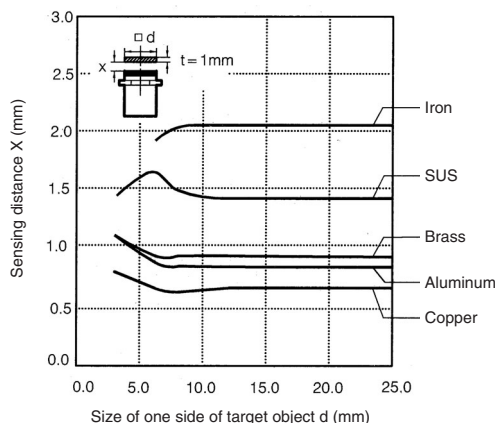
(typical)



### 2. Sensing distance according to material and size of object

The sensing distance varies according to the material and size of the target object.

Sensing distance according to material & size of object (typical)



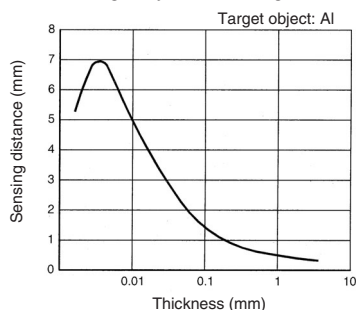
● Generally, the sensing distance on non-iron targets is shorter than that for iron targets.

● The sensing distance is almost the same if the target object is made of iron and is larger than a standard target object.

● If the target object is not made of iron, or its dimensions are smaller than the standard target object, measure the actual sensing distance with the target object while referring to the graph above, and mount the proximity sensor so that the usable sensing distance is 70 % or less of this value.

Below is a plot of the sensing range when the size of one side of the target object is fixed and target thickness changes.

Thickness of target object and sensing distance (typical)



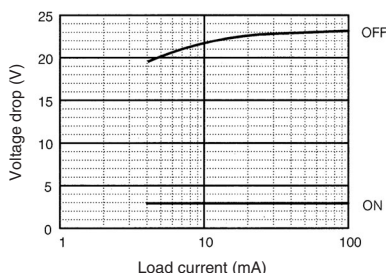
If the target object is 1 mm or more thick, a standard sensing distance can be obtained which will hardly change regardless of the thickness of the target object. If the target object is less than 1 mm thick, the sensing distance will change according to the thickness of the target object. Note particularly that if the target object is non-magnetic metal (e.g. copper, aluminum), the sensing distance increases with decreased thickness and at about 0.01 mm thick is almost the same as for magnetic metal (e.g. iron).

### 3. Voltage drop characteristics diagram

● This indicates the output voltage (V) of the proximity sensor in proportion to load current (A) when the proximity sensor is ON. (This is called "output voltage drop.")

● It also indicates the output voltage (V) when the proximity sensor is turned OFF in proportion to load current (A) when the proximity sensor is ON. The value obtained by subtracting this output voltage value from the power voltage is called "load voltage drop."

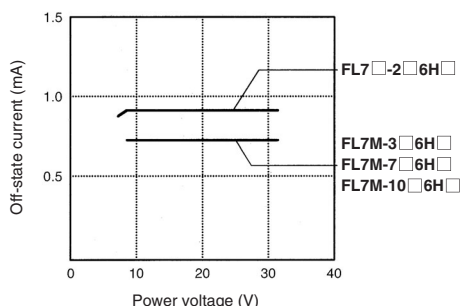
Voltage drop characteristics (typical)



### 4. Off-state current characteristics diagram

This indicates how off-state current (which flows when the proximity sensor is OFF) changes in proportion to changes in the power voltage.

Off-state current characteristics (typical)



## SELECTION OF PROXIMITY SENSORS

The following introduces typical points to take into consideration when selecting a proximity sensor.

### 1. Operating conditions

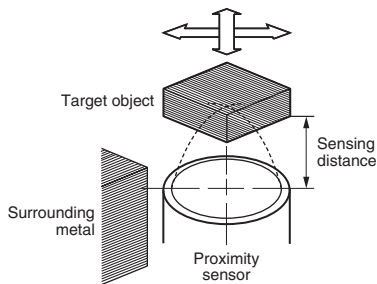
#### Sensing distance

The usable sensing distance is about 70 % of the rated sensing distance. However, to ensure reliable sensing, it is advisable to take factors such as drift in proximity sensor performance, meandering of target objects, and conveyor undulation, and allow a certain degree of margin when using the sensor. On the other hand, for high resolution, using a model with a short sensing distance will provide better results.

### 2. Environmental conditions

#### 2.1 Surrounding metal

When there is a metal object other than the target object near the sensing face of the proximity sensor, the sensing performance of the proximity sensor will be affected, and the apparent sensing distance will increase and become unstable. When the proximity sensor is flush-mounted in metal, use a shielded sensor with a sensing coil whose sides are covered with metal. If you use an unshielded sensor, be sure to mount it away from surrounding metal by at least the recommended distance.



#### 2.2 Environment

The environmental resistance of the proximity sensor is better than that of other types of sensors. However, investigate carefully before using a proximity sensor under harsh temperatures or in special atmospheres.

Temperature and humidity	Highest or lowest values, existence of direct sunlight, etc.	Temperature influence, high-temperature use, low-temperature use, need for shade, etc.
Atmosphere	Water, oil, iron powder, or other special chemicals	Need for water resistance or oil resistance, need for explosion-proof structure.
Vibration and shock	Intensity, duration	Need for durability, mounting method

#### ● Explosive atmosphere

Do not use the sensor in atmospheres where there is a danger of explosion. Use an explosion-proof sensor.

#### ● Aluminum or cast-iron chips

If aluminum or cast-iron chips accumulate on the sensing head, use the FL7M-A series aluminum immunity proximity sensor.

#### ● Spatter

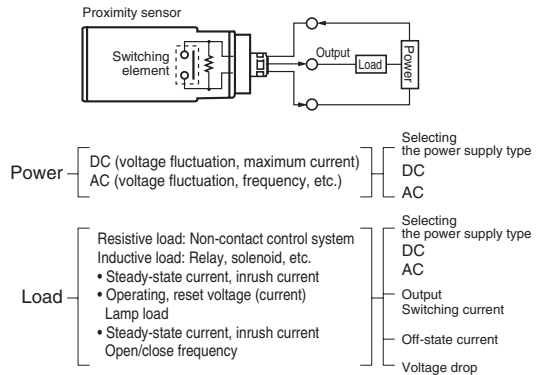
If the proximity sensor is subject to spatter, use spatter-guarded models.

### 3. Sensor body type

Select a body type that is suited to the location where the proximity sensor is to be used.

### 4. Electrical conditions

Verify the electrical conditions of the control system to be used and the electrical performance of the proximity sensor.



### 5. Operating frequency

DC proximity sensors have a higher operating frequency than AC ones. Use DC models if high-speed response is required.

### 6. Target object moving speed

To select a sensor for a target object moving at high speed, use the following calculation based on the operating frequency (operating time) of the proximity sensor, length of the target object, and distance to the target object.

$$\frac{1}{Rt} < \frac{Ds + Dt}{St} + \frac{Db - Dt}{St} \text{ (sec)}$$

Rt: Operating frequency (Hz)

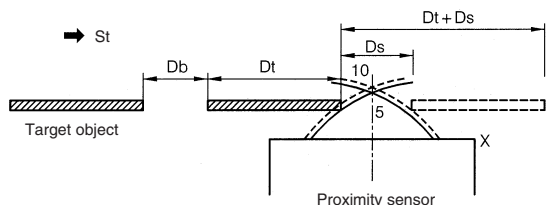
Ds: Width of sensing area (mm)

Dt: Length of target object (mm)

Db: Distance between target objects (mm)

St: Speed of target object (mm/s)

Select a sensor that fits the characteristics of the target object.



## PRECAUTIONS FOR USE

### Design of load circuits

#### ● Load short circuit

If the proximity sensor is connected to an AC power supply without passing through a load, the proximity sensor will be damaged. Be sure to connect a load. If the sensor is connected to a DC load, it will not be damaged as almost all models have a self-contained load short-circuit protection circuit. However, in the case of DC 2-wire proximity sensors, the sensor will be damaged if it is short-circuited and also connected with the leads reversed, even though the sensor has a self-contained load short-circuit protection circuit.

#### ● Series or parallel connection

Connection varies according to whether it is an AC 2-wire or DC 2-wire type. Refer to the precautions for each of these types.

#### ● Preventing reset failure of the load

Off-state current from the proximity sensor causes a voltage equivalent to load resistance x off-state current to be exerted on the load. If this voltage exceeds the load reset voltage, a reset failure will occur. Be sure to check that this voltage is lower than the load reset voltage before using the proximity sensor, or to connect a bleeder resistor in series to the load to lower the total load resistance.

#### ● When switching of a relay load is not possible

Voltage drop occurs across sensor output terminals even if the proximity sensor is OFF. For this reason, the load voltage may be insufficient with some types of relays. For example, when the **FL7M** DC 2-wire type proximity sensor is connected to a 12 V relay load, the voltage drop will be 3.3 V, which may prevent the relay from being switched.

#### ● When the load current is too small to actuate the proximity sensor

If the load current is smaller than the minimum switching current of the proximity sensor, connect a bleeder resistor in series to the load so that a current larger than the minimum switching current flows to the sensor.

#### ● Preventing proximity sensor damage from inrush current

When you connect a load such as a lamp or motor that has a large inrush current, the switching element in the proximity sensor may become damaged or deteriorate. Accordingly, connect such loads via a relay.

#### ● Operation at power ON

After the power is turned ON, it takes a fixed delay time (tens of milliseconds) until the proximity sensor is ready for sensing. If the load and the proximity sensor use different power supplies, be sure to turn the proximity sensor ON before turning the load ON.

#### ● Protecting the sensing face of the proximity sensor

The sensing face of the proximity sensor is made of resin. For this reason, contact with the target object or chips (etc.) hitting the sensing face may cause sensor damage. Attach a protective cover if there is a risk of chips hitting the sensing face.

#### ● Protecting lead-out wires

Cover lead-out wires with flexible tubing.

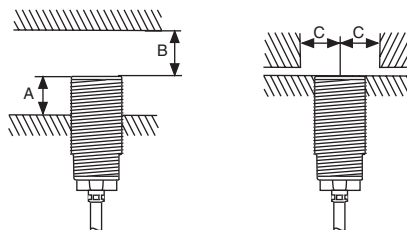
#### ● Recommended cable length

For cable extensions use at least 0.3mm<sup>2</sup> wire and keep length to within 100 m.

#### ● Preventing influence from surrounding metal

Metal other than the target object near the proximity sensor influences sensing characteristics. Mount proximity sensors away from surrounding metal by the recommended distances.

Example of DC 2-wire cylindrical long-distance no-polarity sensor



Catalog listing	A (mm)	B (mm)	C (mm)
<b>FL7M-4</b> □6	2.5 (5.5)	12	9
<b>FL7M-8</b> □6	3.5 (6.5)	24	13.5
<b>FL7M-15</b> □6	6 (10)	45	22.5

Shaded areas indicate surrounding metal other than the target object.

**A:** Distance from sensing face of proximity sensor to mounting surface

( ): Case of mounting included hexagonal nut in front

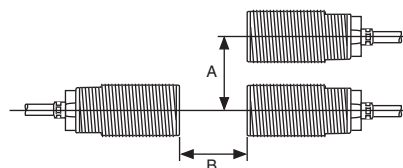
**B:** Distance from surface of iron plate to sensing face of proximity sensor

**C:** Distance from surface of iron plate to center of proximity switch when A=0

#### ● Preventing mutual interference

When mounting proximity sensors in parallel or facing each other, mutual interference may cause the sensor to malfunction. Maintain at least the space indicated in the specifications.

Example of DC 2-wire cylindrical long-distance no-polarity sensor



Catalog listing	A (mm)	B (mm)
<b>FL7M-4</b> □6	25	25
<b>FL7M-8</b> □6	40	50
<b>FL7M-15</b> □6	90	110

#### ● Overtightening of screws

When mounting proximity sensors, tighten screws, etc. at the allowable tightening torque or lower. Be sure to use included toothed washers when mounting cylindrical sensors.

#### ● Cable pullout strength

Do not pull on the cable with excessive force. For details on pullout strength, refer to the specifications.

#### ● Location

Do not use proximity sensors outdoors or in locations where they will be splashed with oil or water or exposed to chemicals (e.g., organic solvents, acids, alkalis) or their vapors.

#### ● Cable bend radius (R)

Do not bend the cable excessively. Since allowable cable bend radius differs according to the model, be sure to check the precautions for each model.

#### ● Routing of wiring

Do not run wires to the proximity sensor together with power lines. Surge noise can cause damage or malfunction. Wire leads to the proximity sensor independently or in a separate wiring duct.

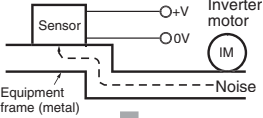
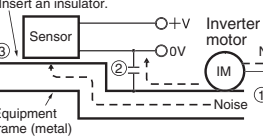

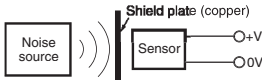
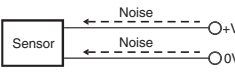
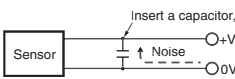
### ● Grounding of switching regulator

If a commercially available switching regulator is being used, ground the frame ground terminal to prevent sensor malfunction due to switching noise.

### Noise

Countermeasures for noise depend on the path of noise entry, frequency components, and wave heights.

Typical measures are as given in the following table:

Type of noise	Noise intrusion path and countermeasures
<b>Common mode noise</b> (inverter noise)  (Common mode noise applied between the equipment frame and the +V and 0 V lines, respectively.)	<p><b>Before countermeasures</b>            Noise enters from the noise source through the frame (metal).</p>  <p><b>After countermeasures</b></p> <ol style="list-style-type: none"> <li>① Ground the inverter motor (to 100Ω or less).</li> <li>② Ground the noise source and the power supply (0 V side) through a capacitor.</li> <li>③ Insert an insulator (plastic, rubber, etc.) between the sensor and the equipment frame (metal).</li> </ol> 
<b>Radiant noise</b>  (Ingress of high-frequency electromagnetic waves directly into sensor, from power line, etc.)	<p><b>Before countermeasures</b>            Noise propagates through the air from the noise source and directly enters the sensor.</p>  <p><b>After countermeasures</b></p> <ul style="list-style-type: none"> <li>• Insert a shield (copper) plate between the sensor and the noise source (e.g. a switching power supply).</li> <li>• Separate the noise source and the sensor to a distance where noise does not affect operation.</li> </ul> 
<b>Normal mode noise</b> (Power line noise)  (Ingress of electromagnetic induction from high-voltage wires and switching noise from the switching power supply)	<p><b>Before countermeasures</b>            Noise enters from the power line.</p>  <p><b>After countermeasures</b>            Insert a capacitor (e.g. a film capacitor), noise filter (e.g. ferrite core or isolation transformer), or varistor in the power line.</p> 

### ● Surface roughness/smoothness

Do not make the mounting surface excessively rough or excessively smooth.

Recommended examples: Ra = 1.6, 3.2 or 6.3.

Avoid application of too much oil, etc. on contact surfaces of screw, nut, washer and mounting areas. It might change the friction coefficient of the surface, resulting in damage to the proximity sensor or loosening of the screw.

### ● Washer

In mounting cylindrical sensor, it is recommended to insert the toothed washer to the opposite side of the tightening nut. The toothed washer does not scratch the nut or mounting panel, maintaining stable tightening.

Recommended mounting hole sizes for cylindrical sensors

Size	Mounting hole
M8	8.2 ± 0.1
M12	12.2 ± 0.1
M18	18.2 ± 0.1
M30	30.2 ± 0.1

### ● Mounting hole shape

When mounting a cylindrical type sensor, avoid mounting it in an elongated hole or on a U-shaped bracket. Since some teeth on the toothed washer would not be in contact with the surface, the sensor might come loose.

Refer also to User's Manual and Specifications of each model.