TECHNICAL GUIDE FOR ULTRASONIC SENSORS

DEFINITIONS

An ultrasonic sensor detects the presence of a target object and measures the distance between the sensor and the object by sending a beam of ultrasound from its emitter and detecting a reflection of the beam from the object with its receiver. The sensor calculates the exact distance between the sensor and the target object by computing the time that the beam has traveled, at the speed of sound, between emission and detection. A through-scan model has an independent emitter and receiver that together detect the presence of a target object when the ultrasonic waves are either decreased or blocked by a target object.

PRINCIPLE

A piezoelectric ceramic element is used for ultrasonic emitters and receivers. A piezoelectric ceramic element is distorted by applied voltage, and produces electromotive force between its electrodes if mechanical force is applied to it. A target object is detected, and the distance between it and the sensor is measured, based on the amount of electromotive force.

GLOSSARY

Velocity of sound
The velocity of sound (C) in the air is expressed by the following formula, where t is temperature (˚C):

\[ C = 331.5 + 0.61 \cdot t \text{ (m/s)} \]

According to the above formula, the velocity of sound varies depending on the temperature, and therefore temperature differences cause measurement errors. The velocity of sound increases 0.607 m/s for every temperature rise of 1 ˚C.

Beam reflection or penetration
Ultrasonic waves travel in a straight line through the same medium, but at the interface between different media, they are either reflected or continue through. This behavior in this case depends on the kind and shape of the medium.

Multiple reflection
This phenomenon occurs when reflected waves from a target object are reflected again by the sensor head face or surrounding objects and then reflected again by the target object. When using a diffuse-scan sensor close to the target object, this phenomenon can occur and create measurement errors.

Sidelobe
Ultrasonic sensors have a sensing area like that shown on the right. Near the sensor, the sensing area decreases as the beam angle increases from the center, and then starts to increase at a point. These features are called the sidelobes, and are the blind range of the sensor. Diffuse reflection by surrounding objects may affect the sidelobes and detection characteristics.

Blind range (St)
Range near the sensor in which the target cannot be detected reliably. In this range, however, there is a chance of detection due to multiple reflection of ultrasonic waves between the sensor and target.

Scanning range far limit (Sde)
The far limit of the sensing range.

Sensing range (Sd)
The area between the blind range far limit and the scanning range far limit.

Far limit setting
A range upper limit setting that can be programmed with Teach-In.

Near limit setting
A range lower limit setting that can be programmed that can be with Teach-In.

Minimum setting interval
The minimum interval between the two settings.
**PRECAUTIONS FOR USE**

1. Types of target objects and notes for detection (diffuse-scan models)

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<th>Images</th>
<th>Examples</th>
<th>Notes</th>
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</thead>
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<tr>
<td>Flat object</td>
<td>Glass, liquid, metal plate</td>
<td>More waves are reflected, but if the target is tilted there is a greater effect on measurement.</td>
</tr>
<tr>
<td>Cylindrical object</td>
<td>Roller, can, bottle</td>
<td>Depending on the diameter of the cylinder, measured distances may be short or detection may be impossible because the cylindrical surface is too small to reflect sound waves.</td>
</tr>
<tr>
<td>Granular and block objects</td>
<td>Plastic pellets, chips</td>
<td>Diffuse reflection occurs and sound waves are not constantly reflected, but if the target is tilted there is less effect on measurement. However, if a small granular targets absorb sound waves, accurate detection may be impossible.</td>
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2. Liquid level detection

When coping with detection errors caused by fluctuating liquid surface, bubbles, and agitation equipment, use a pipe for detection as shown in the figure below. Inside the pipe, the liquid level can be detected correctly without influence by fluctuating liquid or bubbles.

3. Liquid level detection of chemicals such as acids, alkalis, and organic solvents

Only chemical-resistant sensors can detect the level of liquid chemicals without being damaged by the chemicals. However, air purging as shown in the figure below can reduce the influence of chemicals on non-chemical-resistant sensors during detection. But if the airflow is greater than 10 m/s, accurate direction may be impossible.

When detecting the liquid level of organic solvent emitting volatile gas, the output of the sensor may fluctuate because volatile gas from the organic solvent remaining in the sensing area causes ultrasonic velocity to vary.

Note: Our ultrasonic sensors are not explosion-proof.
### 1. Indicator modes

<table>
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<tr>
<th>Sonic level</th>
<th>Orange LED lit</th>
<th>Orange LED blinking</th>
<th>Orange LED out</th>
<th>Red LED lit</th>
</tr>
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<tbody>
<tr>
<td>Analog output</td>
<td>Measurement output</td>
<td>Indefinite</td>
<td>4-20 mA or 0-10 Vdc</td>
<td></td>
</tr>
<tr>
<td>Target position</td>
<td>Within set range</td>
<td>*</td>
<td>Between blind range upper limit and range near limit setting</td>
<td></td>
</tr>
</tbody>
</table>

- The orange LED could be out for any of the following reasons:
  - There is no target.
  - The target is out of range.
  - The target is within the blind range.
  - The ultrasonic reflection from the target is too weak.

### 2. Operating the Teach-In button

Use the Teach-In button for setup. Setup should be completed within five minutes after power-up. The settings are fixed after five minutes to prevent them from being accidentally changed during regular operation. Even after the power is turned off, the settings are saved.

#### 2.1 Setting a scanning range

Set the scanning range as follows.
- Press the button for 2 to 6 seconds until the indicator blinks alternately orange and red.
- Release the button and the indicator will begin to blink red.
- Place the target at the 0 Vdc or 4 mA output position and press the button. The indicator begins to blink orange.
- Place the target at the 10 Vdc or 20 mA output position and press the button to complete setup. The interval between the two set points is linearly interpolated.

There are two ways of setting the scanning range, depending on the target position.

- When setting 0 Vdc or 4 mA output, place the target near the sensor.

![Diagram](image1)

- When setting 0 Vdc or 4 mA output, place the target far from the sensor.

![Diagram](image2)

#### 2.2 Factory defaults

It is possible to revert the settings to the factory defaults by either of the following methods:

1. Press the button for more than 6 seconds until the indicator rapidly blinks alternately orange and red.
2. Release the button, and the indicator will light orange and red at the same time for 2 seconds. The sensor has been reset to the factory defaults.

2. Set a scanning range without a target. The indicator will rapidly blink alternately orange and red for 2 seconds. The sensor has been reset to the factory defaults.
3. Handling precautions

- Be sure to turn off the power before mounting the sensor.
- Do not pull excessively on the sensor cable.
- Do not use the sensor in a place exposed to water or oil, outdoors, or in an atmosphere with chemicals (organic solvents, acids, and alkalis).
- To prevent malfunction and device failure, always use the sensor within the rated temperature.
- An airflow of more than 10 m/s within the sensing area may alter the sensing area boundaries.
- Avoid local differences in temperature and strong convection phenomena, because abrupt changes in airflow in the sensing area may cause the sensor to malfunction.
- A jet of air from an air nozzle may cause the sensor to malfunction. Do not use near an air nozzle or the like.
- Water drops or dust on the sensing face may make the output signals unstable.
- Sound-absorbing materials, such as cotton and fine powder, cannot be detected.
- If there is an ultrasonic cleaner or other ultrasonic equipment in the area, separate it sufficiently from the sensor and verify that it does not cause ultrasonic interference.
- The sensor may not detect a target whose surface is convex, concave, or tilted toward the sensor.
- The output will be unreliable if the target is outside of the measurement range setting.
- When two or more sensors are used in close proximity, mutual interference may cause the sensors to malfunction. Maintain at least the distances indicated in the figures below.
- Parallel sensors facing each other (keep the same distances if the sensors face in the same direction)

\[
\text{Distance greater than 2 times the largest range limit setting}
\]

\[
\text{Distance greater than 4 times the largest range limit setting}
\]

- Sensors mounted back to back

\[
0.1 \text{ m} <
\]

4. Influence by diffuse reflection from surrounding objects

- Diffuse reflection from surrounding objects because of ultrasonic diffusion or sidelobes may cause incorrect detection. If measurement is incorrect, consider the following countermeasures: keep the sensor away from the surrounding objects, use sound-absorbing materials like sponge, or install sound-insulating barriers.

5. Wiring precautions

- Route the cable separately from power lines or though a separate conduit. Otherwise, induction may cause incorrect operation or damage.
- If a switching regulator is used for the power supply, connect the frame ground and ground terminal to ground. If the sensor is used without grounding, faulty operation may occur due to switching noise.
- Although the sensor has a miswiring protection circuit, incorrect wiring involving the input/output terminals may cause damage.