

## Introduction

### What Is an Ultrasonic Sensor?

The Reflective Ultrasonic Sensor (Distance-adjustable or Zone-setting Convergent Reflective Sensor\*) sends ultrasonic waves from an emitter toward a sensing object, then receives the reflected waves with a detector. The Sensor uses the resulting information to determine the presence of an object, or to measure the distance to the object. This type of Sensor determines the distance from the Sensor to an object based on the time required from when the ultrasonic waves are sent until they are received using the speed of sound.

There are also Through-beam Sensors\* that detect the presence of an object by detecting the attenuation or interrupted condition of ultrasonic waves caused by an object passing between the emitter and detector.

\* See *Classifications* below.

### Features

#### 1. Colors Do Not Influence Detection

Unlike photoelectric sensors, Ultrasonic Sensors can detect an object without being influenced by its colors. For example, if two objects have the same shape, even if one is transparent, such as glass, and the other is black plastic, they can both be detected with the same settings.

#### 2. Detecting Objects over a Wide Area

Ultrasonic Sensors detect reflection from a wider area than photoelectric sensors, so they can check a wide area all at the same time.

#### 3. Non-Contact Detection

Because Ultrasonic Sensors detect sensing objects without touching them, they do not scratch the sensing objects.

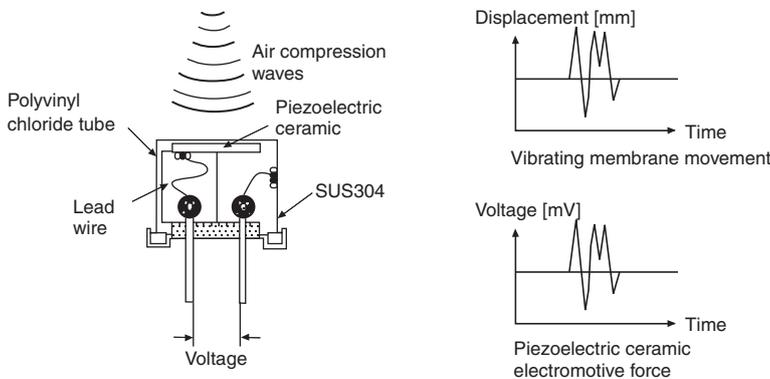
### Operating Principle

Piezoelectric ceramics are used for ultrasonic transmission and reception.

#### What Are Piezoelectric Ceramics?

Piezoelectric ceramics generate electromotive force between the electrodes in proportion to the amount of mechanical force applied to the element. The reverse is also true. If voltage is applied between the electrodes, mechanical displacement is generated proportional to that voltage.

From the magnitude of the electromotive force, the presence of an object is detected and the distance from the Sensor to the object is measured.



### Classifications

#### Classification by Sensing Method

<b>Through-beam</b>		Detects the attenuation or interrupted condition of the ultrasonic beam caused by the object passing between the Emitter and Detector. Typical model: E4E2	
<b>Reflective</b>	<b>Convergent reflective (Distance adjustable)</b>	Detects only the beam reflected from the object existing within the sensing distance range set with the distance adjuster. Typical model: E4C-UDA	
	<b>Convergent reflective (Zone setting)</b>	Detects only the beam reflected from the object existing in the sensing range set with the distance selector. Typical model: E4PA-N	

\* An object may be detected due to multiple reflection if the object is in the unstable range where the distance adjuster is ineffective, in which case however, the detection of the object will not be stable. Therefore, do not attempt to use the Ultrasonic Sensor to detect an object in the unstable range.

## Explanation of terms

### Speed of sound

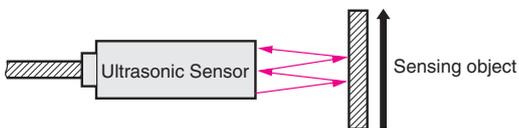
The speed of sound "C" in air is  $C \approx 331.5 + 0.61 \theta$  (m/s), where  $\theta$  is the air temperature (°C). The speed of sound changes as the air temperature changes, and this results in temperature-based distance measurement error.

### Reflection and transmission

Ultrasound waves move straight forward in a uniform medium, and are reflected and transmitted at the boundary between differing media. This phenomenon is affected by the type and shape of the media. A human body in air causes considerable reflection and can be easily detected.

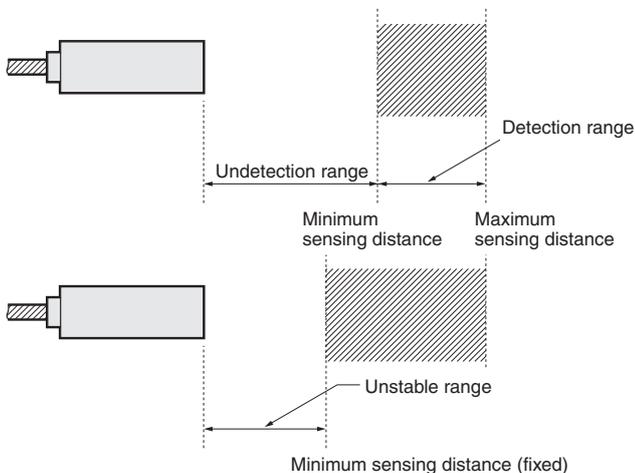
### Multi-reflection

This occurs when ultrasound waves that have already reflected from the detection object once reflect from the sensor head surface, nearby walls, or the ceiling back to the detection object, and then back to the sensor. For example, in the case of double reflection, the same ultrasound waves are received as a single reflection but at twice the distance.



### Limit zone (reflective models)

Not only the maximum detection distance but also the minimum detection distance can be adjusted, in connection with or independently of the maximum distance. This detection range is called the limit zone (zone limit).



### Non-sensitive zone and uncertainty zone (reflective models)

The non-sensitive zone is the interval between the surface of the sensor head and the minimum detection distance resulting from detection distance adjustment. The uncertainty zone is the area close to the sensor where detection is not possible due to the sensor head configuration and reverberations. Detection may occur in the uncertainty zone due to multi-reflection between the sensor and the object.

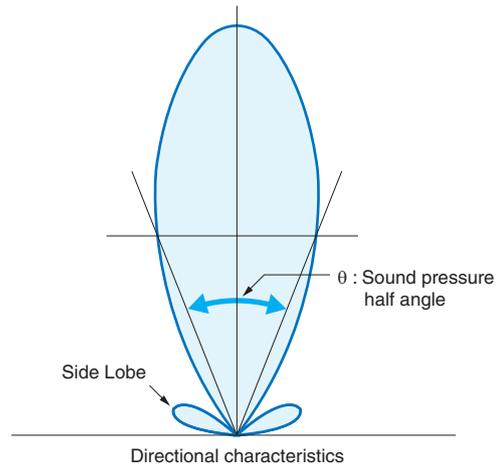
### Directional characteristics

The ratio of the sound output (needed to transmit the specified sound energy to the target object) of the non-directivity emitter to the sound output of the directivity emitter is called the directivity gain.

As the frequency and vibration area increase, the directivity grows sharper and sound waves are emitted with greater efficiency.

The directivity of a sensor unit used as an ultrasound switch is 8° to 30° (sound pressure half-angle).

The directivity is also strongly affected by the shape of the sensor horn and the vibration mode of the transducer, and thus the sensor unit shape, operation frequency, and transducer type are selected to provide the desired operation range.



### Sound pressure half angle

An index of directivity. The half angle is the angle from the center of the transducer where the sound level (sound strength) is a maximum, to the point where the sound level is 1/2 the maximum (the sound decrease is symmetrical, thus the angle is actually twice the above angle).

### Side lobe

Directivity is indicated using a graph showing the sound level as a length from the center as the angle is shifted away from the angle of the transducer center, where the sound level (sound strength) is a maximum. As the angle increases from the center, the directivity decreases, and then after a certain point increases.

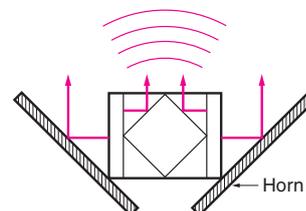
This is called the side lobe, and can result in stray reflection off peripheral objects that will affect the detection characteristics.

### Transducer

This is a device which uses electrical energy to generate ultrasound waves, and which also converts ultrasound vibrational energy into electrical signals. A barium titanate transducer applying piezoelectric effect is normally used in ultrasound switches. The shape can be a disk or a tube.

### Horn

This is a reflector that concentrates and emits ultrasound waves in a certain direction and also receives waves. The shape and dimensions of the horn determine the directivity characteristics of the sensor.



**Transmitted waves**

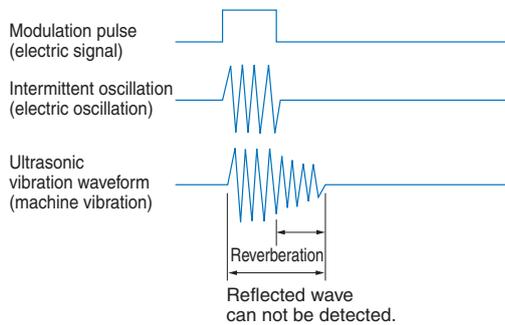
Ultrasound waves that are emitted in the specified direction when the transducer is connected to the oscillator. Normally expressed as a voltage applied to the transducer, or as a sound pressure.

**Received waves**

Transmitted ultrasound waves that are received at the transducer, and which are either direct or reflected from an object. Normally expressed as a converted voltage, or as a sound pressure.

**Reverberation**

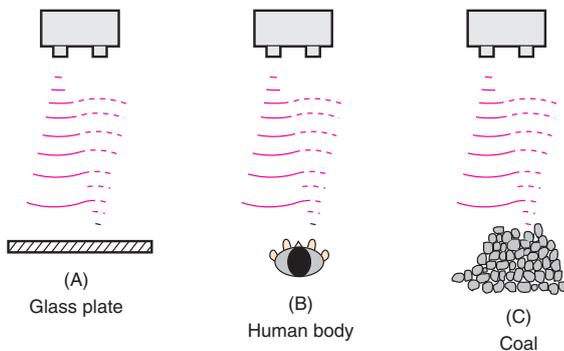
When an electrical signal is applied to the transducer as a pulse at a frequency close to the resonance frequency of the transducer, the ultrasound vibration continues mechanically for a brief interval even after the electrical signal stops. This is called reverberation. If reverberation continues for a long time in a reflective sensor, detection becomes impossible.



**Types and shapes of detection objects**

**(reflective type)**

- Detected objects can be classified as follows:
  - (A) Flat-surface objects such as fluids, boxes, plastic sheets, paper, and glass.
  - (B) Cylindrical objects such as cans, bottles, and human bodies.
  - (C) Powders and chunk-like objects such as minerals, rocks, coal, coke, and plastic.
- The reflective efficiency varies depending on the shape of these objects. In the case of (A), the greatest amount of reflected waves return, however, this is strongly affected by the inclination of the object. In the case of (B) and (C), stray reflections occur and the reflected light is not uniform, however, the effect of inclination is small.



Sensors  
Switches  
Safety Components  
Relays  
Control Components  
Automation Systems  
Motion / Drives  
Energy Conservation Support / Environment Measure Equipment  
Power Supplies / In Addition  
Others  
Common