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WHITE PAPER
ULTRASONIC SENSORS

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1. INTRODUCTION

Ultrasound is a term from the field of acoustics and refers to sound whose frequencies are above the audible frequency range of humans. Ultrasound includes frequencies above 16kHz and is thus no longer auditorily perceptible by the human ear. Ultrasonic sensors detect objects that reflect sound via sound waves without contact or wear. The possible range of such objects is thus extremely diverse, since they can be transparent, opaque, metallic, non-metallic, solid, powdery, solid or liquid, whereby liquids and solid materials in particular reflect sound very well.

From the foregoing, it is clear that the object color has no effect on the sound behavior and thus the operation of ultrasonic sensors. However, sound-absorbing materials such as absorbent cotton or soft foams can reduce the operating range of these sensors. Furthermore, when mounting such devices, installation positions that lead to heavy dirt deposits or water drops on the sensor surface or the so-called transducer should be avoided. This white paper provides an overview of various ultrasonic sensors, describes how they work and provides examples of their use in practice.

2. Classification of ultrasonic sensors

Ultrasonic sensors can be divided into the following categories according to their mode of operation:

- Ultrasonic diffuse-reflection sensors
- Ultrasonic retro-reflective barriers
- Ultrasonic barriers
- Ultrasonic fork sensors

3. OPERATING PRINCIPLE OF VARIOUS ULTRASONIC SENSORS

Regardless of the functional principle according to which ultrasonic sensors operate, they are generally suitable for use in environments with a high level of dust generation or a high dirt load, provided that there are no "sound-absorbing" deposits in the area of the sensor surface. As a rule, they are superior to optical sensors in such applications. In the following, the mode of operation of the ultrasonic sensors mentioned under 2. is described and, in addition, possible fields of application of these devices are presented.

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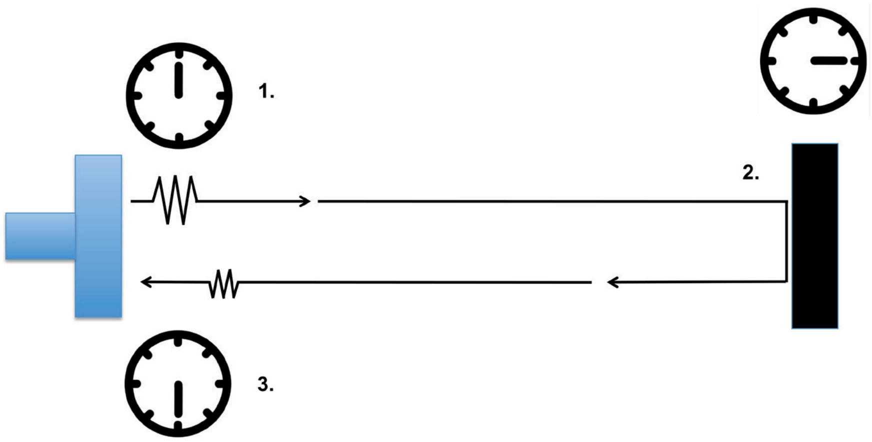
3.1 FUNCTIONALITY OF ULTRASONIC DIFFUSE-REFLECTION SENSORS

An ultrasonic diffuse-reflection sensor cyclically emits a short, high-frequency sound pulse that propagates in the air at the speed of sound. When this sound pulse hits an object, it is reflected by its surface and returns as an echo to the ultrasonic diffuse-reflection sensor's receiver. In this process, the so-called transducer integrated in the device simultaneously assumes the function of both transmitter and receiver. The distance of an object to the probe can be determined from the time taken by the sound pulse from emission to reception of the echo. This principle is also called transit time measurement. Ultrasonic diffuse-reflection sensors are distinguished between devices with analog output or switching output. In the case of devices with an analog output, a current or voltage signal is output which is proportional to the measured transit time. In ultrasonic sensors with a switching output, a switching threshold is defined via a potentiometer or by a teach-in procedure.



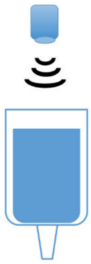
The distance of an object to the sensor can be determined via the time-of-flight measurement of the sound pulse: 1. sound pulse is transmitted. 2. Sound pulse is reflected by the object. 3. the echo of the sound pulse is received.
(All images: ipf electronic gmbh)

Ultrasonic diffuse-reflection sensors have a so-called blind or dead zone, which is located in an area directly in front of the device. The cause of this dead zone lies in the transducer, which on the one hand serves to generate the sound pulse and on the other hand is used as a receiver of an object echo. Naturally, no echo signal can be received during the time in which the transducer is acting as a transmitter. Very close objects, which are quasi in the receiving shadow of the sensor, can therefore not be detected. However, due to the very high signal density in front of the device, multiple reflections may occur between the sensor and the object, which may still result in a switching signal at close range. For these reasons, no reproducible function of the device can be guaranteed within the blind or dead zone. However, by using deflection mirrors or reflectors, this zone can be moved to the spatial axis between the sensor and the deflection mirror, allowing reproducible signals in the near range after the reflector. If several ultrasonic diffuse-reflection sensors are used in close proximity to each other, mutual crosstalk between the devices can be prevented by synchronizing them, i.e. all devices transmit at the same time or at the same instant.

The illustrations on pages 6 and 7 give an impression of the wide potential range of applications for ultrasonic diffuse-reflection sensors. In this context, however, it must be said that a whole series of external factors can influence the functioning of ultrasonic sensors. All potential influences can certainly not be illuminated here. However, two examples should be mentioned here. For example, interrogations with probing systems on hot objects (e.g. heated basins, hot components) are possible to a limited extent or not at all. The reason: The speed at which sound propagates depends on the air temperature. Consequently, reproducible results cannot be obtained in convection over warm or hot parts. Another example is the use of compressed air nozzles in the immediate vicinity of the equipment. Here the problem exists that the strong air flow of the nozzles can deflect the sound signal and thus make the interrogation of objects more difficult, if not completely impossible.

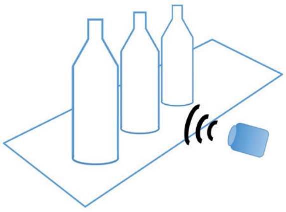
ipf electronic offers ultrasonic diffuse-reflection sensors in sizes ranging from M12x1 to 80x80mm, with a choice of both threaded and rectangular devices that can be used in a temperature range from-25° C to +70° C. The maximum switching distances of the ultrasonic diffuse-reflection sensors range from 200mm to 6m. The active sensor surface is made of plastic.

Ultraschalltaster der Reihen **UT12**, **UT30** und eine Ultraschallreflexschranke der Reihe **UT21** (von links)

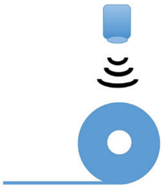


Level monitoring of pasty, solid and liquid media, e.g. in silos

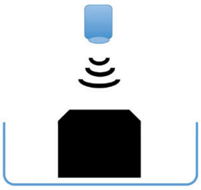
Loop control of foils, metal strips, etc. e.g. for controlling or regulating the material quantity or material tension



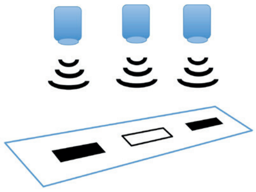
Detection of transparent glass containe



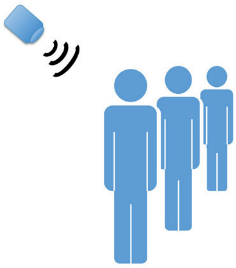
Diameter detection of coils in metal processing as well as in the plastics, paper and textile industries, etc.



Attendance monitoring, e.g. in the packaging industry



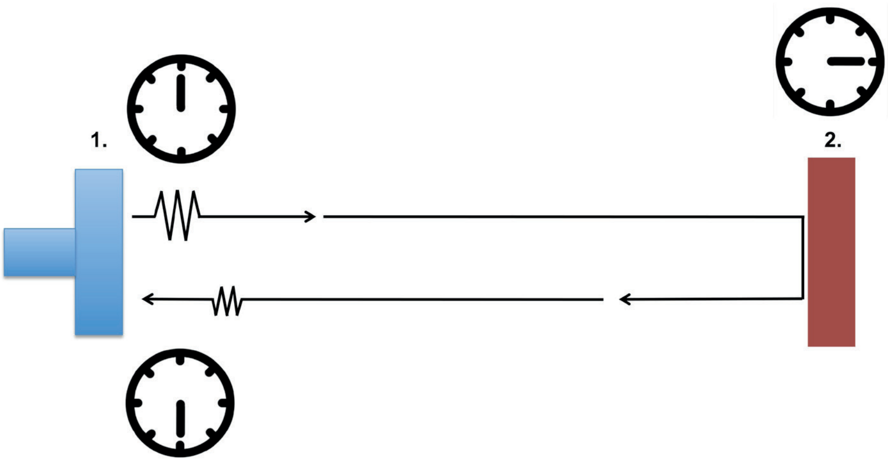
Completeness control of objects in containers.



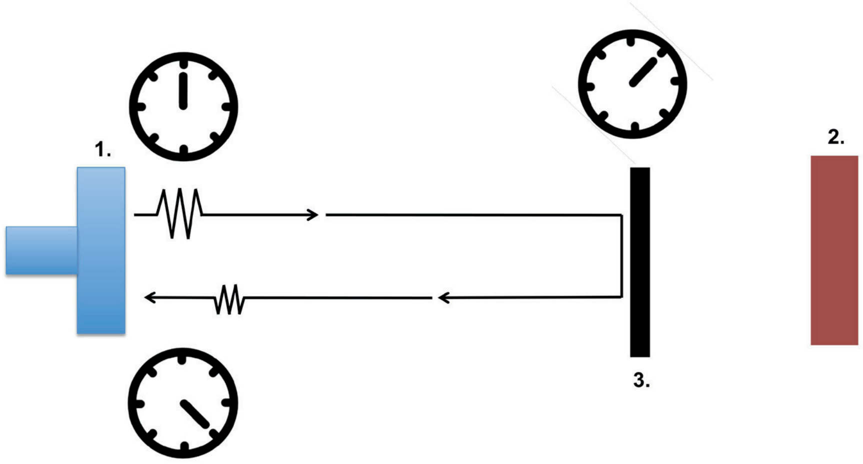
Personal recognition (no personal protection), e.g. in public buildings or sports facilities etc.

3.2 FUNCTIONALITY OF ULTRASONIC RETRO-REFLECTIVE BARRIERS

Ultrasonic retro-reflective barriers work with a so-called reference surface (any sound-reflecting object, usually a machine part), which serves as a stationary reflector and must be within the range of the sensor. The sensor is set to the distance to this reflector . As soon as an object is located between the sensor and the reflector, the propagation time of the sound changes with respect to the sound signal previously defined for the reflector. The switching output of the sensor then changes its signal.

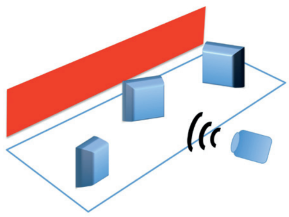


1. Sensor, 2. Reflektor

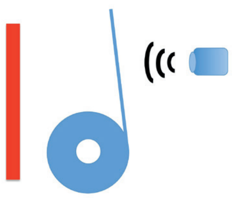


If there is an object (3.) between the sensor (1.) and the reflector (2.), the propagation time of the sound signal changes.

Ultrasonic retro-reflective barriers, unlike ultrasonic diffuse-reflection sensors, have no dead zone (see chapter 3.1). This means that objects to be detected can also pass very close to the detection range of the sensor. Ultrasonic retro-reflective barriers are therefore recommended for all applications in which it is not known exactly at which point an object will enter the detection range of the sensor. In addition, the functional principle also offers advantages in applications in which cylindrical objects or objects that differ greatly in their angular position must be detected. A prerequisite for the use of the devices is a reference surface that can be used as a reflector. Such devices are therefore suitable, for example, for mounting on conveyor belts with guide rails (e.g. in the beverage or packaging industry), with the rail opposite the sensor serving as the reference surface. If no reference surface is available, ultrasonic barriers can be used.



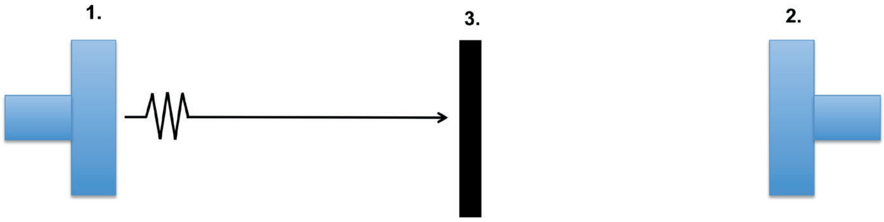
Poor or missing sound reflection signals from the unfavorably positioned objects or object geometries do not have a negative influence on the functioning in case of reflex systems



Poor or missing sound reflection signals in case of unfavorable angular position of objects do not have a negative influence on the functioning in case of reflex systems

3.3 FUNCTIONALITY OF ULTRASONIC BARRIERS

As a through-beam barrier system, ultrasonic barriers consist of a transmitter and receiver. If the sound path between the transmitter and receiver is interrupted by an object, the switching output in the receiver changes its signal.



The switching output of the receiver (2.) of an ultrasonic barrier changes its signal as soon as there is an object (3.) between it and the transmitter (1.) that interrupts the sound path.

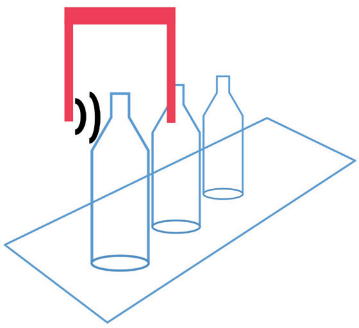
Due to their high switching frequency of 150Hz, ultrasonic barriers are preferably used in applications with fast-running processes, i.e. mostly where objects pass the detection range of the ultrasonic system very quickly. One of the most common applications for ultrasonic barriers is therefore in the beverage industry for detecting transparent bottles made of glass or PET.

In addition, such systems are also used for the detection of very thin materials such as foils. In such applications, care must be taken to ensure that the material is taut when it enters the detection range of the ultrasonic system. If this is not the case, the sound signal generates vibrations in the material. A foil thus quasi emits the signal received on one side on the other side. In the case of disposable systems, ultrasonic forks (see Chapter 3.4) and system variants with reflectors, this can lead to problems with object detection under certain circumstances.

Ultrasonic barriers like the devices of type UY210100 in IP67 have a high switching frequency of 150Hz. The devices are available with ranges up to 300mm and 1100mm	
Ultrasonic forks UG800170 (top) with a fork width of 74mm and UGKB0170 with a fork width of 114mm.	

Ultrasonic forks are suitable for all applications in which ultrasonic barriers can also be used. However, the transmitter and receiver do not have to be aligned with each other, as already described. Due to their equally high switching frequency of 150Hz and a response time of 1ms, such devices can be used in a wide range of applications in the beverage industry, e.g. for detecting transparent bottles. The ultrasonic forks are positioned in such a way that the neck of the bottle passes through the detection range of the transmitter and receiver. If the devices cannot be used in an application for mechanical reasons, e.g. due to the opening widths of the forks, ultrasonic barriers are recommended as an alternative.

Ultrasonic forks are extremely compact. ipf electronic has deliberately based the design of these solutions on optical fork barriers in order to be able to replace such systems with ultrasonic devices if necessary. For example, it is quite conceivable that in an application in which optical fork barriers were previously used, the material properties change and parts or objects become more transparent than before. In such cases, optical forked light barriers can then be replaced very simply and easily by an ultrasonic system.



Ultrasonic forks are suitable for a wide range of applications in the beverage industry, e.g. for detecting transparent bottles.

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