Principle of an echo sounder

Objects of the experiment

- Demonstrating the principle of an echo sounder.
- Determining the velocity of sound in air from the transit time of a sound pulse and the distance to the reflecting object.
- Determining distance by measuring the transit time of the sound pulse.

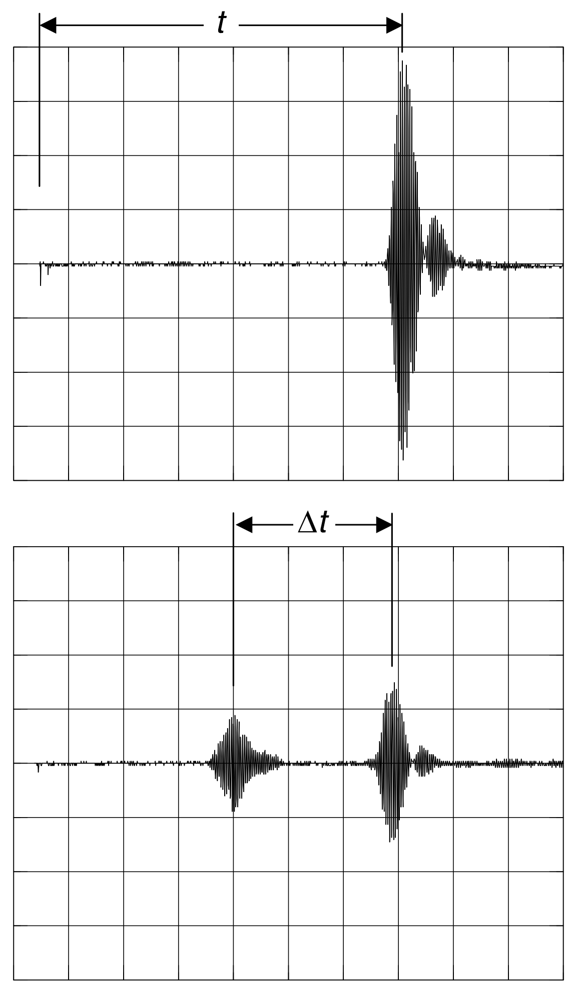

Fig. 1 Echo sounder signal for reflection at
a) the reflection plate (top)
b) the reflection plate and an additional obstacle placed in front of it (bottom)

Principles

Ultrasonic waves are reflected at the boundary surfaces between media with differing resistances to sound waves. An echo sounder (or "sonar") device emits pulsed ultrasonic signals and measures the time in which a signal is reflected from such a boundary surface to the receiver. To simplify the configuration, the transmitter and receiver are in the same location. The time between transmission and reception can be used to determine the distance to the reflecting object (if the velocity of sound is known), or to determine the velocity of sound over a known distance. This method is commonly used e.g. to determine water depths at sea.

In the following experiment, the echo-sounder principle is used to determine the velocity of sound in air, and to determine distances.

Two ultrasonic transducers – flexural resonators – serve as the transmitter and receiver, depending on their connection. A piezoelectric body converts electrical to mechanical energy.

When the AC voltage is applied to the piezoelectric body, the transducer configured as a transmitter supplies a sufficiently high sound amplitude at two different resonance frequencies (approx. 40 kHz and 48 kHz). Conversely, sound waves generate mechanical oscillations in the transducer when configured as a receiver. The amplitude of the resulting piezoelectric AC voltage is proportional to the sonic amplitude.

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Apparatus

2 Ultrasonic transducers, 40 kHz	416 000
1 AC amplifier	416 010
1 Generator 40 kHz	416 012
1 Two-channel oscilloscope 303	575 211
1 Screened cable BNC/4 mm	575 24
1 Reflection plate	578 66
1 Stand rod, 47 cm	300 42
3 Saddle bases	300 11
1 Metal scale, 1 m	311 02

Setup

Set up the experiment as shown in Fig. 2.

First:

– Set up the ultrasonic transducers 1 m apart so that the transducer sides are facing each other.
– Connect ultrasonic transducer **(a)** to the generator, and set the generator to continuous operation.
– Connect ultrasonic transducer **(b)** to oscilloscope channel I via the AC amplifier.
– Reduce the gain of the AC amplifier to minimum and observe the receiver signal on the oscilloscope.
– Adjust the frequency of the generator so that the receiver signal reaches the maximum amplitude.

Then:

– Set up the ultrasonic transmitter and receiver side by side about 10 cm apart.
– Set up the reflection plate with base at a distance of d = 1 m.
– Aim the transmitter and receiver at the reflector plate so that the two are directed at a single point.
– Connect ultrasonic transmitter **(a)** to the generator 40 kHz (pulsed-signal operation).
– Connect the trigger output of the generator to the trigger input of the oscilloscope, and set the oscilloscope to “ext. trigger” mode.
– Connect ultrasonic transducer **(b)** to oscilloscope channel I via the AC amplifier.
– Set the amplitude sensitivity of the oscilloscope to 0.5 V/DIV and the time base to 1 ms/DIV.
– If necessary, place an absorber, e.g. a sheet of rigid polystyrene foam, between the two ultrasonic transducers.

Carrying out the experiment

Qualitative demonstration of the principle of an echo sounder:

– Vary the distance between the ultrasonic transducers and the reflection plate and observe the receiver signal on the oscilloscope (see Fig. 1, top).
– If necessary, increase the gain of the AC amplifier without distorting the receiver signal.

Reflection at a second object:

– Hold a second object (e.g. your hand) between the reflection plate and the ultrasonic transducer and observe the receiver signal.
– Read off the transit-time difference Δt from the oscilloscope (see Fig. 1, bottom).

Determining the velocity of sound:

– Place the reflection plate at a distance d = 0.5 m.
– Read off the transit time t from the oscilloscope (see Fig. 1, top).
– Write down the values d and t in your experiment log.
– Increase the distance d for the reflection plate and repeat the measurement (see Table 1).

Measuring example and evaluation

Table 1: Relationship between the distance d to the reflection plate and the signal transit time (with measurement errors)

$\frac{d}{\text{m}}$	$\frac{t}{\text{ms}}$
0.5	3.3 ± 0.2
1	6.2 ± 0.2
1.5	9.1 ± 0.2
2	12.0 ± 0.4
2.5	15.0 ± 0.4
3	17.8 ± 0.4
3.5	22 ± 1
4	24 ± 1
4.5	27 ± 1
5	30 ± 1

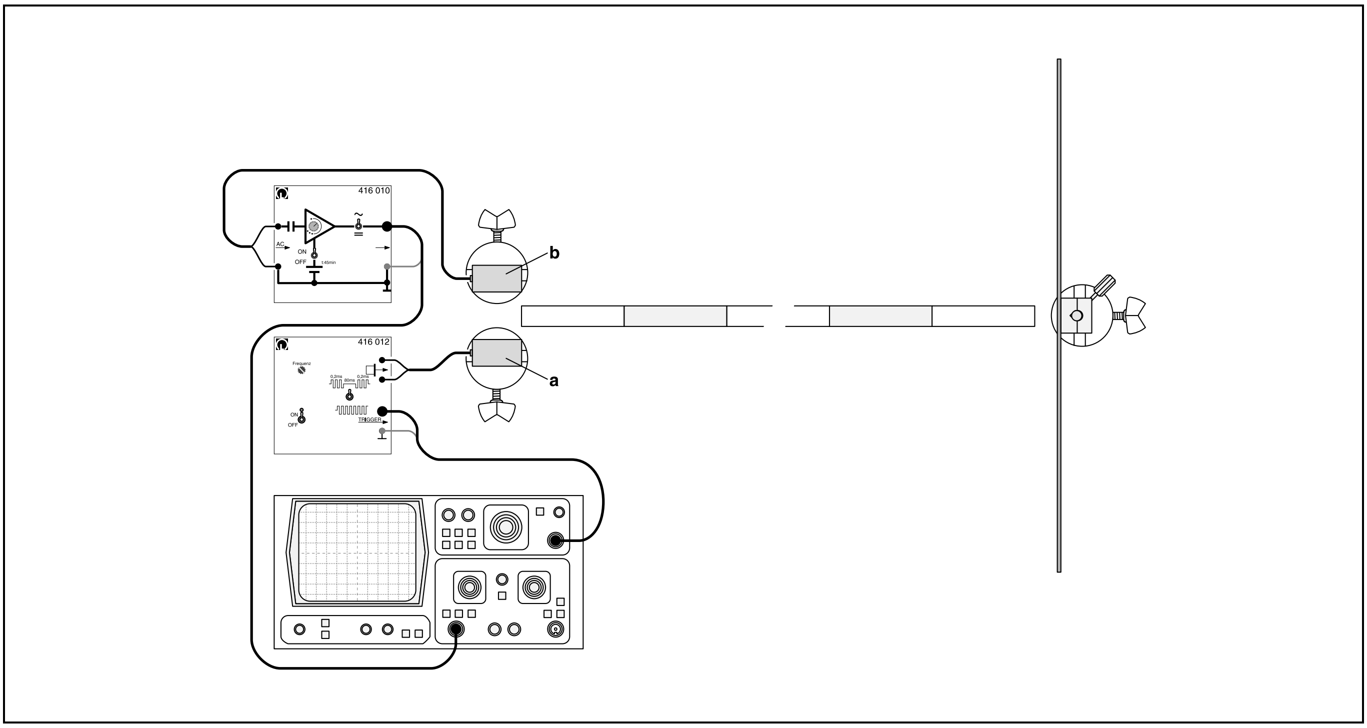
Table 1 shows the measurement results for determining the velocity of sound. Note that the ultrasonic pulse travels the path $s = 2d$. Fig. 3 illustrates the relationship between $2d$ and the transit time in graph form. From the slope of the straight line, we obtain the value for the velocity of sound
$c = 334 \text{ m } s^{-1}$

For the velocity of sound in the air as a function of the ambient temperature ϑ, the literature specifies the value:

$$c = 331.6 \text{ m } s^{-1} + 0.6 \text{ m } s^{-1} \cdot \frac{\vartheta}{°C}.$$

Measuring distances with the echo sounder:

From the transit time difference Δt = 11.6 ms between two signals (see Fig. 1, bottom), we can use the sound velocity calculated above to compute the distance between the two obstacles as Δd = 2 m.



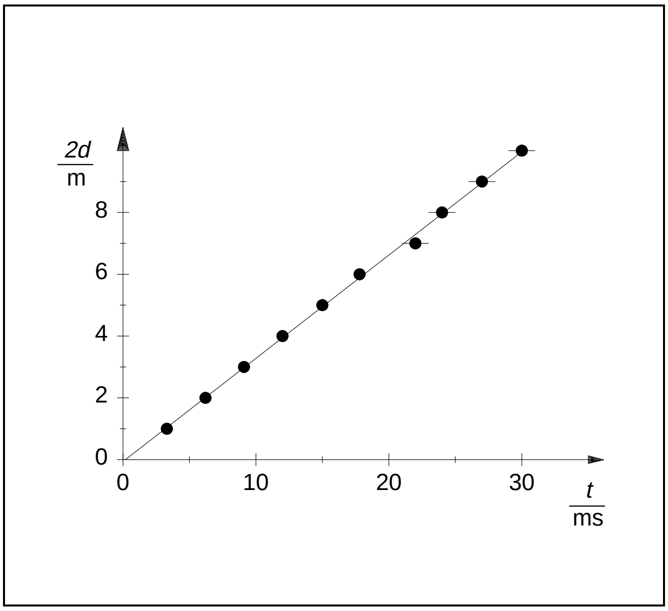


Fig. 2 Experiment setup for echo-sounder principle, top view

Fig. 3 Graph showing the relationship between the signal path 2*d* and the signal transit time *t*

Results

Using an echo sounder, we can determine the velocity of sound in a specific propagation medium for a known distance to a reflecting object, or, when the velocity is known, the distance to the reflecting object.