Faure Herman
Counting every drop

Minisonic II

Supplement for ISD/PSD

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1. Introduction

The Minisonic II range of devices offers ISD or PSD operating modes in addition to their function as flowmeters, with the choice between these two modes depending on the intended purpose.

The ISD mode (Interface & Sphere Detector) of a Minisonic II ISD/PSD is designed to monitor the nature and quality of refined petroleum products during pipeline transport.
Based on measuring the speed of sound in the product and its relationship with other physical characteristics such as density or concentration, it ensures accurate monitoring and rapid detection of any changes, known as an interface, during pumping.
As the detector requires only one probe installed outside the pipeline, analysis can be performed safely at any point along the pipeline, such as 1 km upstream of a station.
Therefore, the Minisonic II-ISD is commonly referred to as a preliminary densitometer. However, it cannot be used as an official densitometer, as the relationship between the speed of sound and density may vary due to factors not accounted for (temperature, composition, etc.).
The ISD mode can also be used in the chemical industry to analyze concentrations or measure mixtures, provided the variations can be correlated. For example, the speed of sound exhibits notable variation in sulphuric acid. Similarly, an ionised salt in solution changes the speed of sound in water (by +1 m/s per g/l for NaOH).

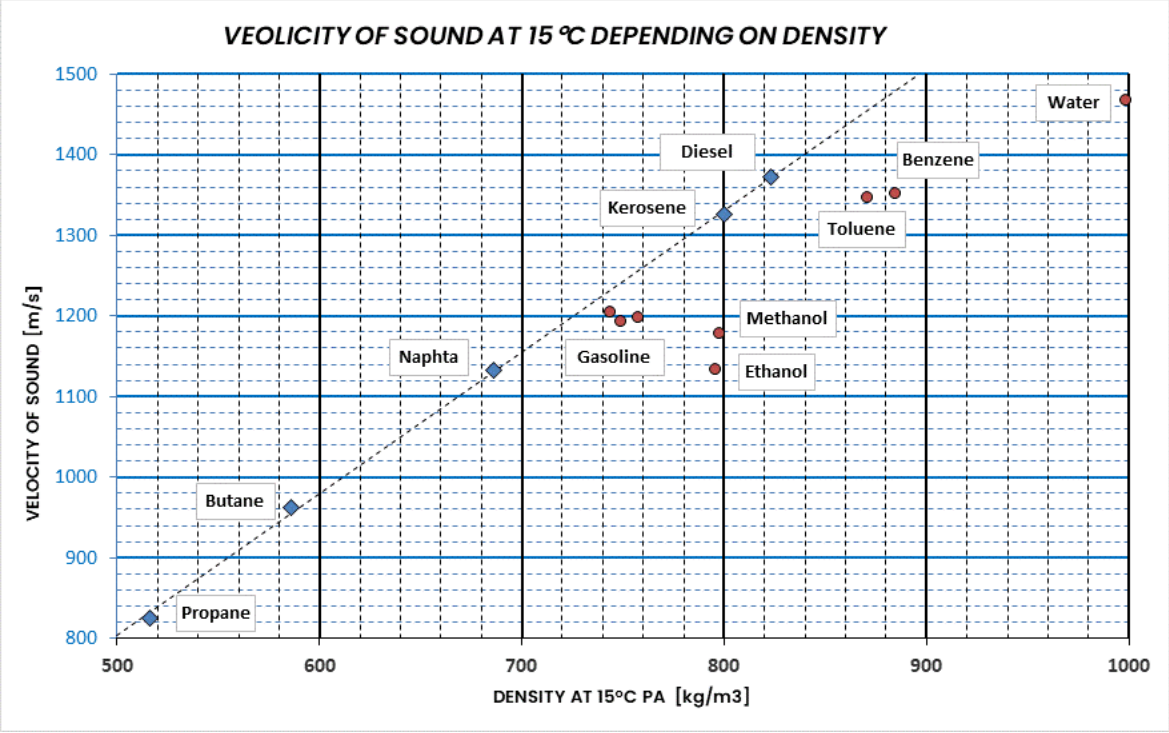
The PSD mode (Pig & Scraper Detector) of a Minisonic II ISD/PSD reliably detects the passage of spheres or scrapers at a lower installation cost: no drilling and no moving parts. This technique can therefore replace outdated mechanical detectors or be used in new projects.
The ease of installation also allows for temporary measurements during pipeline work (e.g., diversions) to identify the product in the pipeline and the position of the spheres. An important feature of ultrasonic detection is its lack of inertia, allowing the detection of two consecutive spheres, even if they are adjacent.

2. Description of Operating modes

2.1. ISD Operation

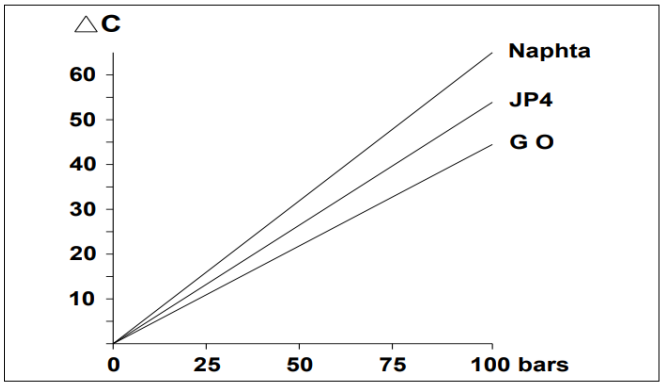
The speed of sound in a fluid is a physical characteristic that can be linked to other properties such as density (d), pressure (P), temperature (T), or the ratio of mixed products.

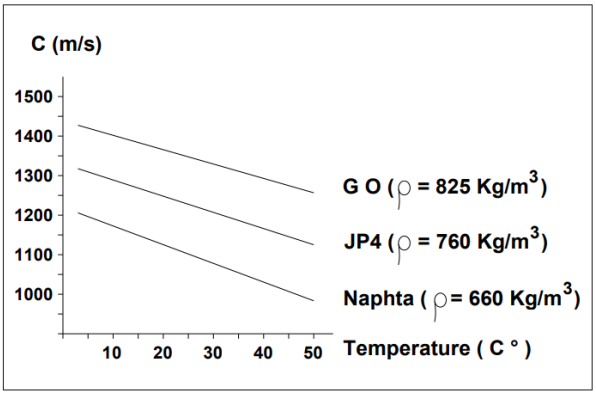
For most refined petroleum products, experience shows a "linear" relationship between the speed of sound and the product's density at constant P and T.
These products are termed "aligned," unlike others that show deviations and are termed "non-aligned." This is typically the case with petrols containing additives to modify compression behavior or optimize combustion characteristics.
Note that while alcohol additives in petrol or biodiesel additives in diesel cause slight deviations, they do not impair detection capabilities.
Below is the relationship between speed of sound and density for several typical fluids under normal conditions according to ISO 13443 (1 Bar, 15°C). The values for propane and butane are given at 10 Bar to reflect their liquid state.



The previous graph shows that, although different petrols with the same speed of sound cannot be distinguished (as they are non-aligned), they can still be differentiated from other petroleum products with significantly different densities, as they remain relatively close to the reference line (unlike products such as ethanol or methanol).

To compare products, it is essential to maintain the same pressure and temperature conditions, as the speed of sound changes with these parameters. Below are examples of variations in petroleum products.



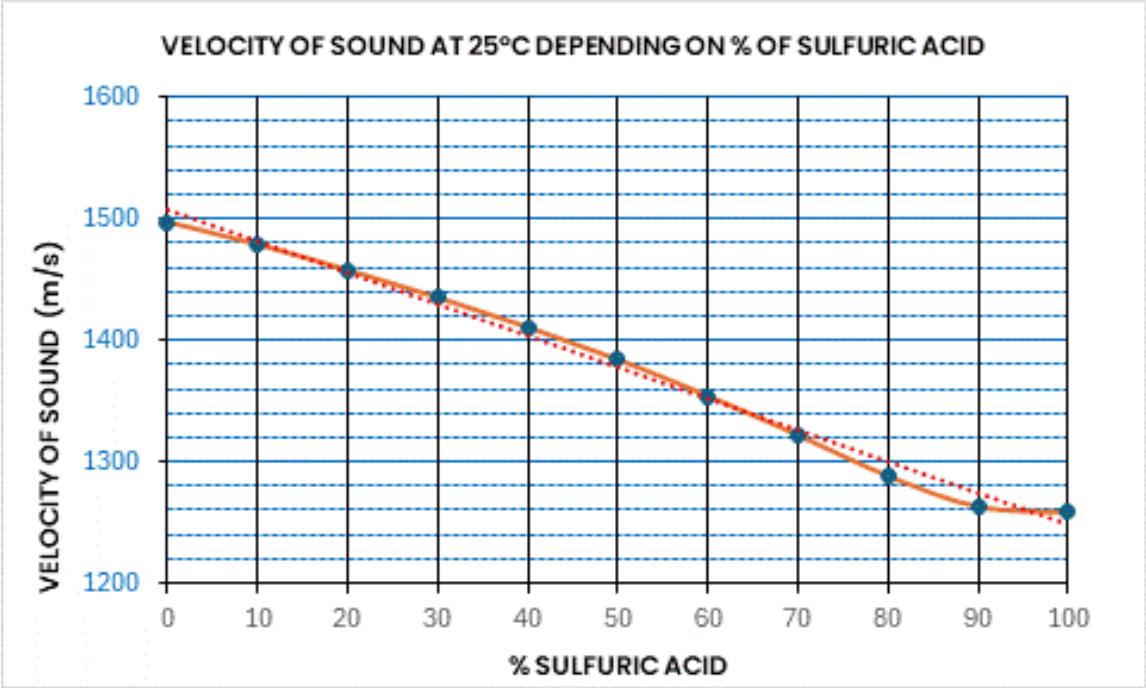


While pressure has a limited impact (approximately 0.5 m/s per Bar, with correction recommended for variations exceeding 10 Bars), temperature has a more significant effect, with variations of approximately -4 m/s per °C.

It is recommended to correct the speed of sound using a temperature measurement near the ultrasonic path for products with variable temperatures (e.g., downstream of a refinery when alternating between stored and freshly produced products).

This correction is unnecessary for seasonal temperature variations, as interface detection sensitivity remains unaffected.

ISD measurement can also determine concentrations. Below is an example for sulphuric acid.



Although the variation is not linear, the Minisonic II ISD can be used as a dosimeter or concentration gauge

2.2. PSD Operation

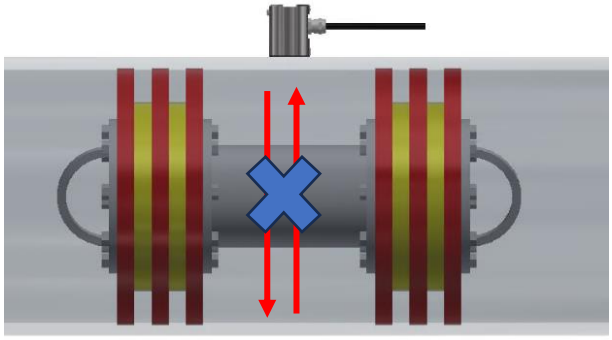
The PSD principle involves counting the number of scrapers (also called "PIGs") or spheres passing through the pipeline during product changes.

The device measures the time taken for the ultrasonic signal to be interrupted and compares it to a time profile defined by process data:

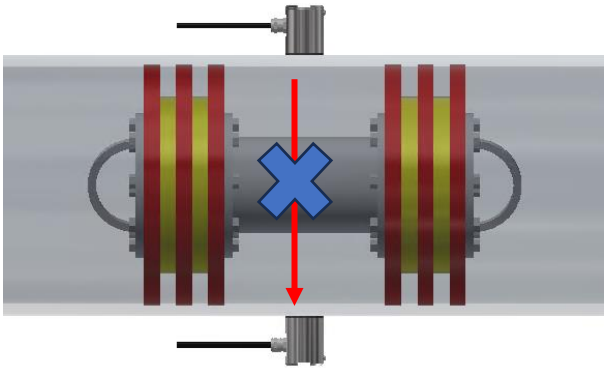
- Minimum/maximum scraper or sphere sizes.
- Minimum/maximum fluid velocities in the pipeline.

The absence of moving parts ensures long-term reliability and reduced maintenance costs. Combined with the temporal resolution of ultrasonic technology (with signals emitted approximately every millisecond), it enables detection in situations where mechanical scrapers might fail. For instance, it can identify two spheres in contact where a mechanical detector would only count one, or it can give a single detection for an instrumented scraper where a mechanical detector might give multiple detections.

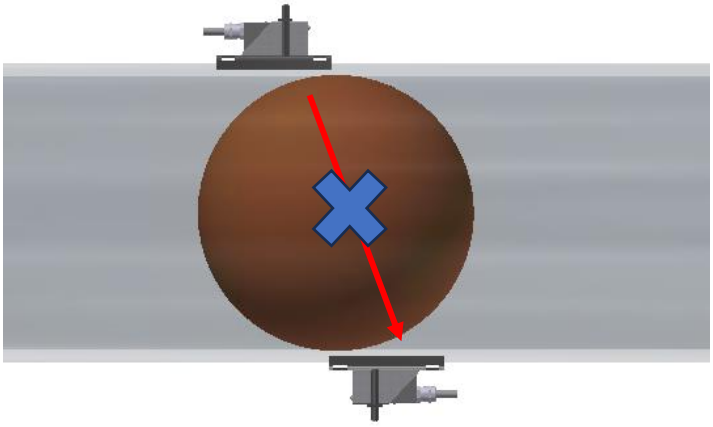
Various installations are possible, with the most standard setup using a single straight probe (1 MHz frequency for refined products and 500 kHz for crude products).



Detection can also use a barrier setup with two probes. This configuration works well in cases with high absorption (e.g., large diameters, viscous crude oil).It also avoids self-interference from the transmitted signal.



For applications where signal transmission is challenging (e.g., clamp-on gas), angled probes can be used, similar to those used for flow measurement. This angle reduces pipeline noise that could interfere with the signal going through the fluid and used for measurement which will require significant amplification.

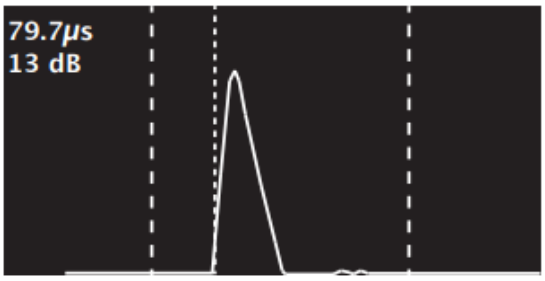


Whether using ISD or PSD modes, installation requires the same checks as for flowmeter operation (refer to the main manual).

These checks include:

- **Ensuring correct installation or configuration via the measured speed of sound.** The device indicates a deltaV, which is the deviation of the measured speed from the configured fluid speed. Ensure the deviation is less than 20 m/s (ideally below 10 m/s).

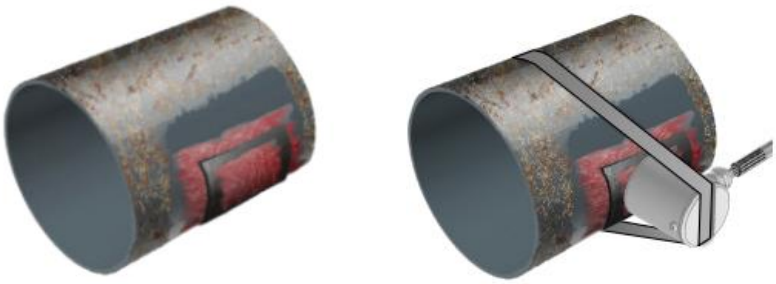
- **Verify that the measurement gain is correct.** A gain below 55 dB is recommended to ensure a sufficient signal-to-noise ratio. The device can operate with higher gains, but in such cases, check noise levels using the "US Signal Visualisation" function in the main menu.



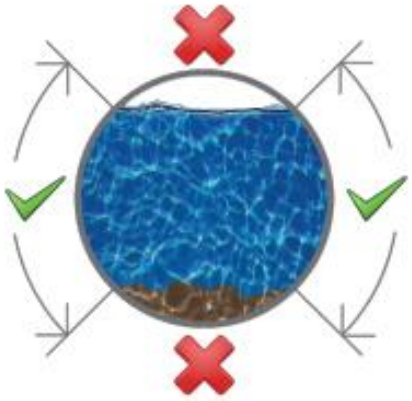
The example above shows very low noise (more evident in the second zoomed image than in the first landscape image) due to low operating gain (only 13 dB).

Possible reasons for high gain include:

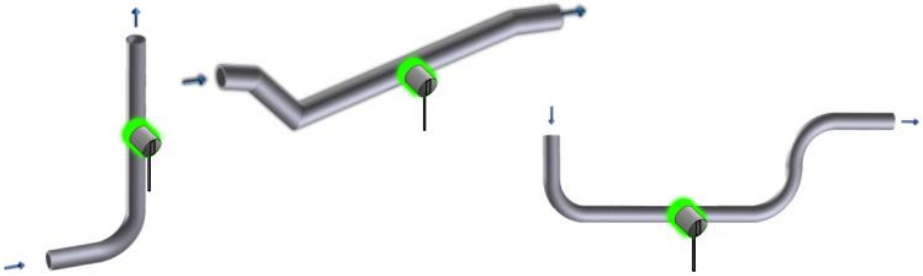
- Poor coupling (grease should be applied on both sides of the polymer strip, avoiding creases).



- Local defects inside the pipeline (change the ultrasonic path angle if needed, avoiding vertical alignment).



- Presence of microbubbles increasing fluid absorption. To limit this phenomenon, it is preferable to place the probe at a low point, or on an upward branch if that is not possible:



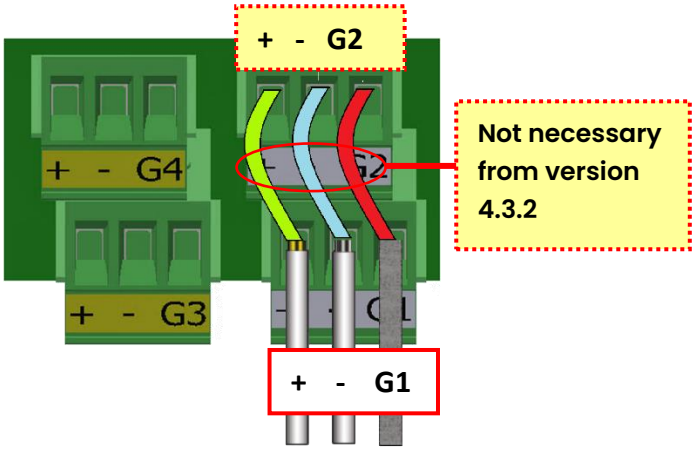
Note that in the case of crude oil, which may contain a significant percentage of water, it is also recommended to install the measurement probe away from disturbances to minimize mixing between the two products.

3. Device Wiring

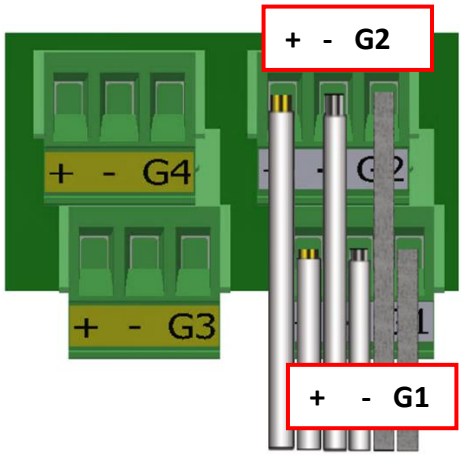
3.1. Connecting Ultrasonic Probes (ATEX device)

Device wiring is identical to the flowmeter version for Power and Input/Output connections.
The only difference is that typically only one probe is connected (though two probes can be used for more complex cases).
For firmware 4.3.1, both connectors must be bridged when using a single probe. From firmware 4.3.2, only connector G1 must be connected.

Bottom view (note that the terminals are reversed in relation to the rear view):



Connection for 1 straight probe



Connection for 2 probes (straight or angled)

Probe 1		
+	-	G1
+ probe no. 1	- Probe no. 1	Shield Probe no. 1
(Strap Probe 1) Probe 2		
+	-	G2
+ probe no. 2 *(Strap + probe no. 1)*	- probe no. 2 (Strap - probe no. 1)	Shield Probe no. 2 (Strap Shield probe no. 1)

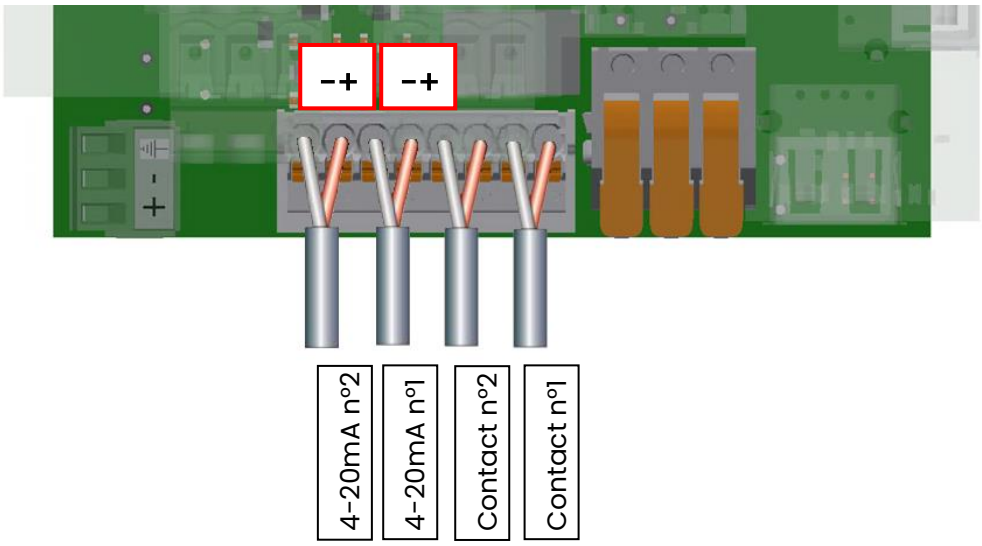
Note: the polarity and order of the probes are irrelevant in ISD/PSD mode.

3.2. Connecting inputs/outputs (ATEX device)

The main manual gives the wiring for the device inputs/outputs. The cabling used for ISD / PSD is shown below:

- For the ISD, the 4-20mA output is used to send back the speed of sound measured by the device. It is also possible to have the speed of sound in standard conditions calculated by the device (requires pressure and temperature information). Note that if the customer knows the relationship between the speed of sound and density (for example, the range of 1100 to 1400 m/s corresponds to 670 to 840 kg/m3 for aligned products), it also gives an image of the density.
- For the PSD, the relay output sends a pulse each time the sphere/scraper passes.

As with the cords, the wiring is reversed between the bottom and rear views. The contact outputs are not polarised.



PIN	1		2		AO1		AO2	
					+	-	+	-
Function	Contact 1	Contact 1	Contact 2	Contact 2	AO1 4-20mA +	AO1 4-20mA -	AO2 4-20mA +	AO2 4-20mA -

4. Device Configuration

4.1. Selecting the Operating Mode

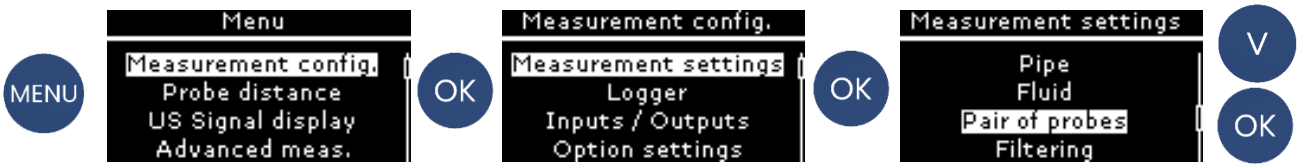
The type of device operation (ISD or PSD) can be identified from the main measurement screen:

PSD Mode

ISD Mode

Both screens display the speed of sound (velocity) and the measurement quality index (IQ).
The PSD screen additionally shows the number of detected sphere/scraper passages, preceded by the label PSD.

The operating mode is linked to a probe pair. To change this, go to the “Measurement Configuration” menu from the main menu, followed by the submenus “Measurement settings” and then “Pair of probes”.



The change is made via the “Usage” parameter, which can be quickly accessed by clicking the up arrow once in the menu.

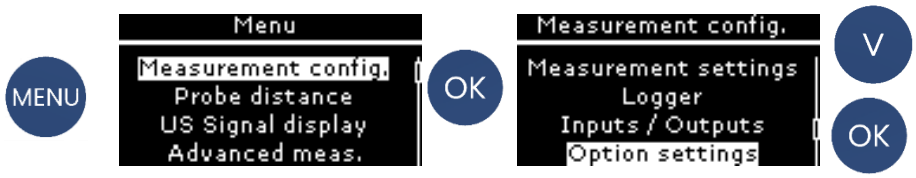
Once the mode is changed, you can either continue making modifications or save the configuration change by pressing the “MENU” button:

4.2. Specific ISD/PSD Functions

In ISD mode, the device now offers pressure/temperature correction to display the speed of sound adjusted to standard temperature and pressure conditions (1 Bar and 15°C).

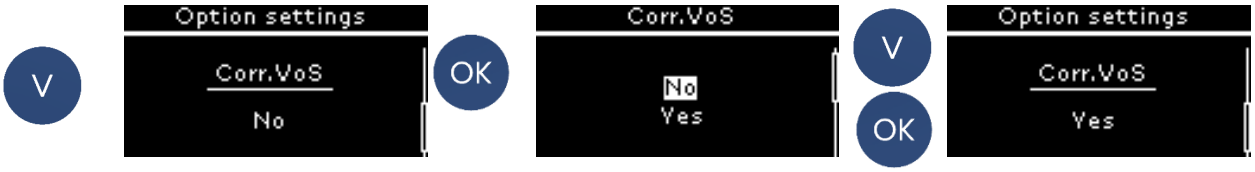
It is also important that the gain type for the probes is set to "AUTO" (static) and not "ESC" (dynamic) to maintain a fixed measurement threshold. This functionality is only available in Expert Mode (normal mode defaults to ESC, recommended for flow measurement). **Therefore, the device must be switched to Expert Mode for ISD/PSD operation.**

These two functions (velocity of sound correction and switching to Expert Mode) are available in the "Options settings" submenu within the "Measurement Configuration" menu:



Switching to Expert Mode:

Switching to Corrected Velocity of Sound Mode:



Switching to Expert Mode becomes visible mainly in the "Pair of probes" menu, where new functionalities will appear (see the next section).

In Corrected Velocity of Sound Mode, a new "ISD" menu will appear within "Measurement settings" (note that this menu only appears if ISD mode, not PSD, is selected). The main measurement screen will also change, with "Velocity" being replaced by "Corrected Velocity".

4.3. Measurement Configuration

This section describes only the ISD/PSD-specific features of the “Measurement Setup” menu.
Other menus (such as “Recorder” or “Inputs/Outputs”) are covered in the main manual common to the flowmeter and ISD/PSD versions.

The various submenus under “Measurement Setup” are as follows:

Pipe	Refer to the main manual: parameters describing the pipeline.
Fluid	Refer to the main manual: parameters describing the fluid.
Pair of probes	See the dedicated section: parameters for the probes used and the associated operating modes.
Filtering	Refer to the main manual: parameters for adjusting memory and damping.
ISD	See the dedicated section: this menu appears when using probe pairs in **ISD** mode and pressure/temperature correction is enabled (C. corrected to “Yes”, see previous section).
PSD	See the dedicated section: this menu appears when using probe pairs in **PSD** mode. Allows calculation of cut-off times based on process data (sphere/scraper sizes, minimum/maximum flow rates).

4.4. Probe Pair Setup

Certain parameters are only accessible in Expert Mode. Refer to “Specific ISD/PSD Functions” to switch the device to Expert Mode (necessary to change the gain from “ESC” to “AUTO” or “ESC+AUTO”).

Probes	Select the probe model from a drop-down list.
Mounting	Select the type of probe mounting. The available options depend on the type of probe (external or intrusive). **In the case of a single probe, the parameter to use is: 1 Reflection (V)**
Length **Axial Distance** **(intrusive probes)**	This parameter only appears for intrusive probes (the device calculates it for external probes).
Gain mode **(Expert)**	Select the gain search mode. **The recommended mode for ISD/PSD is “ESC then Auto”:** the device automatically sets a fixed margin (unlike ESC, where the margin is recalculated).
Margin **(Expert + Auto)**	Select the margin. This appears only in "Automatic" Gain mode. The margin determines the measurement threshold (i.e., the measurement point on the signal). A low margin is used for PSD (measuring near the peak), and a high margin for ISD (measuring at the start of the signal).
Attenuator **(Expert + Auto)**	Choice of whether to activate the attenuator. This appears only in "Automatic" Gain mode. It is recommended to keep it “Disabled” (except for intrusive probes and small diameters).

Polarity (Expert + Auto)	Select the polarity for the margin. This appears only in "Automatic" Gain mode. The choice between positive and negative depends on the signal shape (refer to “US Signal Visualisation” menu).
Time offset (expert)	Apply a time offset to the measurement based on the measurement point on the signal.
Max gain (expert)	Set the maximum gain allowed for measurement. The device determines the gain, whether in ESC or AUTO mode. **In ISD/PSD, set this value to 60 dB to avoid measurements when the pipeline is empty.**
Max margin (expert)	Set the maximum margin allowed in ESC mode. **In ISD/PSD, set this to 34 dB.** This corresponds to a minimum threshold of 2% to prevent measuring noise.
Inter-emission elay (expert)	Set the delay between ultrasonic emissions. The default setting of 1ms corresponds to the maximum firing frequency (1 kHz). It may need to be increased in ISD/PSD for small diameters to avoid self-interference in reception due to the emitted signal not having enough time to dissipate.
Voltage (expert + Auto)	Set the emission voltage. This appears only in "Automatic" Gain mode. "High" Voltage is recommended (except for intrusive probes and small diameters).
Usage	Select the probe usage mode (ISD or PSD). See previous section: “Selecting the Operating Mode”.

4.5. ISD setup

This menu is only accessible if velocity correction is enabled.

Temperature mode	Choice for temperature compensation between a fixed value (“**Constant**”) or a measured value (“**Input**”) when inputs are available on the device.
Temperature	Select the temperature source based on the chosen mode (fixed **value** or **input**)
Pressure mode	Choice for temperature compensation between a fixed value (“**Constant**”) or a measured value (“**Input**”) when inputs are available on the device.
Pressure	Select the pressure source based on the chosen mode (fixed **value** or **input**).

4.6. PSD setup

Minimal length	Minimal length of the sphere/scraper.
Maximal length	Maximal length of the sphere/scraper. In practice, consider increasing by a factor of 2 to 4.
Minimal velocity	Minimal velocity of the sphere/scraper (cannot be less than 0.01 m/s).
Maximal velocity	Maximal velocity of the sphere/scraper.
Reset Totalizer	Resets the PSD counter (Modbus and main measurement screen).
Delete Files	Clears the history of sphere/scraper passages (up to 10 recorded passages).

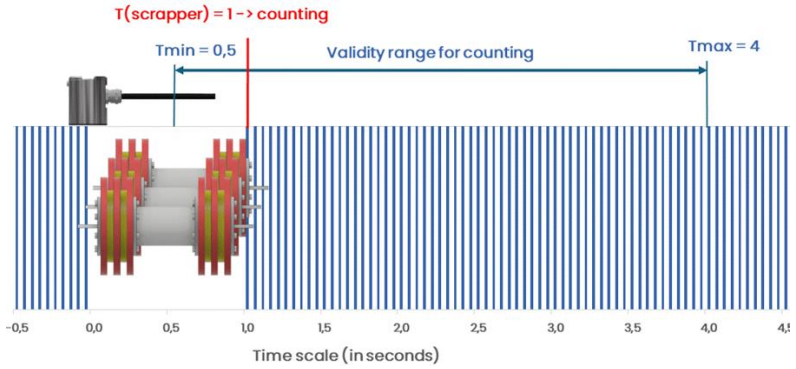
PSD menu parameters define the time window for detection. The aim is to prevent minor measurement losses (e.g., microbubbles or pressure surges during valve operation) from being mistaken for sphere/scraper passages.

The device only considers interruptions within a time window between Tmin and Tmax with:

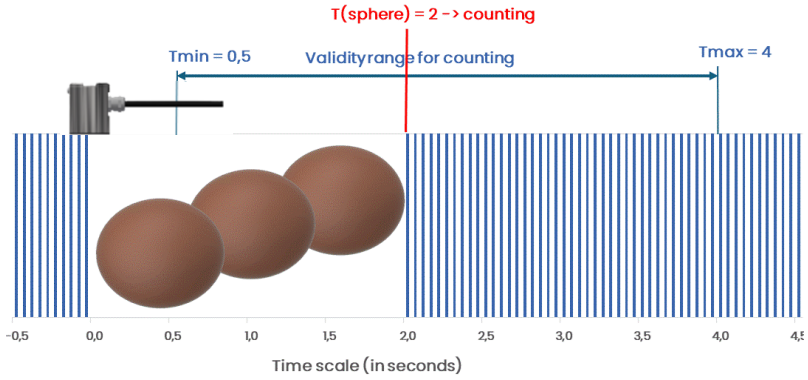
$$T_{min} = \frac{L_{min}}{V_{max}} \text{ and } \quad T_{max} = \frac{L_{max}}{V_{min}}$$

The device compares the measured interruption (resolution of ~1 ms) with this time range.
For example, with a minimum sphere size of 1 metre, a maximum scraper size of 2 metres, and speeds ranging from 0.5 to 2 m/s, Tmin is 0.5 s, and Tmax is 4 s.

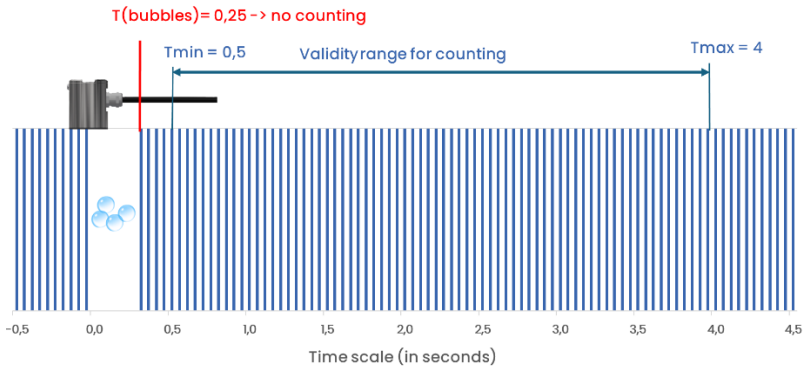
In the case of a scrapper at maximum speed, the theoretical loss of time will therefore be 1s (within the detection range).



In the case of a sphere at minimum speed, the theoretical loss of time will therefore be 2s (within the detection range).



However, for a micro cut (e.g. 0.25s) there will be no detection.

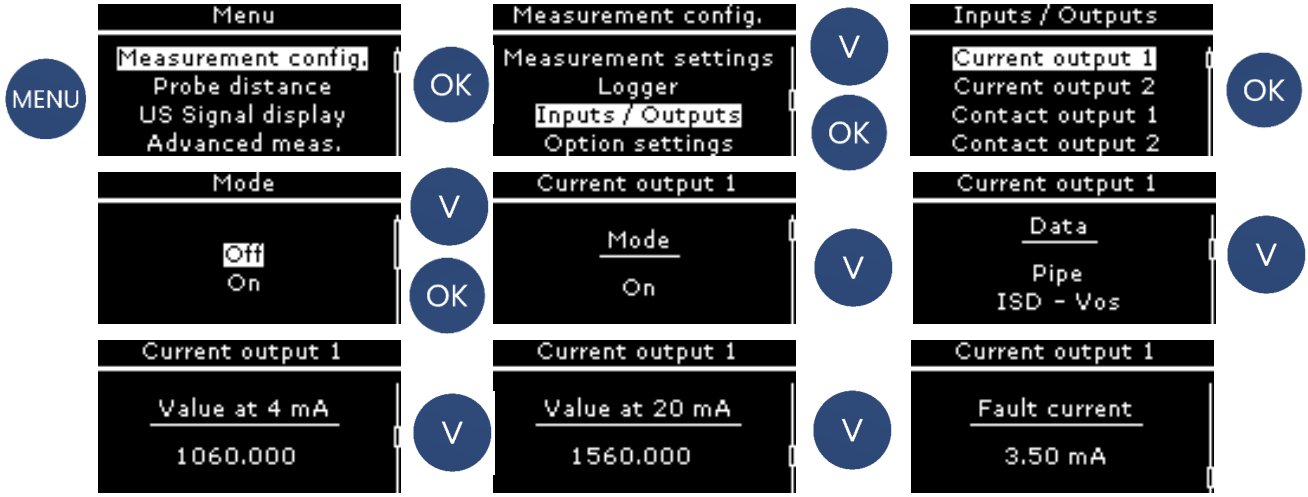


In practice, the measured cut-off times may be greater than those calculated theoretically, as these "Pigs" may push sludge or particles or lead to gas pockets, thus forcing longer echo loss times.

4.7. Setting Inputs/Outputs

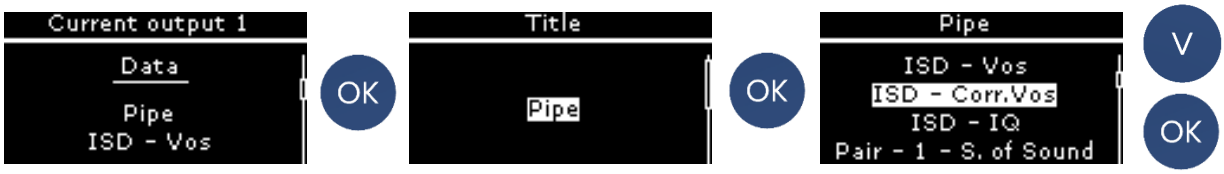
Input/output parameter setting is already described in general terms in the main manual, but the most common setting for ISD/PSD is given here, i.e. setting the 4-20mA output to ISD and setting the relay to PSD.

To configure the 4-20 mA output, it must first be activated. Activation also enables simulation for verification/calibration (available via "Tests & Adjustments" in the "Inputs/Outputs" menu).



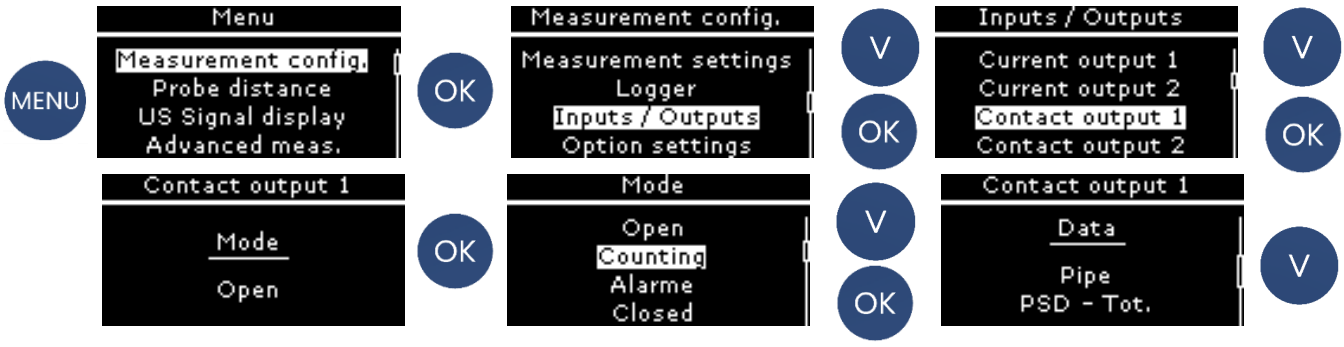
After activation of 4-20mA output, default data used should be "Pipe ISD – Vos" (Velocity of sound). Values at 4mA and 20mA as well as the Fault current have to be set by customer according 4-20mA range set on the DCS.

It's also possible to replace "ISD-Vos" with "ISD-Corr.Vos" if the function has been activated (see "Specific ISD/PSD Functions").



Note: While it is recommended to select a single operating mode (ISD or PSD), mixed ISD/PSD operation is still possible. To enable this, select the PSD operating mode. Although data will not be available for the "ISD - …" outputs, the speed of sound can be retrieved via "Pair – 1 – Velocity".

The output parameter for counting in PSD mode is as follows:



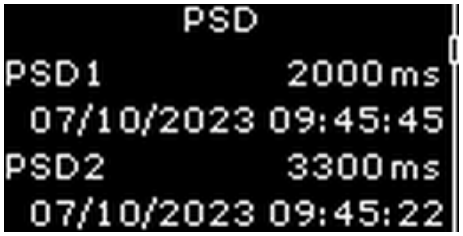
In "Counting" mode, the contact output should default to "Pipe PSD-Tot." .

5. Device Measurements

5.1. Measurement Screens

In addition to the main measurement screen, which changes depending on the selected mode, there are secondary screens with different information for each mode.

In PSD mode, the screen displays details of the last 10 sphere/scraper passages:

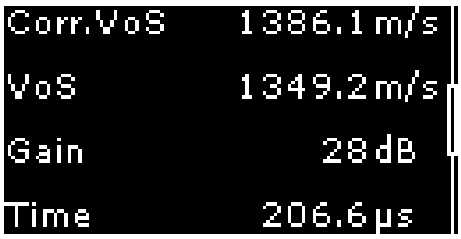


Measured cut-off times (only times consistent with PSD menu parameters are shown)

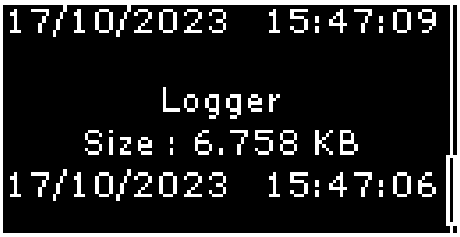
Detection date (day/month/year and time)

Other screens are similar for both PSD and ISD modes:

- Indication of the measurement gain and measured time (used to calculate velocity).
  In ISD mode, the screen also shows the velocity and corrected velocity (if enabled; otherwise, dashes are displayed).



- Recorder Information:
  The content of the recorder can be customised by the user (refer to the main manual).



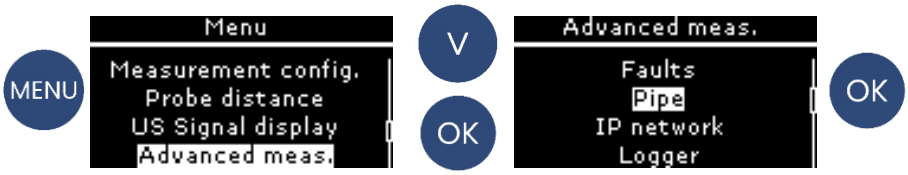
Device time

File size

Date of the last recording

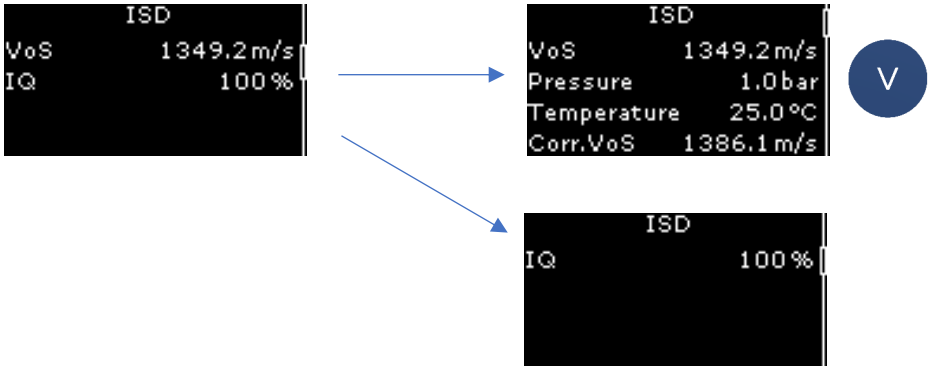
5.2. Advanced measurements

For more detailed measurement data, use the “Advanced Measurement” menu accessible from the main menu.

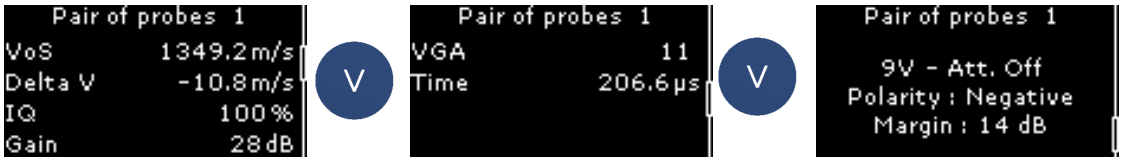


As with the main and secondary measurement screens, displayed data depend on the selected mode.

In ISD mode, enabling corrected velocity provides access to additional data (notably the pressure and temperature values used for correction):



Other measurement screens are shared between ISD and PSD modes.



Velocity and IQ information is available, along with the following additional information:

- **Delta V :** Shows the deviation between the configured and measured velocity of sound. This helps verify correct installation or configuration (the deviation should not exceed 10-20 m/s).
  Note: The database fluids are referenced at 20°C unless stated otherwise. Custom fluids can be created to adjust the reference speed of sound (via “Custom Data” in the “System Configuration” menu).

- **Gain :** Shows the amplification in decibels (dB) applied to the received signal to achieve a sufficient voltage (~1V). The value is normalized for a fixed emission voltage. The optimal range is 5 to 45dB.
  Below 5 dB, an attenuator should be added to avoid measuring a saturated signal and, above 55 dB, the noise level should be checked using the echo visualization feature.

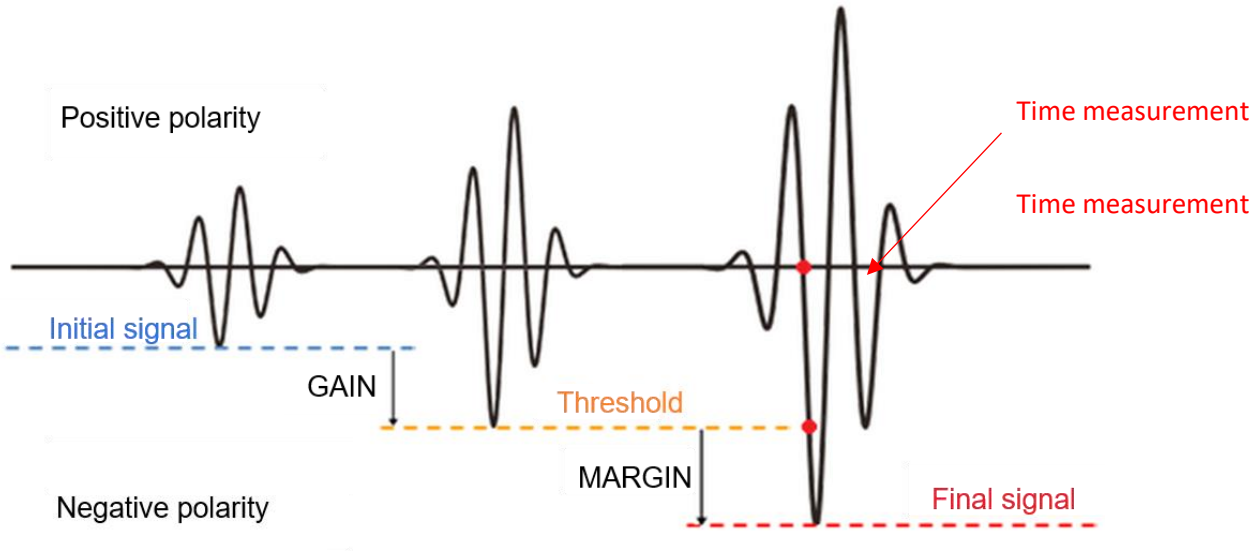
- **VGA :** Indicates the non-normalized voltage amplification (which varies with the selected emission voltage).
- **Time :** Measurement used to calculate the speed of sound, determined by the zero-crossing point based on the margin.
- **Voltage** : Three possible values based on emission voltage. High = 48V / Medium = 9V/ Low = 2V.
- **Attenuator** : Shows whether the attenuator is enabled.
- **Polarity :** Shows the signal polarity (positive or negative) used for time measurement (refer to the following section).
- **Margin :** Indicates the voltage difference between the signal peak and the threshold used for time measurement -> see the following section

5.3. Auto mode description

The main difference between Minisonic II ISD/PSD operation and flowmeter operation is the use of Auto Mode for determining the gain (requires Expert configuration level).

In PSD mode, the margin should be low (below 6 dB) to favor signal loss during sphere/scraper passage, whereas in ISD mode, it may be high (above 12 dB) to measure at the start of the signal.
Therefore, it is necessary to select the preferred mode. A mixed PSD/ISD mode is possible but may result in reduced precision/reliability in speed of sound measurements (measuring further along the signal, favoring signal loss).

The following graph shows the different signal amplifications and the meanings of the various terms used:



Note: The measurement is taken at the first zero-crossing before the threshold is exceeded.

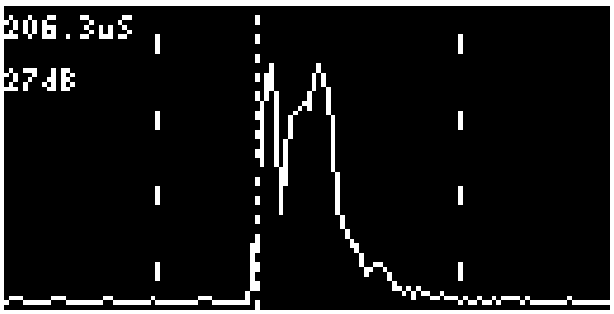
The signal undergoes two amplifications:

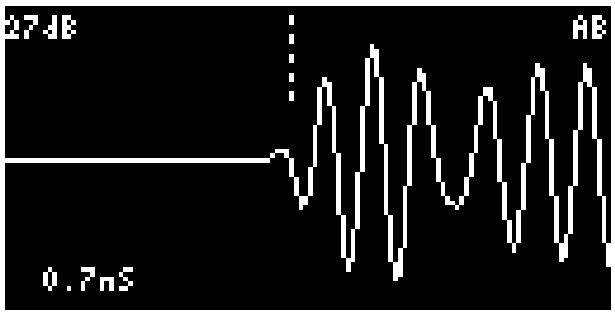
- The first adjusts the amplitude to ~1V (the gain). In the previous graph, doubling the voltage corresponds to a 6 dB gain.
- The second amplifies the signal to position the peak at the measurement point (the margin). It is for this reason that we consider that the value of the margin will permit positioning of the threshold.
  In the previous graph, a margin of 35% (corresponding to ~4 dB) sets the threshold at 65%.

To make it easier to relate the margin to the position of the threshold, we give the thresholds corresponding to different margins:

Threshold (%)	Margin (dB)	Threshold (%)	Margin (dB)	Threshold (%)	Margin (dB)
80%	1.9	40%	8	15%	16.5
70%	3.1	30%	10.5	10%	20
60%	4.4	25%	12	5%	26
50%	6	20%	14	2%	34

To illustrate the difference in parameters between ISD and PSD, we use a concrete case (measurement on a Ø160m pipe with a single straight probe).
To understand the measurement point position, display the signal shape using “US Signal display” from the main menu.



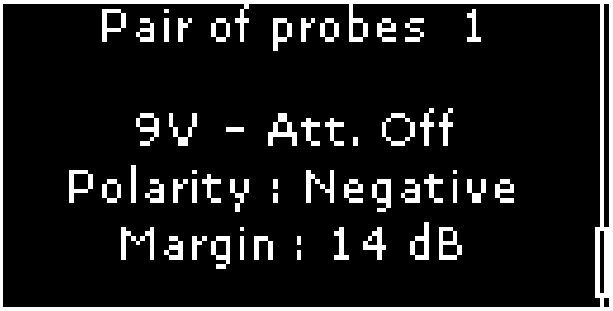


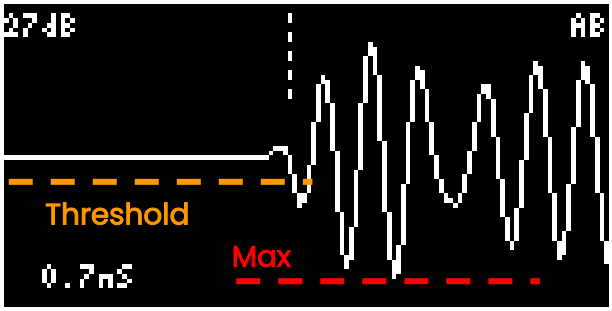
The first one, landscape echo view, provides an overview of the signal envelope, showing the measured time (for speed of sound calculation) and gain (should be below 55 dB).

The second one, zoomed view, shows detailed alternations, identifying the measurement point (first zero-crossing before the threshold).

To determine the threshold used for the measurement in ESC + Auto mode, it is necessary to retrieve the value in "Advanced Measurements" (see the previous section).

Below is a measurement with **ISD Configuration** (case of previous example):



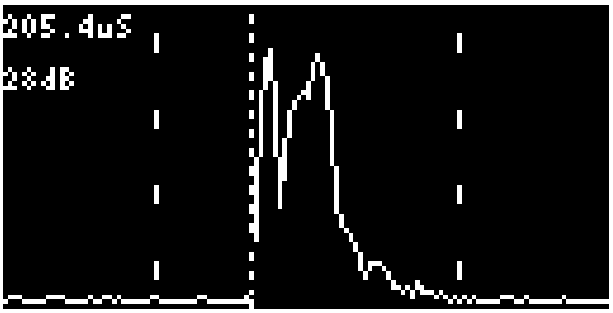


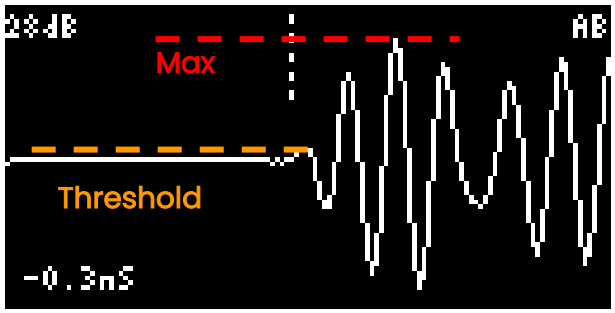
As the margin determined by the ESC is 14dB with negative polarity, the corresponding threshold is set at -20% on the signal.

The ESC mode has chosen the first clear alternation with good contrast. The threshold value corresponds to the middle position of the half-wave, to prevent the measurement point changing in the event of a variation in the shape of the signal.

The measurement point used for the measurement can be modified manually by changing the value of the margin (possible using the "Automatic" gain mode)

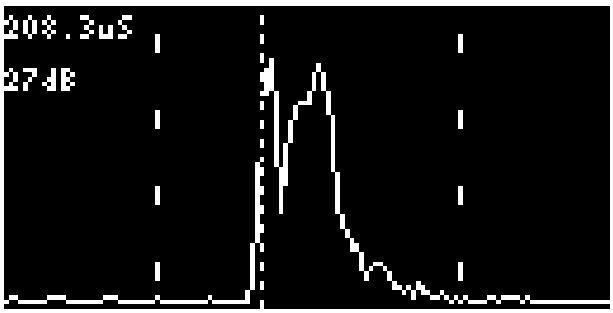
- Margin at 34dB, positive polarity (i.e. a threshold of +2%):

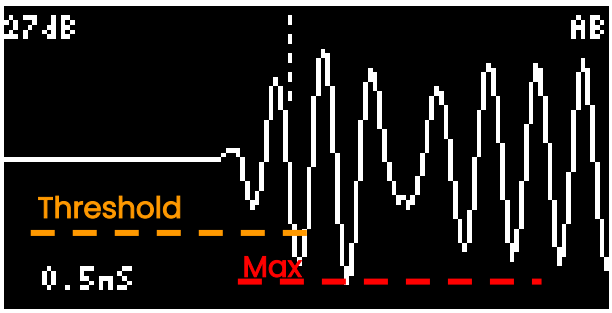




We can see that the time measurement has decreased by half an interval (about 1µs at 500kHz) because we are measuring the signal earlier, but there is a risk of measuring noise.

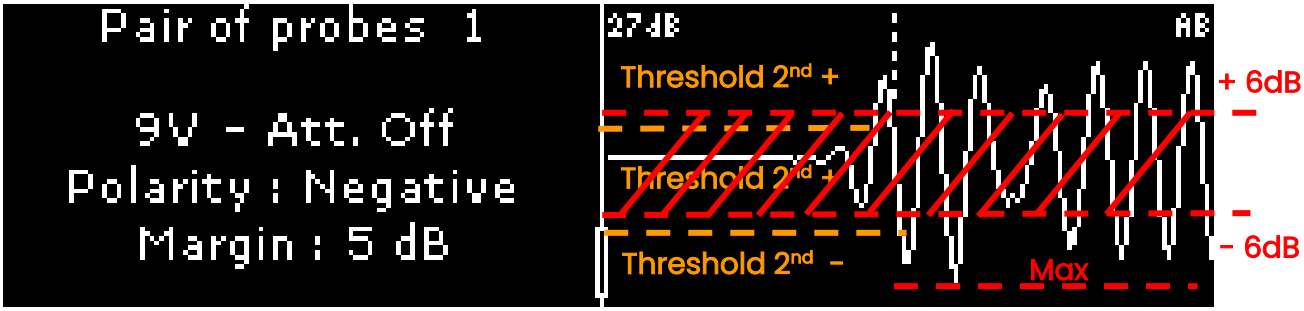
- Margin at 4dB, negative polarity (i.e. a threshold at -63%):





We can see that the time measurement has increased by one half-wave (approximately 2µs at 500kHz) because we are measuring further along the signal. It is advisable to measure earlier on the ISD signal, because the further along the signal you measure, the greater the risk of recombination and therefore of losing accuracy (if you want to differentiate between fluids that are close in speed of sound, with differences of less than 5m/s, i.e. of the order of 0.5%).

To see the impact of the way the probes are used, we then reset the measurement with a pair of probes set to **PSD use**.



The PSD ESC will choose the threshold with the best contrast, with a margin of **less than 6dB**. In this case, it will measure on the 2nd negative alternation, halfway between the 2 alternation peaks, i.e. 5dB here (as the calculation is automatic, it is more accurate than a visually estimated threshold, i.e. 4dB for the previous case in ISD).

In this example, the ESC did not choose the 2nd positive alternation because the corresponding threshold, estimated at between 30 and 40% (i.e. around 9dB), would have been less than 50% (i.e. 6dB).

The device quickly loses the measurement if the sphere/scraper passes over, resulting in a drop in the power of the signal received. This loss will be possible if the gain control (AGC) is not too reactive (which is generally the case with pig/sphere wiper transit times of the order of a second).

In the same way, it is also important to ensure that the device cannot recover a measurement if "long" wipers are used (acoustic path length consistent with the diameter of the pipe after multiple bounces against the scraper).

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