

ULTRASOUND CONTROLLER

Model D72

Manual



AQ Elteknik AB

ULTRASOUND CONTROLLER

D72 RevD

- **Manual version: 4.00**
- **Program version: 4.0x**

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AQ Elteknik AB

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1. Manufacturer information

AQ Elteknik AB operates a policy of on-going development and reserves the right to make changes and improvements to any of the products described in this manual without prior notice.

Under no circumstances shall AQ Elteknik be held responsible for any loss or indirect damage howsoever caused. The contents of this document are provided as it is. AQ Elteknik AB reserves the right to revise this document or withdraw it at any time without prior notice.

Version

It is important that the manual version agree with the software version and hardware revision of D72. See page 2. Note that terminal numbers are different on different revisions.


This manual can be downloaded at www.aqelteknik.se

The software version and hardware revision of D72 is shown briefly on the display when power is switched on.

Manufacturer Declaration of Conformity

Manufacturer: AQ Elteknik AB Sweden declares, that the product:

Ultrasound Controller Model D72 marked with CE-label conforms with the following standards: EN 61000-6-2:2001, EN 61000-6-4:2001, EN55011 (Group 1, Class B).

Ultrasound Controller Model D72 marked with  conforms to WEEE directive 2002/96/EC. The Ultrasound Controller Model D72 also conforms to RoHS directive 2002/95/EC. When the D72 is to be discarded, send it back to AQ Elteknik AB for safe disposal.

Limited Warranty

AQ Elteknik AB warrants to the original end user that the Ultrasound Controller D72 is free from any defects in materials or workmanship for a period of one year from the date of purchase. During the warranty period, should the Ultrasound Controller D72 have indications of failure due to faulty workmanship or materials, AQ Elteknik AB will replace it with no charge. This warranty shall not apply if the Ultrasound Controller D72 is modified, misused or subjected to abnormal working conditions.

Replacement as provided under this warranty is the only remedy of the purchaser. The purchaser pays freight to AQ Elteknik AB. AQ Elteknik AB shall in no event be held liable for indirect or consequential damages of any kind or character to the purchaser.

Warning

The Ultrasound Controller D72 is intended to be used with the Air Sensor or the Level Switch, all of them manufactured by AQ Elteknik AB. AQ Elteknik AB takes no responsibility for any possible damage that could happen if any other sensor not manufactured by AQ Elteknik AB is connected to the Ultrasound Controller D72.

Manufacturer Information

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Certificate of Quality and Function

AQ Elteknik AB guaranties that the Ultrasound Controller D72 has passed function tests and quality tests.

2. Introduction

Ultrasound Controller D72

Ultrasound Controller D72 uses ultrasound to make measurements. It can detect bubbles in flowing liquid or it can detect presence of liquid behind a container wall or it can measure continuous liquid level. The Ultrasound Controller D72 has three different modes of operation:

- **Air Sensor mode:** The Air Sensor monitors the presence of gas or particles in flowing liquid. The Air Sensor is very reliable and easy to use. Two Air Sensors can be connected to one Ultrasound Controller D72.
- **Level Switch mode:** The Level Switch is a small sensor which attached to the outside of the container can sense the presence of liquid inside the container without making hole in the container. Four Level Switches can be connected to one Ultrasound Controller D72.
- **Level Sensor mode:** Continuous liquid level is measured with a Level Switch attached under the container bottom (no hole in the container). High accuracy is achieved with a second Level Switch measuring liquid sound velocity. Two levels can be measured with one Ultrasound Controller D72.

Installing the Ultrasound Controller D72

The Ultrasound Controller D72 should be installed protected from dust and water. It is made to be attached to a DIN-rail, to which it snaps easily and can be removed by pushing up and bending the top out. The connector terminals 1-7 and 8-17 can be removed by pulling the connector out. The D-sub connector has two 4-20mA outputs (or Profibus communication for Profibus version DP72).




D72 D-sub pin	Signal
1	Cable screen
2	
3	(reserved profibus B+P)
4	+ 4-20mA output B
5	Ground - 0V
6	
7	
8	(reserved profibus A-N)
9	+ 4-20mA output A

The Ultrasound Controller D72 should be installed in accordance with national regulations. A person with the required knowledge should perform the installation.

Minus of the power source (24V MINUS) may be connected to the system ground if possible. Voltage on the power inputs should not exceed 35V relative ground.

D72 Connector Terminal	Connections to terminal
1	+ power PLUS 24V
2	- power MINUS Ground
3	Relay 1,2,3,4 common
4	Relay 1
5	Relay 2
6	Relay 3
7	Relay 4

Using the Ultrasound Controller D72

<p>Use the BACK button to go back to previous menu-level or To cancel a Selected operation</p> 	<p>Use the MENU button to scroll trough the menu or Scroll trough a list of parameter-values</p> 	<p>Use the SELECT button to select a menu-item or Confirm the selection of a parameter-value</p> 
--	--	--

Keep MENU pressed to scroll continuous trough parameter values. Press BACK while pressing MENU to scroll backwards.

Sensor MODE and the start-screen

As soon as the power is applied to the Ultrasound Controller D72 it starts displaying the program revision on the LCD-display, quickly followed by the start-screen. Depending on to which mode it is set; the corresponding start-screen will be shown. The Ultrasound Controller D72 can be set to either Air Sensor mode, Level Switch mode or Level Sensor mode. This determines the kind of sensor that can be connected. When the Ultrasound Controller D72 is powered on for the first time "Set sensor MODE" is displayed. Then press MENU to scroll to the desired mode and press SELECT. How to change sensor mode once it has been set is described in ADVANCED SETTINGS.

3. The MENU structure

Air Sensor Mode

CALIBRATION

Calibrate LIQUID AS 1
Calibrate AIR AS 1
Calibrate LIQUID AS 2
Calibrate AIR AS 2

SHOW DATA

Air Sensor 1
Calibration Data
Normal Measurement Data
Very Low Sensitivity Data
Air Sensor 2
same as above
AUXILIARY DATA

SETTINGS

SET Air Sensor 1 parameters
SET TYPE
SET DIAMETER
SET SENSITIVITY
SET FILTER
SET Air Sensor 2 parameters
same as above
SET RELAY 1
SET RELAY 2
SET RELAY 3
SET RELAY 4
SET mA output A
SET mA output B

HELP

CONNECTOR Terminals 1-7
CONNECTOR Terminals 8-17
Information
Program version

ADVANCED SETTINGS

set sensor MODE
SIMULATE
RESTORE settings and calibrations

Level Switch Mode

CALIBRATION

CALIBRATE with AIR (empty)
Level Switch 1
Level Switch 2
Level Switch 3
Level Switch 4
LS1-LS4 together
CALIBRATE with LIQUID (full)
same as above

SHOW DATA

LevelSwitch 1
Echo DATA
WR DATA
Auxiliary data
LevelSwitch 2
same as above
LevelSwitch 3
same as above
LevelSwitch 4
same as above
Test LevelSwitch

SETTINGS

SET parameters LevelSwitch 1
SET Type AND Technique
SET FILTER
SET ECHO-DISTANCE
SET Jacket
SET FREQUENCY
SET parameters LevelSwitch 2
same as above
SET parameters LevelSwitch 3
same as above
SET parameters LevelSwitch 4
same as above
SET RELAY 1
SET RELAY 2
SET RELAY 3
SET RELAY 4

HELP

CONNECTOR terminals 1-7
CONNECTOR terminals 8-17
Information
Program version

ADVANCED SETTINGS

Set sensor MODE
SIMULATE
RESTORE settings and calibrations

Level Sensor Mode

CALIBRATION

CALIBRATE with AIR (low)
Level Sensor 1
Level Sensor 2
CALIBRATE with LIQUID (high)
Level Sensor 1
Level Sensor 2

SHOW DATA

Level Sensor 1
Level
Sound Velocity
Calibration Data
Level Sensor 2
same as above

SETTINGS

SET parameters Level Sensor 1
SET 100% Level
SET 0% Level
SET Liquid Sound VELOCITY
SET Velocity Sensor EchoDISTANCE
SET Velocity Sensor HEIGHT
SET Container Bottom-Thickness
SET Container Wall-Thickness
SET Container Wall-Thickness
SET parameters Level Sensor 2
same as above
SET mA output A
SET mA output B
SET RELAY 1
SET RELAY 2
SET RELAY 3
SET RELAY 4

HELP

CONNECTOR Terminals 1-7
CONNECTOR Terminals 8-17
Information
Program version

ADVANCED SETTINGS

set sensor MODE
SIMULATE
RESTORE settings and calibrations

4. Air Sensor Mode

In Air Sensor mode the Air Sensor is used to measure the presence of bubbles in flowing liquid. One or two Air Sensors model SAC, PAC, FCS or FCP can be connected to one Ultrasound Controller D72.

Functional Description

Bubbles in the liquid flowing through the Air Sensor are monitored by the use of ultrasound. Inside the Air Sensor two low intensity beams of ultrasound are transmitted across the liquid-path in directions perpendicular to the liquid flow. If a bubble moves into one of the ultrasound-beams the ultrasound will be partially deflected and the intensity of the ultrasound decreases. The controller constantly measures the intensity of the ultrasound and if the intensity becomes lower than the threshold it detects a bubble. Dense particles in the liquid can also deflect the ultrasound in a similar way and can therefore be detected.

The measurements of very low sensitivity and very very low sensitivity uses a different measurement technique. It measures how ultrasound vibrations in the Air Sensor walls are dampened by the presence of liquid inside.

The measurement accuracy depend on how well the Air Sensor is calibrated, the flow-rate, the type of liquid, how the Air Sensor is mounted and weather there is a single bubble or many bubbles and the Air Sensor size.

Installing the Air Sensor

How to install the Air Sensor is described in the Air Sensor manual

Connecting the Air Sensor to D72

The cable from the Air Sensor should connect directly to the Ultrasound Controller D72. Maximum cable length is approximately 40m. The cable screen is important and must always be connected to connector terminal 11 or 16. Any unscreened part of the cable should be very short. (The outer screen which exists only on FCS and FCP should not connect to the Ultrasound Controller D72 but may be connected to ground via screened cable glands).

D72 Connector Terminal	Air Sensor	SAC & SAC Ex cable colour	PAC cable colour	FCP cable colour	FCS cable colour	FCS Ex cable colour
8	1	Brown	Brown	Brown	Brown	White
9	1	White	White	Brown Screen & Green Screen	Brown Screen & Green Screen	White Screen & Yellow Screen
10	1	Green	Green	Green	Green	Yellow
11	1	Screen & Yellow	Screen	White Screen	White Screen & Yellow Screen	Brown Screen & Green Screen
12	1		Yellow	White	White & Yellow	Brown & Green
13	2	Brown	Brown	Brown	Brown	White
14	2	White	White	Brown Screen & Green Screen	Brown Screen & Green Screen	White Screen & Yellow Screen
15	2	Green	Green	Green	Green	Yellow
16	2	Screen & Yellow	Screen	White Screen	White Screen & Yellow Screen	Brown Screen & Green Screen
17	2		Yellow	White	White & Yellow	Brown & Green

SETTINGS

Trough the SETTINGS-menu the parameters of the Air Sensor can be set.

Select **“SET TYPE”**: to set the type of Air Sensor connected. This tells the Ultrasound Controller D72 to make the correct adjustments for this Air Sensor type.

Select **“SET DIAMETER”**: to set it to the diameter of the connected Air Sensor or as close as possible. This tells the Ultrasound Controller D72 to make the correct adjustments for this Air Sensor diameter.

Select **“SET SENSITIVITY”**: to set the sensitivity. This determines how sensitive the Air Sensor is for bubbles. “SENSITIVITY” can be set to high, medium, low, very low and very very low.

At high sensitivity, a single bubble of approximately 2mm diameter can be detected.

At medium sensitivity, a single bubble of 3mm diameter can be detected.

At low sensitivity, a single bubble of approximately 10mm diameter can be detected. Low sensitivity is achieved by requiring both detectors inside the Air Sensor to detect bubbles at the same time. Many small bubbles together will be detected as if they were a single big bubble. Even tiny (microscopic almost invisible) bubbles can be detected if there are many of them.

High, medium and low sensitivity are considered normal measurement.

At very low and very very low sensitivity a different measuring technique is used. This technique measures the presence of liquid or no liquid, making the Air Sensor very insensitive for bubbles. Very low sensitivity can not be used for Air Sensors with diameter < 14mm. Very low sensitivity measurements have temperature dependence and should not be used if there are temperature variations of more than $\pm 5^{\circ}\text{C}$.

Select **“SET FILTER”**: to set the “FILTER”-time. It determines how the measurement-data is filtered. . It can be set to either integrate 1ms – 3s or delay 300ms – 10s.

Integrate means integrating (adding) the duration of each bubble. When the integrated sum becomes higher than the “FILTER-integrate”-time, air will be indicated. As soon as liquid again is indicated, the integration-process will start over again.

Delay means that air will be indicated only after air has been detected for a continuous time longer than “FILTER-delay”.

Long “FILTER-delay” and low “SENSITIVITY” is useful if some quantities of bubbles should be undetected.

Short “FILTER-integrate” and high “SENSITIVITY” is useful when few bubbles should be undetected.

Select **“SET RELAY”**: to set how the relays should act. There are four relays each with one normally open contact (at power off the relays are open). Each relay can be set independently. Choose between Closed with air or closed with liquid and choose between Air Sensor 1 and Air Sensor 2. The duration of air being indicated is minimum 0,5 second even if the bubble is quickly passing by (to make sure the indication of air is registered).

Select **“SET mA output”**: to set the assignment of the mA-outputs. There are two mA-outputs: A and B. They can be assigned to Air Sensor 1 or Air Sensor 2. The mA-outputs can be set to:

“Normal Measurement Data” Shows a combination of the analog **Ndata** during the time LIQUID is indicated and switching to 6mA when AIR is indicated according to settings of SENSITIVITY and FILTER. **Ndata** changes very slowly.

20mA = **Ndata** =150%.

16mA = **Ndata** =100%

12mA = **Ndata** = 50%

8mA = **Ndata** = 0%

6mA = Air is detected (Air indication time is minimum 0,5 second)

4mA = error

“All Sensitivities” It shows detecting AIR with all possible SENSITIVITY settings but no analog data. AIR indication time is always minimum 0,5 second.

16mA = Liquid

14mA = small bubble

12mA = medium bubble

10mA = big bubble

8mA = very big bubble

6mA = almost empty

4mA = error.

Air Sensor start-screen

When power is applied, the Air Sensor start-screen is displayed showing something like this:

```
1 --- AirSens
2 --- 1234
```

On the first line to the right is written **AirSens** meaning this is Air Sensor-mode. The first digit to the left indicates Air Sensor 1 and Air Sensor 2. Following the digit is diagnostic information about each Air Sensor:

---	No Air Sensor is connected and "Air Sensor TYPE or DIAMETER" is set to "no Air Sensor"
set	Settings are missing
cal	Waiting for calibration to be done
CalAir	Waiting for calibration of Air to be done
CalLiq	Waiting for calibration of Liquid to be done
err 1	Error, no Air Sensor is detected
err 2	Error, NAir too high, see troubleshooting
err 3	Error, VLthld too low, see troubleshooting
err 4	Error, NLiq too low, see troubleshooting
AIR	Air or bubble is detected
LIQUID	Liquid without bubble is detected.

(LIQUID is blinking if measurement data is higher than expected suggesting a new calibration may be advisable)

On the second line to the right is written **1234** which shows the state of each of the four relays. A dark background signifies a closed relay.

ADVANCED SETTINGS

Select "**Set sensor MODE**": to set either Air Sensor mode, Level Switch mode or Level Sensor mode. It determines which sensor can be connected. Changing sensor mode does not alter any settings or calibrations.

Select "**SIMULATE**": to simulate detection of air or liquid. Press SELECT to toggle between simulation of AIR and LIQ. Press MENU to change between Air Sensor 1 and 2.

Select "**RESTORE settings and calibrations**": to restore all settings and calibrations to factory-settings.

CALIBRATION

Calibration must be done both for air (empty Air Sensor) and liquid (full Air Sensor) and it can be done in any order. To calibrate liquid, make sure there is liquid inside the Air Sensor and select "**calibrate LIQUID**" (and press SELECT one second). To calibrate air make sure the Air Sensor is empty and select "**calibrate AIR**" (and press SELECT one second). During calibration of liquid, D72 adjusts the intensity of the ultrasound-beams to become 100% with liquid. Each Air Sensor should be calibrated after installation. After the calibration it is advisable also to check the values in "SHOW DATA" (see below).

A new calibration of liquid may be required if the liquid properties has changed significantly since the last calibration. For the Air Sensor PAC or FCP a temperature change over 20°C requires a new calibration of liquid and air.

SHOW DATA

During normal measurement the Air Sensor transmits beams of ultrasound and listens to the sound. Bubbles scatter the sound and thereby reduce the sound intensity and in this way the Air Sensor detects air. Each Air Sensor uses two beams to make two measurements, perpendicular to each other. During the very low sensitivity measurements the Air Sensor transmits beams of ultrasound and listens to how fast the vibrations within the walls of the Air Sensor disappears into the liquid inside the Air Sensor.

Select "**Calibration Data**": to show **NLiq**: normal measurement liquid signal, which is measured in dB. **NLiq** is measured and stored during calibration. If **NLiq** is low, err 4 will be shown, see troubleshooting. Also shown is **Nair**: normal measurement air signal relative to **NLiq**, which is measured in %. **Nair** is measured and stored during calibration.

Select "**Normal Measurement Data**": to show **Ndata**: the current normal measurement signal relative to **NLiq** which is measured in %. With liquid in the Air Sensor, **Ndata** is expected to be near 100%. If it deviates too much from 100% (>120% or < 80%) it is advisable to calibrate the Air Sensor with liquid again. With air in the Air Sensor, **Ndata** is typically <20%. The threshold of **Ndata** at which air bubbles are detected depends on the sensitivity setting and the type and size of Air Sensor (approximately at high sensitivity 44% and at low sensitivity 27%).

Select "**Very Low Sensitivity Data**": to show **VLdata**: very low sensitivity measurement data and **VLthld**: very low sensitivity calibrated and stored threshold. With air, **VLdata** becomes close to zero and with liquid, **VLdata** becomes

higher than **VLthld**. **VLthld** depends on the type of Air Sensor. Air Sensors with diameter < 14mm can not use very low sensitivity. err 3 is displayed if **VLthld** becomes too low for reliable measurements, see troubleshooting.

Select “**AUXILIARY DATA**”: to show unprocessed data from the Air Sensor.

HELP

Select “**HELP**”: to show information about connecting the Ultrasound Controller D72.

Sound velocity in the Air Sensor

When there are two liquids with significant different sound velocity in the Air Sensor and these liquids are not well mixed, there can be a false indication of air. It happens because the sound is refracted when it travels from one liquid to the other. Setting longer filter times may filter out the false indication of air. Sound velocity of liquids lies usually in the range 900-2000m/s. If the sound velocity is outside this range the Air Sensor may not work. Air Sensor with sensitivity set to very low is not affected by sound velocity.

Air Sensor TROUBLESHOOTING

Air or Liquid is indicated on the display but the relay does not change = “RELAY” setting is wrong.

Display shows:

cal, **CalAir** or **CalLiq** = Calibration must be done.

set = Settings of “TYPE” or “DIAMETER” is missing

err 1 = No Air Sensor is detected. The reason for this can be wrongly connected Air Sensor, or faulty Air Sensor.

err 2 = The relative signal with Air is too strong (at low, medium or high sensitivity). err 2 is shown if **NAir** is higher than 21-25%.

The reason for this can be:

1. Calibration of AIR has been done with liquid in the Air Sensor.
2. Wrong settings of Air Sensor Type or Diameter.
3. Electric interference.
4. A faulty Air Sensor.

Electric interference will show itself as **Ndata** being high and unstable with Air in the Air Sensor. To minimize the risk of interference it is important that sources of interference like frequency **inverters** should use screened cables to the motor. Also any unscreened part of the cable between the Air Sensor and D72 should be short. If ex-barriers are used, Ex-barriershields must be used especially if there is more than one D72.

err 3 = There is not enough signal difference between air and liquid (at very low or very very low sensitivity). err 3 is shown if Very Low sensitivity threshold is not high enough for reliable measurement (**VLthld**<6). Air Sensor with diameter less than 16mm may have difficulty measuring at very low sensitivity. Change “SENSITIVITY” to low, medium or high instead or try with a larger diameter Air Sensor.

err 4 = The absolute signal with Liquid is too weak (at low, medium or high sensitivity). err 4 is shown if the calibrated data with Liquid **NLiq** is too lower than approximately 38dB for SAC and FCS or 35dB for FCS Ex or lower than 40dB for FCP.

The reason for this can be:

1. Calibration of LIQUID has been done with air in the Air Sensor.
2. Wrong settings of Air Sensor Type or Diameter.
3. Wrong connected Air Sensor.
4. The liquid is attenuating the ultrasound. If the liquid contains many tiny bubbles the signal with Liquid can become too weak.
5. A faulty Air Sensor

5. Level Switch Mode

In Level Switch Mode the Level Switch measures a single level (from the side of the container). It measures the presence or no presence of liquid behind the container (or pipe) wall. The Level Switch senses through the wall (no hole is needed). Four Level Switches can be connected to one Ultrasound Controller D72.

Connecting the Level Switch to D72

The cable from the Level Switch should connect directly to the Ultrasound Controller D72. (Yellow and green cable are not used.) Maximum cable length is approximately 40m. The cable screen is important and must always be connected to connector terminal 11 or 16. Any unscreened part of the cable should be very short. (connections are different in each revision of D72)

Level Switch Type and Technique

There are two different measuring techniques Echo and WR (Wall Reverberate) and there are three different Level Switches: Level Switch KS, Level Switch LS and Level Switch RS.

Echo Technique

The Echo technique uses echo from a reflecting surface inside the container (usually the opposite container wall) to determine if there is liquid or not inside. Level Switch KS or Level Switch LS can be used but not Level Switch RS.

Connector Terminal	Level Switch Cable
8	Level Switch 1 Brown
9	Level Switch 1 White
10	Level Switch 2 Brown
11	Level Switch 1,2 Screen
12	Level Switch 2 White
13	Level Switch 3 Brown
14	Level Switch 3 White
15	Level Switch 4 Brown
16	Level Switch 3,4 Screen
17	Level Switch 4 White

The ECHO-technique transmits short sounds and then measures the echo bouncing on the reflecting surface. When there is an echo, there is liquid inside and with no liquid there is no echo (ultrasound do not travel very well into air). The liquid must not attenuate the sound too much. Small bubbles and particles in the liquid can cause attenuation and unmixed liquids having different sound velocities can cause refraction of the sound and thereby wrong indication of low level. It is important that the soundbeam from the sensor is reflected back to the sensor and not diverted in the wrong direction.

It is desirable that the ultrasound passes as easy as possible through the container wall. How well it passes depend on the wall material and thickness. Steel or glass wall should be in the range 1,2mm - 15 mm and plastic wall <15mm (PP<10mm). Plastic with fibreglass can be troublesome. Testing on the actual container is recommended. Any welding or other unevenness in the wall should be avoided as it can refract (bend) the soundbeam in an unwanted direction.

The ultrasound beam behaves similar to a lightbeam, the direction of the echo depend on from what angle it hits the reflecting surface. Obstructing object in the path between sensor and the reflecting surface should be avoided. The sound beam is approximately 1cm in diameter. A tube in the centre of the container can give an echo but it is weaker than the echo from the opposite container wall. In case there are obstructing objects inside the container, perhaps the Level Switch RS with the WR-technique is a better choice.

On small containers, disturbing background echoes becomes stronger in relation to the echo. Level Switch LS and KS should therefore not be used on containers smaller than 44mm diameter.

WR Technique

The WR technique measures vibrations in the container wall to determine if there is liquid or not behind the wall. Level Switch RS should be used (and in some cases also Level Switch KS can be used)

The WR-technique transmits sound and then measures how quickly vibrations in the container wall disappear. Vibrations in the wall disappear more quickly with liquid inside. The WR-technique works well with most liquids since the sound does not have to travel through the liquid. But the WR-technique is dependent on the material and thickness of the wall. Steel or glass wall 1,2mm - 15 mm or plastic wall < 15mm (PP<10mm) should be ok. Plastic with fibreglass could be troublesome and testing on the actual container is recommended.

On plastic walls it is also possible to use Level Switch KS with the WR-technique however there can be temperature dependence. Level Switch KS can also be used with the WR-technique on a container with jacket to sense the presence of liquid in the inner container (if the gap between the jacket and the container is filled with liquid).

The WR-technique measures very small signal changes and is sensitive to small movements of the Level Switch. The Level Switch must therefore be glued. The WR-technique can also be sensitive to liquid drops remaining on the inside of the wall and sensitive to temperature changes. The advantage of the WR-technique is it is independent of liquid properties and that there is no need for a reflecting surface.

Mounting the Level Switch

How to mount the Level Switch on the container is described in Level Switch manual.

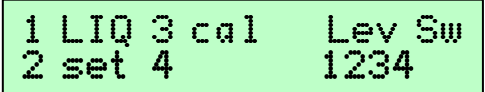
Level Switch start-screen

When power is applied, the Level Switch start-screen is displayed showing **Lev Sw** on first line to the right signifying this is Level Switch start-screen. . On the second line to the right is written **1234** which shows the state of each of the four relays. A dark background signifies a closed relay.

To the left are four small digits signifying Level Switch 1 2 3 and 4 with three-letter-text following each digit showing information about each Level Switch:

AIR	air is detected	LIQ	liquid is detected
cal	Waiting for calibration of Air and/or Liquid	set	parameters need to be set
--	Level Switch disconnected	err	error – see troubleshooting

Example: Level Switch 1 detecting liquid, Level Switch 2 connected but not set, Level Switch 3 need to be calibrated, Level Switch 4 No Level Switch.



```
1 LIQ 3 cal Lev Sw
2 set 4 1234
```

SETTINGS

Trough the SETTINGS-menu the parameters of the Level Switch can be set.

Select **“SET Type AND Technique”**: to set it to either Type “LS” and Technique “ECHO” or Type “RS” and Technique “WR” or “No Level Switch”. All other settings are for special cases only.

Select **“SET DISTANCE to reflecting wall”**: to set it between 46mm (minimum) and 600mm (maximum). This parameter is needed only if the “ECHO” technique is chosen and should be set to actual distance $\pm 10\%$.

Select **“SET FILTER”**: to set the filter-time between 0,5s 1s 2s or 4s. It determines how fast the Level Switch detects air or liquid.

Select **“SET Jacket”**: to set the distance in mm between jacket and container. Set it only if container has a jacket.

Select **“SET FREQUENCY”**: to set the measurement frequency. If set to Auto, the best frequency (1=1,1MHz, 2=1,5MHz, 3=2MHz or 4=2,2MHz) is automatically selected. Changing the “FREQUENCY” does not change the calibration.

Select **“SET RELAY”**: to set how the relays should act. Each relay have one normally open contact (at power off the relay is open). There are four relays and each relay can be controlled independently by any Level Switch. Choose between Closed with air or closed with liquid. It is also possible to set one relay to be controlled by two Level Switches.

Example (pump filling a container): LS1 is placed high and LS2 is placed low on a container. The relay is set to: “Open LS1 Liq, Closed LS2 Air”. When liquid level drops below LS2, the relay closes (starting the pump to fill the container). When liquid level rises to LS1, the relay opens (stopping the pump).

Example (pump emptying container): LS1 is placed high and LS2 is placed low on a container. The relay is set to: “Open LS2 Air, Closed LS1 Liq”. When liquid level rises to LS1, the relay closes (starting the pump to empty the container). When liquid level drops to LS2, the relay opens (stopping the pump).

Container with jacket

In a container with a jacket the small space between the container and the jacket is filled with liquid to regulate the temperature of the inner container. This is a special case when a Level Switch KS can use the Technique set to “WR” and “Jacket” set to the distance between the jacket and container walls. Measurements will then be made on the inner container using the WR technique. The space between the jacket and container must be filled with liquid.

CALIBRATION

Select **“CALIBRATION”**: to calibrate the Level Switch. Each Level Switch must be calibrated after installation. Calibration must be done both for liquid and for air. The order or the time between the calibration of air and liquid is of no importance.

A new calibration has to be done if the Level Switch is moved and should be done if the temperature or the liquid properties has changed significantly since the last calibration. To see how well the Level Switch behaves at different temperatures or with a different liquid the measurement data can be checked.

SHOW DATA

Select “**Echo DATA**”: to show **Edata**: echo measurement data relative to **ELiq**. During calibration it is set to be 100% with liquid. **Efrq**: shows the frequency (1, 2, 3 or 4). On the second line threshold **Ethd**: is displayed. If **Edata** is higher than **Ethd** then liquid is detected. **ELiq**: shows echo calibrated liquid data in 0,7dB units. Maximum is 100 and measuring becomes unreliable when it is too low.

Select “**WR DATA**”: to show measurement data of the WR-technique. This screen shows first **Wdata**: WR measurement data. **Wdata** is approximately zero when there is air. With Liquid it becomes approximately twice **Wthld**. **Wfrq**: shows the frequency that has been chosen either manually or automatically (1, 2, 3 or 4). The best frequency depends on the container wall thickness. On the second line is **Wthd**: WR threshold which is the value of **Wdata** at which indication changes between Air and Liquid. If **Wdata** is higher than **Wthd** then liquid is indicated. **Wthd** is set during calibration to half the value of **Wdata** with Liquid. **Wss**: approximate signal (set at calibration) in 0,3dB units.

Select “**Auxiliary data**”: to show unprocessed data from the Level Switch.

Select “**Test Level Switch**”: to show test-data for the Level Switch when it is not attached to a container. A value is shown for each Level Switch. If the Level Switch is correctly connected a value between 0 and 100 should be shown. If by pressing on the inner side of the Level Switch with your finger this value increases then the Level Switch is working. A Level Switch wrongly connected or unconnected may show a value higher than 100.

ADVANCED SETTINGS

Select “**Set sensor MODE**”: to set either Air Sensor mode or Level Switch mode or Level Sensor mode. It determines which sensor can be connected. Changing sensor mode does not alter any settings or calibrations.

Select “**SIMULATE**”: to simulate detection of air or liquid. Press SELECT to toggle between simulation of Air and Liq. Press MENU to change between Level Switch 1, 2, 3 and 4.

Select “**RESTORE settings and calibrations**”: to restore all settings and calibrations to factory-settings.

HELP

Select “**HELP**”: to show information about connecting the Ultrasound Controller D72.

Sound velocity and the Level Switch

When “ECHO Technique” is used and there are two liquids with significant different sound velocity in the container and these liquids are not well mixed, then there can be a false indication of air because the sound is refracted at the surface between the two liquids. Sound velocity of liquids lies usually within 900-2000m/s. A sound velocity outside this range may be compensated by increasing or decreasing “DISTANCE to reflecting wall”.

Measurement Reliability

Measurement reliability is good but many factors determine the reliability (wall material, wall thickness, liquid properties, temperature and glue). Therefore it is always advisable to make tests under varying conditions and temperatures. Best is to test and evaluate both Level Switch RS and Level Switch KS before deciding.

Level Switch TROUBLESHOOTING

Display shows:

-- = The Level Switch is not connected or there is a short circuit.

cal = Calibration has not been done. It must be calibrated both for Air and Liquid before cal disappears.

set = "Echo" technique is chosen and the "DISTANCE to reflecting wall" is not set.

The relay does not change but the display changes between Air and Liquid. Wrong setting of "RELAY".

err = Measurement can not be done. During calibration there was not enough difference between the signal with air and with liquid: For "Echo" technique Echo threshold **Ethd** must be < 50% and for "WR" technique WR threshold **Wthd** must be > 5. The reason for **err** can be:

- Calibration was made for Air but there was Liquid in the container or calibration was made for Liquid but there was Air in the container.
- The Level Switch is not attached correctly to the container. There is a tiny air-gap between the Level Switch and the container.
- If "ECHO" technique is chosen and the "DISTANCE to reflecting wall" is wrong.
- If "ECHO" technique is chosen and the echo is reflected in a direction where it does not reach the Level Switch.
- If "ECHO" technique is chosen and the something is between the Level Switch and the reflecting wall.
- The liquid does not let through enough sound. Try Level Switch RS instead of Level Switch LS.
- The container wall does not let through enough sound. Try a different "FREQUENCY" or set it to Auto.
- Wrong connection or faulty Level Switch. Select "**Test Level Switch**": to test the level switch and its connection.

Electric interference can show itself as **Edata** being unstable with Air or **Wdata** being unstable with liquid. To minimize the risk of interference it is important that sources of interference (like frequency inverters) should use screened cables to the motor. Also any unscreened part of the cable between the Level Switch and D72 should be short. If ex-barriers are used, Ex-barriershields must be used especially if there is more than one D72.

6. Level Sensor Mode

In Level Sensor mode a level sensor is attached at the bottom of the container and measures the continuous liquid level. The level sensor is attached outside the container and senses through the bottom (no hole is needed).

A velocity sensor can also be attached, measuring sound velocity.

Two level sensors and two velocity sensors can be connected to one Ultrasound Controller D72.

Functional Description

The level sensor is attached under the container. It sends ultrasound through the bottom and through the liquid, towards the surface where the sound bounces back to the level sensor. D72 measures the time for the echo and calculates the level.

Measurement accuracy is dependent on liquid sound velocity which can vary with liquid and temperature. A velocity sensor can be attached on the container's vertical wall sending ultrasound through the wall and through the liquid. D72 measures the echo that bounces on the opposite container wall (or other reflecting surface inside the container). The velocity sensor can also make level measurement. It can tell whether there is liquid or air behind the wall and this can be used for increased reliability, see SETTINGS.

In order to measure properly the echo should be as loud as possible. The echo is attenuated by travelling through the bottom and travelling through the liquid. Small bubbles and particles in the liquid cause additional attenuation. The echo can disappear completely if it does not bounce back toward the level sensor. Unmixed liquids having different sound velocities can cause refraction of the sound beam so it does not bounce back toward the level sensor. How quiet the echo has become can be checked in SHOW DATA.

Either Level Switch KS or LS can be used as level sensor and as velocity sensor; Level Switch RS can not be used.

D72 Connector Terminal	Cable
8	Level sensor 1 Brown
9	Level sensor 1 White
10	Velocity sensor 2 Brown
11	Level sensor 1 Screen , Velocity sensor 2 Screen
12	Velocity sensor 2 White
13	Level sensor 2 Brown
14	Level sensor 2 White
15	Velocity sensor 1 Brown
16	Level sensor 2 Screen , Velocity sensor 1 Screen
17	Velocity sensor 1 White

Connecting the level sensor to D72

The cable from the level sensor and velocity sensor should connect directly to the Ultrasound Controller D72. (Yellow and green cable are not used.) Maximum cable length is approximately 40m. (Short cable is better because it has less attenuation) The cable screen is important and must always be connected to connector terminal 11 or 16. Any unshielded part of the cable should be very short.

Mounting the level sensor

The level sensor (= Level Switch) is mounted under the container. It is important the ultrasound pass as easy as possible through the container bottom. How well it passes depends on the wall material and thickness. Steel or glass bottom 1,2mm - 6 mm are ok. Plastic bottom < 15mm (PP<10mm) is ok. Plastic with fiberglass < 8mm is ok. Testing on the actual container is recommended.

When the bottom is very thick, vibrations within the wall makes accurate measurements of low levels difficult. Minimum level that can be measured depends on the bottom thickness and its material. As the sound passes through the bottom it makes the bottom vibrate and these vibrations take time to decay especially if the bottom is thick. On a 3mm thick stainless-steel-bottom liquid levels down to 30mm can be measured.

If the bottom thickness can be chosen, a thickness with resonance at 2MHz is preferred since at this frequency the sensor has maximum gain. For stainless steel this is approximately 1,5mm, 3mm or 4,5mm.

The ultrasound beam is narrow (less than 10°) so the level sensor must be aimed in such a way that the echo from the surface is properly returned back to the level sensor. See below what to do with a non-horizontal container bottom.

See Level Switch manual how to glue the level sensor.

Installing the level sensor on a non horizontal bottom

If the bottom is not horizontal or has uneven thickness, a lot of silicone can be used to glue the level sensor inclined. In this case the level sensor should be connected to D72 and be active measuring while it is being glued so that it can be adjusted for loudest echo. Loudest echo may not be at exactly horizontal position. The deviation from horizontal bottom for stainless steel must be less than 10°. Fill the container above half and place the level sensor with silicone in a position expected to be good and calibrate liquid. If there is no error go to SHOW DATA Level Sensor measured data. The echo strength is shown in dB. Adjust the angle of the level sensor for maximum echo strength. Then calibrate liquid again and check the angle of the level sensor. Then hold it there for 24hours.

Another solution is to make a level sensor in such a shape that it fits the container.

Mounting the velocity sensor

A velocity sensor (= Level Switch) must be mounted so it can measure the echo bouncing at the opposite container wall. Preferably it is mounted quite low on the container since it needs liquid to measure the velocity. How well sound passes trough the wall depend on the material and thickness, see above.

See Level Switch manual how to glue the velocity sensor.

Container top

When the container is full with liquid all the way up to the top the ultrasound will bounce on the top. If the inside of the top is not horizontal and flat just above the level sensor the echo may bounce in wrong direction.

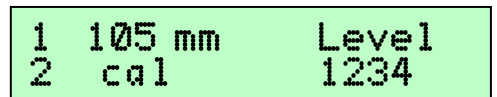
Level Sensor start-screen

When power is applied, the Level Sensor start-screen is displayed showing **LevlSens** on first line to the right signifying this is Level Sensor start-screen. On the second line to the right there are four small numbers **1234** which shows the state of each of the four relays. A dark background signifies a closed relay.

To the left, the digit 1 signifies Level Sensor 1, followed by the measured level in %. If no measurement can be done there is text with information instead. On the second line, the digit 2 signifies Level Sensor 2.

cal	calibration needs to be done of air or liquid	set	parameters need to be set
---	not active	err	error – see troubleshooting
> xx	level is over xx mm (over 100%)		
< xx	level is below xx mm		

Example: Level Sensor 1 105mm
Level Sensor 2 need to be calibrated



SETTINGS

Trough the SETTINGS-menu the parameters of the Level Sensor can be set.

Select **“SET 100% Level”**: to set the level which correspond to 100% level. Level between 100% and 170% will be shown as >xxx. Any level over 170% will not be measured at all and should be impossible level.

Select **“SET 0% Level”**: to set the level xx which correspond to 0% level. Any level below 0% will be shown as <xx.

Select **“SET Liquid Sound Velocity”**: This parameter is used only if sound velocity measurement can not done because of no velocity sensor. It should be set to the value of the liquid.

Select **“SET Velocity Sensor EchoDISTANCE”**: to set distance (in mm), from the velocity sensor to the reflecting surface, but it is only the distance trough liquid. Set it to “.” if no velocity sensor is used to make velocity measurements. Distance < 70mm can be troublesome

Select **“SET Velocity Sensor HEIGHT”**: to set the height (in mm) above the bottom where the velocity sensor is placed. If this value is set, the level measurements of the velocity sensor are used to limit the level sensor measurement. Set it to “.” if the velocity sensor should be used only for velocity measurements.

Select **“SET Velocity Sensor Control”**: to set how the Velocity Sensors Air/Liq-measurement is used. Set to “Velocity only” it is not used. Set to “Limits” it sets limits for the level measurements. Set to “Zero below” it makes level zero below Velocity Sensor.

Select **“SET Container Bottom-Thickness”**: it is used to add sound travelling time trough the bottom.

Select **“SET Container Wall-Thickness”**: it is used to add sound travelling time through the wall.

Select **“SET RELAY”**: to set how the relays should act. Each relay has one normally open contact (at power off the relay is open). There are four relays and each relay can be controlled independently.

CALIBRATION

Select **“CALIBRATION”**: to calibrate. Each level sensor must be calibrated after installation. Calibration should be done for liquid with minimum 70% full container. Do not fill completely if the container top does not reflect the echo well. During calibration D72 measures different frequencies and selects the one producing the strongest echo. Calibration should also be done for air (with liquid level below the velocity sensor) but only necessary if a velocity sensor is used. If possible calibrate with the liquid that is going to be used or a similar one.

A new calibration has to be done if the level sensor or the velocity sensor is moved.

If there is a velocity sensor the calibration measures the sound velocity and this measurement will be used when the liquid level is below the velocity sensor.

It is important to check (in SHOW DATA) that the echo is at least 10dB above the threshold.

SHOW DATA

Select **“Level Sensor x measured data”**: to show level **mm** echo strength **dB** average good echo **%Echo** and threshold **Thld dB**. It is important to check the value of echo strength and threshold to make sure the echo strength is above threshold. Echo strength below threshold will not be accepted. Threshold is determined by the amount of background noise.

Select **“Velocity Sensor x measured data”**: to show sound velocity **m/s**, echo strength **dB** and echo strength divided by calibrated liquid echo strength **%**.

Select **“Level Sensor x calibrated data”**: to show calibrated signal strength **dB** and calibrated frequency **MHz**.

Select **“Velocity Sensor x calibrated data”**: to show calibrated velocity **m/s**, calibrated signal strength **dB**, calibrated frequency **MHz** and calibrated threshold for detecting liquid **%**. Calibrated threshold must not be too high, less than 50% is good.

ADVANCED SETTINGS

Select **“Set sensor MODE”**: to set either Air Sensor mode, Level Switch mode or Level Sensor mode. It determines which sensor can be connected. Changing sensor mode does not alter any settings or calibrations.

Select **“RESTORE settings and calibrations”**: to restore all settings and calibrations to factory-settings.

HELP

Select **“HELP”**: to show information about connecting the ULTRASOUND CONTROLLER D72.

Level Sensor TROUBLESHOOTING

Display shows:

set = Settings is missing

cal = Calibration of air and/or liquid must to be done.

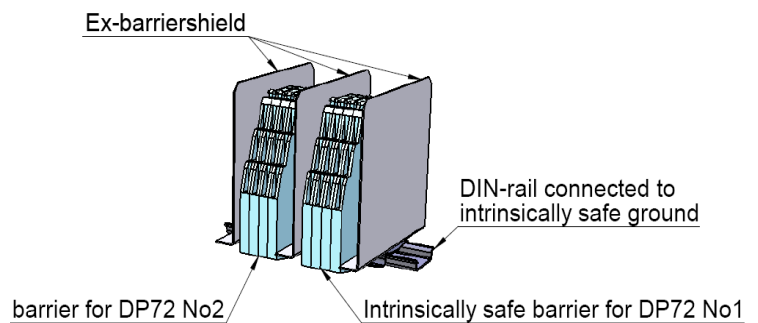
set = Some setting is missing.

err = Measurement can not be done due to an error that was measured during calibration: Either level sensor or velocity sensor echo is too weak or the velocity sensor echo with air is too strong.

OVER = Measured level is between 100% and 170%.

The echo strength, threshold and %echo should be checked: If the echo is weak compared to threshold there can be problem measuring the level. Make sure the echo is reflected properly back to the level sensor. The bottom thickness and material also influences the echo strength, see Mounting the Level Sensor.

Electric interference can cause trouble because it can increase the threshold. To minimize the risk of electric interference it is important that sources of interference like frequency inverters should use screened cables for the motor. Also any unscreened part of the cable between the Level Switches and D72 should be short. If ex-barriers are used, Ex-barriershields must be used.



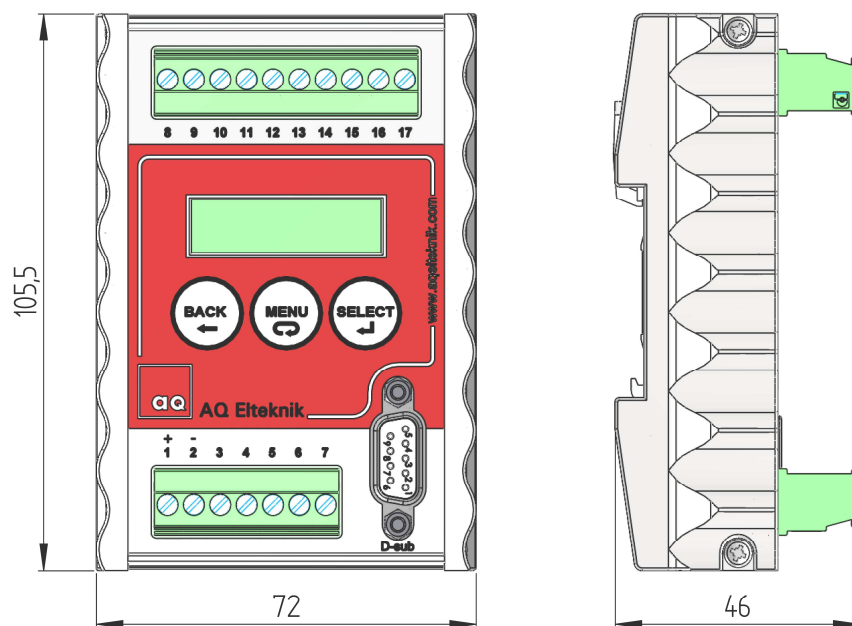
In order for D72 to measure the level well it needs echoes from the surface. Due to various reasons however the echoes can become too weak to be able to be detected. An indication of how well the echoes are detected is **%Echo**, which is 100% with good echo but becomes less with weak echo. Also echo strength **dB** and threshold **Thld dB** indicates how strong the echo is compared to background noise. In an empty container there is no echo but **%Echo** may still show more than 0% because noises are misinterpreted as echoes.

For reliable measurement strong echo is good. Some reasons for weak echo:

- Container is empty. - This is ok there should be no echo then.
- Bottom is thick. – If possible make bottom thinner. Also consider ideal thickness for resonance at 2 MHz.
- Bottom thickness is such that resonance is not at 2MHz. – If possible make bottom so resonance is at 1,9-2MHz ($d = n * \lambda / 2 = n * v / 4000000$ λ = wavelength at 2MHz d = bottom thickness $n = 1,2,3\dots$ v = sound velocity).
- Liquid level is very low. – The echo is veiled by echoes within the bottom. Measuring very low level is difficult.
- Bubbles or particles scatter the echo.
- Level is outside the range (170%). – Set the range.
- Container is full and the inside surface of the top of the container is shaped in such a way that echoes are reflected in wrong direction. – Make a small portion of the inside surface flat just above the level sensor.
- Level sensor is aimed in wrong direction. – Aim the level sensor in the right direction.
- The container is inclined and thereby the level sensor becomes aimed in wrong direction. – Unincline the container or aim the level sensor.
- The liquid is rotating and the centrifugal force makes the surface parabolic thereby reflecting echo in wrong direction. – Try finding better position for the level sensor, maybe in the middle of the container.

7. Technical specifications D72

D72Revision	D
Weight	210g
Operating temperature	0°C to 50°C
Supply voltage	24V ± 3V DC
Current consumption max	200mA
Relay 1-4	potential free contacts (open when power is off) Maximum load: 30V DC/AC 500mA All four relays are connected to a single common (terminal 3)
mA output	4-20mA active output, max voltage drop on connected load: 11V
Protection class	IP20
Ambient Humidity	0% - 90%
Material	Aluminium, polyamide and polycarbonate
Measurement frequency	1,1 – 2,2 MHz
Average output power	10 mW
Profibus DP	Is available on the Profibus version



8. Parameter settings

Air Sensor

MODE

Possible values	
	Not set ☼
	Air Sensor
	Level Switch
	Level Sensor

TYPE

Air Sensor		Possible values
1	2	
		No Air Sensor ☼
		SAC
		SAC Ex
		FCP
		FCS
		FCS Ex

DIAMETER

Air Sensor		Possible values
1	2	
		No Air Sensor ☼
		2mm
		3mm
		4mm
		4,5mm
		6mm
		8mm
		10mm
		12mm
		14mm
		16mm
		18mm
		20mm
		22mm
		26mm
		30mm
		35mm
		38mm
		46mm
		51mm
		58mm
		64mm
		70mm

SENSITIVITY

Air Sensor		Possible values
1	2	
		very very low
		very low
		low
		medium ☼
		high

FILTER

Air Sensor		Possible values
1	2	
		integrate 1ms
		integrate 3ms
		integrate 10ms
		integrate 30ms ☼
		integrate 0,1s
		integrate 0,3s
		integrate 1s
		integrate 3s
		delay 0,3s
		delay 1s
		delay 3s
		delay 10s

Air Sensor

RELAY		Possible values		
1	2	3	4	
				not assigned ☼
				Open AS1 Liq, Closed AS1 Air
				Open AS1 Air, Closed AS1 Liq
				Open AS2 Liq, Closed AS2 Air
				Open AS2 Air, Closed AS2 Liq

Air Sensor mA

mA output		Possible values
A	B	
		not assigned ☼
		AS1 Normal Measurement Data
		AS2 Normal Measurement Data
		AS1 All Sensitivites
		AS2 All Sensitivites

Level Switch

TECHNIQUE of measurements

Level Switch		Possible values		
1	2	3	4	
				No Level Switch ☼
				Type LS, Technique EHCO
				Type RS, Technique WR
				Type LS, Technique WR

FILTER

Level Switch		Possible values		
1	2	3	4	
				0,5s
				1s ☼
				2s
				4s
				8s
				12s
				16s

ECHO-DISTANCE

Lev		(Technique ECHO only)		
1	2	3	4	Possible values
			 ☼
				34mm
				38mm
				42mm
				46mm
				49mm
				53mm
				58mm
				65mm
				75mm
				85mm
				100mm
				115mm
				135mm
				165mm
				200mm
				250mm
				300mm
				350mm
				400mm
				500mm
				600mm

Jac

Lev		(Technique WR special)		
1	2	3	4	Possible values
				no Jacket ☼
				..... mm
				..... mm
				..... mm
				..... mm

FR

Lev		Possible values		
1	2	3	4	
				Auto ☼
				1 - 1,1 MHz
				2 - 1,5 MHz
				3 - 1,7 MHz
				4 - 2,0 MHz
				5 - 2,2 MHz

Lev

RE		Possible values		
1	2	3	4	
				not assigned ☼
				Open LS1 Air, Closed LS1 Liq
				Open LS1 Liq, Closed LS1 Air
				Open LS2 Air, Closed LS2 Liq
				Open LS2 Liq, Closed LS2 Air
				Open LS3 Air, Closed LS3 Liq
				Open LS3 Liq, Closed LS3 Air
				Open LS4 Air, Closed LS4 Liq
				Open LS4 Liq, Closed LS4 Air
				Open LS2 Air, Closed LS1 Liq
				Open LS1 Liq, Closed LS2 Air
				Open LS2 Air, Closed LS3 Liq
				Open LS3 Liq, Closed LS2 Air
				Open LS3 Air, Closed LS4 Liq
				Open LS4 Liq, Closed LS3 Air

Level Sensor

100% Level

Level Sensor		Possible values
1	2	
		..... mm
		..... mm

0% Level

Level Sensor		Possible values
1	2	
		..... mm
		..... mm

Liquid Sound VELOCITY

Velocity Sensor		Possible values
1	2	
		..... m/s
		..... m/s

Velocity Sensor Echo DISTANCE

Velocity Sensor		Possible values
1	2	
		..... mm
		..... mm

Velocity Sensor HEIGHT

Velocity Sensor		Possible values
1	2	
		..... mm
		..... mm

Velocity Sensor Control

Velocity Sensor		Possible values
1	2	
		Velocity only
		Limits
		Zero below

Container Bottom-THICKNESS

Level Sensor		Possible values
1	2	
		..... mm
		..... mm

Container Wall-THICKNESS

Velocity Sensor		Possible values
1	2	
		..... mm
		..... mm

Level Sensor

RELAY		Possible values		
1	2	3	4	
				1 ON mm
				1 OFF mm
				2 ON mm
				2 OFF mm
				1 ON mm
				1 OFF mm
				2 ON mm
				2 OFF mm

Level Sensor

mA output		Possible values
A	B	
		Level 1
		Level 2
		Velocity 1
		Velocity 2

☼ indicates default setting