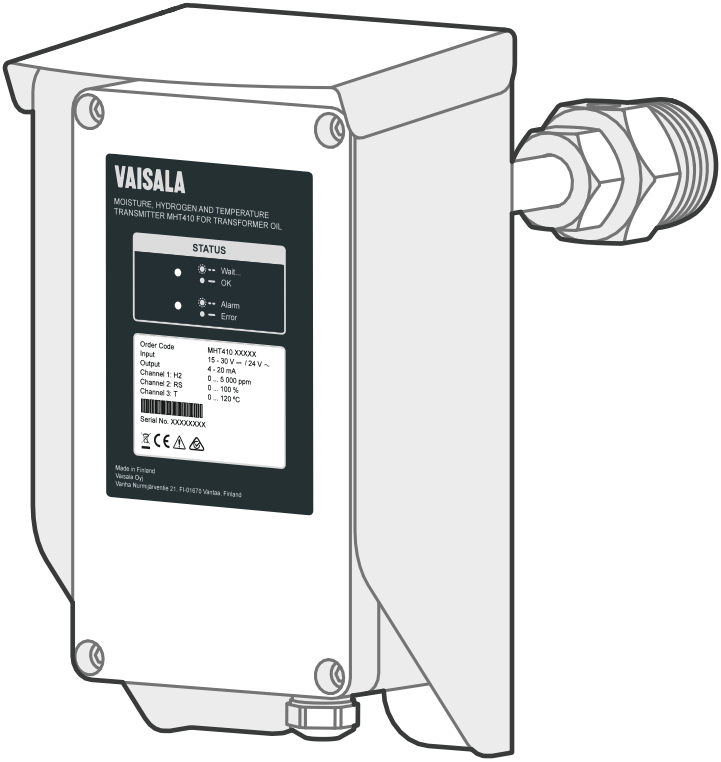
M211737EN-G

User Guide

Vaisala Moisture, Hydrogen and Temperature Transmitter for Transformer Oil

MHT410



VAISALA

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1. Safety

Vaisala Moisture, Hydrogen and Temperature Transmitter MHT410 for Transformer Oil delivered to you has been tested for safety and approved as shipped from the factory. Note the following precautions:

CAUTION! Read the Quick Guide (including installation instructions) carefully before installing the product.

WARNING! Ground the product and verify installation grounding periodically to minimize shock hazard.

DANGER! Severe risk of death and of damage to transformer:
Pay attention to transmitter installation depth and possible energized parts inside the power transformer to minimize electric shock hazard and equipment damage.

CAUTION! Do not modify the unit or use it in ways not described in the documentation. Improper modification may lead to safety hazards, equipment damage, failure to perform according to specification, or decreased equipment lifetime.

CAUTION! Do not try to close the ball valve when the transmitter is fully installed. The probe body goes through the valve into the oil flow, and trying to close the valve will damage the probe body and/or the valve.
If you must close the ball valve while the transmitter is on the valve, first open the small tightening nut and pull the probe body out as far as possible. Then close the valve.

CAUTION! To avoid damage to the installation valve of the transformer, do not step on the transmitter when the transmitter is installed.

CAUTION! Follow the safety regulations related to the application and installation site.

1.1 ESD Protection

Electrostatic Discharge (ESD) can cause immediate or latent damage to electronic circuits. Vaisala products are adequately protected against ESD for their intended use. However, it is possible to damage the product by delivering an electrostatic discharge when touching, removing or inserting any objects inside the equipment housing.

Use appropriate ESD protective equipment when handling the wiring and connectors under the front cover. Do not touch any parts under the circuit board cover.

2. About This Document

Table 1 Document Version History

Document Code	Date	Description
M211737EN-G	November 2018	This document. Added natural and synthetic ester oil support information and instructions on checking the oil type set at the factory from the product label. Added instructions on configuring oil-specific moisture in oil calculation coefficients. Clarified the information on the temperature range for accurate measurement in hydrogen and temperature accuracy specifications and added sensor head temperature tolerance specification. Added instructions on using a safety pin with a warning label to lock the valve handle in open position after installation.
M211737EN-F	May 2018	Previous version. Updated installation instructions regarding PTFE tape and installation depth. Added DNP3 protocol information. Added clarification about using the RS-485 line of the screw terminals with Modbus or Vaisala Industrial Protocol. Added maximum power consumption specification. Added new parameter options for analog outputs: daily, weekly, and monthly ROC and 24-hour average for H_2 and H_2O. Added clarification about the calculation of rate of change (ROC) readings. Changed unit "ppm" to "ppm_v" for H_2 and to "ppm_w" for H_2O.
M211737EN-E	January 2016	Logging interval configuration added, log output and error log tags updated, log tag descriptions added. Wiring diagrams updated.

Table 2 Related Manuals

Document Code	Description
M211736EN	MHT410 Quick Guide
M211784EN	Loop-Powered Display 242003 for MHT410 Technical Note

2.1 Documentation Conventions

WARNING! Warning alerts you to a serious hazard. If you do not read and follow instructions carefully at this point, there is a risk of injury or even death.

CAUTION! Caution warns you of a potential hazard. If you do not read and follow instructions carefully at this point, the product could be damaged or important data could be lost.

Note highlights important information on using the product.

Tip gives information for using the product more efficiently.

Lists tools needed to perform the task.

Indicates that you need to take some notes during the task.

2.2 Regulatory Compliances

Up-to-date declarations of conformity are available at request from Vaisala (www.vaisala.com).

This product is in compliance with the following EU directives:

- EMC Directive
- RoHS Directive

Conformity is shown by compliance to standards listed in Technical Data (page 90).

2.3 Trademarks

HUMICAP® is a registered trademark of Vaisala Oyj.

All other product or company names that may be mentioned in this publication are trade names, trademarks, or registered trademarks of their respective owners.

3. Product Overview

Vaisala Moisture, Hydrogen and Temperature Transmitter MHT410 for Transformer Oil is designed for online monitoring of insulating oil in power transformers. The transmitter provides an accurate real-time measurement result of moisture, hydrogen and temperature measured in oil, enabling reliable conclusions on the transformer's condition without delay.

The transmitter provides digital and analog outputs of all the measured parameters.

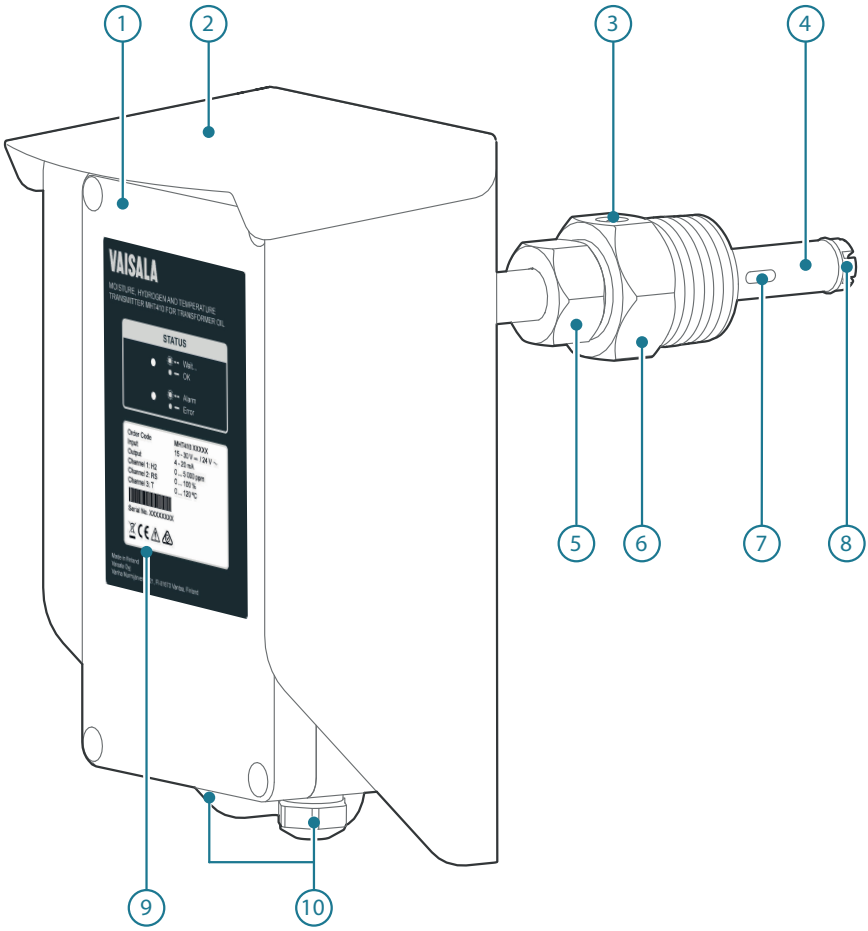
3.1 Main Features

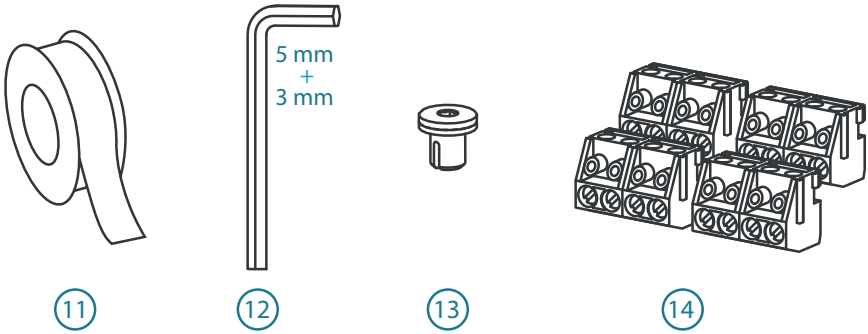
- Reliable online measurement of transformer oil for the following parameters:
  - Moisture: relative saturation (%RS), water activity, and water content (ppm_W)
  - Hydrogen concentration (ppm_V in oil)
  - Temperature (°C and °F)
- Compatible with mineral oils, natural ester oils, and synthetic ester oils
- No need to take oil samples for measurement
- Installable and retro-fittable on a ball valve (ball valve thread: female 1.5″ NPT)
- Low maintenance requirements due to excellent long term stability
- Outputs
  - Digital: Modbus, DNP3, and Vaisala industrial protocol over RS-485
  - Analog: three channels with scalable current output
- Status indication LEDs in the front panel
- Built-in data logging
- USB connectivity for service connections using an optional USB M8 cable
- Display options:
  - Loop-powered display for continuous use
  - MI70 hand-held meter for temporary use

More Information

- Oil Types (page 15)
- Status LEDs (page 16)
- Data Logging (page 16)
- Connecting via Service Port (page 40)
- Loop-Powered Display (page 30)
- MI70 Hand-Held Indicator (page 75)
- Technical Data (page 90)

3.2 Product Parts and Package Contents





No.		Item
1	=	Electronics housing. The front cover is additionally connected to the housing with a grounding wire.
2	=	Weather shield
3	=	Bleed screw
4	=	Probe body
5	=	Small tightening nut, used to adjust and fix the depth of the transmitter in the valve. You can move the tightening nut and the mounting nut along the probe body.
6	=	Mounting nut, used to fasten the transmitter in the ball valve. You can move the tightening nut and the mounting nut along the probe body.
7	=	Hydrogen sensor
8	=	Moisture and temperature sensors under the filter
9	=	Product label
10	=	Lead-throughs (2 pcs) with a minimum of one cable gland (size M20x1.5) or conduit fitting. Unused lead-throughs are plugged.
Installation Kit:		
11	=	PTFE tape roll
12	=	Allen keys (3 mm and 5 mm)
13	=	Extra bleed screw and sealing ring
14	=	Extra terminal blocks (4 x 4 screw terminals)

More Information

- Dimensions (page 95)

3.3 Measurement Parameters and Units

Parameter	Abbreviation	Unit
H_2 concentration in oil		
• 1 h average • 24 h average	H2	ppm_v
Rate of change of H_2 concentration		
In a day	Daily ROC	ppm_v/day
In a week	Weekly ROC	ppm_v/week
In a month	Monthly ROC	ppm_v/month
Moisture in oil		
Relative saturation	RS	%RS
Water activity	aw (=RS/100)	(no unit)
H_2O concentration in oil (current)	H2O	ppm_w
H_2O concentration in oil (24 h average)	H2O	ppm_w
Rate of change of H_2O concentration in oil		
In a day	Daily ROC	ppm_w/day
In a week	Weekly ROC	ppm_w/week
In a month	Monthly ROC	ppm_w/month
Temperature		
Oil temperature	T	°C or °F

The rate of change (ROC) for H_2 and for H_2O shows the difference in ppm between the latest 24-hour average and the 24-hour average 1 day ago (daily ROC), 7 days ago (weekly ROC), or 30 days ago (monthly ROC). ROC readings are updated every 12 hours.

After starting up or resetting the transmitter, ROC readings are available as follows:

- Daily ROC: after 2 days
- Weekly ROC: after 8 days
- Monthly ROC: after 31 days

Before the ROC readings are available, the ROC measurement registers in digital outputs contain a "NaN" value, and the ROC analog outputs are set to 3.0 mA (= measurement not ready).

3.4 Oil Types

MHT410 is compatible with the following oil types:

- Mineral oils
- Natural ester oils
- Synthetic ester oils

CAUTION! Never use MHT410 with any other oil type than the one configured for the unit at the factory. Using the transmitter with a different oil type requires sending the unit to Vaisala for reconfiguration.

The oil type that MHT410 measures (mineral oils, natural ester oils, or synthetic ester oils) is selected when ordering the transmitter. For instructions on checking the oil type set at the factory from the product label, see Oil Type Information in Order Code (page 15).

3.4.1 Oil Type Information in Order Code

MHT410 has been configured for a specific oil type based on the selection made when ordering the transmitter, and must not be used with other oil types. The oil type configuration set at the factory can be checked from the first digit (1, 2 or 3) of the order code in the MHT410 product label.

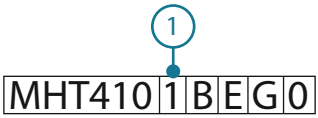


Figure 1 MHT410 Order Code Example (First Digit 1 = Mineral Oil)

1 First digit of the order code. The oil type configuration is shown in the first digit as 1, 2, or 3:

- 1 = Mineral oils (shown)
- 2 = Natural ester oils
- 3 = Synthetic ester oils

3.4.2 Oil-Specific Coefficients for ppm_W Moisture Measurement

MHT410 can be ordered with ppm_W moisture output (average mass concentration of water in oil). The calculation model that MHT410 uses for ppm_W measurement is based on the average water solubility behavior of transformer oils (see Calculation Model with Average Coefficients (page 110)). If additional accuracy is required, you can configure oil-specific coefficients into MHT410 using Vaisala Industrial Protocol serial commands (see Table 40 (page 69)), or contact Vaisala about setting the coefficients.

More Information

- Moisture ppmw Calculation for Transformer Oils (page 110)
- Other Commands (page 67)

3.5 Data Logging

The transmitter automatically saves the measurement readings and other events in a log every 12 hours (configurable interval). The log can contain approximately 32000 entries.

The following events are logged:

- Hydrogen (ppm_v) reading as 1 h average or 24 h average
- Moisture in oil (%RS and ppm_w) and temperature (°C) readings as instant values or 24 h averages
- Power outages
  - Short power outages that don't turn off transmitter power (flagged "UPS")
  - Long power outages that turn off transmitter power (flagged first as "UPS" and then as "Reset")
- Manual resets (flagged as "Reset")
- Uptime and total operating time
- Occasions of exceeding hydrogen alarm level (optional)

To view the log and change the logging settings, use Vaisala Industrial Protocol.

You can save the log as a file from PuTTY by configuring the following settings in PuTTY before opening the connection:
In the **Session > Logging** view:

- **Session logging**: Select "Printable output".
- **Log file name**: Type a name for the log file (use the file extension .txt) and browse to the save location.

To prevent the log from getting very long, consider saving and then clearing the log every few years.

More Information

- Vaisala Industrial Protocol (page 39)
- Measurement Output Commands (page 51)

3.6 Status LEDs

When the transmitter is ON, one of the LEDs is always illuminated (steady or blinking). If no LED is illuminated, the transmitter is OFF.

LED Color and Text	Description
Green, blinking: 	Transmitter is preparing H_2 measurement after start-up or reset.
Green, steady: 	Transmitter is measuring.
Red, blinking: 	H_2 concentration is above the alarm limit.
Red, steady: 	Transmitter is in error state.

4. Installation

Before you install the transmitter:

- Go through the check list in section Planning the Installation (page 18).
- Read this whole guide carefully.

CAUTION! Make sure the oil type of the transformer matches the oil type configured for MHT410. See Oil Type Information in Order Code (page 15).

The installation instructions in this section are the same as in the MHT410 Quick Guide.

4.1 Planning the Installation

- Choose the installation location on the transformer (see Recommended Installation Locations (page 19)).

  CAUTION! Make sure the installation valve and threads are appropriate from the valve specifications. The correct thread of the valve is **female 1.5″ NPT**. Do not install the transmitter in a valve with a different thread. For example, the R thread is incorrect. If you use a different thread than female 1.5″ NPT, your equipment may be damaged and the connection is not leak tight. If you are not sure which thread your installation valve has, verify the thread with a 1.5″ NPT thread gauge.

- Make sure the oil type of the transformer matches the one configured for MHT410 (mineral oil, natural ester oil, or synthetic ester oil).
- Make sure you have all the required tools for installing the transmitter. The required tools are presented in the installation instructions.
- Choose the output signals: analog and/or digital.
- Choose the electrical wiring option. If the transmitter was ordered with the Vaisala cable CBL210392-5M, the cable is already pre-connected to the transmitter according to Wiring Option 1.

More Information

- Wiring Diagrams (page 96)

4.1.1 Recommended Installation Locations

The probe must always be installed in a valve. The correct thread of the valve is **female 1.5″ NPT**. Do not install the transmitter in a valve with a different thread. For example, the R thread is incorrect. If you use a different thread than female 1.5″ NPT, your equipment may be damaged and the connection is not leak tight.

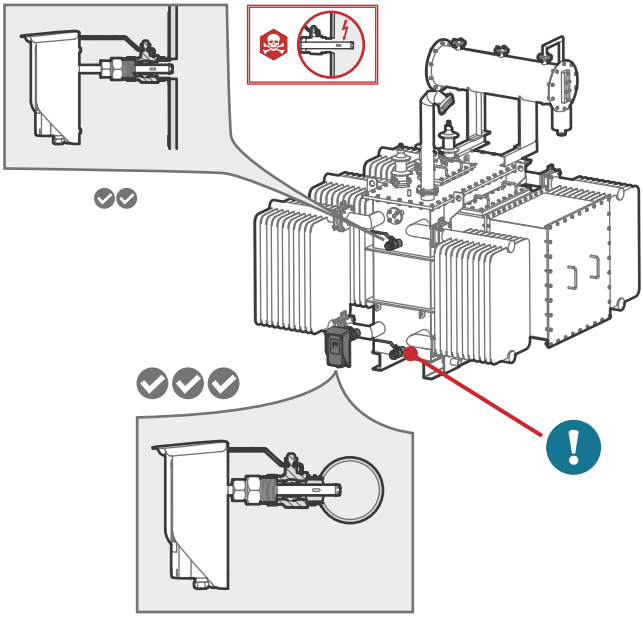


Figure 2 Recommended Installation Locations

Recommendation	Description
✓✓✓ Recommended: Straight section in the radiator's outlet pipe.	This is the best location for the transmitter. The oil is measured in flow, which makes the oil sample representative and instant. This is essential especially for correct oil moisture measurement. Compared to the radiator inlet pipe, oil in the outlet pipe is cooled, preventing unnecessary heating of the sensors and the transmitter.

Recommendation	Description
 Possible alternative: Wall of the oil tank, high enough from the bottom to enable proper oil movement.	An instrumentation valve is recommended. This is a typical valve that is meant for oil analysis. Moisture response time is moderate depending on the oil volume and transmitter installation.  **DANGER! Severe risk of death and of damage to transformer:** Pay attention to transmitter installation depth and possible energized parts inside the power transformer to minimize electric shock hazard and equipment damage.
 Not recommended: Drain valve of the oil tank.	The moisture response can be poor due to static oil flow. There is also a risk of separated water (leading to wrong results) and oil sludge (risk of sensor contamination and clogged filters).

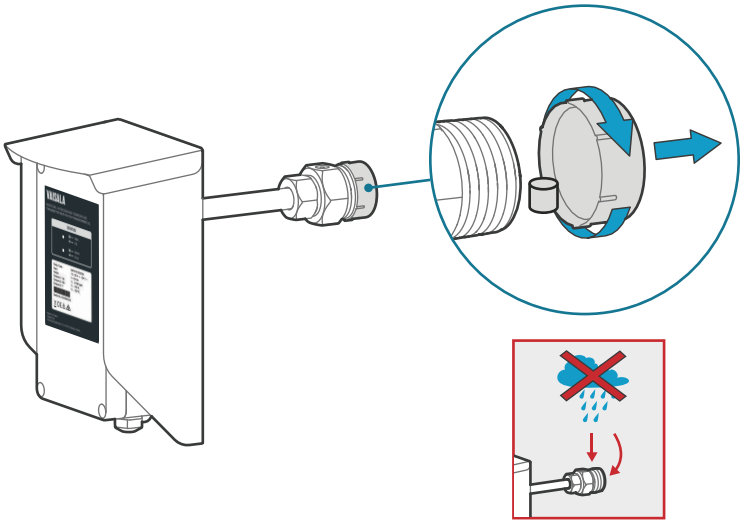
4.2 Mechanical Installation

CAUTION! Before you install the transmitter:

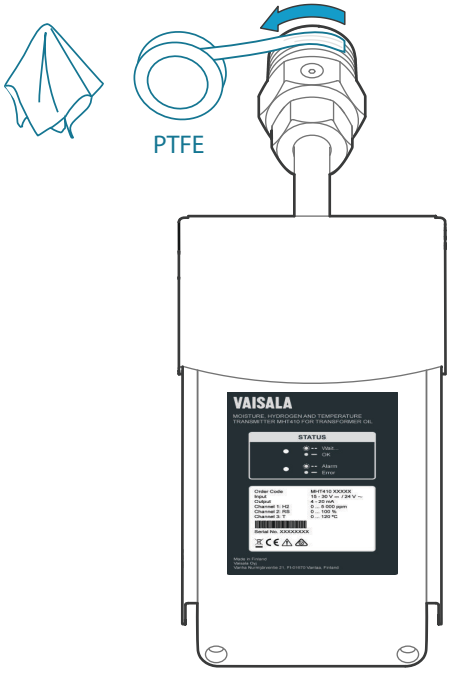
- Make sure there is no negative pressure in the transformer. If there is negative pressure when you open the bleed screw during installation, air will flow into the transformer oil tank.
- Do not open the ball valve on the transformer until you are instructed to do so in this guide.
- Make sure the bleed screw on the mounting nut is closed.

- 2 wrenches (50 mm and 36 mm)
- Allen key (3 mm, provided)
- PTFE tape (provided)
- Gloves
- Bucket and cloth

1. Remove the protective cap with sorbent packet from the mounting nut.
   In case of rain, do not let any water fall on the filter.

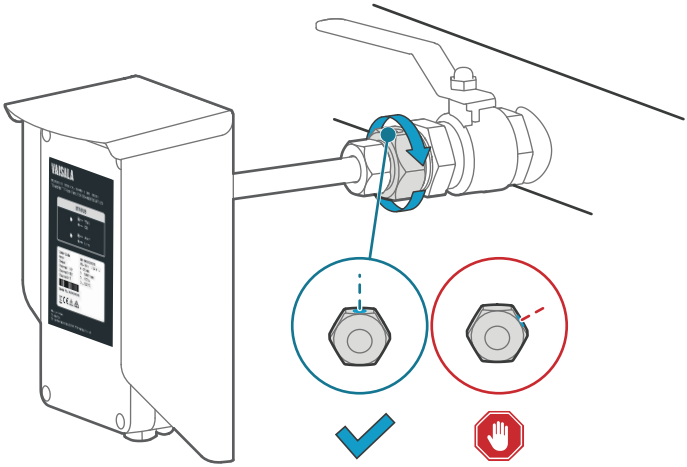


2. Apply PTFE tape tightly on the mounting nut threads.
   a. Before you start, clean the threads with a cloth.
   b. To make sure you wrap the tape in the correct direction, hold the transmitter so that the product label is facing you and the mounting nut points away from you.
   c. Start wrapping counter-clockwise from the second thread on the tip of the mounting nut.
   d. Wrap each round very tightly about half way on top of the previous round so that the tape overlaps. Stretch the tape for optimal tightness. Apply a couple of rounds of tape.

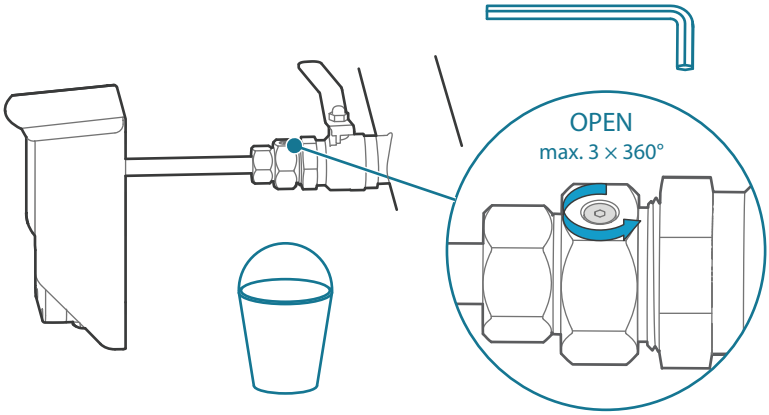


3. Make sure the bleed screw is closed. Fasten the mounting nut on the ball valve to **finger-tightness** with your hand. Leave the bleed screw directly on top of the nut.
   If you cannot position the bleed screw on top of the mounting nut by tightening just with your hand, you can use a wrench (50 mm) to turn the mounting nut **a maximum of a ½ turn**.

> **CAUTION!** If you need to loosen the mounting nut after you have fastened it on the valve, you must remove the transmitter from the valve, remove the PTFE tape, and start again from step 2 with new PTFE tape.



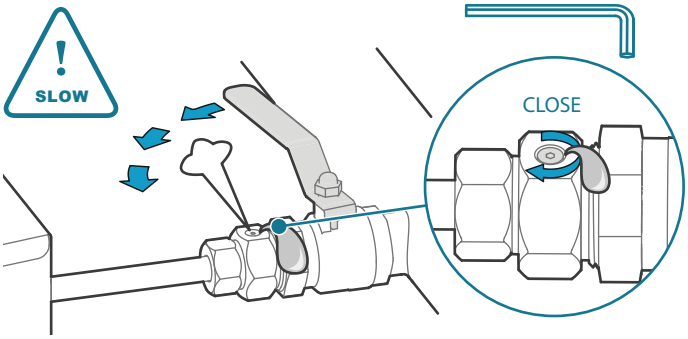
4. With a 3 mm Allen key, loosen the bleed screw. Place a bucket under the mounting nut.



5. Start opening the valve very carefully to let air out through the bleed screw.

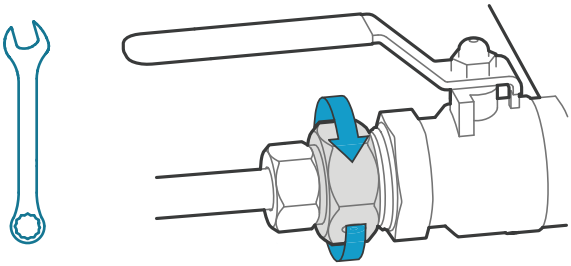
> **CAUTION!** If you open the valve too quickly, the air inside the mounting nut will flow into the transformer instead.

When oil flows out, close the bleed screw. Clean the area with a cloth and open the ball valve fully.

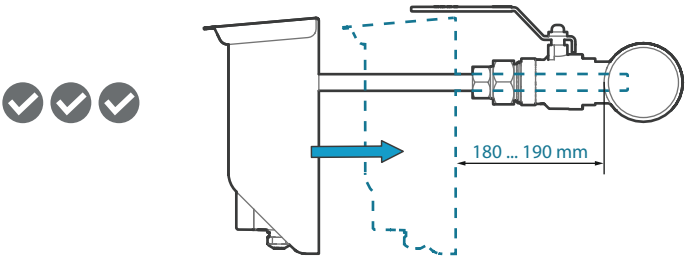


6. Continue tightening the mounting nut with a wrench. Be very careful not to over-tighten the connection. Approximately 5 ... 8 mm of the mounting nut threads remain outside the valve.

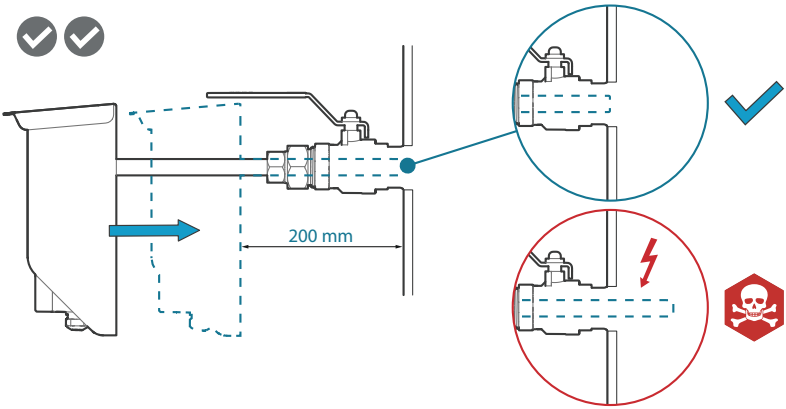
> If the connection leaks after you have tightened the mounting nut, check the thread type of the installation valve.
> - If the valve thread is **other than female 1.5″ NPT (incorrect)**, do not install the transmitter in that valve.
> - If the valve thread is **female 1.5″ NPT (correct)**, close the valve, open the mounting nut and remove the transmitter, remove old PTFE tape and apply a thicker layer of new PTFE tape. Then continue from step 3.



7. Push the probe to the correct depth. The correct depth depends on where the installation valve is located: radiator pipe or transformer wall.
   - **Valve in radiator pipe:** Install the probe so that the back of the weather shield is 180 ... 190 mm from the pipe surface.



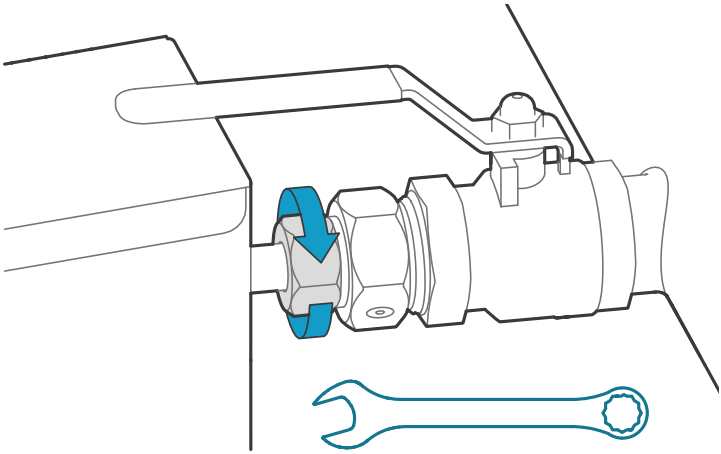
   - **Valve in transformer wall:** Install the probe so that the back of the weather shield is 200 mm from the transformer wall.



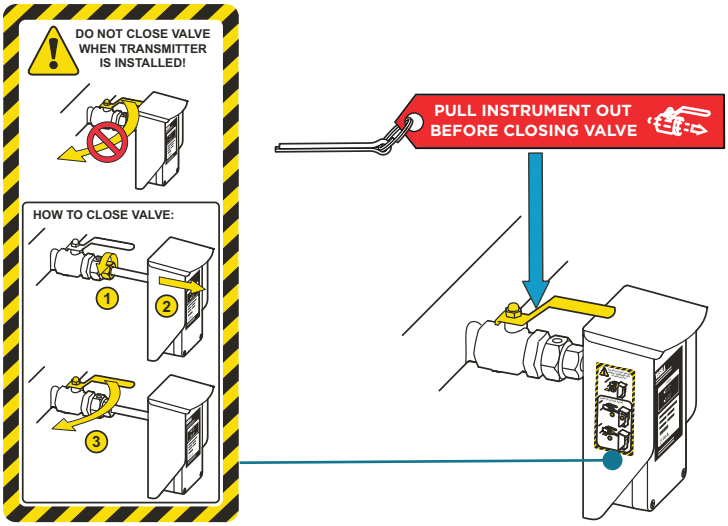
DANGER! Severe risk of death and of damage to transformer:
Pay attention to transmitter installation depth and possible energized parts inside the power transformer to minimize electric shock hazard and equipment damage.

When the probe is in the correct depth, turn the transmitter 90 degrees two to three times to remove any air bubbles from the sensor area.

8. Tighten the small tightening nut with a wrench until the probe is securely fastened.



9. Press the caution sticker on the MHT410 weather shield or other visible location nearby, and lock the handle of the valve in the open position with the safety pin.



More Information

- Dimensions (page 95)

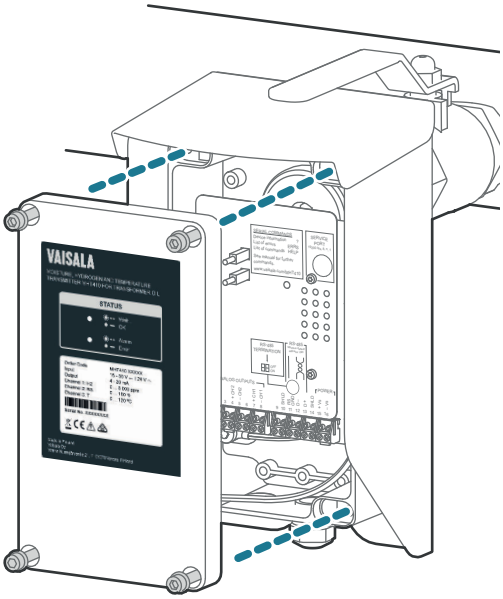
4.3 Electrical Installation

If the transmitter was ordered with the Vaisala cable CBL210392-5M, the cable is already pre-connected to the transmitter according to Wiring Option 1.

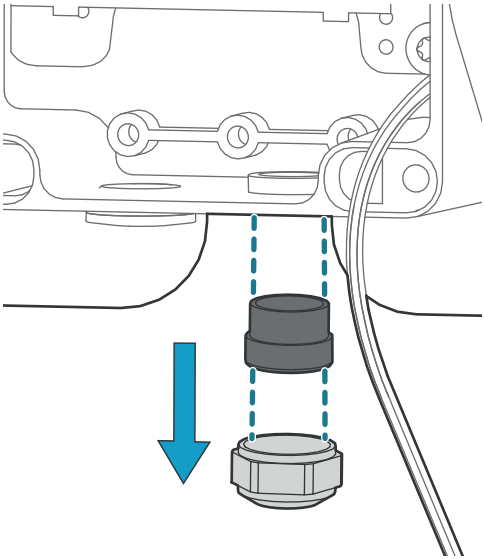
If cable is not pre-wired:

- Allen key (5 mm, provided)
- 2 medium wrenches (24 mm)
- Flat head screwdriver (2.5 mm)
- Wire-cutting pliers
- Suitable cable. You can order the following cables from Vaisala:
  - 5 m shielded PUR cable (order code: CBL210392-5MSP)
  - 10 m shielded PUR cable (order code: CBL210392-10MSP)

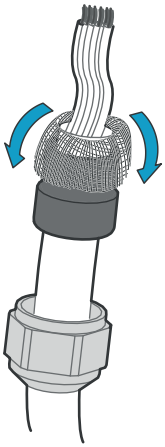
1. Open the electronics housing with a 5 mm Allen key to access the screw terminals.



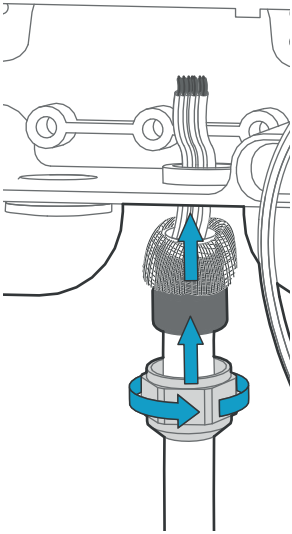
2. Hold the upper nut of the cable gland in place with a wrench (24 mm), and loosen the sealing nut of the gland with another wrench (24 mm).



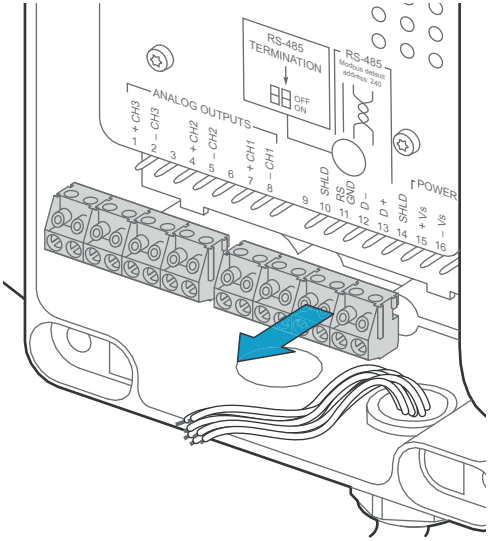
3. Lead the cable through the sealing nut and the rubber seal. Turn the shield over the edge of the rubber seal.



4. Lead the cable through the cable gland. Push the rubber seal back in place with the shield. Cut off any excess shield. Tighten the sealing nut with wrench (24 mm).



5. Pull the screw terminal blocks (2 pcs) off from the circuit board.



6. Connect the wiring to the detachable screw terminals according to your chosen wiring option. Note that wiring for digital output (RS-485) is the same in all wiring options.

7. When you are finished with the wiring, plug the screw terminals back in and close the electronics housing.

More Information

- Wiring Diagrams (page 96)

4.4 Loop-Powered Display

The analog outputs of the transmitter can be connected to an external loop-powered LED display (order code 242003). The display is a pre-configured Nokeval 302 display intended for Vaisala MHT410 hydrogen channel measurements.

The display also includes two alarm relays to trigger an external hydrogen warning and alarm.

This display can be configured for other parameters (moisture/temperature in oil). If needed, you can install up to three displays, each showing a different parameter.

The default display settings are presented in the Vaisala Technical Note inside the display package. If needed, configure the display functions and scaling according to the manufacturer's instructions delivered with the display. Manufacturer's documentation is also available from http://www.nokeval.com.

Figure 3 Loop-Powered Display 242003

The loop resistance of the display must be included in the loop resistance calculation for the complete current loop. For the loop resistance of the display, refer to the manufacturer's documentation.

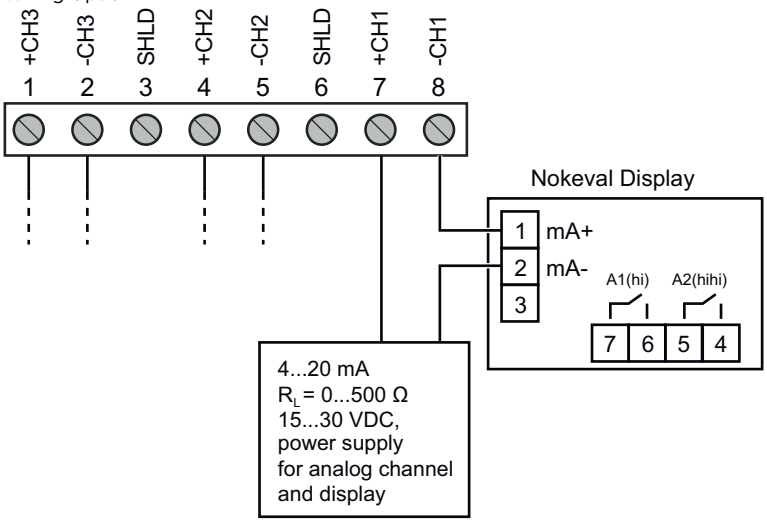
More Information

- Wiring the Loop-Powered Display (page 31)

4.4.1 Wiring the Loop-Powered Display

If one of the cable lead-throughs on your transmitter is plugged and you want to use that lead-through for the Nokeval display cable, you can order a cable gland from Vaisala.

1. Connect the loop-powered display to the transmitter as shown in the following wiring diagram. In the diagram, the display is connected to analog output Channel 1 according to Wiring Option 1.



All the Wiring Options (1, 2, 3, and 4) have the same principle for connecting the display:

- Wire from port 1 of the display connects to the minus port of the transmitter's analog output channel (for example, to "-CH1").
- Wire from port 2 of the display connects to where the minus port wire of the analog output channel would have connected without the display.

More Information

- Spare Parts and Accessories (page 94)
- Wiring Diagrams (page 96)

4.5 Checklist After Installation

After the installation, check the following indicators to make sure the installation was successful:

- No oil is leaking from the transformer and the transmitter.
  If the connection leaks after you have tightened the mounting nut, the probable reason is that the PTFE tape was applied incorrectly or the valve thread is other than female 1.5″ NPT.
- The H_2 level LED indicator settles to a steady green. Note that it can take up to 30 minutes for the H_2 level measurement to settle after start-up or reset.
  - Steady **green** indicates that the H_2 level is below alarm limit.
  - Blinking **red** indicates that the H_2 level is above alarm limit (by default, the alarm is off).
- After the initial stabilization period (approx. 24 h power on), the reading is correct.

4.6 Oil Fittings Check After Installation

After the first month of continuous use, all oil fittings should be checked for leaks.

An annual check thereafter is recommended.

4.7 Removing the Transmitter

To disconnect wiring:

- Allen key (5 mm, provided)
- 2 medium wrenches (24 mm)
- Flat head screwdriver (2.5 mm)

To remove transmitter:

- Large wrench (50 mm)
- Medium wrench (36 mm)
- Gloves
- Bucket and cloth

CAUTION! Do not try to close the ball valve when the transmitter is fully installed. The probe body goes through the valve into the oil flow, and trying to close the valve will damage the probe body and/or the valve.

1. If needed, disconnect the wiring:
   a. Open the front cover and disconnect the wires from the detachable screw terminals.
   b. Hold the upper nut of the cable gland in place with a wrench (24 mm), and loosen the sealing nut of the gland with another wrench (24 mm).
   c. Pull the cable out of the cable gland.
   d. Re-attach the cable gland in its place.
2. Put a bucket under the ball valve to catch any oil falling from the valve.
3. Loosen the small tightening nut with a wrench.

   To keep the larger mounting nut from opening, hold it in place with a wrench as you are opening the smaller tightening nut.

4. Pull the transmitter outward so that the probe body is out of the ball valve.
5. Close the ball valve.
6. Open the mounting nut with a wrench and pull the transmitter out. Use the cloth to clean up any spills.

   Always make sure the bleed screw is closed before you turn the mounting nut with a wrench.

4.8 Re-installing the Transmitter in New Location

If you re-install the transmitter in a new location, you must initialize the transmitter after the re-installation by connecting to the service port and giving the initialization command using Vaisala Industrial Protocol.

1. Remove the transmitter. See Removing the Transmitter (page 32).
2. Install the transmitter in the new location as instructed in Installation (page 18) and its subsections.

3. Connect to the transmitter via the service port and start communication using Vaisala Industrial Protocol.
   a. Connect to the service port (Connecting via Service Port (page 40)).
   b. If needed, install the USB driver (Installing the Driver for the USB Service Cable (page 40)).
   c. Connect the USB cable (Connecting USB Cable (page 41)).
   d. Configure the terminal application settings (Configuring Terminal Application Settings (page 41)).
4. Start the initialization sequence by issuing the command **h2**. The transmitter starts outputting H_2 measurement data.

```
> h2
Start hydrogen measurement module command line operation, quit by pressing
+

15832291.00 33.5719 50.06586 209.87 8413520 8410294 106 0.0 0 28.7938 0
15832292.00 33.5852 50.06617 209.82 8413484 8410254 106 0.0 0 28.7938 0
...
```

5. Stop the output by pressing the **Esc** key:

```
...
15832292.00 33.5852 50.06617 209.82 8413484 8410254 106 0.0 0 28.7938 0
<"Esc key">
H2scan:
```

6. Give the initialization command **is**, and when asked to erase the data log, confirm by pressing the **y** key.

```
H2scan: is

Clearing old data:
...wait...Erase the Data Log (Y/N)? y
Clearing log

; SSN=B13.21L.10306TN1X, FW=3.85F  , MDN=104400-FF02-P1, DF=0xB4B4s, L
TimeSec  PcbTemp   SnsrTemp HCurrent  Res1Adc  AdjRes1 H2Res.ppm
H2.ppm H2_DG.ppm   OilTemp  H2_G.ppm  H2_SldAv Messages
```

7. Start the H_2 measurement output again by pressing the **v** key.

```
v
15832363.00 31.9850 30.88629 0.00 8087342 8087342 641 - - - - - htr_off
wait
15832364.00 31.9565 30.84680 0.00 8086663 8086663 582 - - - - - htr_off
wait
...
```

8. Finish the initialization sequence by pressing the **+** key.

```
...
15832364.00 31.9565 30.84680 0.00 8086663 8086663 582 - - - - - htr_off
wait
<"+ key">
Quit hydrogen measurement module command line operation
```

9. Close the PuTTY terminal application.
10. Disconnect from the service port and close the transmitter cover.

5. Analog Output

There are three analog output channels available for H_2, moisture in oil, and temperature using 4 ... 20 mA current outputs.

The parameter for each output is configured at the factory according to order. If needed, you can change the parameters using the **`asel`** command via Vaisala Industrial Protocol.

Table 3 Analog Output Values in Different Transmitter Statuses

Transmitter Status	Analog Output Value
Normal	4 ... 20mA
Error	3.5 mA (default)
Measurement not ready	3.0 mA

More Information

- Analog Output Commands (page 62)

5.1 Analog Output Overrange Behavior

If the measured hydrogen, moisture and temperature levels go below or above their scaled range, the analog output is clipped at the low (4 mA) or high (20 mA) end of the output range. This means the analog output will not indicate measurement readings that are outside the scaled ranges.

If needed, you can allow the analog outputs to extend 10 % of the range over 20 mA using the **`aover`** command via Vaisala Industrial Protocol. With this extension, the allowed range for analog outputs is 4 ... 21.6 mA. The aover command does not affect the scaling of the outputs.

You can also change the scaling of the outputs for each channel using the **`asel`** command via Vaisala Industrial Protocol.

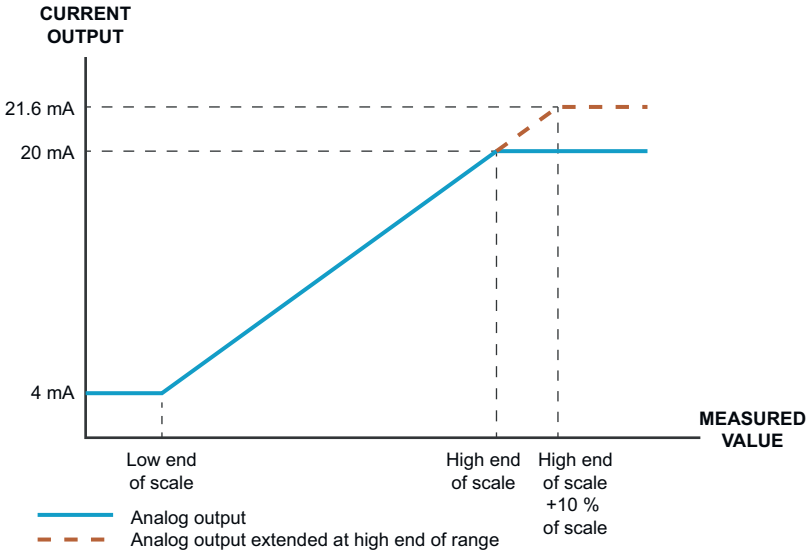


Figure 4 Analog Output Overrange Behavior

More Information

- Analog Output Commands (page 62)

6. Modbus

6.1 Overview of Modbus Protocol Support

MHT410 can be accessed using the Modbus serial communication protocol on the RS-485 line of the screw terminals. The supported Modbus variant is Modbus RTU (Serial Modbus).

The supported Modbus functions and registers are described in Modbus Reference (page 104).

By default, the RS-485 line of the screw terminals is in Modbus mode. The pre-configured default software settings are presented in the following table.

Description	Default value
Serial bit rate	19200
Parity	N
Number of data bits	8 (read-only)
Number of stop bits	1
Modbus device address	240

You can change the serial line communication settings using Vaisala Industrial Protocol.

The minimum time between requests from Modbus is 1 second.

More Information

- Modbus Reference (page 104)
- Serial Line Communication Commands (page 58)
- Vaisala Industrial Protocol (page 39)

7. Vaisala Industrial Protocol

The transmitter provides an implementation of the Vaisala Industrial Protocol that can be used for service and configuration use, or for interfacing with the system to which the transmitter is integrated. The protocol is a plaintext protocol suitable for use both by human operators and automated systems.

You can access the Vaisala Industrial Protocol in two ways:

- For temporary connection with a computer, use the service port. See Connecting via Service Port (page 40).
- For permanent connection, use the RS-485 line of the screw terminals.

The RS-485 line of the screw terminals is in Modbus mode by default. To use Vaisala Industrial Protocol on the RS-485 line, you must first change the communication mode for that line:

1. Connect to the service port (see Connecting via Service Port (page 40)).
2. Change the mode using the **`smode`** command (see Table 28 (page 61)).

You can use Vaisala Industrial Protocol via the RS-485 line of the screw terminals and the service port at the same time.
However, the transmitter responds to the commands one at a time from either line, which may result in delayed responses if a command is entered from one line while another command is in progress on the other line.

Table 4 Default Serial Interface Settings

Property	Description/Value
Baud rate	19200
Parity	None
Number of data bits	8
Number of stop bits	1
Flow control	None

More Information

- Serial Commands Summary (page 43)

7.1 Connecting via Service Port

- Vaisala USB service cable (219690)
- Computer with:
  - Windows operating system
  - Free USB port
  - Terminal application (e.g. PuTTy available from http://www.vaisala.com/software)
  - Driver for Vaisala USB service cable installed (available on the cable installation media and from http://www.vaisala.com/software)

You can connect to the transmitter via Vaisala Industrial Protocol on a computer using the service port located under the transmitter cover.

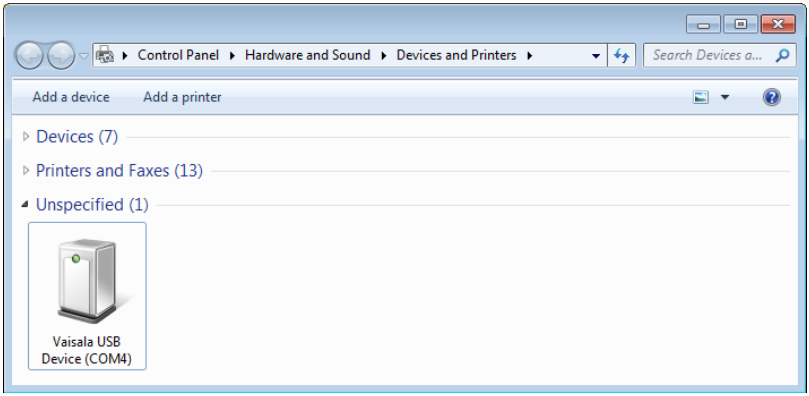
If you have not used the Vaisala USB cable before, install the driver before attempting to use the cable.

7.1.1 Installing the Driver for the USB Service Cable

Only Windows® operating systems are supported by the driver of the USB service cable.

1. Connect the USB service cable to a USB port on your computer. Windows® detects the new device and installs the appropriate driver.
2. Open **Devices and Printers** from the Windows® Start menu. Use search to find it if necessary (search for "devices").

3. Locate the cable in the list of devices:
   - If the device is listed as **Vaisala USB Device** with a COM port number in brackets, the cable is ready for use. **Note the COM port number, you will need it later.**
   - If the device is listed as **Vaisala USB Instrument Cable** without a COM port number listed, you must install the driver manually.



4. To install the driver manually:
   a. Disconnect the USB service cable from the computer.
   b. Download the Vaisala USB driver at http://www.vaisala.com/software (select the appropriate USB Instrument Driver Setup for your cable).
   c. Run the USB driver installation program *`Vaisala USB Device Driver Setup.exe`*. Accept the installation defaults.
   d. Go back to step 1 and verify that the driver installation works as expected.

7.1.2 Connecting USB Cable

To connect the USB service cable to the service port:

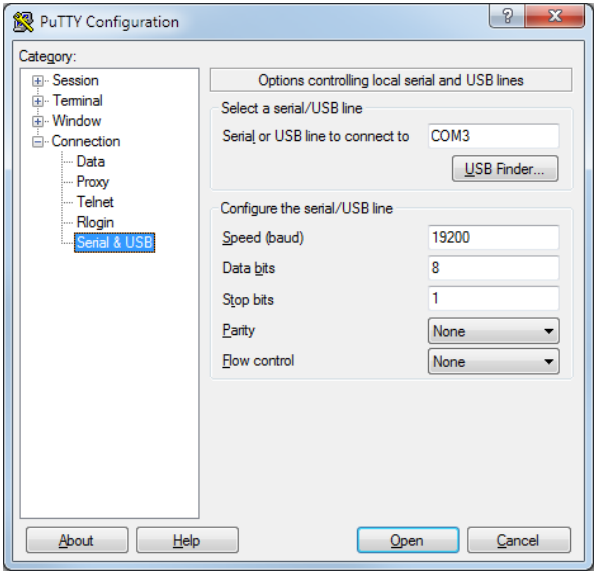
1. Make sure the USB cable is connected to your computer.
2. Open the screws on the transmitter cover, and open the cover.
3. Connect the USB service cable to the service port connector on the transmitter.
4. Configure the terminal application settings.

7.1.3 Configuring Terminal Application Settings

The steps below describe how to connect to the transmitter using the PuTTY terminal application for Windows (available for download at http://www.vaisala.com/software) and a USB service cable:

1. Make sure the USB service cable is connected to your PC and the service port of the transmitter.

2. Start the PuTTY application.
3. Select **Connection > Serial & USB** and check that the correct COM port is selected in the **Serial or USB line to connect to** field. If you are using the PuTTY terminal application supplied by Vaisala, you can click the **USB Finder** button to open the Vaisala USB Instrument Finder program.



4. Check that the other serial settings are correct, and change if necessary.

Table 5 Service Port Serial Interface Settings

Property	Value
Baud rate	19200
Parity	None
Data bits	8
Stop bits	1
Flow control	None

5. Select **Terminal**. Use the following settings:
   - **Local Echo**: "Force on". This setting ensures that your typing is shown on the session window.
   - **Send line ends with line feeds (CR+LF)**: Selected. This setting ensures that all text lines remain visible on the session window.

6. Click the **Open** button to open the connection window and start using the serial line.

> If PuTTY is unable to open the serial port you selected, it will show you an error message instead. If this happens, restart PuTTY and check the settings.

7.2 Serial Commands Summary

The notation **<cr>** refers to the carriage return control character, which you can send in a terminal application by pressing Enter on your keyboard. Before entering commands, send a **<cr>** to clear the command buffer.

You can enter the commands in uppercase or lowercase. In the command examples, the keyboard input by the user is in **bold** type.

Table 6 Serial Commands

Command	Description	More information
Device information and status:		
?	Show device information.	Table 7 (page 45)
??	Show device information (will respond in poll mode).	
alarm	Show or set H_2 alarm level.	Table 8 (page 46)
errlog	Show error log records.	Table 9 (page 47)
errs	Show active errors.	Table 10 (page 48)
help	Show list of serial commands.	Table 11 (page 49)
system	Show firmware information.	Table 12 (page 49)
time	Show transmitter uptime (time since last reset).	Table 13 (page 50)
vers	Show the software version information.	Table 14 (page 50)
Serial line output and communication:		
addr	Show or set device address used in Modbus communication and in Vaisala Industrial Protocol when the device is in POLL mode.	Table 23 (page 58)

Command	Description	More information
close	Close connection to device in POLL mode. This command cannot be used via the Service Port.	Table 24 (page 59)
form	Set output format of measurement messages.	Table 19 (page 55)
intv	Set measurement output interval.	Table 15 (page 51)
log	Show measurement log records and configure logging settings.	Table 16 (page 51)
open	Open connection to device in POLL mode. This command cannot be used via the Service Port.	Table 25 (page 59)
r	Start continuous output of measurement messages.	Table 17 (page 54)
sdelay	Show or set serial line transmission delay.	Table 26 (page 59)
send	Output one measurement message.	Table 18 (page 54)
seri	Set serial line settings for the RS-485 line of the screw terminals. Default is 19200 N 8 1. This command does not affect the service port settings.	Table 27 (page 60)
smode	Set serial line operation mode for the RS-485 line of the screw terminals. This command does not affect the service port settings. The service port is always in stop mode.	Table 28 (page 61)
unit	Set temperature unit to metric (°C) or non-metric (°F).	Table 22 (page 58)
Analog output:		
aerr	Show or set error level for analog output.	Table 29 (page 62)
aover	Enable or disable analog output 10 % over range.	Table 30 (page 62)
asel	Show or set analog output parameters and scaling.	Table 31 (page 63)
atest	Test analog outputs by forcing them to a given value.	Table 32 (page 65)
Calibration and adjustment:		
cdate	Show or set adjustment date.	Table 33 (page 66)

Command	Description	More information
ctext	Show or set adjustment information text.	Table 34 (page 66)
h2 da **h2 db**	Start or continue hydrogen calibration and adjustment sequence.	Table 35 (page 67)
Other commands:		
dnp3 addr	Change the data link address of the transmitter in DNP3 communication.	Table 36 (page 67)
filt	Show or set measurement filtering.	Table 37 (page 68)
frestore	Restore factory settings. Clears all user settings, factory calibration remains.	Table 38 (page 68)
oil	Show or set oil-specific coefficients for moisture ppm_w calculation.	Table 40 (page 69)
reset	Reset the device.	Table 39 (page 69)
h2 is	Initialize the device after it has been re-installed in a new location.	Table 41 (page 69)

7.3 Device Information and Status Commands

Table 7 ? Command

Syntax	Description
?<cr>	Show listing of device information.
??<cr>	Show listing of device information when device is in poll mode and connection has not been opened using the **open** command.

Syntax	Description

Example:
`?`
`MHT410 / 0.1.20`
`Serial number : L2110001`
`Batch number : L1940010`
`Sensor number : L102`
`Sensor model : Humicap L2`
`Order code : MHT410 1CXEO`
`Cal. date : 20150414`
`Cal. info : Vaisala`
`Uptime : 0000d 04:04:41`
`Total time : 0000d 04:04:41`
`Serial mode : STOP`
`Baud P D S : 19200 N 8 1`
`Output interval : 1 S`
`Serial delay : 25`
`Address : 0`
`Filter : 1.000`
`Ch1 output : 4 ... 20 mA`
`Ch2 output : 4 ... 20 mA`
`Ch3 output : 4 ... 20 mA`
`Ch1 RS lo : 0.00 %`
`Ch1 RS hi : 100.00 %`
`Ch2 T lo : -40.00 'C`
`Ch2 T hi : 100.00 'C`
`Ch3 H2 lo : 0.00 ppm`
`Ch3 H2 hi : 5000.00 ppm`	

Table 8 Alarm Command

Syntax	Description
alarm<cr>	Check the status and setpoint (ppm_v) of the hydrogen alarm. The alarm is activated when the 1-hour average for hydrogen exceeds the setpoint.
alarm [on | off] [setpoint]<cr>	Set the hydrogen alarm status. on = Alarm indication is on. off = Alarm indication is off. setpoint = Hydrogen level above which the alarm is activated.

Example (check the hydrogen alarm status, alarm is off):
`alarm`
`Alarm display : OFF ?`
`Setpoint (ppm) : 300 ?`	

Syntax	Description

Example (enable the hydrogen alarm and set the alarm limit to 200 ppm_v hydrogen):
`alarm on 200`
`Alarm display  : ON`
`Setpoint (ppm) : 200`	

Table 9 Errlog Command

Syntax	Description
`errlog print<cr>`	Show the error log with max. 25 last log entries. The error log stores the error status each time the status changes. You can save the error log as a file from PuTTY by configuring the following settings in PuTTY before opening the connection: In the **Session > Logging** window: • **Session logging**: Select "Printable output". • **Log file name**: Type a name for the log file (use extension .txt) and browse for the location where to save the file.
`errlog print [n] [i]<cr>`	Show the error log with a chosen number of entries. `n` = Number of entries to show (max. 9999). `i` = Optional: Index number of the first shown entry. If this parameter is not used, the list will show the last n number of entries.
`errlog save<cr>`	Save the current error status for troubleshooting purposes.
`errlog clear<cr>`	Remove all entries from the error log. Clearing the error log may make troubleshooting more difficult later if a problem occurs.

Syntax	Description

Example (show error log):
`errlog print`
`index RecNum Reset Days Time ERRS H2err Y(T) Y(RH) fm_cnt`
`1 1 1 0 00:00:00 8 0 1.0947 4.7467 0`
`2 2 2 0 00:37:29 8 0 1.0984 0.5565 6`
`3 3 2 0 00:37:14 8 0 1.1004 2.4597 0`
`4 4 2 0 00:38:46 8 0 1.1027 0.5147 7`
`5 5 2 0 01:10:02 8 0 1.1146 2.5202 0`
`6 6 2 0 01:15:57 8 0 1.1156 0.5876 6`
`7 7 3 0 00:36:21 8 0 1.1160 -3.9274 1`	

Example (show the last 5 entries):
`errlog print 5`
`index RecNum Reset Days Time ERRS H2err Y(T) Y(RH) fm_cnt`
`27 27 19 0 04:59:27 8 0 1.1160 -3.9274 1`
`28 28 19 0 05:11:40 0 0 1.1167 0.5479 6`
`29 29 19 0 05:18:53 8 0 0.7497 0.3019 6`
`30 30 19 0 05:21:12 0 0 0.2000 -0.1030 6`
`31 31 19 0 05:22:36 8 0 1.1187 0.5538 7`	

Example (save the current error status):
`errlog save`
`New value stored.`	

Example (remove all entries from the error log):
`errlog clear`
`Erase all Error Log data? (Y/N) y`
`Erasing...`
`Error Log cleared.`	

Table 10 Errs Command

Syntax	Description
errs<cr>	Show currently active errors. The possible errors and their remedies are listed in Table 44 (page 87).

Syntax	Description

Example (no errors active):
`errs`
`No errors`
 	
Example (active error):
`errs`
`0008 H2 module communication error`
`H2scan message: wait`	

Table 11 Help Command

Syntax	Description
help<cr>	Show a list of available commands.

Example:
`help`
`Stop mode commands:`
`ADDR AERR ALARM AOVER ASEL ATEST CDATE CLOSE`
`CTEXT DNP3 ERRLOG ERRS FILT FORM FRESTORE H2`
`HELP INTV LOG R RESET SDELAY SEND SERI`
`SMODE SYSTEM TIME UNIT VERS ?`
 	
`Poll mode commands:`
`OPEN SEND ??`	

Table 12 System Command

Syntax	Description
system<cr>	Show firmware information.

Example:
`system`
`Device Name : MHT410`
`Copyright : Copyright (c) Vaisala Oyj 2015. All rights reserved.`
`SW Name : MHP410`
`SW date : 2015-05-05`
`SW version : 1.0.0`
`OS version : TSF 1.0`	

Table 13 Time Command

Syntax	Description
time [mode]<cr>	Show transmitter uptime (time since last reset). Default output: hh:mm:ss. **mode** = alternative output option (optional) • **1** = include days (dddd hh:mm:ss) • **2** = include decimals of seconds (hh:mm:ss.sss) • **3** = include days and decimals of seconds • **4** = include total operating time

Example (show transmitter uptime in hh:mm:ss):
`time`
`Uptime : 00:50:04`	

Example (show transmitter uptime with days):
`time 1`
`Uptime : 2d 01:50:39`	

Table 14 Vers Command

Syntax	Description
vers<cr>	Show the software version information.

Example:
`vers`
`MHT410 / 1.0.0`	

7.4 Serial Line Output and Communication Commands

7.4.1 Measurement Output Commands

Table 15 Intv Command

Syntax	Description
intv<cr>	Show the output interval of the automatically repeating measurement messages (**r** command and run mode). This command has no effect on the operation of the analog output.
intv [iii uuu]<cr>	Set the output interval. **iii** = interval, range 1 ... 255 **uuu** = unit for interval setting: • **s** = seconds • **min** = minutes • **h** = hours

Example (set the output interval to 1 second):
`intv 1 s`
`Output interval: 1 S`	

Table 16 Log Command

Syntax	Description
log print<cr>	Show the measurement log with max. 100 last log entries. You can save the log as a file from PuTTY by configuring the following settings in PuTTY before opening the connection: In the **Session > Logging** window: • **Session logging**: Select "Printable output". • **Log file name**: Type a name for the log file (use extension .txt) and browse for the location where to save the file. To prevent the log from getting very long, consider saving and then clearing the log every few years.

Syntax	Description
log print [n] [i]<cr>	Show the measurement log with a chosen number of entries. **n** = Number of entries to show (max. 32767). **i** = Optional: Index number of the first shown entry. If this parameter is not used, the list will show the last **n** number of entries.
log alarm [on|off]<cr>	Enable or disable storing a log item when the H_2 concentration (1 hour average) exceeds the alarm level. Logging continues once an hour until the H_2 level returns below the alarm limit or until alarm logging is disabled. The log entries contain the additional tag "H2alarm". You set the H_2 alarm level using the **alarm** command (see Table 8 (page 46)).
log filt [on|off]<cr>	Enable or disable the filtering of measurement values in the log. **on** = For each parameter, the 24 h average value is stored. The log entries contain the additional tag "F". **off** = For H_2, 1 h average is stored. For RS and T, instant values are stored.
log save<cr>	Save the current measurement values in the log. The log entry contains the additional tag "Tst".
log clear<cr>	Remove all entries from the measurement log.
log intv [interval]<cr>	Set the logging interval in minutes (range: 15 ... 1440). The default interval is 720 minutes (12 hours).

Example (show up to 100 last entries in the log):

```
log print
index Reset Days Uptime   Total Time  RS(%)  H2O(ppm) Temp('C) H2(ppm) Flags
1     2     0    00:08:23 0     00:17 10.000 13.900   45.406   18.0    N Tst
2     2     0    00:13:02 0     00:22 10.000 13.900   45.467   18.0    N Tst
3     5     0    00:37:17 0     00:59 10.000 13.900   45.303   18.0    N Tst
4     5     0    00:52:54 0     01:14 10.000 13.900   45.278   18.0    N Tst
5     7     0    12:00:43 0     13:14 10.000 13.900   45.887   18.0    N
6     11    0    00:04:31 0     13:18 10.000 13.900   45.495   18.0    N
7     11    0    00:12:08 0     13:26 10.000 12.900   45.716   18.1    N
8     12    0    00:03:15 0     13:29 10.000 13.900   45.531   18.2    N
```

Example (show the last 5 entries):

```
log print 5
index Reset Days Uptime   Total Time  RS(%)  H2O(ppm) Temp('C) H2(ppm) Flags
4     5     0    00:52:05 0     01:14 10.000 13.900   45.278   18.0    N Tst
5     7     0    12:00:24 0     13:14 10.000 13.900   45.887   18.0    N
6     11    0    00:04:41 0     13:18 10.000 13.900   45.495   18.0    N
7     11    0    00:12:16 0     13:26 10.000 12.900   45.716   18.1    N
8     12    0    00:03:43 0     13:29 10.000 13.900   45.531   18.2    N
```

Syntax	Description

Example (show 5 entries starting from the 3rd entry):

```
log print 5 3
index Reset Days Uptime   Total Time  RS(%)  H2O(ppm) Temp('C) H2(ppm) Flags
3     5     0    00:37:23 0     00:59 10.000 13.900   45.303   18.0    N Tst
4     5     0    00:52:31 0     01:14 10.000 13.900   45.278   18.0    N Tst
5     7     0    12:00:12 0     13:14 10.000 13.900   45.887   18.0    N
6     11    0    00:04:57 0     13:18 10.000 13.900   45.495   18.0    N
7     11    0    00:12:48 0     13:26 10.000 12.900   45.716   18.1    N
```

Example (enable storing a log item when H_2 alarm level is exceeded):

```
log alarm on
Alarm loggings: OFF -> ON
```

Example (disable filtering the measurement values in the log):

```
log filt off
24h rolling average filter: ON -> OFF
```

Measurement log column information

Column	Description
index	Log record number (1 to 32767)
Reset	Reset count
Days	Number of days since last reset (uptime)
Uptime	Hours, minutes, and seconds of uptime
Total Time	Total operating time (days, hours, minutes)
RS (%)	H_2O relative saturation in oil
H2O (ppm)	H_2O concentration, absolute (ppm by weight)
Temp (°C)	Oil temperature
H2 (ppm)	Hydrogen concentration in oil (ppm by volume)
Flags	See flag descriptions below.

Log entry type indicators in Flags column

ID	Description
N	Log item stored every 12 hours (or at selected rate)
H2alarm	H_2 value (1 hour average) has exceeded alarm limit

Syntax	Description
RESET	Power-on or reset has occurred. In a RESET log entry, the H2 (ppm) column shows the reset cause, and measurement columns show dashes (-.---) instead of measurement information.
UPS	Power down detected, UPS is running
Tst	The log item was saved using **log save** command
F	Filter was on when the log record was saved
ERR	Error was active when the log record was saved
CRC ERR	Checksum error in the log record

Table 17 R Command

Syntax	Description
r<cr>	Start the continuous outputting of measurement values as an ASCII text string to the serial line. The transmitter keeps outputting measurement messages at the interval that has been set with the **intv** command until stopped with the **s** command.

Example:
`r`
`T= 45.1 'C  RS= 10.0 %  H2O= 13.9 ppm  aw= 0.100  H2= 17 ppm`
`T= 45.0 'C  RS= 10.0 %  H2O= 13.9 ppm  aw= 0.100  H2= 17 ppm`
`T= 45.0 'C  RS= 10.0 %  H2O= 13.9 ppm  aw= 0.100  H2= 17 ppm`
`T= 45.1 'C  RS= 10.0 %  H2O= 13.9 ppm  aw= 0.100  H2= 17 ppm`
`T= 45.1 'C  RS= 10.0 %  H2O= 13.9 ppm  aw= 0.100  H2= 18 ppm`
`T= 45.1 'C  RS= 10.0 %  H2O= 13.9 ppm  aw= 0.100  H2= 18 ppm`
`T= 45.1 'C  RS= 10.0 %  H2O= 13.9 ppm  aw= 0.100  H2= 18 ppm`
`T= 45.2 'C  RS= 10.0 %  H2O= 13.9 ppm  aw= 0.100  H2= 18 ppm`
`...`	

Table 18 Send Command

Syntax	Description
send<cr>	Output a single measurement message. The output uses the format defined with the **form** command.
send [yyy]<cr>	Output a single measurement message when the transmitter is in poll mode and connection has not been opened using the **open** command. **yyy** = Address of the transmitter, range 0 ... 255. The address is set with the **addr** command.

Syntax	Description
send ROC<cr>	Output the rate-of-change readings for H_2 and H_2O (daily, weekly and monthly ROC for each parameter).
send a<cr>	Output a single measurement message with the following parameters: • T • RS • aw • H_2O • H_2

Example (transmitter in stop mode, no address needed):
`send`
`T= 45.1 'C  RS= 10.0 %  H2O= 13.9 ppm  aw= 0.100  H2= 17 ppm`	

Example (transmitter in poll mode, with address 10):
`send 10`
`T= 45.1 'C  RS= 10.0 %  H2O= 13.9 ppm  aw= 0.100  H2= 17 ppm`	

Example (transmitter in stop mode, output rate-of-change readings):
`> send roc`
`ROCs:  61  H2:  0.7  1.6  3.7  H2O:  -0.362  1.262  2.458`
`>`	

7.4.2 Measurement Output Format Commands

Table 19 Form Command

Syntax	Description
form<cr>	Show the currently used measurement format.
form /<cr>	Reset measurement format to default.
form [sss]<cr>	Set a new measurement format. **sss** = String consisting of modifiers and abbreviations for measured parameters. See Table 20 (page 56) and Table 21 (page 57). Maximum length is 150 characters. Maximum length may be shorter when text strings are used.

Syntax	Description

Example (show currently used measurement format, default format shown here):
`form`
`3.1 "T=" t " " U3 3.1 "RS=" rs " " U4 6.1 "H2O=" h2o " " U5 4.3 "aw=" aw " "`
`6.0 "H2=" h2 " " U5 \r \n`
Output example (continuous output in RUN mode):
`T= 45.0 'C RS= 10.0 % H2O= 13.9 ppm aw= 0.100 H2= 18 ppm`	

Example (change the order of the output to show H_2 first, with Modulus-65536 checksum at the end):
`form 6.0 "H2=" h2 " " U5 3.1 "T=" t " " U3 3.1 "RS=" rs " " U4 6.1 "H2O=" h2o`
`" " U5 4.3 "aw=" aw " " cs4 #r #n`
`OK`
Output example (continuous output in RUN mode):
`H2= 18 ppm T= 45.0 'C RS= 10.0 % H2O= 13.9 ppm aw= 0.1 0E22`	

Example (show H_2O in ppm_w without decimals, with **start of text** (ASCII character 002) and **end of text** (003) ASCII codes, and without line feed and carriage return at the end):
`form #002 6.0 "H2=" h2 " " U5 3.1 "T=" t " " U3 3.1 "RS=" rs " " U4`
`6.0 "H2O=" h2o " " U5 4.3 "aw=" aw " " #003`
`OK`
Output example (continuous output in RUN mode):
`H2= 18 ppm T= 45.0 'C RS= 10.0 % H2O= 14 ppm aw= 0.100`	

Table 20 Output Parameters for Form Command

Measurement Parameter	Abbreviation in Form Command
Relative saturation of water in oil, %RS	**rs**
Water activity in oil, aw (range 0.0 ... 1.0)	**aw**
Water content in oil, ppm_w	**h2o**
Water content in oil, ppm_w. 24 hour average.	**h2oa**
H_2O daily ROC, ppm_w.	**h2od**
H_2O weekly ROC, ppm_w.	**h2ow**
H_2O monthly ROC, ppm_w.	**h2om**

Measurement Parameter	Abbreviation in Form Command
Hydrogen content in oil, ppm_v. One hour average.	**h2**
Hydrogen content in oil, ppm_v. 24 hour average.	**h2a**
H_2 daily ROC, ppm_v.	**h2d**
H_2 weekly ROC, ppm_v.	**h2w**
H_2 monthly ROC, ppm_v.	**h2m**
Oil temperature, °C or °F	**t**

Table 21 Modifiers for Form Command

Modifier	Description
x.y	Length modifier (number of digits and decimal places).
#t	Tabulator.
#r	Carriage-return.
#n	Line feed.
" "	String constant, length 1 ... 15 characters.
#xxx	ASCII code value (decimal) of a special character; for example, #027 for ESC.
addr	Transmitter address (0 ... 254).
date	Uptime in days.
err	Error code, ASCII encoded hexadecimal notation.
sn	Transmitter serial number.
time	Uptime (hh:mm:ss).
ux	Name of the measurement unit using **x** number of characters (1 ... 9). For example, **u3** shows the name of the measurement unit with three characters.
cs2	Modulus-256 checksum of message sent so far, ASCII encoded hexadecimal notation.
cs4	Modulus-65536 checksum of message sent so far, ASCII encoded hexadecimal notation.
csx	NMEA xor-checksum of message sent so far, ASCII encoded hexadecimal notation.

You can also use the backslash character \ instead of the hash character #.

Table 22 Unit Command

Syntax	Description
unit<cr>	Show the current temperature unit system (metric °C or non-metric °F).
unit [m|n]<cr>	Change the temperature unit. **m** = Metric unit, °C **n** = Non-metric unit, °F

Example (show current unit and check the output):
`unit`
`Units : Metric`
`send`
`T= 45.0 'C RS= 10.0 % H2O= 13.9 ppm aw= 0.100 H2= 18 ppm`	

Example (change temperature unit from °C to °F and check the output):
`unit n`
`Units : Non metric`
`send`
`T=113.0 'F RS= 10.0 % H2O= 13.9 ppm aw= 0.100 H2= 18 ppm`	

7.4.3 Serial Line Communication Commands

Table 23 Addr Command

Syntax	Description
addr<cr>	Show current device address and prompt for a new address. This device address is used in Modbus communication, and in Vaisala Industrial Protocol communication in POLL mode. The transmitter's data link address for DNP3 communication is configured with the **dnp addr3** command, see Table 36 (page 67).
addr [aaa]<cr>	Set new device address. **aaa** = address, 0 ... 255

Syntax	Description

Example (shows 0 as current address, enter 5 as the new address):
`addr`
`Address : 0 ? 5`	

Table 24 Close Command

Syntax	Description
close<cr>	Close the connection that was opened with the **open** command. This command cannot be used via the service port.

Example:
`close`
`line closed`	

Table 25 Open Command

Syntax	Description
open [aaa]	Connect to a transmitter that is in poll mode. **aaa** = transmitter address, 0 ... 255 If you do not know the address of the transmitter, use the **??** command to view the transmitter information. This command cannot be used via the service port.

Example (target transmitter in poll mode, with address 5):
`open 5`
`MHT410 5 line opened for operator commands`	

Table 26 Sdelay Command

Syntax	Description
sdelay<cr>	Show serial line transmission delay.
sdelay [delay]<cr>	Set a new serial line transmission delay. delay = 0 ... 255. Value corresponds to four milliseconds (for example, 5 = 0.020 second transmission delay) Note that setting a too short delay may result in missing characters at the beginning of the transmission (requirements vary depending on use case).

Syntax	Description

Example (set serial delay to 0.1 seconds using the delay value 25):
`sdelay 25`
`Serial delay : 25`	

Table 27 Seri Command

Syntax	Description
seri<cr>	Show current serial line settings for the RS-485 line of the screw terminals. This command does not affect the service port settings.
seri [p b d s] <cr>	Set new serial line settings. The new settings will be taken into use when the transmitter is reset or powered up. **b** = baud rate (300, 600, 1200, 2400, 4800, 9600, 19200, 38400, 57600) **p** = parity • **n** = none • **e** = even • **o** = odd **d** = data bits (7 or 8) **s** = stop bits (1 or 2) For Modbus, baud rate must be 9600 ... 57600 and parity must be none.

Example (show current settings):
`seri`
`Baud P D S : 19200 N 8 1`	

Example (set baud rate to 9600, and reset the transmitter take the new baud rate in use):
`seri 9600 N 8 1`
`Baud P D S : 9600 N 8 1`
`reset`
`MHT410 / 1.2.0`	

Table 28 Smode Command

Syntax	Description
smode<cr>	Show current start-up operating mode for the RS-485 line of the screw terminals, and prompt to enter new mode. This command does not affect the service port settings. The service port is always in **stop** mode.
smode [mode]<cr>	Set the start-up operating mode for the RS-485 line of the screw terminals. The new mode is taken into use when the transmitter is reset or powered up. This command does not affect the service port settings. The service port is always in **stop** mode. Available modes: **modbus** = Default mode. Modbus protocol is used for communication on the RS-485 line of the screw terminals, including measurement output. See Overview of Modbus Protocol Support (page 38). **dnp3** = DNP3 protocol. See DNP3 Protocol (page 70). **stop** = Vaisala Industrial Protocol: no automatic output. All commands available. **run** = Vaisala Industrial Protocol: automatic output of measurement messages. You can stop the output with the **s** command, and recontinue with the **r** command. **poll** = Vaisala Industrial Protocol: no automatic output. Will respond to addressed **send [aaa]** command and **??** command. You can use other commands after opening a connection using an addressed **open [aaa]** command. Use the **poll** mode with RS-485 buses where multiple transmitters can share the same line.

Example (check current serial operating mode (default setting with Modbus mode in use)):
`smode`
`Serial mode : MODBUS`	

Example (set serial operating mode to poll, and reset the transmitter to start up in that mode):
`smode poll`
`Serial mode : POLL`
`reset`
`MHT410 / 1.2.0`	

7.5 Analog Output Commands

Table 29 Aerr Command

Syntax	Description
aerr<cr>	Show error levels for the analog outputs channel by channel and prompt to enter a new value.
aerr [ch1 ch2 ch3]<cr>	Set new error levels for analog outputs. **ch1** = Error level of the analog output for channel 1. **ch2** = Error level of the analog output for channel 2. **ch3** = Error level of the analog output for channel 3. When you set new error levels, make sure they are outside the scaled output range 4 ... 20 mA (or 4.0 ... 21.6 mA if **aover** extension is on, see Table 30 (page 62)).

Example (show current error levels, default levels shown here):
`aerr`
`Ch1 error out : 3.500 mA ?`
`Ch2 error out : 3.500 mA ?`
`Ch3 error out : 3.500 mA ?`	

Example (set the error level to 21 mA on all channels):
`aerr 21 21 21`
`Ch1 error out : 21.000 mA`
`Ch2 error out : 21.000 mA`
`Ch3 error out : 21.000 mA`	

Table 30 Aover Command

Syntax	Description
aover<cr>	Check whether the high end of the analog outputs is extended by 10 percent of the range (from 20 mA to 21.6 mA).
aover [off|on]<cr>	Enable or disable the analog output overrange extension. **off** = The range of the analog outputs is 4 ... 20 mA. **on** = The range of the analog outputs is 4 ... 21.6 mA. The scaling of the outputs is not affected.

Syntax	Description

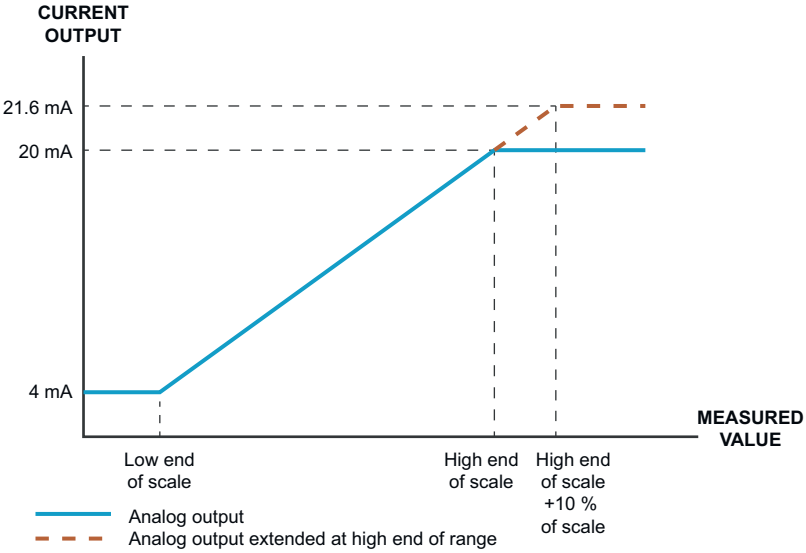
Example (check whether the analog output range is extended (extension is off), and enable the extension):
`aover`
`AOVER : OFF`
`aover on`
`AOVER : ON`
For example, channel 3 outputs temperature with output 4 ... 20 mA (-40 ... 100 °C). After giving the aover on command, the range is 4 ... 21.6 mA (-40 ... 124 °C). Note that the 100 °C point is still at 20 mA.
 
 	
Figure 5 Analog Output Overrange Behavior	

Table 31 Asel Command

Syntax	Description
asel<cr>	Show analog output parameters and scaling and prompt to enter new scaling.
asel ?<cr>	Show analog output parameters and scaling without prompting to enter new scaling.

Syntax	Description
asel [ch1 ch2 ch3] [ch1low ch1high ch2low ch2high ch3low ch3high]<cr>	Set analog output parameters and scaling. **ch1** = Output parameter for channel 1. • **rs** = relative saturation of water, %RS • **aw** = water activity (range 0.0 ... 1.0) • **h2o** = H_2O concentration in oil, ppm_w • **h2** = H_2 concentration in oil, ppm_v • **t** = temperature, °C • **h2oa** = H_2O concentration in oil (24 h average), ppm_w • **h2od** = H_2O daily ROC, ppm_w • **h2ow** = H_2O weekly ROC, ppm_w • **h2om** = H_2O monthly ROC, ppm_w • **h2a** = H_2 concentration in oil (24 h average), ppm_v • **h2d** = H_2 daily ROC, ppm_v • **h2w** = H_2 weekly ROC, ppm_v • **h2m** = H_2 monthly, ppm_v **ch2** = Output parameter for channel 2. The options are the same as for channel 1. **ch3** = Output parameter for channel 3. The options are the same as for channel 1. Optional: **ch1low** = Low limit for channel 1 output scaling. **ch1high** = High limit for channel 1 output scaling. **ch2low** = Low limit for channel 2 output scaling. **ch2high** = High limit for channel 2 output scaling. **ch3low** = Low limit for channel 3 output scaling. **ch3high** = High limit for channel 3 output scaling. The default scaling of H_2O and H_2 ROC readings is as follows: • H_2O daily, weekly, and monthly ROC: -50 ... 50 ppm_w • H_2 daily, weekly, and monthly ROC: -500 ... 500 ppm_w

Example (show current parameters and scaling for each channel and prompt to enter new scaling):

```
asel
Ch1 RS   lo   :   0.00 % ?
Ch1 RS   hi   :   100.00 % ?
Ch2 T    lo   :   -40.00 'C ?
Ch2 T    hi   :   100.00 'C ?
Ch3 H2   lo   :   0.00 ppm ?
Ch3 H2   hi   :   5000.00 ppm ?
```

Syntax	Description

Example (show current parameters and scaling for each channel without prompting to enter new scaling):

```
> asel ?
Ch1 RS   lo    :     0.00 %
Ch1 RS   hi    :   100.00 %
Ch2 T    lo    :   -40.00 'C
Ch2 T    hi    :   100.00 'C
Ch3 H2   lo    :     0.00 ppm
Ch3 H2   hi    :  5000.00 ppm
```

Example (change channel 1 to output water activity, adjust scaling to 0 ... 1 for channel 1, and to 0 ... 2000 ppm_v for channel 3):

```
asel aw t h2 0 1 -40 100 0 2000
Ch1 aw   lo   :   0.00
Ch1 aw   hi   :   1.00
Ch2 T    lo   :   -40.00 'C
Ch2 T    hi   :   100.00 'C
Ch3 H2   lo   :   0.00 ppm
Ch3 H2   hi   :   2000.00 ppm
```

Example (change channel 3 to output H_2 weekly ROC):

```
asel aw t h2w
Ch1 aw   lo    :     0.00  ?
Ch1 aw   hi    :     1.00  ?
Ch2 T    lo    :   -40.00 'C ?
Ch2 T    hi    :   100.00 'C ?
Ch3 H2W  lo    :  -500.00 ppm ?
Ch3 H2W  hi    :   500.00 ppm ?
```

If you change the output parameters, the scaling for each channel is set to default and you are prompted to enter new low and high limits for each channel. If you do not want to change one of more of the default limits, press Enter at those prompts.

Table 32 Atest Command

Syntax	Description
atest [ch1 ch2 ch3]	Set analog channel to defined output value (in mA). You can then measure the output with a calibrated multimeter. **ch1** = Output level for channel 1 in mA. **ch2** = Output level for channel 2 in mA. **ch3** = Output level for channel 3 in mA.

Syntax	Description

Example (enable analog output test mode, set level to 20 mA on all channels):
`atest 20 20 20`
`Analog output test mode: ON`
`CH1: 20.000 mA`
`CH2: 20.000 mA`
`CH3: 20.000 mA`	

Example (disable analog output test mode, resume normal output):
`atest`
`Analog output test mode: OFF`
`CH1: 7.568 mA`
`CH2: 13.714 mA`
`CH3: 4.038 mA`	

7.6 Calibration and Adjustment Commands

Table 33 Cdate Command

Syntax	Description
cdate<cr>	Show the date of the last adjustment.
cdate [yyyymmdd]<cr>	Set a new calibration and adjustment date (format "yyyymmdd").

Example (show current calibration date):
`cdate`
`Cal. date : 20150201`	

Example (set new calibration date):
`cdate 20150630`
`Cal. date : 20150630`	

Table 34 Ctext Command

Syntax	Description
ctext<cr>	Show adjustment information text.
ctext [text]<cr>	Set a new calibration and adjustment information text.

Syntax	Description

Example (show current calibration text):
`ctext`
`Cal. info : Vaisala`	

Example (set new calibration text):
`ctext H2 cal DGA lab sample`
`Cal. info : H2 cal DGA lab sample`	

Table 35 H2 da and h2 db Commands

Syntax	Description
See H 2 Calibration and Adjustment (page 83).	Calibrate and adjust H_2 measurement. When you start the adjustment, normal measurement stops temporarily and the transmitter goes into error state. Measurement returns to normal when you exit the H_2 calibration. After the adjustment, set the adjustment date and information using the **cdate** and **ctext** commands.

7.7 Other Commands

Table 36 Dnp3 Addr Command

Syntax	Description
dnp3 addr [aaa]<cr>	Change the data link address of the transmitter in DNP3 communication. **aaa** = Data link address of the transmitter
See DNP3 Protocol (page 70) and Taking DNP3 Protocol into Use (page 73).	

Table 37 Filt Command

Syntax	Description
filt [f.fff]<cr>	Set the speed at which the latest moisture and temperature measurement (approximately one measurement per second) is integrated into readings. The command affects both analog output and serial line output. This command does not affect the H_2 reading. **f.fff** = Measurement filtering factor setting, range 0.001 ... 1.0. The default value is 1.0 (no filtering). When filtering is used, the output is calculated based on the following formula: output = [(new (unfiltered) measurement × filtering factor) + (previous output × (1.0 - filtering factor))] With filtering factor value 1 the transmitter takes only the latest measurement into account, but with filtering factor value 0.1 the new output is a combination of previous measurements (90%) and the latest measurement (10%). Filtering factor value examples: • 1.0 = No filtering, the latest measurement is output directly without integrating previous measurements. • 0.5 = The reading output shows ~75% of the measurement change after two one-second measurement cycles and ~93% after four cycles. • 0.1 = The reading output shows ~90% of the measurement change after 22 measurements.
filt<cr>	Shows the current setting and prompts for a new value.

Example (view the current value and set filtering factor value to 0.5):
`filt`
`Filter : 1.000 ? 0.5`	

Table 38 Frestore Command

Syntax	Description
frestore<cr>	Restore factory settings. Clears all user settings, including serial communication settings, transmitter address, and analog output configurations. H_2 calibration remains.

Example:
`frestore`
`Factory settings restored`	

Table 39 Reset Command

Syntax	Description
reset<cr>	Reset the transmitter. The transmitter will restart as if it had just been powered on.

Example:
`reset`
`MHT410 / 1.0.0`	

Table 40 Oil Command

Syntax	Description
oil<cr>	View oil-specific parameters (oil coefficients A and B) for moisture ppm_w calculation. Leave current values in place by pressing **<cr>** at the prompt. See Moisture ppm w Calculation for Transformer Oils (page 110).
oil<cr>	Set oil-specific parameters for moisture ppm_w calculation by entering oil coeffecients A (**Oil[0]**) and B (**Oil[1]**) when prompted.

Example:
`oil`
`Oil[0]  : -1662.6999 ?`
`Oil[1]  : 7.3694 ?`	

Table 41 H2 is Command

Syntax	Description
See Re-installing the Transmitter in New Location (page 33).	Initialize the device after it has been re-installed in a new location.

8. DNP3 Protocol

MHT410 can be used as a DNP3 outstation (starting from software version 1.2.0). It supports serial communication only. Serial communication is based on RS-485 hardware, and therefore MHT410 can be used in multidrop topology.

The MHT410 device profile files for DNP3 are available for download at http://www.vaisala.com.

DNP3 protocol is available from the RS-485 line of the MHT410 screw terminals, which can support only one protocol at a time (DNP3, Modbus, or Vaisala Industrial Protocol). The factory default protocol is Modbus. To take DNP3 to use, you must change the communication protocol and other DNP3-related settings via the MHT410 service port, using Vaisala Industrial Protocol commands.

Table 42 Default Communication Settings

Setting	Factory default	Options
Communication protocol	Modbus	DNP3, Modbus, Vaisala Industrial Protocol
Communication parameters	Baud rate: 19200 Parity: None Number of data bits: 8 Number of stop bits: 1	Baud rate: 300, 600, 1200, 4800, 9600, 19200, 38400, 57600 Parity: None Number of data bits: 8 Number of stop bits: 1, 2
Data link address	4	0 ... 32767
Host address	3	0 ... 32767

8.1 Connecting via Service Port

- Vaisala USB service cable (219690)
- Computer with:
  - Windows operating system
  - Free USB port
  - Terminal application (e.g. PuTTy available from http://www.vaisala.com/software)
  - Driver for Vaisala USB service cable installed (available on the cable installation media and from http://www.vaisala.com/software)

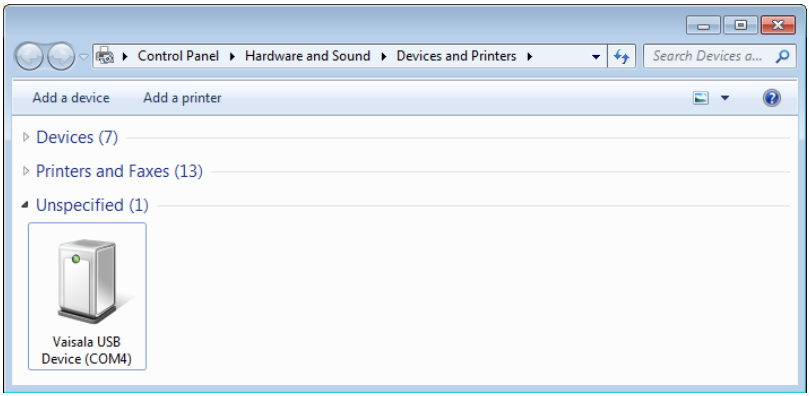
You can connect to the transmitter via Vaisala Industrial Protocol on a computer using the service port located under the transmitter cover.

If you have not used the Vaisala USB cable before, install the driver before attempting to use the cable.

8.1.1 Installing the Driver for the USB Service Cable

Only Windows® operating systems are supported by the driver of the USB service cable.

1. Connect the USB service cable to a USB port on your computer. Windows® detects the new device and installs the appropriate driver.
2. Open **Devices and Printers** from the Windows® Start menu. Use search to find it if necessary (search for "devices").
3. Locate the cable in the list of devices:
   - If the device is listed as **Vaisala USB Device** with a COM port number in brackets, the cable is ready for use. **Note the COM port number, you will need it later.**
   - If the device is listed as **Vaisala USB Instrument Cable** without a COM port number listed, you must install the driver manually.



4. To install the driver manually:
   a. Disconnect the USB service cable from the computer.
   b. Download the Vaisala USB driver at http://www.vaisala.com/software (select the appropriate USB Instrument Driver Setup for your cable).
   c. Run the USB driver installation program *`Vaisala USB Device Driver Setup.exe`*. Accept the installation defaults.
   d. Go back to step 1 and verify that the driver installation works as expected.

8.1.2 Connecting USB Cable

To connect the USB service cable to the service port:

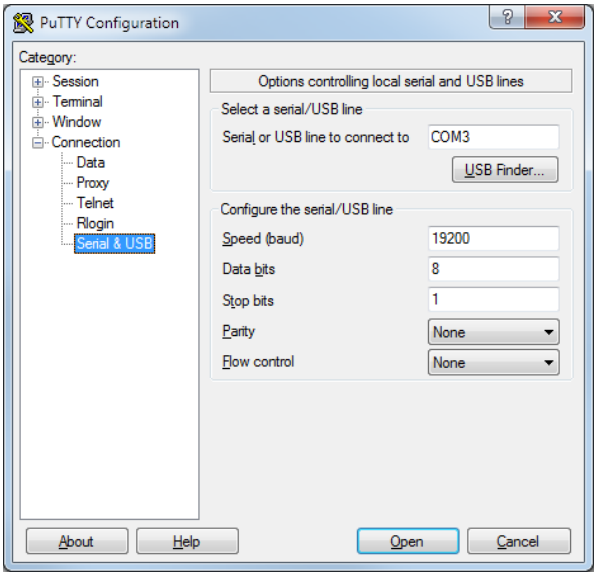
1. Make sure the USB cable is connected to your computer.
2. Open the screws on the transmitter cover, and open the cover.

3. Connect the USB service cable to the service port connector on the transmitter.
4. Configure the terminal application settings.

8.1.3 Configuring Terminal Application Settings

The steps below describe how to connect to the transmitter using the PuTTY terminal application for Windows (available for download at http://www.vaisala.com/software) and a USB service cable:

1. Make sure the USB service cable is connected to your PC and the service port of the transmitter.
2. Start the PuTTY application.
3. Select **Connection > Serial & USB** and check that the correct COM port is selected in the **Serial or USB line to connect to** field. If you are using the PuTTY terminal application supplied by Vaisala, you can click the **USB Finder** button to open the Vaisala USB Instrument Finder program.



4. Check that the other serial settings are correct, and change if necessary.

   Table 43 Service Port Serial Interface Settings

Property	Value
Baud rate	19200
Parity	None
Data bits	8
Stop bits	1
Flow control	None

5. Select **Terminal**. Use the following settings:
   - **Local Echo**: "Force on". This setting ensures that your typing is shown on the session window.
   - **Send line ends with line feeds (CR+LF)**: Selected. This setting ensures that all text lines remain visible on the session window.
6. Click the **Open** button to open the connection window and start using the serial line.

If PuTTY is unable to open the serial port you selected, it will show you an error message instead. If this happens, restart PuTTY and check the settings.

8.2 Taking DNP3 Protocol into Use

1. To active the DNP3 communication mode, type `smode dnp3` in the terminal window and press Enter.
   Example:

```
smode dnp3
Serial mode    :     DNP3
```

2. Optional: To change the baud rate or number of stop bits, type **`seri [baud rate] N 8 [number or stop bits]`** and press Enter.
   - Baud rate options: 300, 600, 1200, 4800, 9600, 19200 (default), 38400, 57600
   - Stop bit number options: 1 (default), 2

   Example (set baud rate to "38400" and number of stop bits to "2"):

```
seri 38400 N 8 2
Baud P D S     :    38400 N 8 2
```

Do not change the other communication parameters: parity ("N") or number of data bits ("8"). If you change these settings, DNP3 communication will not work on MHT410.

3. Optional: To change the data link address (default: 4), type **`dnp3 addr [data link address]`** and press Enter.
   Data link address range: 0 ... 32767
   Example (change data link address to "10"):

```
dnp3 addr 10
DNP3 ADDR      :        4 -> 10
DNP3 HOST      :        3
```

The DNP HOST setting is currently not used. The current implementation of the DNP3 protocol on MHT410 only sends responses to the host that sends a request.

4. To save the settings, reset the transmitter by typing **`reset`** and pressing Enter.

```
reset
MHT410 / 1.2.0
```

5. Close the PuTTY terminal application.
6. Disconnect the USB cable from the service port, and close the transmitter cover.

9. MI70 Hand-Held Indicator

You can use the Vaisala MI70 hand-held indicator as a temporary display for the transmitter.

MI70 shows the readings for all the parameters measured by the transmitter. You can also view the trend of the measurement on the graphical display, and compare the moisture and temperature readings of MHT410 to a Vaisala MM70 reference probe.

The MI70 hand-held indicator is intended to be used as display only. You cannot use the MI70 to configure and calibrate MHT410.
To configure the transmitter, use Vaisala Industrial Protocol (see Vaisala Industrial Protocol (page 39)). For H_2 calibration instructions, see H 2 Calibration and Adjustment (page 83).

9.1 MI70 Indicator Overview

9.1.1 MI70 Indicator Parts

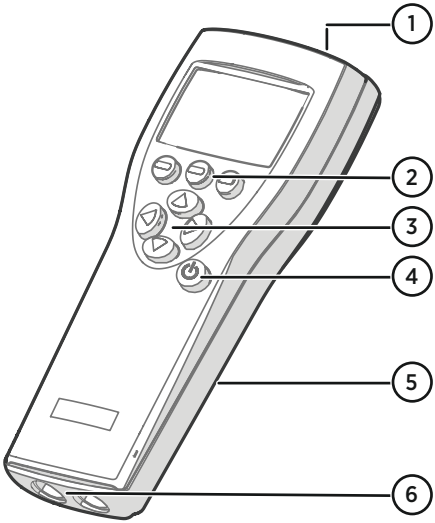


Figure 6 MI70 Indicator Parts

1 Charger socket
2 Function key shortcut buttons. The functions change according to what you are doing with the indicator.
3 Arrow buttons:
   - Move up in a menu
   - Move down in a menu
   - Enter a sub-menu
   - Return to previous menu level
4 Power On/Off button
5 Battery compartment at the back of the indicator
6 Two ports (labeled I and II) for connecting probes and instruments.

To open menus, press an arrow button and then press the shortcut buttons. To activate a function shown above the shortcut button, press the shortcut button. To navigate in the menus, press arrow buttons.

9.1.2 Basic Display

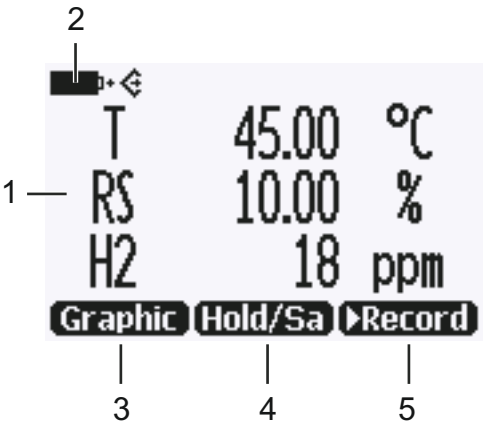


Figure 7 MI70 Basic Display

1 Measured parameter and compensations (up to three items on display simultaneously). You can change the shown items in **Main menu > Display > Quantities and units**.
2 Battery indicator. Shows current status (charge) of the battery.
3 Function key **Graphic** shows the readings as a curve.
4 Function key **Hold/Save** freezes the display and you can save the reading in the MI70 memory.
5 Function key **Record** is a quick access to the **Recording/Viewing** menu.

You can change the default function key shortcuts (**Graphic**, **Hold/Save**, **Record**) to other menus or functions in **Main menu > Settings > User interface > Program shortcut keys**.

9.1.3 Graphical Display

The graphical display shows you the measurements as a curve (the curve of the uppermost quantity shown in the basic display). From the curve you can examine the data trend and history of the last minutes.

To open the graphical display, select **Graphic** in the basic display or select **Main menu > Display > Graphic history > Show**.

To get the statistical info on the graph area (minimum, maximum, and average values), press **Info**.

To get the curve of the other selected quantities, press **Next**. To get the curves of all the quantities, press **Next** until the text **All** appears, and then select **All**.

To zoom in and out, press the up/down arrow keys.

To move back and forward in the timeline, use the left/right arrow keys.

9.1.4 Main Menu

To open the main menu:

1. Go to the basic display.
2. Press any arrow key, then select OPEN.

In the main menu, you can configure the MI70 settings and basic display. You can also perform certain operations with the transmitter.

More Information

- Holding and Saving the Display (page 78)
- Recording Data (page 79)
- Comparing Readings with MM70 Probe (page 80)

9.2 Installing and Recharging MI70 Batteries

If you are using **alkaline** batteries, unscrew the back plate of the indicator and insert the batteries. Do not attempt to recharge standard alkaline batteries.

If you ordered MI70 with a **rechargeable** battery, it is already in place as shipped from the factory. The delivered batteries have been pre-charged.

To recharge the battery:

1. Plug in charger connector to the indicator. The plug is located at the top of the indicator, covered by rubber seal.
2. Connect the charger to wall socket. A battery symbol in the left corner of the display starts to roll. The recharge duration (typically 4 ... 5 h) depends on the charge level of the battery.

A new battery takes approximately three charging cycles to reach maximum battery life.

Do not store the batteries empty. Empty batteries may not charge after extended storage period.

9.3 Connecting MI70 to Service Port

- MI70 Indicator or MM70 Moisture Meter (includes MI70 indicator, a moisture-in-oil probe and a ball valve)
- Connection cable (Vaisala order code 219980)
- Power supply for MHT410

1. Open the screws on the transmitter cover, and open the cover.
2. Connect the cable (219980) to the service port connector on the transmitter and to port I or II of MI70 indicator.
3. Switch the MI70 indicator on.

9.4 Holding and Saving the Display

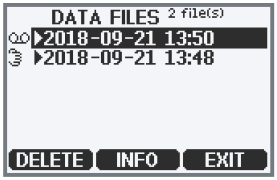
With the **Hold/Save** function, you can freeze a certain display reading. This reading can be saved in the MI70 memory and it will be available even after MI70 is disconnected from the transmitter.

1. In the basic display, select **Hold/Save**. Alternatively, select **Main menu > Display > Hold/Save display > Hold**.
2. Press **Save**.
3. To view the saved display, go to basic display and select **Record > View recorded data**. Alternatively, select **Main menu > Recording/Viewing > View recorded data**.
   A list of saved displays and data recordings appears. The icons on the left of the date and time indicate whether the file is a saved display or a longer recording of data:

   Saved display

   Data recording
4. Select the saved display based on date and time by pressing the right arrow key.



9.5 Recording Data

With MI70, you can record transmitter measurement data over a certain period at chosen intervals. These recordings are saved in MI70 memory and are available even after MI70 is disconnected from the transmitter. To start recording, select the **Record** function key in the basic display, or navigate to the recording menu: **Main menu > Recording/Viewing > Record data**.

9.5.1 Starting and Stopping the Recording

You can record the measurement of the parameters that are currently shown on the MI70 basic display. You can change the shown parameters in **Main menu > Display > Quantities and units**.

1. In the basic display, select **Record > Record data**. Alternatively, select **Main menu > Recording/Viewing > Record data**.
2. If needed, change the interval and duration of the recording in the **RECORD DATA** view. The measurement intervals and maximum recording times are shown in the following table.

Recording Interval	Maximum Recording Time (memory full)		
	1 Parameter	2 Parameters	3 Parameters
1 s	45 min	22 min	15 min
5 s	3 h	113 min	75 min
15 s	11 h	5 h	3 h
30 s	22 h	11 h	7 h
1 min	45 h	22 h	15 h
5 min	9 days	4 days	3 days
15 min	28 days	14 days	9 days
30 min	56 days	28 days	18 days
1 h	113 days	56 days	37 days
3 h	339 days	169 days	112 days
12 h	1359 days	678 days	451 days

If you set the duration to "Memory full", the recording continues until the MI70 memory is full or until you stop the recording manually. The maximum recording time is shown when you start the recording.

3. Select **Start/Stop recording > Start**.
   The recording continues until the duration has passed or until you stop the recording manually.
   You can switch the MI70 off during recording to save battery. A progress bar  is shown on the display every 10 seconds (or all the time, if a charger is connected). The progress bar shows the amount of recorded data.

   CAUTION! Do not disconnect the probe when the data recording is on, even if the indicator is off. This may cause loss of recorded data.

4. To stop the recording manually, in the basic display select **Record > Record data > Start/stop recording > Stop**. To view the recorded file, select **Show**.

9.5.2 Viewing Recorded Data

1. Open the menu by pressing ▶ ⊖ **Open**.
2. Select **Recording/Viewing** and press ⊖.
3. Select **View recorded data** and press ▶.
4. Select the file you want to view and press ▶. The files are identified according to the starting date and time of recording.
5. To go to the graphical view, press ⊖ **Graph**. To view the recording time stamps, press ⊖ **Times**. To return to the recording values, press ⊖ **Values**.
6. To return to the basic display, press ⊖ **Exit**.

9.5.3 Clearing Data Memory

To clear the data memory:

1. Open the menu by pressing ▶ ⊖ **Open**.
2. Select **Recording/Viewing** and press ▶.
3. Select **Clear data memory** and press ⊖ **Clear**. To confirm the deletion, press ⊖ **Yes**.
4. To return to the basic display, press ⊖ **Exit**.

9.6 Comparing Readings with MM70 Probe

- Vaisala HUMICAP® Hand-held Moisture Meter for Oil MM70

You can use MI70 to compare the measurement readings of MHT410 to an MM70 reference probe.

The indicator shows the readings from both devices at the same time. You can also show the difference in reading for water activity (Δaw) and temperature (ΔT).

1. Install the MM70 probe in the same transformer as MHT410. For instructions, see the MM70 User's Guide (available at http://www.vaisala.com/manuals).
2. Turn off the MI70 indicator.
3. If MHT410 is not connected to MI70, connect it to one of the MI70 ports (I or II).
4. Connect the MM70 probe to the other MI70 port.
5. Turn on the MI70.

The basic display now shows the readings from both devices. The port of the device is indicated next to the measured parameter. You can change the shown parameters in **Main menu > Display > Quantities and units**.

Figure 8 Example of MI70 Display with MHT410 in Port I and MM70 Probe in Port II. Shown Parameters: aw (I), aw (II), Δ aw.

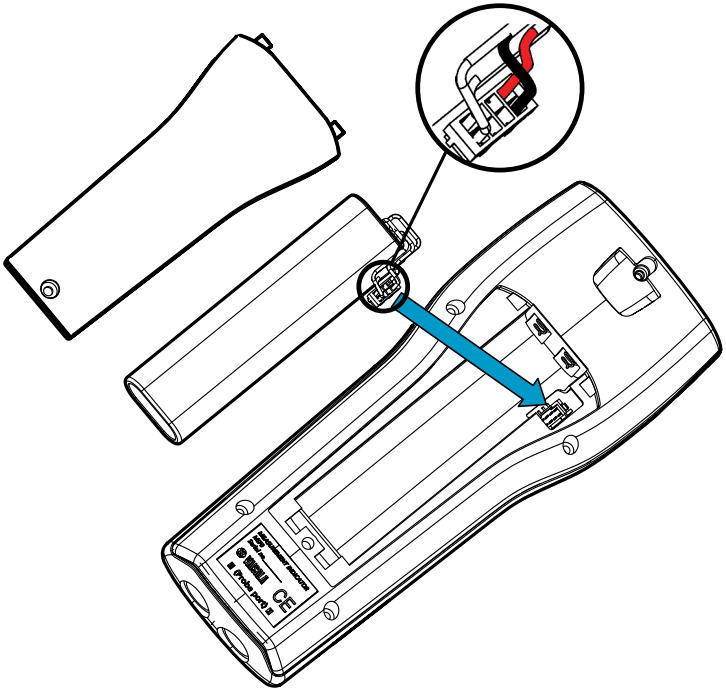
9.7 Changing the Rechargeable Battery Pack

- New rechargeable battery pack
- Medium-sized flathead screwdriver

In case you are installing a battery pack and you have a device with alkaline batteries, remove the metal contact from the probe port end of the battery compartment before installing the battery pack.

1. Open the back plate of the indicator by opening the screw of the back plate.
2. Remove the old battery pack. Detach the black connector by carefully pulling it up from the wires.

3. Connect the black connector of the new battery pack. Make sure the position of the connector is as shown in the following figure (red and black wires are on the upper edge of the connector). Do not push the connector with conducting material.



4. Place the battery pack in the compartment.
5. Close the back plate and tighten the screw.
6. Recharge the indicator before use.

10. Calibration and Adjustment

MHT410 is fully calibrated and adjusted as shipped from factory.

10.1 H_2 Calibration and Adjustment

You can calibrate MHT410 for H_2 by comparing the H_2 reading on the MHT410 to the H_2 concentration of a laboratory-analyzed DGA oil sample. There is no need to remove the transmitter from the transformer to perform calibration and adjustment.

In the calibration procedure, you take a DGA oil sample from the transformer and save the H_2 concentration measured by the transmitter at that time. When you have analyzed the H_2 concentration of the sample, you enter the analyzed H_2 reading to MHT410. The transmitter then implements the adjustment to the H_2 measurement.

More Information

- Entering DGA H2 Reading to Transmitter (page 84)
- Taking DGA Sample and Saving Current H2 Reading (page 83)

10.1.1 Taking DGA Sample and Saving Current H_2 Reading

- Tools for taking a DGA oil sample
- Connection to the transmitter using Vaisala Industrial Protocol in one of the following ways:
  - Service port (see Connecting via Service Port (page 40))
  - RS-485 line of the screw terminals (User Port is configured for Modbus by default: to enable command entry, connect to the transmitter via Service Port and switch the operating mode of the screw terminals (see Table 28 (page 61)))

In the following instructions, the keyboard input by the user is in **`bold`** type.

When you start the adjustment with the **h2** command, normal measurement stops temporarily and the transmitter goes into error state. Measurement returns to normal when you exit the H_2 calibration.

1. Take the DGA oil sample from the transformer.
2. Open the connection on Vaisala Industrial Protocol (see Connecting via Service Port (page 40)).

3. Start the calibration sequence with the command **h2**. The transmitter starts outputting H_2 measurement data.

```
h2
SSN=b11.04rt.10432tn1x, FW=3.85F , MDN=104400-FF02-P1, DF=0xB4B4v,
L.
..
```

4. Stop the output by pressing the **Esc** key:

```
...
7997.00 34.0852 50.11176 186.69 2654140 2652818 23
0.0 0 22.2649 0 0 wait
<"ESC key">
H2scan:
```

5. Save the H_2 reading with the **da** command:

```
H2scan: da
Current H2 value is 14.4 ppm...wait...
```

6. When the H_2 measurement output resumes, exit the calibration sequence by pressing the **+** key:

```
...
79842.00 33.8725 50.11766 186.97 2654214 2652858 359
14.4 0 28.5654 200 200 wait <"+ key">
Quit hydrogen measurement module command line operation
```

Do not exit the calibration sequence before the H_2 measurement output has resumed.
If the H_2 output does not resume automatically, issue the command **g** and the command **v** to start the H_2 output, and then exit the calibration sequence.

10.1.2 Entering DGA H_2 Reading to Transmitter

- Connection to the transmitter using Vaisala Industrial Protocol in one of the following ways:
  - Service port (see Connecting via Service Port (page 40))
  - RS-485 line of the screw terminals (User Port is configured for Modbus by default: to enable command entry, connect to the transmitter via Service Port and switch the operating mode of the screw terminals (see Table 28 (page 61)))

When you start the adjustment with the **h2** command, normal measurement stops temporarily and the transmitter goes into error state. Measurement returns to normal when you exit the H_2 calibration.

1. Open the connection on Vaisala Industrial Protocol (see Connecting via Service Port (page 40)).
2. Start the calibration sequence with the command **h2**. The transmitter starts outputting H_2 measurement data.

```
h2
SSN=b11.04rt.10432tn1x, FW=3.85F , MDN=104400-FF02-P1, DF=0xB4B4v,
L
...
```

3. Stop the output by pressing the **Esc** key:

```
...
7997.00 34.0852 50.11176 186.69 2654140 2652818 23
0.0 0 22.2649 0 0 wait
<"ESC key">
H2scan:
```

4. Enter the DGA H_2 reading with the **db** command:

```
H2scan: db
Enter actual hydrogen in ppm: 10
Set hydrogen to 10.0ppm (Y/N)? y
Enter Today's Date:
Month: 4
Day: 14
Year: 2015
...wait...
```

5. When the H_2 measurement output resumes, exit the calibration sequence by pressing the **+** key:

```
...
79842.00 33.8725 50.11766 186.97 2654214 2652858 359
10.0 10 28.5654 200 200 wait <"+ key">
Quit hydrogen measurement module command line operation
```

Do not exit the calibration sequence before the H_2 measurement output has resumed.
If the H_2 output does not resume automatically, issue the command **g** and the command **v** to start the H_2 output, and then exit the calibration sequence.

6. Enter the calibration date and information using the **cdate** and **ctext** commands. For example:

```
cdate 20150630
Cal. date : 20150630
ctext H2 cal DGA lab sample
Cal. info : H2 cal DGA lab sample
```

10.2 RS & T Calibration and Adjustment

MHT410 is calibrated at the factory for RS and T. In normal transformer conditions, the moisture in oil sensor is very stable and regular RS and T calibration is not needed. Moisture in oil can be checked, for example, when taking an oil laboratory sample, or when checking with a hand-held indicator.

The reference oil sample should be taken near the MHT410 in order to get a sample that matches the measurement conditions of the MHT410 sensor. The same also applies to hand-held reference checks. If changes are suspected, MHT410 can be sent to Vaisala for RS and T calibration.

For more information on the calibration and adjustment services provided by Vaisala, visit the Vaisala calibration website at http://www.vaisala.com/calibration.

When installing the hand-held reference probe inside the transformer, it may take up to 24 hours for the moisture readings to stabilize. An insufficient stabilization time may lead to incorrect results. To get the best results with hand-held measurements, always make them under flowing conditions when possible.

11. Troubleshooting

11.1 Error States

MHT410 has the following states that indicate a problem with the transmitter:

- Error indication on analog outputs at 3.5 mA (default):
  - With hydrogen measurement errors, the hydrogen channel is in error state.
  - With moisture in oil measurement errors, the moisture in oil channel is in error state.
  - With temperature measurement errors, the temperature and moisture in oil channels are in error state.
  - With general errors, all three channels are in error state.
- Error messages on the serial line:
  - Modbus statuses (see Table 60 (page 107))
  - Vaisala Industrial Protocol error list

Table 44 Possible Error Messages via Vaisala Industrial Protocol

Error Number and Text	Description	Action
0001 Temperature measurement error	Temperature measurement raw value is outside the allowed range.	Remove the transmitter from the transformer and visually check the integrity of the transmitter and the sensor area of the probe body (see Removing the Transmitter (page 32)). Contact Vaisala technical support.
0002 Frequency measurement error	Moisture measurement raw value is outside the allowed range.	
0004 H2 measurement error	H_2 module has reported an error.	Check the connection to the H_2 module: 1. Connect using Vaisala Industrial protocol (see Connecting via Service Port (page 40)). 2. Open the connection to H_2 module by giving the command **h2**. 3. Verify whether the transmitter starts outputting H_2 measurement data. 4. Close the connection to H_2 module by pressing the **+** key. Contact Vaisala technical support.
0008 H2 module communication error	No message was received from H_2 module in the last 5 seconds.	
0010 RH sensor failure	Capacitance value is outside the allowed range.	Remove the transmitter from the transformer and visually check the integrity of the transmitter and the sensor area of the probe body (see Removing the Transmitter (page 32)). Contact Vaisala technical support.

Error Number and Text	Description	Action
0020 Temperature too high/low	Measured temperature is outside the error limits (below -45 °C or above +125 °C).	Ensure that the operating temperature is within the valid range -40 ... +120 °C. If the error persists, contact Vaisala technical support.
0040 Program flash CRC error	Internal transmitter failure.	Contact Vaisala technical support.
0080 Parameter flash check sum error		
0100 INFOA check sum error		
0200 SCOEFS check sum error		
0400 CURRENT check sum error		
0800 DEFAULT (factory) check sum error		
1000 General flash failure W/R		

In case of constant error, please contact Vaisala technical support.

11.2 Changing Bleed Screw

If oil starts flowing out from the bleed screw on the mounting nut, tighten the bleed screw. If oil still flows out, change the bleed screw.

- New bleed screw (provided in the MHT410 installation kit)
- Medium wrench (36 mm)
- Large wrench (50 mm)
- Allen key (3 mm, provided in the MHT410 installation kit)

1. Remove the transmitter. See Removing the Transmitter (page 32).

2. Remove the bleed screw from the mounting nut.
3. Clean the mounting nut of any oil.
4. Install a new bleed screw and tighten it firmly.
5. Remove the old PTFE tape from the mounting nut.
6. Re-install the transmitter. See Mechanical Installation (page 20).

12. Technical Data

Table 45 Measurement Performance

Property	Description/Value
Hydrogen	
Measurement range (in oil)	0 ... 5000 ppm_v
Accuracy (in oil temperature range -20 ... +60 °C (-4 ... +140 °F)) [1]	±20 % of reading or ±25 ppm_v (whichever is greater)
Repeatability	±10 % of reading or ±15 ppm_v (whichever is greater)
Minimum detection limit	25 ppm_v
Typical long-term stability	3 % of reading / year
Cross sensitivity to other gases	< 2 % (CO_2, C_2H_2, C_2H_4, CO)
Response time	63 % of full response: 2.5 h (when sensor is not in reference cycle) 90 % of full response: 17 h
Warm-up time	2 h, 12 h for full specification
Sensor	Catalytic palladium-nickel alloy film solid-state sensor
Moisture in Oil	
Measurement range (in oil)	0 ... 100 %RS / a_w 0 ... 1
Response time (90 % of full response at +20 °C (+68 °F) in still oil)	10 min
Sensor	HUMICAP® 180L2
Accuracy (including non-linearity, hysteresis, and repeatability):	
0 ... 90 %RS	±2 %RS (a_w ± 0.02)
90 ... 100 %RS	±3 %RS (a_w ± 0.03)
Temperature	
Measurement range	-40 ... +120 °C (-40 ... +248 °F) [1]
Accuracy at +20 °C (+68 °F)	±0.2 °C (0.36 °F)
Sensor	Pt1000 RTD Class F0.1 IEC 60751

1) *Note that the temperature range for specified measurement accuracy differs between measurement parameters. Measuring a parameter outside its temperature range does not damage the sensor, but results in reduced accuracy for that parameter.*

Table 46 Operating Environment

Property	Description/Value
Oil type	Selected when ordering, available options: [1] • Mineral oil • Natural ester oil • Synthetic ester oil
Operating temperature (electronics)	-40 ... +60 °C (-40 ... +140 °F)
Storage temperature	-40 ... +60 °C (-40 ... +140 °F)
Operating humidity	0 ... 100 %RH, condensing
Pressure tolerance (probe, short-term)	Max. 10 bara
Pressure tolerance (probe, continuous)	Max. 4 bara
Temperature tolerance, sensor head	-40 ... +120 °C (-40 ... +248 °F)
Integrated protection for short power outages	> 3 s
EMC standard EN61326-1, Industrial environment; CISPR22 class B emission limits when DC powered	Fulfills the requirements of IEC 61000-6-5 in the following tests: IEC 61000-4-2, IEC 61000-4-3, IEC 61000-4-4, IEC 61000-4-5, IEC 61000-4-6, IEC 61000-4-8, IEC 61000-4-11, IEC 61000-4-12, IEC 61000-4-16, IEC 61000-4-17.

1) *Changing the oil type MHT410 measures requires reconfiguration at Vaisala.*

Table 47 Inputs And Outputs

Property	Description/Value
Operating voltage	15 ... 30 VDC, 24 VAC (±15 %) (power supply input is galvanically isolated) [1]
Power consumption	Typical 4 W, maximum 12 W
Recommended external power supply	24 VDC / 0.5 A minimum
Analog Output (Current) [1]	
Channels	Three isolated 4 ... 20 mA (loop powering required)
External load	Max. 500 Ω
Error status indication in case of device error	3.5 mA default, user-configurable for each channel
mA output accuracy at +20 °C (+68 F)	±0.125 % full scale
Temperature dependence of the analog outputs	±0.006 % / °C full scale
Digital Outputs [1]	

Property	Description/Value
Interfaces	Isolated RS-485 half-duplex RS-485 (Service Port)
Protocols	Modbus RTU, DNP3, serial ASCII commands
Screw terminals	Wire size AWG 22-14 Single wire (solid) 1.5 mm^2 Stranded wire (flex.) 1.0 mm^2 Recommended wire torque 0.4 Nm

1) Max. isolation voltage 1.5 kV DC.

Table 48 Mechanical Specifications

Property	Description/Value
Mechanical connection on transmitter	1.5 in NPT (male)
Cable bushing (optional)	M20 × 1.5 for cable diameter 8 ... 11 mm (0.31 ... 0.43 in)
Conduit fitting (optional)	1/2 in NPT
Interface cable (optional, pre-assembled)	5 m (16 ft 5 in), 9.2 mm (0.36 in) outer diameter
Housing material	AlSi 10 Mg
IP rating	IP66
Transmitter weight without cables	4.1 kg (9.04 lb)
Self-diagnostics indication	Status LEDs, analog output, Modbus
Integrated data logging capabilities	Non-volatile memory, up to 44 years' storage with default logging
Individual functional test reports	Calibration test reports for moisture, hydrogen, and temperature; probe leak test report (5 bara nominal)
Factory warranty	5 years

Table 49 Compliance

Property	Description/Value
IP rating	IP66

Property	Description/Value
EMC compliance	EMC standard EN61326-1, Industrial environment CISPR22 class B emission limits when DC powered Fulfills the requirements of IEC 61000-6-5 in the following tests: • IEC 61000-4-2 • IEC 61000-4-3 • IEC 61000-4-4 • IEC 61000-4-5 • IEC 61000-4-6 • IEC 61000-4-8 • IEC 61000-4-11 • IEC 61000-4-12 • IEC 61000-4-16 • IEC 61000-4-17

Table 50 Display with Relays (External Option)

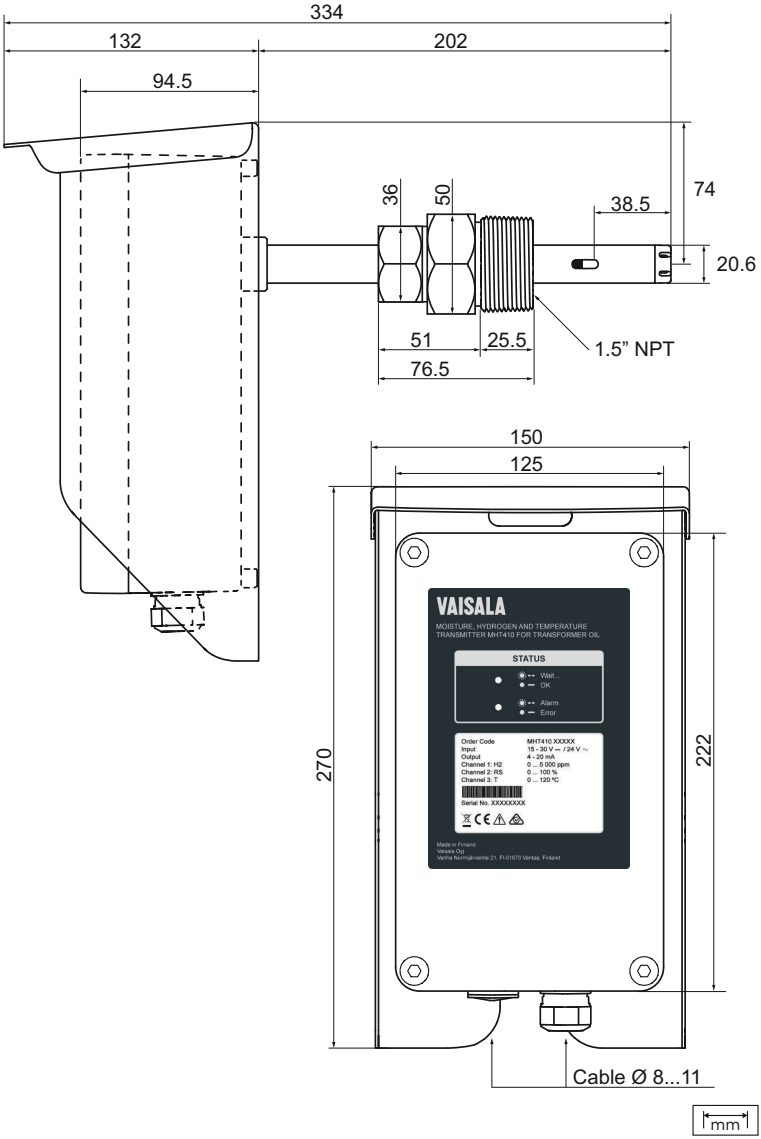
Property	Description/Value
Pre-configured range for hydrogen	0 ... 5000 ppm_v
Pre-configured alarm relays (user-reconfigurable)	Relay 1 trigger limit 200 ppm_v (hi) Relay 2 trigger limit 1500 ppm_v (hihi)
Input	4 ... 20 mA, loop-powered
Accuracy	0.05 % of span (-10 ... +60 °C (-14 ... +140 °F))
Relays	2 × solid state (SSR) Max. 250 VAC, 150 mA
Display	4-digit red LED, 14.5 mm
Dimensions (H × W × D)	100 × 100 × 57 mm (3.94 × 3.94 × 2.24 in)
Case protection	IP65
Case material and color	ABS plastic, grey
Cable glands	2 × M16×1.5

12.1 Spare Parts and Accessories

Table 51 Spare Parts and Accessories

Item	Order Code
USB cable for PC connection	219690
External DIN rail power 100 ... 240 VAC / 95 ... 220 VDC to 24 VDC	242422
5 m shielded PUR cable	CBL210392-5MSP
10 m shielded PUR cable	CBL210392-10MSP
Cable gland	214728SP
Detachable screw terminal block	236620SP
Loop-powered external display, Nokeval 302 (with alarm relays)	242003
MI70 connection cable	219980
Conduit fitting	214780SP
1.5-inch NPT ball valve with welding fitting	BALLVALVE-3SET

12.2 Dimensions



12.3 Wiring Diagrams

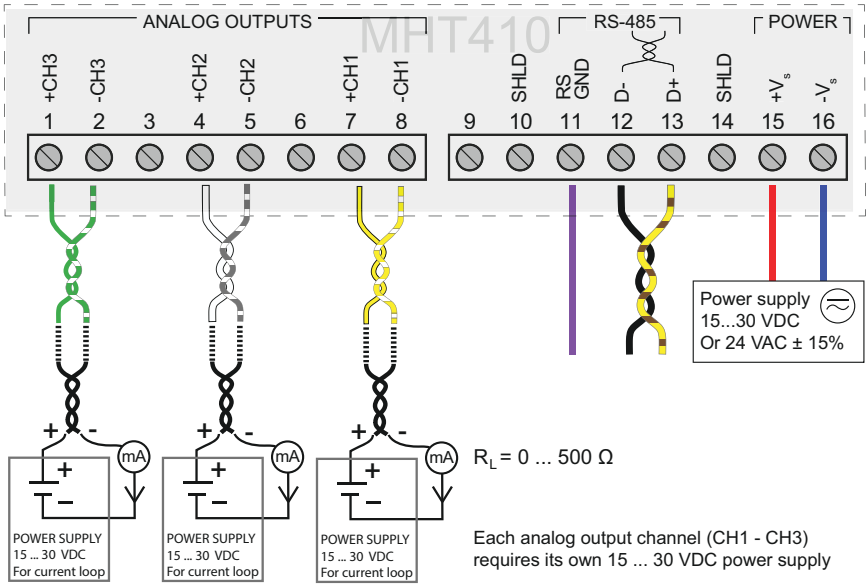


Figure 9 Wiring Option 1: Wiring with Four Power Supplies. Separate Loop Powering and Galvanic Isolation for Analog Outputs. In transmitters ordered with Vaisala cable CBL210392-5M, the cable is pre-wired according to this option.

Table 52 Vaisala Cable CBL210392-5M Wire Colors (When Pre-Wired)

Terminal	Wire Color
+CH3	Green
-CH3	White-Green
+CH2	White
-CH2	Gray-White
+CH1	Yellow
-CH1	White-Yellow
RSGND	Purple
D-	Black

Terminal	Wire Color
D+	Yellow-Brown
$+V_s$	Red
$-V_s$	Blue

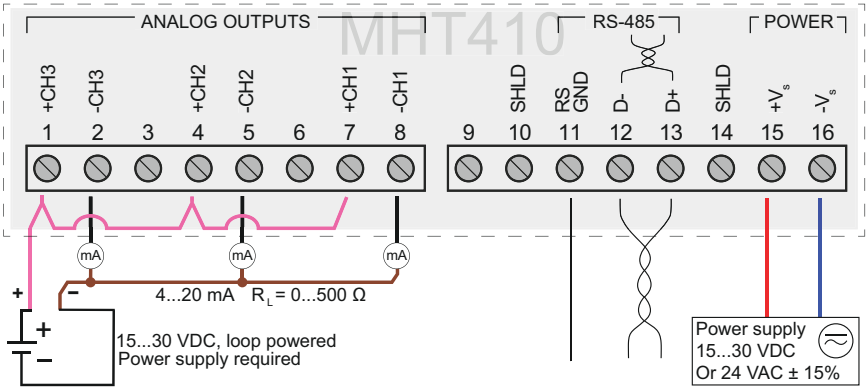


Figure 10 Wiring Option 2: Wiring with Two Power Supplies. Common Loop Powering And Galvanic Isolation for Analog Outputs.

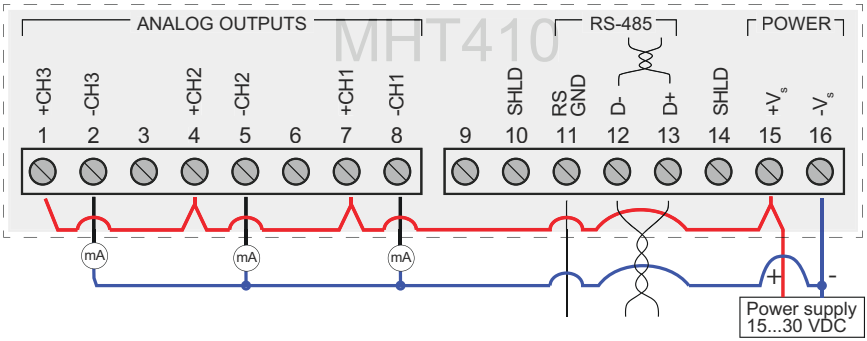


Figure 11 Wiring Option 3: Wiring with One Power Supply. Non-Isolated Configuration for Analog Outputs Sharing Transmitter Power Supply.

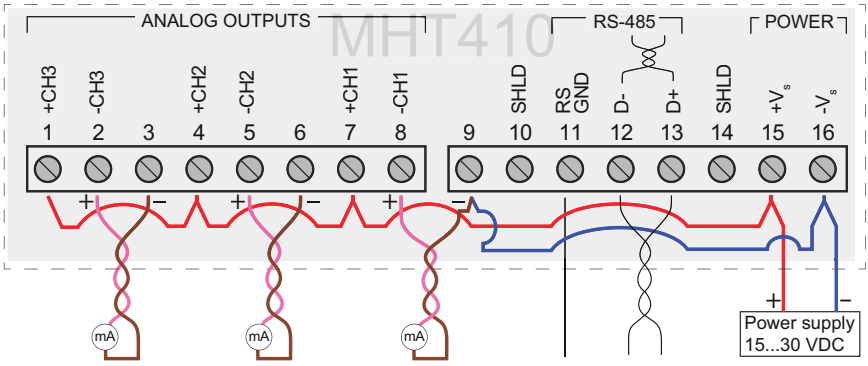


Figure 12 Wiring Option 4: Wiring with one Power Supply. Alternative Wiring to Option 3, Providing Reduced Current Loop Area for Analog Outputs.

12.4 Recycling

Recycle all applicable material.

Disposal of Vaisala products is to be done according to local laws and regulations. We encourage end-users to segregate the products from other waste at end-of-life and use best available recycling practices to minimize related environmental impacts.
Almost all of the parts in our products can be recovered as material or energy. If applicable, Vaisala recommends removing the battery unit before recycling the rest of the device as typical electronic waste. The battery unit can be recycled separately in accordance with local waste management practices and regulations. Integrated small sized batteries are typically left in place and removed by professionals at the recycling facilities.

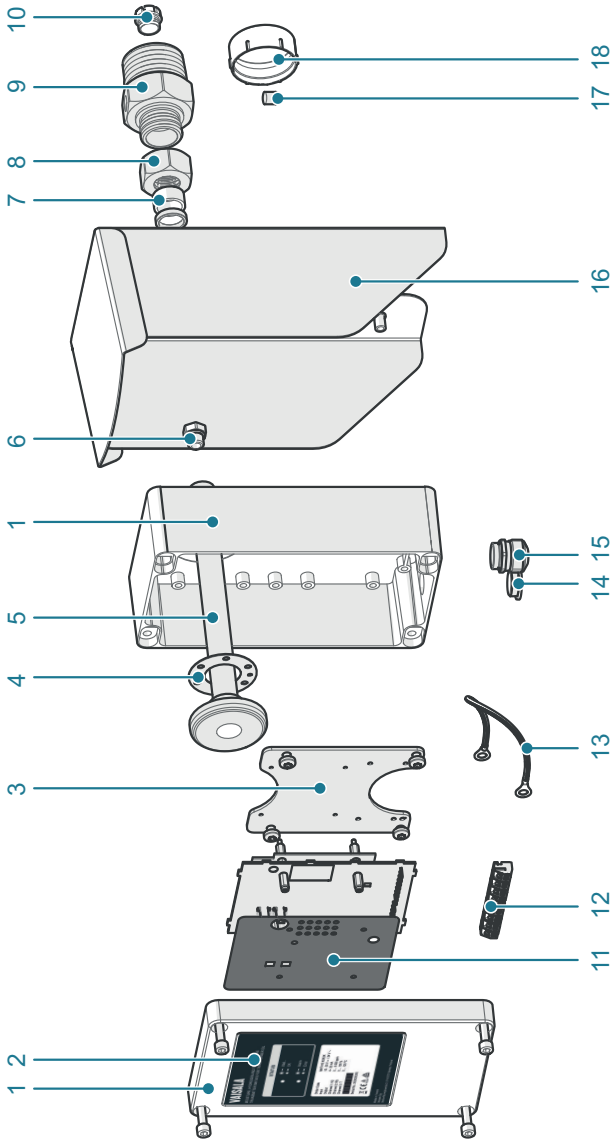


Figure 13 Materials for Recycling

Table 53 Materials for Recycling

Part		Materials
Packaging		
Product package		Cardboard
Padding foam		Polyethylene
Device parts		
1	Electronics housing and front cover	AlSi 10Mg
2	Product label	Polyester
3	Circuit board mounting plate	EN 1.4404
4	Flange gasket	Silicone
5	Probe shaft	Outer shaft: EN 1.4404 Inner plastic: Polyphenylene sulfide, glass-fiber reinforced
6	Ventilation valve	Polyester
7	Sealing ring	PTFE
8	Tightening nut	EN 1.4404
9	Mounting nut	EN 1.4404
10	Filter	EN 1.4404
11	Circuit board cover	Polypropylene
12	Terminal blocks	Polyamide PA66
13	Grounding cable	Copper wire
14	Plug for cable lead-through	Polyamide
15	Cable gland	Nickel-plated brass
16	Weather shield	EN 1.4404
17	Sorbent packet	Silica
18	Thread cap	LDPE
Screws		A4

Appendix A. Operating Principle

Power transformers are critical components in the electric grid. Age, increased load levels and network failures all take a toll on transformers, increasing the risk of unpredicted faults and outages.

- Hydrogen levels and their rate of change indicate the severity of a fault situation.
- Moisture has a direct impact on the lifetime of a transformer. Oil moisture has a significant effect on transformer cellulose condition and the oil's ability to insulate. These changes in moisture levels can occur rapidly.

Continuously monitoring hydrogen and moisture levels with an in-situ transmitter is the first step in extending the life of a transformer through implementation of predictive maintenance practices leading to lower total cost of ownership.

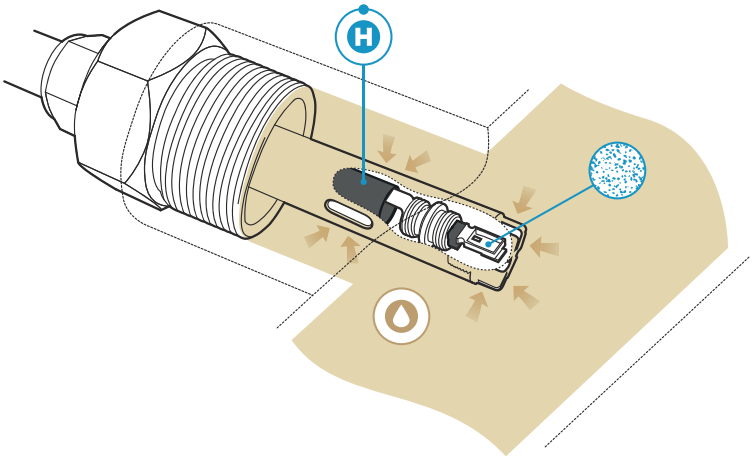


Figure 14 Measuring Hydrogen and Moisture in Oil with MHT410

The optimal locations for the MHT410 hydrogen, moisture and temperature sensors are presented in the following table.

Table 54 Optimal Sensor Positions

Installation Location	Optimal Sensor Position
Valve in Radiator Pipe	• Moisture and temperature sensors are directly in the oil flow. This position is optimal because water molecule diffusion rate in oil is slow, and therefore moisture must be measured in moving oil. • Hydrogen sensor is in the valve area. This position is optimal because the hydrogen sensor needs an accurate temperature control, and therefore hydrogen must be measured in still oil.

Installation Location	Optimal Sensor Position
Valve in Transformer Wall	Tip of the probe is level with transformer inner wall. No part of the probe must enter the transformer chamber. All sensors remain within the valve area. **DANGER! Severe risk of death and of damage to transformer:** Pay attention to transmitter installation depth and possible energized parts inside the power transformer to minimize electric shock hazard and equipment damage.

A.1 Method Used for Measuring Moisture in Oil

MHT410 measures water in oil in terms of relative saturation (%RS) which can be determined as follows: relative saturation indicates the amount of water in oil in the scale of 0 ... 100 %RS. In this scale, 0 %RS is an indication of completely water free oil and 100 %RS an indication of oil fully saturated with water. Water is present in free form.

The most advanced feature which distinguishes the measurement of relative saturation (%RS) from the traditional measurement of absolute water content (in ppm_w) is that the saturation point remains stable regardless of the oil type, aging of oil or additives used. As relative saturation exceeds 90 %RS in any system, there is a risk for segregation (especially if the temperature decreases). The relative saturation is used for alarming at the point of > 90 %RS that the risk for free water in the system is obvious.

The most important advantages of this system are the fact that relative saturation is immune to the aging of oil and to additives, and that the MHT410 transmitter can be used for continuous on-line measurements.

A.2 Transformer Oil

The determination of moisture in oil is an essential part of a comprehensive transformer maintenance program. Aging and deterioration increase the capacity of oil to absorb water. The primary interest in transformers is to measure the water not in oil but in the cellulosic insulation around the transformer windings. The MHT410 method provides for a reliable detection of the aging of oil and possible leakages.

Moisture level in oil is a true indicator of moisture present in the paper insulation. Heating and cooling have a considerable effect on moisture levels in oil. The paper insulation around the transformer windings tends to lose moisture as temperature rises. This moisture is absorbed by the oil surrounding it.

Oil-immersed transformers rely on the oil for cooling, protection from corrosion and as an important component of their insulation. Excessive moisture content in oil causes accelerated aging of the insulation materials and reduces their dielectric strength. In extreme cases, this can result in arcing and short circuits within the windings. Accurate moisture measurements can also warn about leaks in the oil system, as water is absorbed from the surrounding air.

The water solubility of oil is also temperature dependent. In general, water solubility increases as temperature rises, see Figure 15 (page 103).

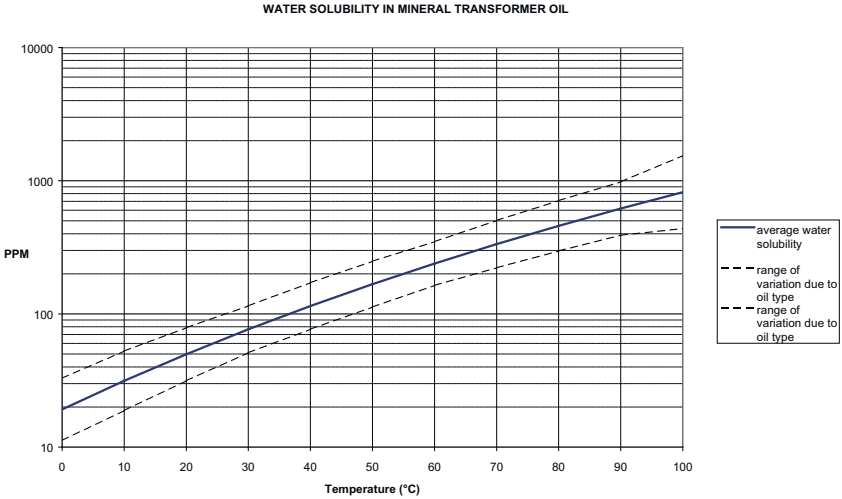


Figure 15 Water Solubility of Transformer Oils versus Temperature. The margins show the range of variation of water solubility found in mineral oils.

In addition, it must be noted that the capacity of oil to absorb water depends both on the chemical structure of the oil and the additives.

Appendix B. Modbus Reference

B.1 Function Codes

Conformance class 0 function codes are enough to access the measurement data and configuration settings of MHT410.

Device identification data can be read out only with the function code dedicated for that purpose (43 / 14).

Table 55 Modbus Function Codes

Function Code (Decimal)	Function Code (Hexadecimal)	Name	Notes
03	03_{hex}	Read Holding Registers	Class 0
43 / 14	$2B_{hex}$ / $0E_{hex}$	Read Device Identification	

B.2 Data Encoding

In the data registers, the numeric values are available in one or two formats with separate register addresses: 32-bit IEEE floating point format and/or 16-bit signed integer format.

B.2.1 32-Bit Floating Point or Integer Format

Least significant 16 bits of floating point or integer numbers are placed at the smaller Modbus address as specified in Open Modbus TCP Specification, Release 1.0. This is also known as "little-endian" or "Modicon" word order. Floating point values are represented in standard IEEE 32-bit floating point format.

Despite the specification, some Modbus masters may expect "big-endian" word order (most significant word first). In such case, you must select "word-swapped" floating point format in your Modbus master for the Modbus registers of the device.

A "quiet NaN" value is returned for unavailable values. A quiet NaN is, for example, $7FC00000_{hex}$; however, the master should understand any NaN value.

A complete 32-bit floating point or integer value should be read and written in a single Modbus transaction.

B.2.2 16-Bit Integer Format

Some 16-bit integer values in the data registers are scaled to include the necessary decimals. The scaling factors for those values are shown in the register tables.

Table 56 16-bit Signed Integer Format Details

Value	Description
0000_{hex} ... $7FFE_{hex}$	Value in range 0 ... 32766
8002_{hex} ... $FFFF_{hex}$	Value in range -32766 ... -1 (2's complement)
8000_{hex}	Value is not available (quiet NaN)

Some values may exceed the signed 16-bit range even in normal operation. To access such values, use the floating point registers instead.

B.3 Register Map

All data available via the Modbus interface is grouped in three contiguous blocks of registers.

Table 57 Modbus Register Blocks

Register Numbers	Data Format	Description
1 ... 54	32-bit IEEE float	Measurement data (read only)
257 ... 271	16-bit signed integer	
513 ... 513	16-bit signed integer	Status registers (read-only)

B.4 Modbus Registers

CAUTION! Registers are numbered in decimal, starting from one. Register addresses in actual Modbus messages (Modbus Protocol Data Unit (PDU)) start from zero.
Please check the reference documentation of your Modbus host (PLC) for the notation of Modbus register addresses.

Accessing unavailable (temporarily missing) measurement data does not generate an exception. "Unavailable" value (a quiet NaN for floating point data or 0000_{hex} for integer data) is returned instead. An exception is generated only for any access outside the applicable register ranges.

B.4.1 Measurement Data Registers

Table 58 Modbus Measurement Data Registers (Read-Only)

Register Number	Address (Hexadecimal)	Register Description		Data Format	Unit
1	0000_{hex}	H_2, 1 hour average	LSW	32-bit float	ppm_v (in oil)
2	0001_{hex}		MSW		
3	0002_{hex}	H_2, 24 hour average	LSW	32-bit float	ppm_v (in oil)
4	0003_{hex}		MSW		
5	0004_{hex}	H_2, Daily ROC	LSW	32-bit float	ppm_v (in oil)
6	0005_{hex}		MSW		
7	0006_{hex}	H_2, Weekly ROC	LSW	32-bit float	ppm_v (in oil)
8	0007_{hex}		MSW		
9	0008_{hex}	H_2, Monthly ROC	LSW	32-bit float	ppm_v (in oil)
10	0009_{hex}		MSW		
15	$000E_{hex}$	Oil moisture, relative saturation	LSW	32-bit float	%RS
16	$000F_{hex}$		MSW		
17	0010_{hex}	Oil moisture, current	LSW	32-bit float	ppm_w
18	0011_{hex}		MSW		
19	0012_{hex}	Oil moisture, 24 h average	LSW	32-bit float	ppm_w
20	0013_{hex}		MSW		
21	0014_{hex}	Oil moisture, Daily ROC	LSW	32-bit float	ppm_w
22	0015_{hex}		MSW		
23	0016_{hex}	Oil moisture, Weekly ROC	LSW	32-bit float	ppm_w
24	0017_{hex}		MSW		
25	0018_{hex}	Oil moisture, Monthly ROC	LSW	32-bit float	ppm_w
26	0019_{hex}		MSW		
27	$001A_{hex}$	Oil temperature	LSW	32-bit float	°C
28	$001B_{hex}$		MSW		
257	0100_{hex}	H_2, 1 h average		16-bit integer	ppm_v (in oil)
258	0101_{hex}	H_2, 24 h average		16-bit integer	ppm_v (in oil)

Register Number	Address (Hexadecimal)	Register Description		Data Format	Unit
259	0102_{hex}	H_2, Daily ROC		16-bit integer	ppm_v (in oil)
260	0103_{hex}	H_2, Weekly ROC		16-bit integer	ppm_v (in oil)
261	0104_{hex}	H_2, Monthly ROC		16-bit integer	ppm_v (in oil)
264	0107_{hex}	Oil moisture, relative saturation		16-bit integer	%RS*10
265	0108_{hex}	Oil moisture, current		16-bit integer	ppm_w*10
266	0109_{hex}	Oil moisture, 24h average		16-bit integer	ppm_w*10
267	$010A_{hex}$	Oil moisture, Daily ROC		16-bit integer	ppm_w*10
268	$010B_{hex}$	Oil moisture, Weekly ROC		16-bit integer	ppm_w*10
269	$010C_{hex}$	Oil moisture, Monthly ROC		16-bit integer	ppm_w*10
270	$010D_{hex}$	Oil temperature		16-bit integer	°C *10

PDU address — Actual address bytes used in a Modbus Protocol Data Unit
LSW — Least Significant Word (bits 15...0)
MSW — Most Significant Word (bits 31...16)
16-bit integer — Numeric value in range -32768...32767
32-bit float — Floating point number encoded according to IEEE 754

B.4.2 Status Registers

Table 59 Modbus Status Registers (Read-only)

Register Number	Address (Hexadecimal)	Register Description	Data Format
513	02 00_{hex}	Device status bits	16-bit integer

Table 60 Modbus Device Status Bits

Output (bit mask)	Output Name	Notes
0	Status OK	
1	Critical Error active	Maintenance needed.
2	Error active	Device may recover automatically.

Output (bit mask)	Output Name	Notes
4	RH measurement error	Remove the transmitter from the transformer and visually check the integrity of the transmitter and the sensor area of the probe body (see Removing the Transmitter (page 32)). Contact Vaisala technical support.
8	T measurement error	
16	H_2 measurement error	Check the connection to the H_2 module: 1. Connect using Vaisala Industrial protocol (see Connecting via Service Port (page 40)). 2. Open the connection to H_2 module by giving the command **h2**. 3. Verify whether the transmitter starts outputting H_2 measurement data. 4. Close the connection to H_2 module by pressing the **+** key. Contact Vaisala technical support.
32	Other error	Contact Vaisala technical support.
64	H_2 alarm level exceeded	

Multiple device statuses can be present simultaneously. In those cases, the value of the device status register is the sum of the applicable numbers, for example, 5 if a critical error (1) and an RH measurement error (4) are present simultaneously.

B.5 Device Identification Objects

Table 61 Device Identification Objects

Object Id (Decimal)	Object Id (Hexadecimal)	Object Name	Example Contents
0	00_{hex}	VendorName	"Vaisala"
1	01_{hex}	ProductCode	MHT410
2	02_{hex}	MajorMinorVersion	Software version (for example "1.2.3")
3	03_{hex}	VendorUrl	"http://www.vaisala.com/"
4	04_{hex}	ProductName	Vaisala Moisture, Hydrogen and Temperature Transmitter MHT410 for Transformer Oil
128	80_{hex}	SerialNumber [1)]	Serial number of the device (for example "K0710040")

Object Id (Decimal)	Object Id (Hexadecimal)	Object Name	Example Contents
129	81_{hex}	CalibrationDate [1)]	Date of the factory calibration
130	82_{hex}	CalibrationText [1)]	Information text of the factory calibration

1) Vaisala-specific device identification object.

B.6 Exception Responses

Table 62 Modbus Exception Responses

Code	Name	Reason
01	ILLEGAL FUNCTION	Unsupported function code
02	ILLEGAL DATA ADDRESS	Address out of valid ranges
03	ILLEGAL DATA VALUE	Otherwise invalid request

Accessing unavailable (unsupported or temporarily missing) measurement data does not generate an exception. “Unavailable” value (a quiet NaN for floating point data or 0000_{hex} for integer data) is returned instead. An exception is generated only for any access outside the register blocks.

Appendix C. Moisture ppm_w Calculation for Transformer Oils

Traditionally, moisture in transformer oil is measured in ppm_w units. The ppm_w output shows the average mass concentration of water in oil.

MHT410 has an option for ppm_w output.

C.1 Calculation Model with Average Coefficients

The calculation model of MHT410 is based on the average water solubility behavior of transformer oils. The ppm_w output is calculated as follows:

$$ppm_w = a_w \times 10^{(A/(T+273.15)+B)}$$

a_w water activity
A, B coefficients (average or oil specific)
T temperature (°C)

Generally, moisture in oil measurement with MHT410 has an accuracy of ±2 ... 3 % of the reading. If additional accuracy is needed, see Calculation Model with Oil-specific Coefficients (page 110).

C.2 Calculation Model with Oil-specific Coefficients

For additional accuracy, an oil-specific calculation model can be used. An oil sample has to be sent to Vaisala for modeling. As a result, the specific coefficients (A and B: see formula in Calculation Model with Average Coefficients (page 110)) for the transformer oil are determined by Vaisala. Using these coefficients increases measurement accuracy.

You can program the determined coefficients of the transformer oil to MHT410 using Vaisala Industrial Protocol (see Table 40 (page 69)), or contact Vaisala about setting the coefficients.

Warranty

For standard warranty terms and conditions, see www.vaisala.com/warranty.
Please observe that any such warranty may not be valid in case of damage due to normal wear and tear, exceptional operating conditions, negligent handling or installation, or unauthorized modifications. Please see the applicable supply contract or Conditions of Sale for details of the warranty for each product.

Technical Support

Contact Vaisala technical support at helpdesk@vaisala.com. Provide at least the following supporting information:

- Product name, model, and serial number
- Name and location of the installation site
- Name and contact information of a technical person who can provide further information on the problem

For more information, see www.vaisala.com/support.

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