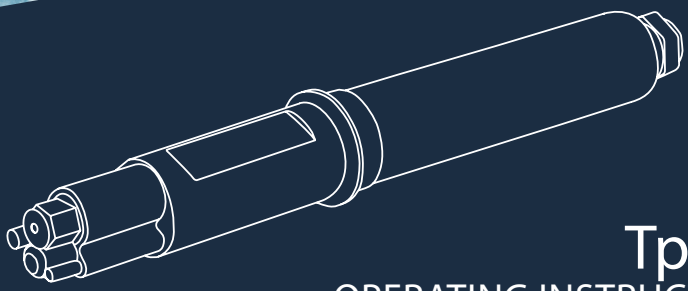
TriOS
Optical Sensors



TpH-D

OPERATING INSTRUCTIONS

Table of Contents

1 General Information

1.1 Introduction

Welcome to TriOS.

We are glad that you have chosen to purchase our TpH-D differential pH sensor.

The TpH-D is based on the electrochemical measuring method with salt bridge to protect the electrolyte. This intelligent sensor stores calibrations internally. This enables a "plug-and-play" system without recalibration when the location or measuring transducer is changed.

In this manual, you will find all the information you will need to commission the pH sensor. Technical specifications as well as detection limits and the dimensions can be found in chapter 7.

Please note that the user is responsible for complying with local and national regulations on the installation of electronic devices. Any damage caused by incorrect use or unprofessional installation will not be covered by the warranty. All sensors and accessories supplied by TriOS Mess- und Datentechnik GmbH must be installed and operated in accordance with the specifications provided by TriOS Mess- und Datentechnik GmbH. All parts were designed and tested in accordance with international rules on electronic instruments. The device meets the requirements of the international regulations on electromagnetic compatibility. Please use only original TriOS accessories and cables to ensure smooth and professional operation of the devices.

Before using the device, read the manual carefully, and keep this manual on hand so it can be used later. Before commissioning the sensor, please make sure that you have read and understood the following safety precautions. Always make sure that the sensor is correctly operated. The safety precautions described on the following pages should ensure the smooth and correct operation of the device and any additional associated devices and should prevent injuries to yourself or other persons and damage to other equipment.

The sensor TpH-D was tested according to DIN EN 60746-2:2003-09 and the electrodes according to BS 2586:1979.

NOTICE	**If translations deviate from the original German text, the German version shall prevail.**

Software Updates

The illustrations used in this manual refer to software version 1.0.8 and higher. Updates include bug fixes and new features and options. Units with older software versions may not have all the functions described here.

Copyright Notice

1.2 Health and Safety Information

This manual contains important information about health and safety rules. This information is labelled according to the international specifications of ANSI Z535.6 ("Product safety information in product manuals, instructions and other collateral materials") and must be strictly followed. A distinction is made between the following categories:

⚠ DANGER	**Danger warning / will lead to serious injury or death**
⚠ WARNING	**Warning / may lead to serious injury or death**
⚠ CAUTION	**Caution / may cause moderate injury**
NOTICE	**Can result in damage to property**

Tip / Useful Information

Electromagnetic Waves

Devices that radiate strong electromagnetic waves can influence the measurement data or result in a malfunction of the sensor. Avoid using the following devices in the same room as the TriOS sensor: mobile phones, cordless phones, transmitters/ receivers and other electrical devices that produce electromagnetic waves.

Reagents

Follow the safety and operating instructions of the manufacturer when using reagents. Observe the valid Hazardous Materials Ordinance for reagents (German GefStoffV)!

Biological Safety

Liquid waste may be biologically dangerous. Therefore, you should always wear gloves when working with such materials. Please observe the currently valid biological agents regulation!

Waste

When handling liquid waste, the regulations on water pollution, drainage and waste disposal must be observed.

1.3 Warnings

- This sensor has been developed for use in industry and science. It should only be used for the measurement of aqueous solutions, e.g. process waste water, river water or sea water.
- The material resistance should be checked after every use.
- Do not cut, damage or change the cord. Make sure that no heavy objects are placed on the cord and that the cord is not folded. Make sure that the cord is not run near hot surfaces.
- If the sensor cable is damaged, it must be replaced with an original part by the customer service of TriOS Mess- und Datentechnik GmbH.
- Stop operation of the sensor in the event of excessive heat development (i.e. if it is hot to the touch). Switch off the sensor immediately and remove the cable from the power supply. Please contact your dealer or the TriOS technical support.
- Never try to disassemble or modify a part of the sensor if such a procedure is not explicitly described in this manual. Inspections, modifications and repairs may only be carried out by the dealer or by qualified experts authorized by TriOS.

Devices from TriOS Mess- und Datentechnik GmbH meet the highest safety standards. Repairs to the device (which involve the replacement of the connecting cable) must be carried out by TriOS Mess- und Datentechnik GmbH or by a workshop authorized by TriOS. Faulty, improper repairs can result in accidents and injuries.

TriOS does not guarantee the plausibility of the measured values. The user is always responsible for the monitoring and interpretation of the measured values.

1.4 Users and Operating Requirements

The TpH-D sensor has been developed for use in industry and science. The target group for the operation of the TpH-D sensor is technically skilled staff in plants, sewage treatment plants, water plants and institutes. The use of this device often requires the handling of hazardous substances. We assume that the operating personnel are familiar with dealing with dangerous substances based on their professional training and experience. The operating personnel must be able to correctly understand and implement the safety labels and information on the packaging and in the package inserts of the test kits.

1.5 Intended Use

The purpose of the TpH-D sensor is exclusively to measure pH values in aqueous solutions, as described in this manual. In this respect, the TpH-D sensor is an immersion sensor used under water or in conjunction with FlowCells. Please note the technical data of the accessory parts. Any other use is not considered to be in compliance with the intended use.

The compact and robust sensor is particularly suitable for the following areas of application:

- Industrial and municipal sewage treatment plants
- Wastewater management
- Monitoring of surface waters
- Aquaculture and fish farming
- Drinking water monitoring

Use in other media can damage the sensor. For the use of the TpH-D sensor in other media than those specified in this manual, please contact the technical support of TriOS Mess- und Datentechnik GmbH (support@trios.de).

According to current scientific knowledge, the device is safe to use when it is handled according to the instructions in this user manual.

1.6 Disposal Instructions

At the end of the device's life or use, the device and its accessories can be returned to the manufacturer for environmentally friendly disposal for a fee (see address below). The preceding professional decontamination must be proven with a certificate. Please contact us before you send the device back to find out more details.

Address of the manufacturer:

TriOS Mess- und Datentechnik GmbH
Bürgermeister-Brötje-Str. 25
26180 Rastede
Germany
Telephone: +49 (0) 4402 69670 - 0
Fax: +49 (0) 4402 69670 - 20

1.7 Certificates and Approvals

This product meets all the requirements of the harmonized European standards. It therefore meets the legal requirements of the EC guidelines. TriOS Mess- und Datentechnik GmbH confirms the successful testing of the product by affixing the CE marking (see annex).

The pH sensor TpH-D has a type approval for MEPC.340(77) for the monitoring of pH, as specified in the regulations. Please note the restrictions of use of the TpH-D (see chapter 4.4 and annex).

2 Introduction

The TpH-D is based on the electrochemical measuring method with salt bridge to protect the electrolyte. This intelligent sensor stores calibrations internally. This enables a "plug-and-play" system without recalibration when the location or measuring transducer is changed.

Exceptional performance thanks to differential electrodes

This technology has proven itself in practice: Three electrodes are used instead of the two normally used in conventional pH sensors. The pH value is measured differentially via process and reference electrodes using a third ground electrode. The result is unsurpassed measurement accuracy, reduced reference junction potential, and elimination of sensor ground loops. These process pH sensors provide greater reliability, resulting in less downtime and less maintenance.

Salt bridge with double ceramic separation layer for lower maintenance requirements

The salt bridge with double ceramic separation layer forms a barrier against contamination, minimizing dilution of the internal electrolyte solution. This leads to lower maintenance requirements and longer intervals between calibrations.

Replaceable salt bridge/protection device for extended service life

The unique, replaceable salt bridge contains a large amount of buffer to protect the reference electrode from difficult process conditions and thus extend the life of the sensor. The salt bridge can be replaced by simply unscrewing it from the end of the sensor. Over time, liquid from the process can contaminate or dilute the reference. However, with a buffered electrolyte reference, an accurate reading can be maintained even with some contamination. Differential pH sensors are manufactured so the double junction salt bridge and the reference cell buffer may be removed and replaced in the field.

Built-in encapsulated preamplifier for reliability

The encapsulated design protects the sensor's built-in preamplifier from moisture and humidity, ensuring reliable sensor operation. The preamplifier produces a strong signal so that the sensor can be located up to 300 m away from the controller.

2.1 Product Identification

All TriOS Mess- und Datentechnik GmbH products have a label, which clearly shows the product designation.

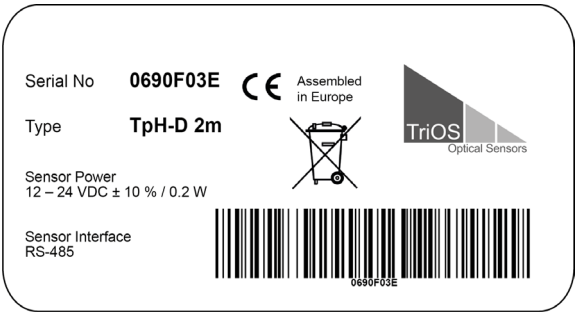
There is also a rating plate on the sensor with the following information that you can use to uniquely identify the product:

Serial number

Product type

Power supply

Interface



In addition to the product bar code, the rating plate includes the TriOS Mess- und Datentechnik GmbH logo and the CE quality label.

Please note that the specifications given here are for illustration purposes only and may deviate depending on the version of the product.

2.2 Scope of Delivery

The delivery contains the following components:

- Sensor
- Operating Instructions
- Accessories (if applicable)

Keep the original packaging of the device in case it needs to be returned for maintenance or repairs.

2.3 Measurement Principle and Design

3 Commissioning

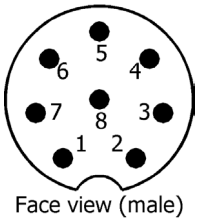
This chapter deals with the commissioning of the sensor. Please pay particular attention to this section and follow the safety precautions to protect the sensor from damage and yourself from injury.

Before the sensor is put into operation, it is important to ensure that it is securely attached and all connections are connected correctly.

3.1 Electrical Installation

NOTICE **The sensor can be operated with 12–24 VDC.**

3.1.1 Fixed Cable with M12 Industrial Plug



Face view (male)

1. RS-485 A
2. RS-485 B
3. Not assigned
4. Not assigned
5. Not assigned
6. Not assigned
7. Ground (Power + Ser. Interface)
8. Power 12–24 VDC

The sensor is ready for commissioning as soon as the installation of accessories is complete, it is connected to your control device and the configuration is complete.

NOTICE **Ensure correct polarity of the supply voltage, because otherwise the sensor may be damaged.**

3.2 Interface

3.2.1 Serial Interface

The serial interface of the sensor is RS-485 (9600/8-N-1).

With RS-485, voltages from -5 V to +5 V to ground are possible. RS-485 uses a differential signal with the sign-negative potential of the A line is put on the B line. The A-B difference is decisive, where the transmission is most resistant to interactive interference signals.

The protocol used is Modbus RTU. A detailed description of the Modbus RTU protocol for TpH-D can be found in the annex.

4 Use

The TpH-D sensor can be operated with all TriOS controllers. Instructions for correct installation can be found in the relevant controller manual.

4.1 Normal Operation

The sensor is ready for commissioning as soon as the installation of accessories is complete, it is connected to your control device and the configuration is complete. The container with the solution must remain on the sensor until it is used. If the pH sensor is used irregularly, the container and the liquid should be kept and the sensor stored in it in the meantime. If the storage liquid is discarded, the sensor can also be stored in a pH4 buffer solution (or if available, in a 3 molar KCl solution).

Remove the protective container by holding the sensor vertically downwards and twisting off the cap. If possible, make sure that the lid is turned and not the cup, otherwise the swelling layer of the membrane could be damaged. The sensor is supplied with a filled protective cap containing a solution of pH4 buffer and potassium chloride. Therefore, the sensor does not need to be reconditioned to achieve optimal readings. Please note the minimum immersion depth up to the ring on the sensor housing.

NOTICE	**If the sensor is dry, it must first be conditioned for several hours (>12h) in pH4 buffer.**

The sensor is now immersed vertically up to the ring on the sensor, with the measuring window facing downwards (inclination of max. 45°) into the measuring medium . The black sensor head must be completely surrounded by the medium. Otherwise, measurement fluctuations may occur.

Before a measurement, all air bubbles under the membrane must first be removed by light shaking.

As soon as the sensor is connected to the power supply, it starts to measure. This is indicated by the green light in the upper sensor area. To obtain stable and safe measurements, please wait for temperature stabilisation after introducing the sensor into the measuring environment.

The TpH-D sensor should be calibrated at regular intervals. The intervals depend on the respective application. If the TpH-D is used in the highly alkaline range, the calibration intervals should be as close as possible. For information on calibration, see Chapter 5.

The TpH-D are classified as consumables and therefore have a limited service life, depending on the user's application. Under normal conditions, the typical life span is about one year. High temperatures with high or low pH values reduce the service life of the sensor (see also chapter 5.2.1 Influences on the measurement). The service life of the TpH-D can be extended by regular cleaning and replacement of the electrolyte.

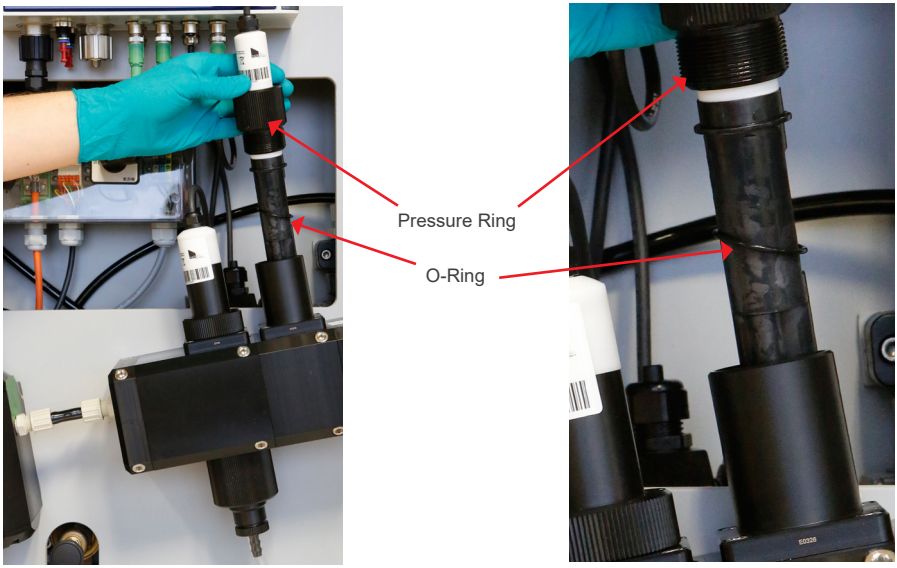
4.2 Bypass Installation

A suitable TriOS FlowCell is available to integrate the sensor into a bypass installation. The FlowCell is designed according to a modular system and makes it possible to adapt or extend the system as required.

Follow the steps in the following description in order to install the TpH-D into the FlowCell.

1. Remove the pressure ring of the FlowCell. You can easily open it by hand.
2. First, slide the O-ring (which is in the bag that sticks on the Flow Cell) onto the TpH-D. Next, plug the TpH-D into the FlowCell.

If the TpH-D is mounted on the FlowCell, lead the pressure ring along the cable over the sensor to fix it on the Flow Cell.



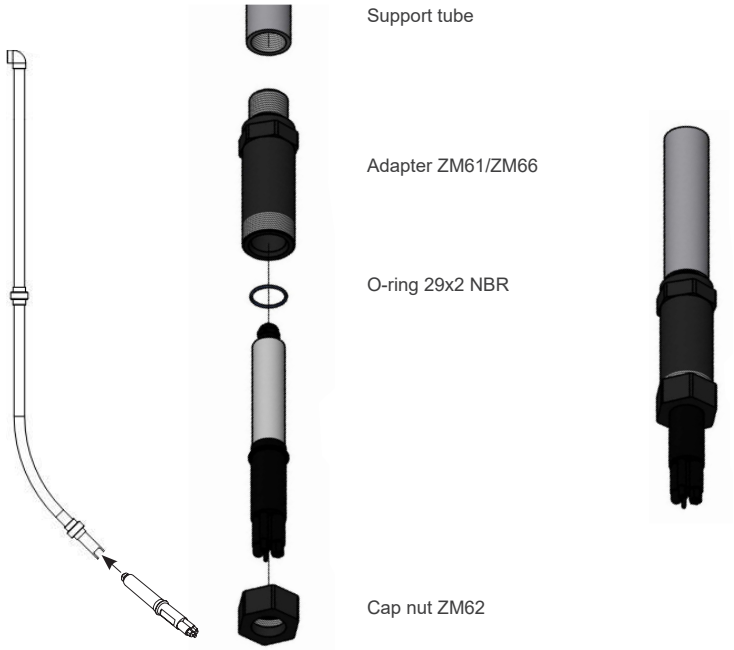
3. When the TpH-D is positioned correctly, tighten the pressure ring.
4. The sensor is then connected to a COM-Port of the TriBox3.

4.3 Support Tube Installation

TriOS provides two adapter pieces for installing the TpH-D sensor in existing tube systems:

- NPT1 adapter ZM66 (incl. cap nut ZM62)
- G1 adapter ZM61 (incl. cap nut ZM62)

Assembly process



1. Guide the sensor cable from the side through the adapter, onto which the screw cap is later screwed (short thread).

2. Pull the complete cable through and push the sensor into the adapter as far as it will go (up to the guide obstacle).

3. Fix the sensor with the mounting cap.

4. The sensor and adapter can now be installed in the support tube.

4.4 Operation with Type Approval according to IMO regulations

The TpH-D has a type approval in accordance with IMO Regulation MEPC.340(77) for monitoring the pH value in discharge water of exhaust gas cleaning systems.

4.4.1 Specification according to MEPC.340(77)

With ship approval, an operating temperature between 5 °C and 55 °C is assumed. To be in compliance with the MEPC guidelines, please order the version MEPC of TpH-D (see Chapter 7.2.3).

4.4.2 Mounting

The TpH-D can be installed with a FlowCell (FlowCell eCHEM) as a bypass (see section 4.2). Install the sensor in frost-free rooms only. Do not install the sensor in closed housings together with strong heat generating devices.

NOTICE	**Negative pressure at the outlet of the EGC Water Analyzer damages the sensor!**

Outside the EGC Water Analyser, the TpH-D MEPC variant must be used to comply with IMO regulations.

4.4.3 Electrical Installation

Type approved applications shall be set up with TpH-D with a fixed cable of maximum 5 m length.

The shielded cable has an M12 industrial plug as connection.

The sensor should be connected to an external control unit for power supply (12 VDC or 24 VDC) and recording measuring data.

The shielding of the M12 industrial plug must also be grounded (see chapter 3.1.1 Fixed Cable with M12 Industrial Plug).

4.5 Storage

Shelf life of the sensor will be 1 year under ideal conditions.

NOTICE **Never store the TpH-D sensor dry.**

The sensor should always be stored wet, ideally in the supplied container in the pH4 buffered potassium chloride solution. Keep the container for storage and feel free to reuse it for storage in a solution of pH4 buffer and potassium chloride or alternatively a 3 molar solution of potassium chloride.

If a sensor or the electrode of the sensor should nevertheless have dried out, the hydrated layer on the electrode must form anew. The sensor must be immersed in a 3 molar KCl solution for several hours (>12h).

NOTICE **Never store the TpH-D sensor in distilled water!**

If a TpH-D has been stored in distilled water for a prolonged period, the electrolyte and the salt bridge must be changed, as ions from the electrode diffuse into the distilled water. See also chapter 6 Maintenance.

The storage temperature should be between +5 °C and +15 °C.

pH sensors behave like batteries - they age over time. Please replace your pH sensors regularly and always use the oldest one from stock.

The saltbridge is stored in a Potassium Chloride (KCl-) solution. Ensure, the saltbridge is covered with this solution. If it is not covered with Potassium Chloride solution, please refill the container with KCl-solution and let the saltbridge recondition for 24 h before use.

5 Calibration

TpH-D sensors that have not been used for a long time or that are new should be calibrated before measurement. Calibration should then be repeated at regular intervals. The calibration intervals depend on the type of application (strongly fluctuating pH values, abrasive measuring medium or deposits on the measuring electrodes). Checks with standard solutions are recommended to determine the intervals. TriOS offers suitably bottled buffer solutions pH4 and pH7 (see chapter 8). The frequency of calibration depends on experience. For newly installed systems, an hourly check and calibration may be necessary. If you find stable values, the calibration interval can be increased.

Calibration is possible both on the controllers (see chapter 8) and via Modbus. The calibrations performed are stored internally by the sensor. Thus, the current calibration is always present.

5.1 pH Calibration

With the calibration, the zero value (pH7) and the scaling factor (pH4 or pH10, depending on the application) are calibrated. For calibration, select pH buffer solutions with an accuracy of ±0.01 pH and observe the temperature. Fresh or newly prepared solutions must be used for each calibration! TriOS offers an ideal set for the TpH-D calibration with a sensor holder and buffer solutions for 6 calibrations.

Buffer Solution pH4
6 x 25 ml

Buffer Solution pH7
6 x 25 ml

Procedure:

- Since the pH value is temperature-dependent, it is recommended to check the temperature with a reference thermometer before the first pH calibration.
- If the temperature measured by the sensor deviates more than 1 °C from the one measured by the reference thermometer, a calibration of the temperature offset is necessary.
- Rinse the sensor with distilled water and carefully dab off excess water with a soft, clean cloth.

NOTICE **The electrode must only be dabbed with a soft, clean paper or cloth and never wiped. Do not use a brush to clean the glass membrane.**

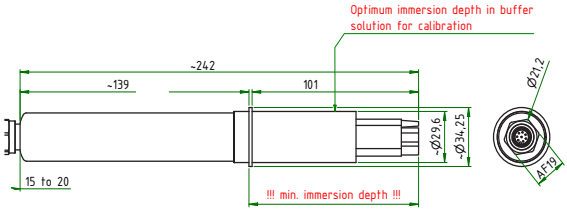
- Immerse the TpH-D in pH7 buffer solution, the sensor head (black) should be immersed as completely as possible (see illustrations on next page). Otherwise, measurement fluctuations may occur.
- Let the sensor warm up as long as possible until the measured values have stabilised (at least 5 minutes) and now calibrate to pH7. Pay attention to the temperature!

NOTICE **Do not stir the sensor in the buffer solution**

NOTICE **The pH value depends on temperature!**

- Rinse the sensor again with distilled water and carefully remove water drops with a soft, clean cloth.
- Immerse the TpH-D in pH4 buffer solution, the sensor head (black) should be immersed as completely as possible (see illustrations below, for the immersion depth in the pH buffer cup, note the red arrow). Otherwise, measurement fluctuations may occur.
- First let the sensor run for at least 5 minutes to stabilise and now calibrate to pH4 (or pH10). Observe the temperature!
- Rinse the sensor with distilled water and carefully dab off excess water with a soft, clean cloth.
- You can now begin your measurements.
- Dispose the buffer solutions after use.

NOTICE **The offset should ideally be ±1 pH and the slope should ideally be between 0.95–1.43.**



5.2 Measurement Properties

5.2.1 Influences on the Measurement

- The pH measurement depends on the following parameters:
- High temperatures of the measuring medium accelerate the ageing of the electrode.
- Note the immersion depth: a too shallow immersion depth can lead to fluctuating measured values.
- Air bubbles on the sensor can cause measurement errors.
- Alkali error: at pH values above pH12, alkali ions (Li+, Na+) can cause lower pH values to be displayed, as the alkaliions are detected in addition to the H+ ions.
- Flow can influence the measured value.
- Coatings on the electrode surface can have an influence on the measurement. Before the salt bridge is replaced due to suspected ageing of the pH sensor, the surface of the electrodes should be checked and cleaned if necessary

5.2.2 Temperature Compensation

Temperature compensation is performed automatically by the integrated temperature sensor (Pt1000).

6 Malfunction and Maintenance

6.1 Cleaning and Upkeep

The sensor requires only minimal maintenance. In applications which cause heavy soiling of the sensor, the sensor should be serviced more often.

NOTICE **Do not disassemble the sensor for cleaning and maintenance.**

- The sensor should always be kept clean. If there is a residue on the sensor, this can lead to measurement errors and to a shortened service life and long reaction times.
- A dirty sensor should be rinsed with fresh water and then immersed in e.g. 5% citric or acetic acid or alkaline rinsing agent solution for 5–10 minutes, depending on the degree of soiling. The sensor should then be rinsed again thoroughly with fresh water.
- The sensor can also be soaked in a mild soap solution for 2–3 minutes for cleaning. Then clean the measuring head with a soft cloth and rinse it with warm water (be careful not to damage or scratch the glass membrane).
- Oil-containing deposits are best removed with washing-up liquid that is compatible with the sensor material used.
- If possible, mechanical influences on the glass membrane should be avoided.
- For stubborn soiling, a very soft brush or a soft sponge can be used carefully.
- For more solid deposits, the sensor can be immersed in a diluted HCl solution or a base. Pepsin can also be used in the case of organic deposits.

NOTICE **After cleaning, always rinse the sensor and the sensor system carefully with distilled water.**

⚠ CAUTION **Always wear appropriate protective equipment for eyes, face, hands, skin and respiratory system when handling chemicals.**

When the sensor is taken out of service, it should be stored cleaned. If the solution from the container is discarded, fill pH4 buffer solution (or if available, a 3-molar KCl solution) to store the sensor in.

6.2 Maintenance and Inspection

NOTICE **Avoid touching the sensors, as they could be damaged. If this is the case, the functionality of the sensor can no longer be guaranteed.**

The average lifetime of a TpH-D sensor is about 1 year. If difficulties occur during calibration, the electrolyte and the salt bridge must first be replaced (see chapter 6.2.2). If this does not bring any improvement either, the sensor probably has to be replaced.

If you are working with a TriBox3 with a 4-digit serial number, the SQI can be displayed. The following limits apply here:

SQI yellow:

- pH value –0.5 to +0.5 or +12.5 to +14.5
- Temperature –10.0 °C to 0.0 °C or +65 °C to +95 °C

SQI red:

- pH value < –0.5 or > +14.5
- Temp < –10.0 °C or > +95 °C

6.2.1 Temperature Calibration

Since the pH value is temperature-dependent, it is recommended to check the temperature with a reference thermometer before the first pH calibration. If the temperature measured by the sensor deviates more than 1 °C from the one measured by the reference thermometer, a calibration of the temperature offset is necessary.

1. If you need calibrate the temperature sensor, set the controller to Maintenance mode: “Options” → “Service mode”
2. Select the TpH-D sensor under “Sensor” and the corresponding port (COM-port).
3. Press the “Calibrate” button and select the temperature.
4. The following calibration wizard will guide you through the next steps:
    - Enter the measured temperature (reference thermometer) as the setpoint and press “Next”
    - Then initiate a measurement by pressing “Measurement”
    - Wait until “Continue” is active and then press it.
5. At the end you will be asked if you want to save the calibration. By pressing “Next”, the new calibration is saved in the sensor; “Cancel” restores the previous calibration.

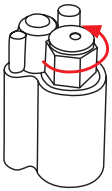
6.2.2 Replacing the Electrolyte and Salt Bridge

Replacing the salt bridge (art. no. 80P00000) and the electrolyte solution (art. no. 80P00001) is recommended when the measurement results can no longer be corrected and/or the response time of the sensor slows down considerably. Replacing the salt bridge and the electrolyte solution affects the offset determination. Both salt bridge and electrolyte solution are available from TriOS, see chapter 8.

In addition, it is necessary to exchange the electrolyte solution and the salt bridge if a TpH-D has been stored in distilled water for a longer period of time, since ions from these solutions have diffused from the electrode into the distilled water to establish an equilibrium.

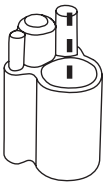
It is recommended that both the salt bridge and the electrolyte solution be changed.

Clean the sensor as described in 6.1 prior to changing electrolyte solution and salt bridge.

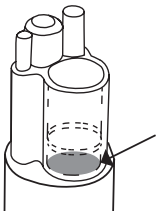


1. Remove the salt bridge by carefully turning it counter clockwise with a spanner (11 mm open-end spanner) or pliers.

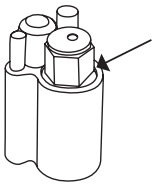
2. Pull up the salt bridge to remove it.



3. Remove the old electrolyte solution from the chamber. Rinse the chamber with 1 ml of fresh electrolyte solution.



4. Fill the cell with about 2 ml of fresh electrolyte solution (refill solution) up to the level shown in the illustration (below the housing boundary). A disposable pipette is suitable here.



5. Insert the new salt bridge by turning it clockwise. Do not overtighten! Make sure the O-ring is properly seated.

6.2.3 Replacing the Sensor at TriBox3

NOTICE **If you need to replace the sensor, the controller settings for the new sensor need to be configured again.**

1. If you need to replace your sensor, set the controller to Maintenance mode: “Options” → „Service mode”
2. Remove the sensor from the FlowCell / tube system. At this point you should also check whether the O-rings are still perfect. Replace the O-rings if necessary.
3. Commissioning the new sensor:

   Connect the new sensor to the TriBox3. Press “Sensor Scan”. After a short time, the TriBox3 should have recognized the new sensor.

   Display:

   “Display” → select the display → click on the window(s) for TpH-D → “Current value” → select the value to be displayed.

   Automatic measurements:

   In the „Sensor“ menu, click on the TpH-D sensor (blue button).

   Select “Automatic measurement” → “Automatic measurement” or “Burst mode” (as required).

   For setting the automatic measurements (if not burst mode), select „Options“ → „Automatic measurements“ → „Raster“ → Set the selection of the measuring interval as required.

   Set Modbus Address:

   “Sensor” menu → click on the TpH-D sensor button → “Modbus server settings” → “Slave address” → change the address.

   Set Analog output:

   “Options” → “Analog outputs” → select the previous analog output where the old sensor was set → “Measurement value used” → select the new sensor from the drop down list → set scaling information.

   Post-processing:

   If you want to keep previous post-processing settings, you can set them with “Sensor” → “pH” → here you can configure the sensor settings as required.

6.2.4 Sensor is not Recognised

If the sensor is not recognised on a controller, the following steps can be carried out:

- Perform Sensor Scan again
- Remove sensor in maintenance mode, switch off system, connect sensor, switch on system, SensorScan
- Connect another sensor to the COM port to rule out the possibility that the COM port is defective.
- If the other sensor on the COM port is also not detected, check the fuses of the COM port on the controller, (refer to the relevant chapter in the controller manual)
- Do the sensor LEDs light up in RGB when connected to the controller? If yes, then the sensor is supplied with voltage but there is no data transmission. In this case, please contact the TriOS technical support support@trios.de

If the sensor does not respond via Modbus RTU, please check the following:

- Has the slave ID been changed?
- Do the sensor LEDs light up in RGB when connected?
- Has the correct COM port been selected for data communication?
- Is the peripheral set correctly (Modbus RTU, RS-485, 9600 baud, 8N1)?
- If it is ensured that the settings are configured correctly, but still no communication takes place, contact TriOS technical support support@trios.de.

6.3 Returns

Please observe the following procedure for your returns.

If returning a sensor, please contact technical support first. To ensure a smooth return and to avoid incorrect deliveries, each return package must first be reported to the technical support. You will then receive a numbered RMA form, which you need to fill out completely, check and send back to us. Please attach the form with the number so it is clearly visible on the outside of the return package or write it in large numbers on the packaging. This is the only way your return package can be correctly allocated and accepted.

Caution! Return shipments without an RMA number cannot be accepted and processed!

Please make sure that the sensor is cleaned and disinfected before shipping. In order to ship the goods undamaged, use the original packaging. If this is not on hand, make sure that safe transport is guaranteed and the sensor is safely packed using enough packing material.

7 Technical Data

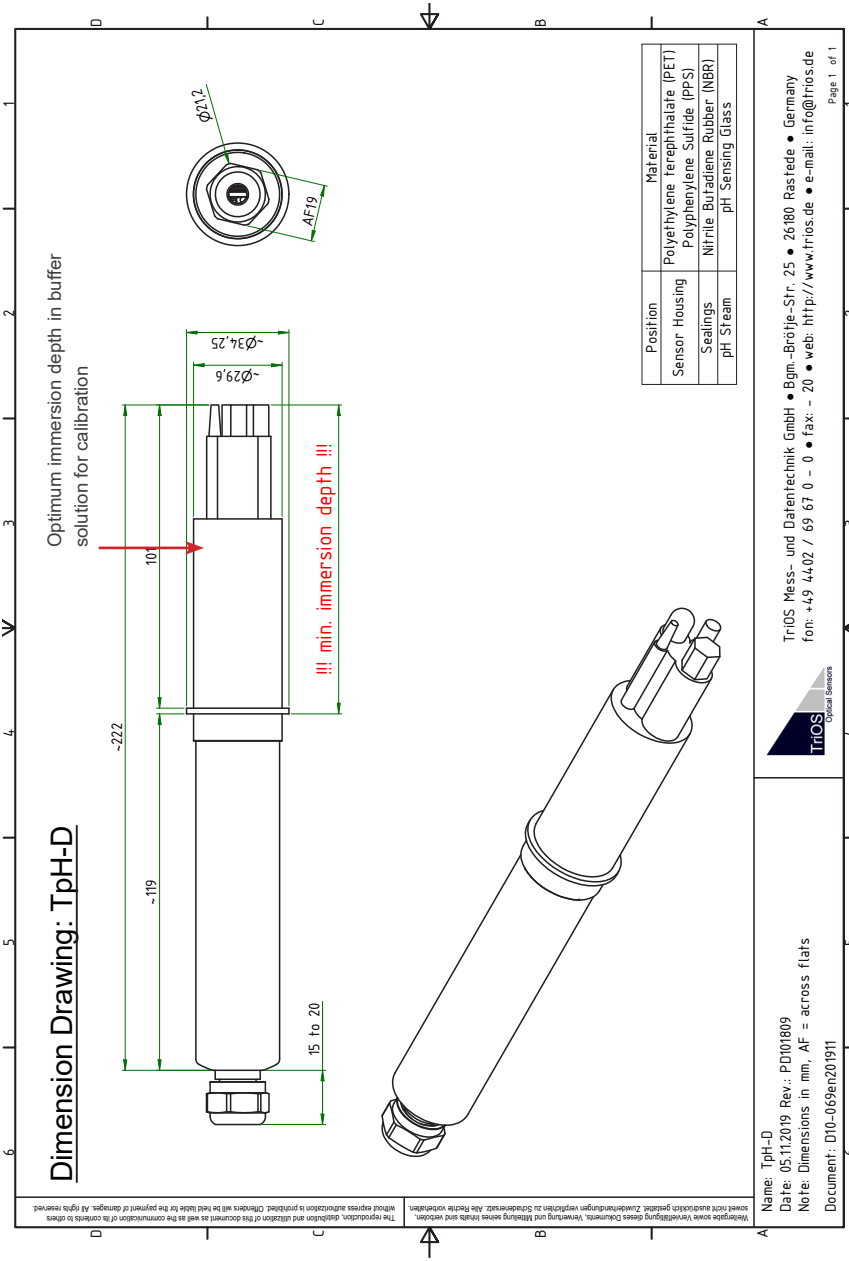
7.1 Technical Specifications

Measurement technology		pH electrode with additional reference pH electrode in pH7 buffer solution
Measurement principle		Potentiometry
Parameters		pH value, temperature
Measuring range	pH	0–14 pH
	Temperature	0 °C to +65 °C
Resolution	pH	0.01 pH
	Temperature	0.1 °C
Accuracy	pH	±0.06 pH
	Temperature	±0.5 °C
Intrinsic error	pH1	±0.05 pH
	pH7	±0.05 pH
	pH13	±0.35 pH
Linearity measurement error		±0.1 pH
Repeatability	pH1	±0.1 pH
	pH7	±0.05 pH
	pH13	±0.1 pH
Output signal fluctuation	pH7	±0.025 pH
	pH4	±0.05 pH
Warm-up time		< 5 min
Drift	Short-term drift 24 h	< 0.03 pH
	Long-term drift 1 week	< 0.05 pH
10% time and 90% time	T10 ascending	< 2 s
	T10 falling	< 2 s
	T90 ascending	≤ 5 s
	T90 falling	≤ 5 s
Temperature compensation		Pt1000
Measurement interval		2 s
Housing material		PPS / PET / NBR / PVDF / ceramic junction / Viton O-ring / titanium ground electrode / pH glass
Dimensions (L x Ø)		~ 225 x 32 mm / ~ 8.9″ x 1.3″
Weight		180 g / ~ 0.4 lbs

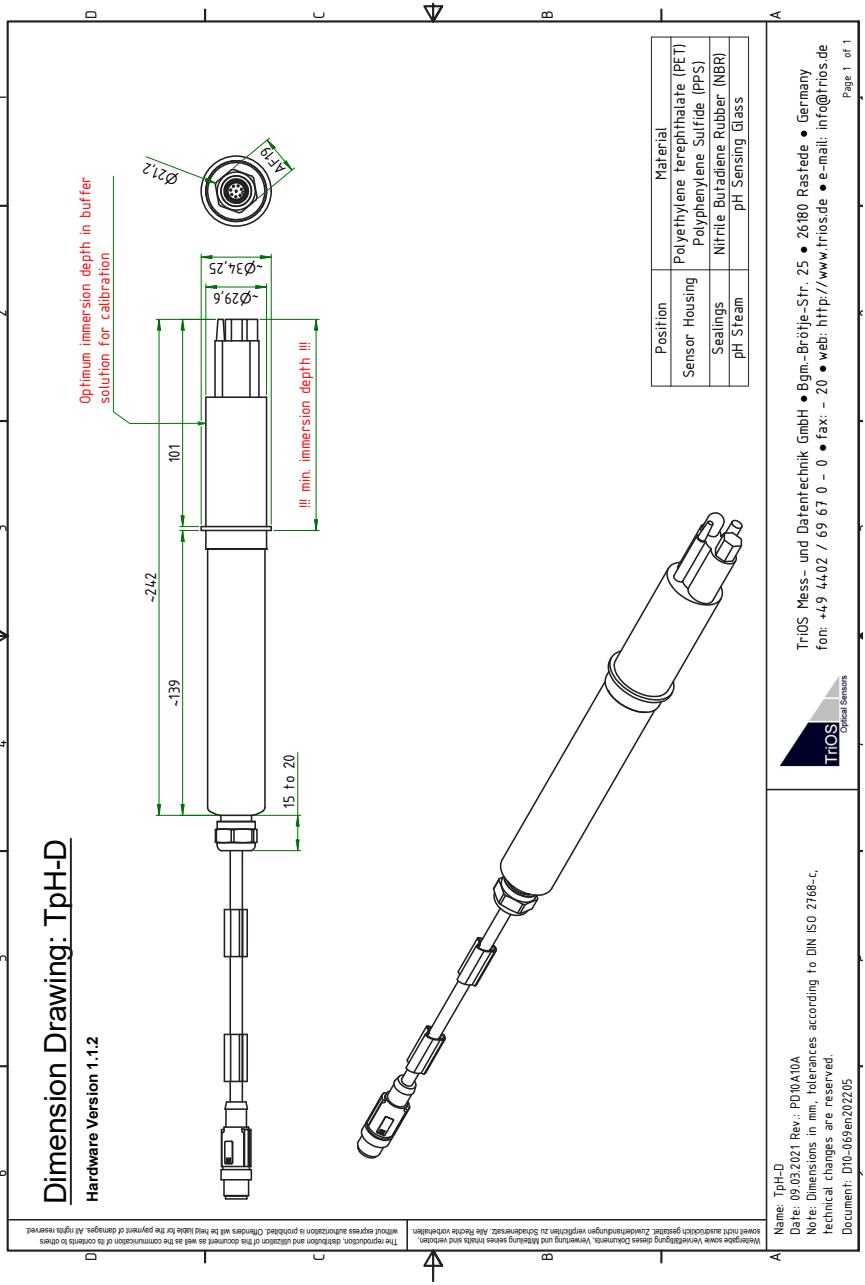
Interface		RS-485, Modbus RTU	
Power consumption		0.2 W	
Power supply		12–24 VDC (±10 %)	
Connection		8-pin M12 plug	
Sensor cable		0.5 m, 2 m and 10 m	
Required supervision		Typically ≤ 0.5 h/month	
Calibration / maintenance interval		Typically 4 weeks	
System compatibility		Modbus RTU	
Warranty		1 year (EU&US: 2 years) on electronics; wearing parts are excluded from the warranty	
Max. pressure	with fixed cable	3 bar	~ 43.5 psig
	in flow cell	1 bar, 2–4 L/min	~ 14.5 psig, 0.5 to 1 gpm
Protection type		IP68	NEMA 6P
Sample temperature		+2 °C to +40 °C	~ +36 °F to +104 °F
Ambient temperature		-5 °C to +55 °C	~ +23 °F to +131 °F
Storage temperature		+5 °C to +15 °C	~ +41 °F to +59 °F
Inflow velocity		0–3 m/s	~ 0–10 fps

7.2 External Dimensions

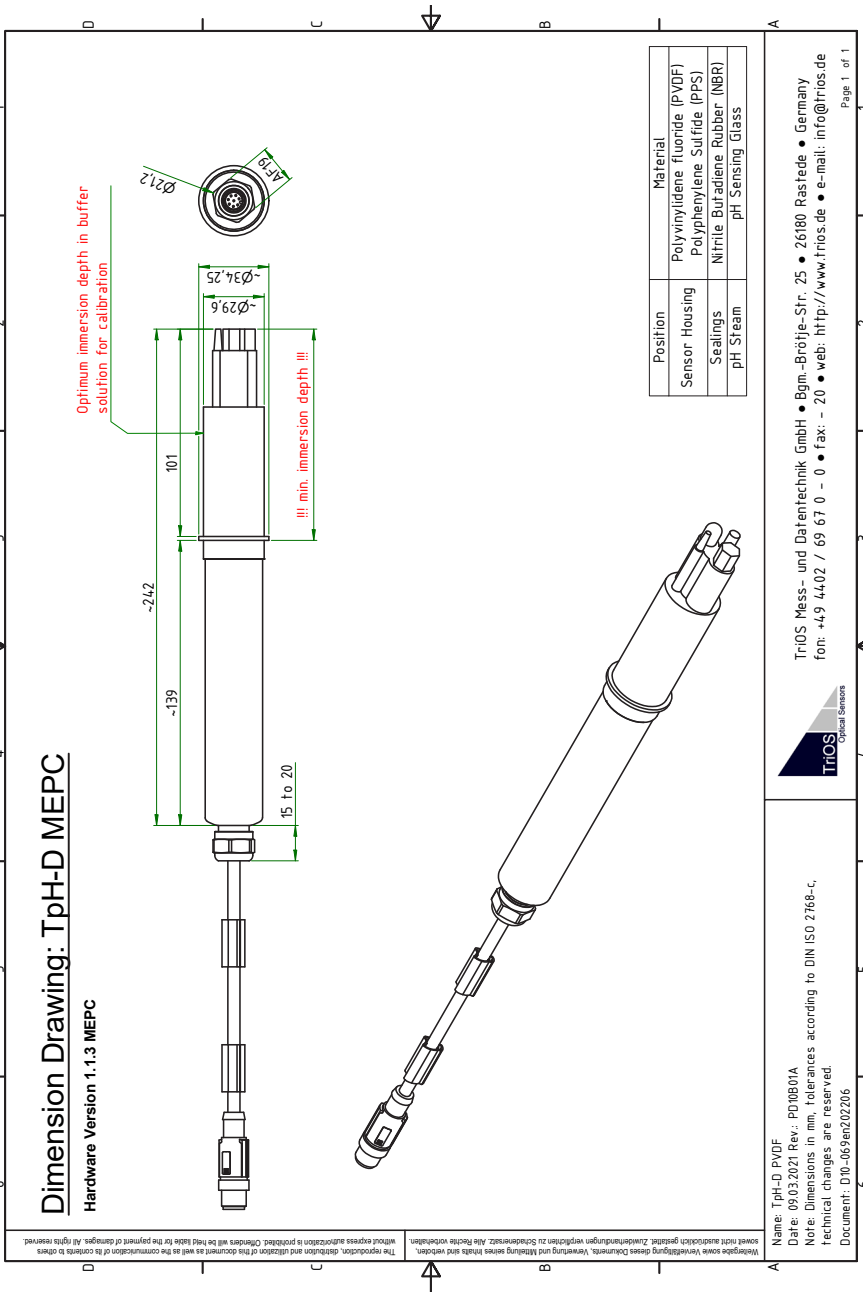
7.2.1 Hardware Version 1.1.1



7.2.2 Hardware Version 1.1.2



7.2.3 Hardware Version 1.1.3 MEPC



8 Accessories

8.1 TriBox3

Digital, 4-channel display and control unit with integrated solenoid valve for compressed-air control

TriBox3 is a measurement and control system for all TriOS sensors. The device offers 4 sensor channels with selectable RS-232 or RS-485 function. In addition to the Modbus RTU, various other protocols are available. A built-in valve allows the use of compressed-air cleaning for the sensors The TriBox3 also offers TCP/IP and WLAN networks, USB connection and 6 analogue outputs (4–20 mA). An integrated relay can be used to trigger alarms or to control external devices. Features such as low power consumption, a robust aluminium housing and a range of interfaces make it suitable for all applications that have to do with environmental monitoring, drinking water, wastewater treatment plants and many other areas.

Firmware 1.4.11. or higher.

8.2 TriBox mini

Digital 2-channel controller

Mini controller with two digital and serial sensor channels and two 4–20mA outputs. All stored measured values and diagnostic data can be read out via an integrated web browser.

Firmware 1.2.0. or higher.

8.3 FlowCell for eCHEM Sensors

The flow cell designed specifically for the eCHEM series is used for bypass installations of our eCHEM sensors. The measuring medium is passed through the cell via an inflow. Thus, a reagent-free measurement outside of the medium is possible. The modular system makes it possible to adapt or extend the system as required.

8.4 pH Buffer Set

The pH buffer set contains six pH4 and pH7 liquid standards, which are used to calibrate the TriOS pH sensor TpH-D. Thus, a reliable detection of pH can be guaranteed. Together with the sensor holder and the FlowCell, it further enables you to carry out a quick and precise check of the pH sensor on site.

pH values of TriOS buffer solutions and their temperature dependency

pH 4.01

°C	°F	pH
0	32	4,01
5	41	4,00
10	50	4,00
15	59	4,00
20	68	4,00
25	77	4,01
30	86	4,02
35	95	4,03
40	104	4,04
45	113	4,05
50	122	4,06
55	131	4,08
60	140	4,09
65	149	4,11
70	158	4,12
75	167	4,14
80	176	4,16
85	185	4,17
90	194	4,19
95	203	4,20

pH 7.01

°C	°F	pH
0	32	7,13
5	41	7,10
10	50	7,07
15	59	7,05
20	68	7,03
25	77	7,01
30	86	7,00
35	95	6,99
40	104	6,98
45	113	6,98
50	122	6,98
55	131	6,98
60	140	6,98
65	149	6,99
70	158	6,99
75	167	7,00
80	176	7,01
85	185	7,02
90	194	7,03
95	203	7,04

8.5 Salt Bridge & Electrolyte Solution

The salt bridge and electrolyte solution are sold separately, but it is recommended that they are always replaced together. These two components ensure that these sensors can be maintained and do not need to be replaced.

9 Warranty

The warranty period of our devices within the EU and the United States is 2 years from the date of invoice. Outside of the EU, the warranty period is one year. All normal consumables, such as light sources, are not included in the warranty.

The warranty is subject to the following conditions:

- The device and all accessories must be installed as described in the corresponding manual and must be operated according to the specifications.
- Damage due to contact with corrosive and damaging substances, liquids or gases and damage during transport are not covered by the warranty.
- Damage due to improper handling and use of the device is not covered by the warranty.
- Damage resulting from modification or unprofessional attachment of accessories by the customer is not covered by the warranty.

NOTICE	**Opening the sensor voids the warranty!**

10 Customer Service

If you are having a problem with the sensor, please contact the TriOS customer service.

Technical support contact:

support@trios.de

Telephone: +49 (0) 4402 69670 - 0

Fax: +49 (0) 4402 69670 - 20

For quick help, please send us the sensor ID number by e-mail.

11 Contact

We are constantly working to improve our devices. Visit our website for news.
If you have found an error or bug in one of our devices or programs, please let us know:

Customer service:	support@trios.de
General questions / sales:	sales@trios.de
Website:	www.trios.de

TriOS Mess- und Datentechnik GmbH
Bürgermeister-Brötje-Str. 25
26180 Rastede
Germany

Telephone	**+49 (0) 4402 69670 - 0**
Fax	**+49 (0) 4402 69670 - 20**

12 Keyword Index

Annex

CE Declaration of Conformity

Hersteller/Manufacturer/Fabricant: TriOS Mess- und Datentechnik GmbH
Bürgermeister-Brötje-Str. 25
D- 26180 Rastede

Konformitätserklärung
Declaration of Conformity
Déclaration de Conformité

Die TriOS GmbH bescheinigt die Konformität für das Produkt
The TriOS GmbH herewith declares conformity of the product
TriOS GmbH déclare la conformité du produit

Bezeichnung Product name Designation	**TpH-D**
Typ / Type / Type	TpH-D Art.Nr.80S2000x0
Mit den folgenden Bestimmungen With applicable regulations Avec les directives suivantes	2014/30/EU EMV-Richtlinie 2011/65/EU RoHS-Richtlinie + (EU) 2015/863 + (EU) 2017/2102
Angewendete harmonisierte Normen Harmonized standards applied Normes harmonisées utilisées	EN 61326-1:2013 EN 61010-1:2010 +A1:2019 +A1:2019/AC:2019 EN IEC 63000:2018
Datum / Date / Date 25.10.2021	Unterschrift / Signature / Signatur R. Heuermann

DNV

Certificate No:
TAA000035H

TYPE APPROVAL CERTIFICATE

This is to certify:

That the Miscellaneous Transmitter

with type designation(s)
TpH-D differential pH sensor.

Issued to
TriOS Mess- und Datentechnik GmbH
Rastede, **Germany**

is found to comply with
DNV rules for classification – Ships, offshore units, and high speed and light craft

Application :

Product(s) approved by this certificate is/are accepted for installation on all vessels classed by DNV.

Temperature	**A**
Humidity	**B**
Vibration	**A**
EMC	**B**
Enclosure	**B (IP68)**

Issued at **Hamburg** on **2022-06-24**
This Certificate is valid until **2027-06-09**.
DNV local station: **Hamburg – CMC North/East**

Approval Engineer: **Jens Dietrich**

for **DNV**

.....

Joannis Papanuskas
Head of Section

Job Id: **262.1-030657-1**
Certificate No: **TAA000035H**

Product description

Differential pH transmitter with temperature compensation
Measuring principle: Potentiometry
pH measuring range: 0…14pH
Resolution 0.01pH
Response times: T10 falling: <2s, T90 ascending: <2s, T90 falling <5s
Temperature compensation: Pt1000
Measurement interval: 2s
Housing material PPS/PET/NBR
Interface: RS485, Modbus RTU
Power supply: 12…24VDC (+/-10%).

The TpH-D differential pH sensor is generally in compliance with the requirements of Resolution MEPC.259(68) – “2015 Guidelines for exhaust gas cleaning systems”, Chapter 10.2 “Washwater monitoring” and Resolution MEPC.340(77) – “2021 Guidelines for exhaust gas cleaning systems”, Chapter 10.2 “Discharge water monitoring”

Application/Limitation

The Type Approval covers hardware listed under Product description. When the hardware is used in applications to be classed by DNV, documentation for the actual application is to be submitted for approval by the manufacturer of the application system in each case. Reference is made to DNV rules for classification of ships Pt.4 Ch.9 Control and monitoring systems.

The TpH-D differential pH sensor is generally in compliance with the requirements of Resolution MEPC.259(68) – “2015 Guidelines for exhaust gas cleaning systems”, Chapter 10.2 “Wash water monitoring” and Resolution MEPC.340(77) – “2021 Guidelines for exhaust gas cleaning systems”, Chapter 10.2 “Discharge water monitoring”.

Correct on-board configuration and integration into the wash water monitoring system will still be subject to verification against the requirements of MEPC.259(68) and MEPC.340(77) for each delivery and is to be tested during commissioning after installation. The TpH-D sensor shall be installed, operated and calibrated in accordance with the requirements and intervals as specified in the operating instructions.

The sensor needs to be connected to a monitoring unit providing:
-sufficient protection to potential surges to the TpH transmitter
-sufficient protection to superimposed conducted low frequencies to the TpH transmitter
-limited power supply variations, to be in the range of +/-10%.

Tests carried out

Applicable tests according to DNV CG-0339, 2021.
Tests according to the relevant parts of the referenced MEPC resolutions.

Marking of product

Manufacturer name, product type, serial number, interface, power supply, measurement range.

Periodical assessment

The scope of the periodical assessment is to verify that the conditions stipulated for the type are complied with, and that no alterations are made to the product design or choice of systems, software versions, components and/or materials.

The main elements of the assessment are:

- Ensure that type approved documentation is available
- Inspection of factory samples, selected at random from the production line (where practicable)
- Review of production and inspection routines, including test records from product sample tests and control routines
- Ensuring that systems, software versions, components and/or materials used comply with type approved documents and/or referenced system, software, component and material specifications
- Review of possible changes in design of systems, software versions, components, materials and/or performance, and make sure that such changes do not affect the type approval given
- Ensuring traceability between manufacturer’s product type marking and the type approval certificate

Periodical assessment is to be performed after 2 years and after 3.5 years. A renewal assessment will be performed at renewal of the certificate.

END OF CERTIFICATE

Modbus RTU

Software Version

This Modbus protocol refers to software version 1.0.8 and higher.

Serial Interface

The serial port configuration for the RS-485 interface is (9600, 8N1):

- Baud rate: 9600 bps
- Data bits: 8
- Stop bits: 1
- Parity: none

Data types

Name	Register	Format
Bool	1	False: 0x0000, True: 0xFF00
Uint8	1	8-bit positive integer. Value range: 0x0000 - 0x00FF
Uint16	1	16-bit positive integer. Value range: 0x0000 - 0xFFFF
Uint32	2	32-bit positive integer. Value range: 0x00000000 - 0xFFFFFFFF
Float	2	IEEE 754 32-bit floating-point number
Char[n]	$\left[\frac{n}{2}\right]$	Null-terminated ASCII string of n characters
Uint16[n]	n	Field of n Uint16 values
Float[n]	2n	Field of n float values

Function Codes

TpH-D supports the following Modbus function codes:

Name	Code	Description / Use
Read multiple registers	0x03	Read the serial number, configuration, calibration and measurement data.
Write multiple registers	0x10	Write the configuration and calibration.
Write single register	0x06	Write the configuration and calibration.
Report slave ID	0x11	Read the serial number and firmware version.

Default slave address

The factory default setting of the slave address is 21 (0x15).

Read / Write multiple registers (0x03 / 0x10)

The following table describes the Modbus register mapping:

Name	R/W	Address	Data type	Description
Modbus slave ID	RW	0	Uint16	The Modbus slave ID of this device.
Measurement timeout	R	1	Uint16	The remaining time in [10^{-1} s] of a running measurement process.
Serial Setting - Baudrate	RW	2	Uint16	• 0x0000 9600 baud • 0x0001: 19200 baud • 0x0002: 38400 baud • 0x0003: 56700 baud
Serial Setting - Parity	RW	3	Uint16	• 0x0000: None • 0x0001: Odd • 0x0002: Even
Serial Setting - Stopbits	RW	4	Uint16	• 0x0001: 1 stop bit • 0x0002: 2 stop bits
Device serial number	R	10	Char[10]	Serial number of the sensor.
Firmware version	R	15	Char[10]	Installed firmware version of the sensor.
System date and time	RW	107	Uint32	The current time in seconds since 1 January 1970. (Internal counter with ±0.9 % accuracy @ 8.00MHz)
Device description	RW	109	Char[64]	A custom device description. E.g. “Drain pipe south”
Index for Moving Average / Offset / Scaling	RW	400	Uint16	The index of the parameter for the following offset and scaling settings. The parameter list is shown in this document starting at Modbus address 1000. • 0x0000: pH • 0x0001: Temperature
Offset	RW	402	Float	Parameter offset. Formula: scaled = (raw – offset) * scaling
Scaling	RW	404	Float	Scaling factor parameter. Formula: scaled = (raw – offset) * scaling
pH	R	1000	Float	pH value
Temperature	R	1002	Float	The temperature in degrees Celsius (°C)
SQI	R	1004	Float	Sensor quality index.
pH scaled	R	1500	Float	Scaled pH value
Temperature scaled	R	1502	Float	The temperature is in degrees Celsius (°C).

FSM Control	RW	5000	Uint16	Finite-state machine control register.
FSM Parameter	RW	5001	Uint16	The parameter to be processed in the finite-state machine.
FSM Status	R	5002	Uint16	The current status of the finite-state machine.
Calibration Control	RW	6000	Uint16	Reset all parameters to: • 0x0001: Factory calibration • 0x0002: Last calibration
Factory calibration - Parameter	RW	6001	Uint16	• 0x0000: pH • 0x0001: Temperature
Factory calibration - Offset	RW	6002	Float	Offset factor of the factory calibration
Factory calibration – Scaling	RW	6004	Float	Scaling factor of the factory calibration.
Factory calibration – Square	RW	6006	Float	Square factor of the factory calibration.
Factory calibration – Timestamp	RW	6008	Uint32	Timestamp of the factory calibration.
Active calibration - Parameter	RW	6010	Uint16	• 0x0000: pH • 0x0001: Temperature
Active calibration – Offset	RW	6011	Float	Offset factor of the active calibration.
Active calibration – Scaling	RW	6013	Float	Scaling factor of the active calibration.
Active calibration – Square	RW	6015	Float	Square factor of the active calibration.
Active calibration – Timestamp	RW	6017	Uint32	Timestamp of the active calibration.
Last calibration - Parameter	RW	6019	Uint16	• 0x0000: pH • 0x0001: Temperature
Last calibration – Offset	RW	6020	Float	Offset factor of the last calibration.
Last calibration – Scaling	RW	6022	Float	Scaling factor of the last calibration.
Last calibration – Square	RW	6024	Float	Square factor of the last calibration.
Last calibration – Timestamp	RW	6026	Uint32	Timestamp of the last calibration.

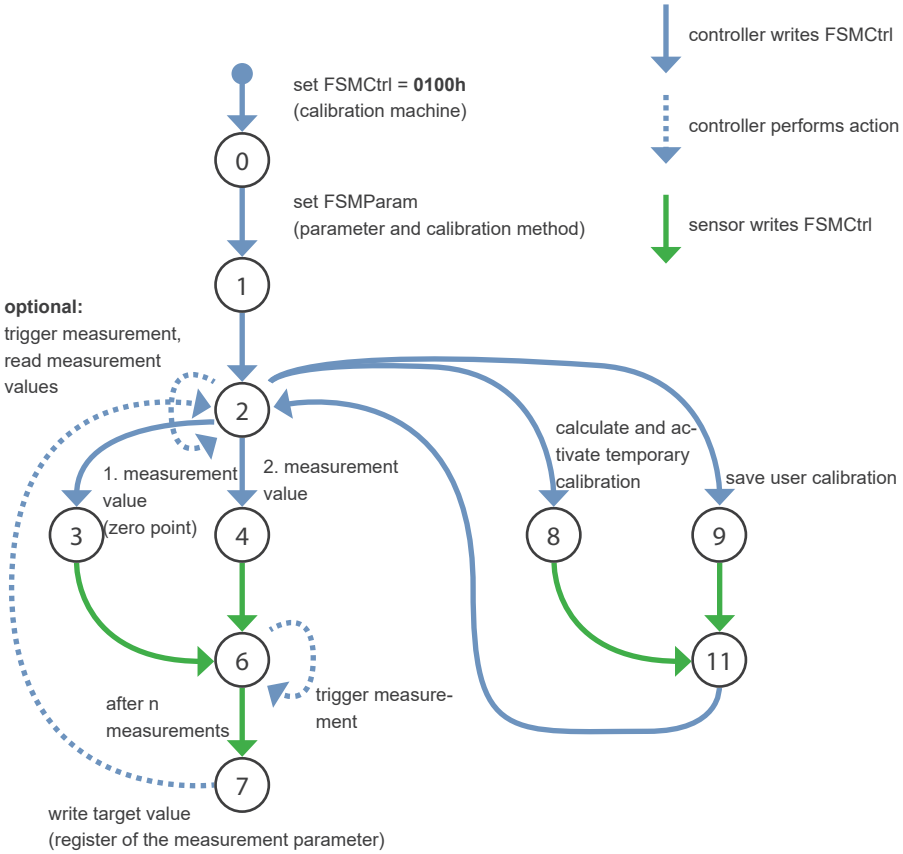
Report Slave ID (0x11)

The sensor name, serial number and firmware version is replied each as null terminated ASCII string.

Example:

T	R	I	O	S	0x0	T	p	H	-	D	0x0	0	6	9	0	0	0	0	0	0x00	1	.	0	.	8	0x0

State machine for pH calibration



State machines number

The calibration machine has number 1.

States

0: Activate state machine

The state machine is activated; the sensor leaves the normal operating mode.

1: Validation of parameters and calibration method

Select the calibration method (in low byte) and the parameter (in high byte) to be calibrated via parameter register FSMParam. After that, the change to state 1 initializes the state ma-chine for that parameter and this calibration method.

If the selected calibration procedure is possible, the sensor changes to state 2 and deactivates the current calibration coefficients for the selected parameter.

Otherwise, the sensor stays in state 1; the error can be determined by reading out the error registers.

2: Idle state

The calibration machine was successfully activated or the last action was successfully com-pleted. The sensor is now waiting for further commands.

3 and 4: Measurements

On the part of the control unit, the measurements required for this calibration method can now be started by the change to states 3 or 4. Regardless of the calibration method, state 3 is al-ways the first measuring point, etc.

6: Performing measurement

After the control unit has informed the sensor to start the measurement (by changing to state 3 or 4), the sensor changes to state 6 for the duration of the measurements. During this phase, the control unit should continuously trigger measurements and read out the measure-ment results. As soon as the sensor has collected enough measurement values, it switches to state 7 and awaits the transmission of the setpoint.

7: Acquisition of the target value

The control unit writes the target value into the register of the measurement parameter of the calibrated param-eter. This is the same register from which the measured values of the pa-rameter are read out. If the sensor accepts the target value, it acknowledges this with a change back to state 2.

Otherwise the sensor will stay in state 7.

8: Coefficient calculation

Once all the required measurements have been taken and the target values stored, the sen-sor can be prompt-ed to calculate a new calibration by changing to state 8. This new calibra-tion is then temporarily activated and will be used to calculate the measurement values. How-ever, this calibration is not saved yet and will be lost if you leave the calibration machine now.

After successful calculation, the sensor changes to state 11 (see below). If the sensor cannot calculate a cali-bration, the sensor remains in state 8.

9: Save user calibration

Changing to state 9 will save the customer calibration. The previous calibration data is marked as the last calibration and the new calibration data is marked as the active calibration. Once the customer calibration has been saved, the parameters determined during this calibration remain active even after leaving the calibration machine.

11: Successful execution

After successful calculation or storage, the sensor changes to state 11 and awaits the ac-knowledgment by the control unit. The control unit needs to transmit the sensor to change to state 2.

Termination / cancellation

The state machine can be terminated at any time by setting the state control register to the value 0 and, thus, changed back to the normal operation mode. If the calibration has not yet been completed and the coefficients are not saved, the original coefficients are restored.

If error bits are set, the controller unit must reset the state machine by changing to state 0.

Then, by selecting the parameter and the calibration method, the calibration must be re-initialized.

Error conditions

If an error occurs during calibration and the sensor remains in one of the above-mentioned error states, the calibration machine must be terminated in any case and needs to be restart-ed if necessary. An error recovery within the calibration machine does not take place.

State parameter register

State parameter register is divided into two parts:

FSMParam	
High Byte	**Low Byte**
Parameter Index	Calibration method

The **Parameter Index** determines the parameter to be calibrated. The index depends on the parameter list as shown in the measurement register area.

The **Calibration method** is determined by one of the following values:

Calibration method	Definition	State
0x00	**No calibration (Reset FSM)**	–
0x01	Linear (2 point-) calibration (Offset, Scaling)	3, 4

pH Calibration

Register		
5000	FSM Control	
5001	FSM Parameter	1 = pH
	High Byte	Low Byte
5002	FSM on = 1 always	FSM Status

Requirements and notes	Functionality	Function code	Register	Value	Length	FSM Status	Type	Result
Step 1	pH Calibration							
Requirements:	Activate Calibration mode pH							
Temperature is calibrated	Activate Calibration mode	0x06	5000	0x0100				
Sensor in normal function (LED green)	Activate pH calibration	0x06	5001	0x0001				
	Start calibration	0x06	5000	0x0101				
	Wait until Sensor LED gets blue and FSM status gets 2	0x03	5002		1	2	Integer	LED gets blue
Step 2								
Requirements:	Calibrate pH 7							
FSM Status 2	Start calibrate pH 7	0x06	5000	0x0103				
Insert buffer pH7								
Stable readings	Wait until FSM Status gets 7; to check read FSM Status (takes a little while)	0x03	5002		1	7	Integer	
	Write specified value of standard solution	0x10	1000	IEEE 754 Float	2		IEEE 754 Float	
Notes:								
Use 40E0 40E0 (pH7) if you can't write floats	Wait until FSM Status gets 2; to check read FSM Status	0x03	5002		1	2	Integer	
Step 3								
Requirements:	Calibrate pH10 or pH4							
FSM Status 2	Start calibrate pH10 or pH4	0x06	5000	0x0104				
Insert buffer pH10 or 4								

Requirements and notes	Functionality	Function code	Regis-ter	Value	Length	FSM Status	Type	Result
Stable readings	Wait until FSM Status gets 7; to check read FSM Status	0x03	5002		1	7	Integer	
	Write specified value of standard solution	0x10	1000	IEEE 754 Float	2		IEEE 754 Float	
Use 4120 4120 (ph 10) or 4080 4080 (pH 4) if you can't write floats	Wait until FSM Status gets 2; to check read FSM Status	0x03	5002		1	2	Integer	
Step 4								
Requirements:	Apply and check Calibration							
Calibration success	Apply calibration and wait for FSM Status to get 11	0x06	5000	0x0108				
FSM Status 2								
	Wait until FSM Status gets 11; to check read FSM Status	0x03	5002		1	11	Integer	
	Set FSM Status again to 2	0x06	5000	0x0102				
	Wait until FSM Status gets 2; to check read FSM Status	0x03	5002		1	2	Integer	
Notes:								
Now poll readings to check if values satisfying.	Poll pH data	0x03	1000		2		IEEE 754 Float	
Step 5								
Requirements:	Save Calibration							
Calibration process success	Save Calibration and wait for FSM Status to get 11	0x06	5000	0x0109				
	Wait until FSM Status gets 11; to check read FSM Status	0x03	5002		1	11	Integer	
	Set FSM Status again to 2	0x06	5000	0x0102				
	Wait until FSM Status gets 2; to check read FSM Status	0x03	5002		1	2	Integer	
	Calibration is saved.							
Step 6								
Notes:	Leave Calibration process	0x06	5000	0x0000				
If done between calibration steps, calibration is abort	Wait until FSM Status gets 0; to check read FSM Status	0x03	5002		1	0	Integer	LED gets green

Temperature Calibration

Register		
5000	FSM Control	
5001	FSM Parameter	259 = Temp
	High Byte	Low Byte
5002	FSM on = 1 always	FSM Status

Requirements and notes	Functionality	Function code	Register	Value	Length	FSM Status	Type	Result
Step 1	Temperature Calibration							
Requirements:	Activate Calibration mode temperature							
Sensor in normal function (LED green)	Activate Calibration mode	0x06	5000	0x0100				
	Activate temperature calibration	0x06	5001	0x0103				
	Start calibration	0x06	5000	0x0101				
	Wait until Sensor LED gets blue and FSM status gets 2	0x03	5002		1	2	Integer	LED gets blue
Step 2								
Requirements:	Calibrate temperature							
FSM Status 2	Start calibrate temperature	0x06	5000	0x0103				
Measure reference temperature								
Stable readings	Wait until FSM Status gets 7; to check read FSM Status (takes a little while)	0x03	5002		1	7	Integer	
	Write reference temperature value	0x10	1002	IEEE 754 Float	2		IEEE 754 Float	
Notes:	Wait until FSM Status gets 2; to check read FSM Status	0x03	5002		1	2	Integer	
Step 3								
Requirements:	Apply and check Calibration							
Calibration success	Apply calibration and wait for FSM Status to get 11	0x06	5000	0x0108				
FSM Status 2								

Requirements and notes	Functionality	Function code	Regis-ter	Value	Length	FSM Status	Type	Result
	Wait until FSM Status gets 11; to check read FSM Status	0x03	5002		1	11	Integer	
	Set FSM Status to 2 again	0x06	5000	0x0102				
	Wait until FSM Status gets 2; to check read FSM Status	0x03	5002		1	2	Integer	
Notes:								
Now poll readings to check if values are satisfying.	Poll temperature data	0x03	1002		2		IEEE 754 Float	
Calibration isn't saved yet. If you leave calibration process or power down between step 1 and 5, the calibration is lost.								
Step 4								
Requirements:	Save Calibration							
Calibration process succeeded	Save Calibration and wait for FSM Status to get 11	0x06	5000	0x0109				
	Wait until FSM Status gets 11; to check read FSM Status	0x03	5002		1	11	Integer	
	Set FSM Status to 2 again	0x06	5000	0x0102				
	Wait until FSM Status gets 2; to check read FSM Status	0x03	5002		1	2	Integer	
Calibration is saved.								
Step 5								
Notes:	Leave Calibration process	0x06	5000	0x0000				
If done between calibration steps, calibration is aborted.	Wait until FSM Status gets 0; to check read FSM Status	0x03	5002		1	0	Integer	LED gets green