TriOS
Optical Sensors

TpH

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 pH sensor.

The TpH is based on the electrochemical measuring method with a measuring electrode and a reference electrode. 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 to comply with local and state regulations for the installation of electronic equipment. 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 standards on electronic instruments. The device meets the requirements of the international standards on electromagnetic compatibility. Please use only original TriOS accessories and cables to ensure smooth and professional use of the devices.

Read this manual carefully before using the equipment and save this manual for future reference. Before commissioning the sensor, please make sure that you have read and understood the following safety precautions. Always make sure that the sensor is operated correctly. The safety precautions noted on the following pages are intended to provide a simple and correct operation of the instrument and all its accessories to prevent harm from coming to you, other people or devices.

NOTICE **In case of inconsistence, the German original version shall prevail.**

Copyright Notice

1.2 Health and safety information

This manual contains important information on 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 customer service.
- 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. Defective, improper repairs can lead to accidents and injuries.

⚠ DANGER **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 sensor has been developed for use in industry and science. The target group for the operation of the TpH 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 operators are familiar with dealing with hazardous substances due to 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 sensor is exclusively to measure pH values in aqueous solutions, as described in this manual. In this respect, the TpH sensor is an immersion sensor used under water or in conjunction with flow cells. 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 sensor in other media than those specified in this manual, please contact the customer service 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 Proper disposal

At the end of its service life, the device and its accessories may be returned for environmentally friendly disposal. The preceding professional decontamination must be proven with a certificate. Please contact us for more details before you send the device back.

Shipping address:

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

Tel.: +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).

2 Introduction

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

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.

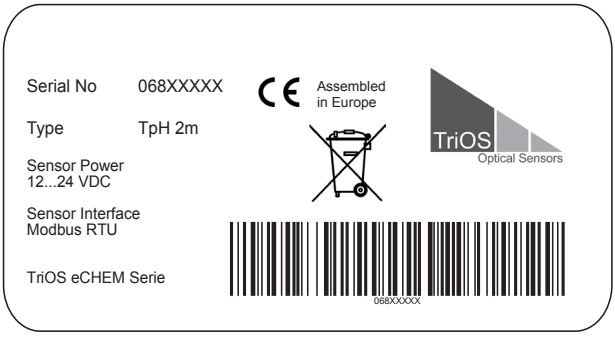
There is also a rating plate on the sensor with the following information that you can use to uniquely identify the product:

Serial number

Product type

Power supply

Electric



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

* High-density polyethylene.

3 Commissioning

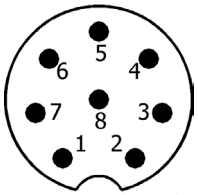
This chapter deals with the commissioning of the sensor. Please pay particular attention to this section and follow the safety precautions to protect the sensor from damage and yourself from injury.

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 Electric

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 differential value between lines A and B is the decisive factor for the transmission robustness against conducted noise signals.

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

4 Use

The TpH 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.

Remove the black protective cap by holding the sensor vertically downwards and unscrewing the cap. 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 activated in order to achieve optimum measurements. Please note the minimum immersion depth up to the ring.

NOTICE **If the sensor is dry, it must first be conditioned in pH4 buffer for 24 hours.**

The sensor is now immersed in the measuring medium. The black sensor head should 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 sensor should be calibrated at regular intervals. The intervals depend on the respective application. If the TpH 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 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. The service life of the TpH can be extended by regular cleaning.

4.2 Bypass Installation

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

4.3 Support Tube Installation

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

- NPT1 adapter ZM46 (incl. cap nut ZM13)
- G1 adapter ZM41 (incl. cap nut ZM13)

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 Storage

Never store the sensor dry. Always keep the protective cap and reuse it for storage in a solution of pH4 buffer and potassium chloride or a 3 molar KCl solution.

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

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 sensor in distilled water!**

5 Calibration

TpH 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. Checks with standard solutions are recommended to determine the intervals. TriOS offers suitably bottled buffer solutions pH4 and pH7 (see chapter 8).

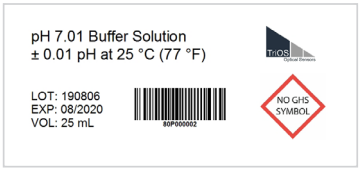
Calibration is possible both on the controllers (see chapter 8) and via Modbus. The calibrations performed are stored internally by the sensor. Thus, the current calibration is always present.

5.1 pH Calibration

With the calibration, the zero value (pH7) and the scaling factor (pH4) are calibrated. For calibration, select pH buffer solutions with an accuracy of +/- 0.01pH and observe the temperature. Fresh or newly prepared solutions must be used for each calibration! TriOS offers an ideal set for the TpH 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.

NOTICE **Do not wipe the electrode.**

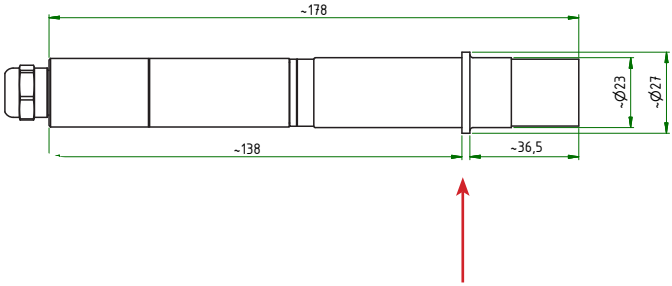
- Immerse the TpH in pH7 buffer solution, the sensor head (black) should be immersed as completely as possible (the picture on the next page shows the immersion depth in the beaker with the buffer solution as a red line). Otherwise, measurement fluctuations may occur.

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

- Immerse the sensor slowly into the small buffer solution and move it slightly so the membrane is wetted by the buffer solution.
- Allow the sensor to warm up for approx. 5 minutes and then calibrate to pH7. Observe the temperature!

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

- Rinse the sensor again with distilled water.
- Immerse the TpH in pH4 buffer solution, the sensor head (black) should be immersed as completely as possible (the picture below shows the immersion depth in the beaker with the buffer solution as a red line). Otherwise, measurement fluctuations may occur.
- Allow the sensor to warm up for approx. 5 minutes and then calibrate to pH4 (or pH10). Observe the temperature!
- Rinse the sensor with distilled water.
- You can now begin your measurements.
- Dispose the buffer solutions after use.



Optimum immersion depth in application with TriOS buffer solution.

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.

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 biofilm on the sensors, this can lead to measurement errors.
- A dirty sensor should be cleaned with buffer solution.
- 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.**

If the sensor is taken out of operation, it should be cleaned before being stored. The protective cap must be filled with a 3-molar KCl solution.

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 sensor is about 1 year. If difficulties occur during calibration, the sensor probably has to be replaced.

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 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 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 → "Current value" →select the value to be displayed.

   Automatic measurements:

   In the „Sensor" menu, click on the TpH 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 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.

6.3 Returns

Please observe the following instructions when returning items.

If returning a sensor, please contact customer service first. To ensure a smooth return and to avoid incorrect deliveries, each return package must first be reported to the customer service. 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 can not 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.

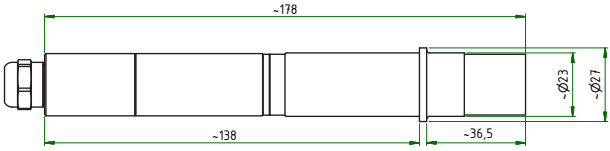
7 Technical Data

7.1 Technical specifications

Measurement technology		pH electrode	
Measurement principle		Potentiometry	
Parameter		pH value, temperature	
measuring range	pH	0...14 pH	
	Temperature	0...+65 °C	
resolution	pH	0.01 pH	
	Temperature	0.1 °C	
precision	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	
Dimensions (L x Ø)		~ 180 x 27 mm	~ 7.1˝ x 1.1˝
Weight		110 g	~ 0.2 lbs
Interface		RS-485, Modbus RTU	
Power consumption		0.2 W	

Power supply		12...24 VDC (± 10 %)	
Connection		8-pin M12 plug	
Sensor cable		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: 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...+40 °C	~ +36 °F to +104 °F
Ambient temperature		-5...+55 °C	~ +23 °F to +131 °F
Storage temperature		0...+80 °C	~ +32 °F to +176 °F
Inflow velocity		0...3 m/second	~ 0...10 fps

7.2 External Dimensions



8 Accessories

8.1 TriBox 3

Digital 4-channel display and control unit with integrated solenoid valve for pneumatic control

TriBox3 is a measurement and control system for all TriOS sensors. The device provides 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 analog 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 version 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 measurement data and diagnostic data can be read out via a built-in web browser.

Firmware version 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. 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

9 Warranty

The warranty only applies to the electronics of the device. The warranty period of our devices within the EU is 2 years from the date of the invoice. Outside of the EU, the warranty period is one year. All wearing parts are excluded from 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

Tel.: +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
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12 Keyword Index

Annex

CE Declaration of Conformity

CE

TriOS Optical Sensors

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**
Typ / Type / Type:	Art. Nr. 80S1000x0
Mit den folgenden Bestimmungen With applicable regulations Avec les directives suivantes	2014/30/EU EMV-Richtlinie 2011/65/EU RoHS-Richtlinie
Angewendete harmonisierte Normen Harmonized standards applied Normes harmonisées utilisées	EN 61326-1:2013 EN 55011:2009 + A1:2010 EN 61010-1:2010 EN 50581:2012
Datum / Date / Date	Unterschrift / Signature / Signatur
02.05.2018	R. Heuermann

D05-068yy201805

Modbus RTU

Serial Interface

Upon delivery, the serial interface is configured with the following settings:

- 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

Functions

The sensor supports the following Modbus functions:

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.

Standard Modbus server address

Upon delivery, the sensor is set to address 20 (0x14).

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

The following values are in the registers:

Name	R/W	Address	Data type	Description
Modbus slave ID	RW	0	Uint16	Modbus server address of the sensor.
Measurement timeout	R	1	Uint16	The remaining time in [10-1 s] of the active measurement.
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[20]	Serial number of the sensor.
Firmware version	R	15	Char[20]	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]	Sensor description (e.g.: "Inlet South").
Index for Moving Average / Offset / Scaling	RW	400	Uint16	The index of the parameter for the following offset and scaling settings. The index depends on the parameter list in this description from register 1000: • 0x0000: pH • 0x0001: Temperature
Moving average	RW	401	Uint16	The number of measurements over which a moving average is calculated. Value range: 1 – 25 Delivery state: 10
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	The pH value of the medium (original value).
Temperature	R	1002	Float	The temperature of the medium in °C (original value).
SQI	R	1004	Float	Sensor quality index.
pH scaled	R	1500	Float	The pH value of the medium (customer scaled).
Temperature scaled	R	1502	Float	The temperature of the medium in °C (customer scaled).

FSM Control	RW	5000	Uint16	FSM control register (calibration).
FSM Parameter	RW	5001	Uint16	FSM parameter register (calibration). Contains parameter index and calibration method. • 0x0001: pH • 0x0103: Temperature
FSM Status	R	5002	Uint16	FSM status register (calibration).
Permanent errors	R	5100	Uint16	Permanent errors (bit field).
Permanent warnings	R	5101	Uint16	Permanent warnings (bit field).
Temporary errors	R	5102	Uint16	Temporary errors (bit field).
Temporary warnings	R	5103	Uint16	Temporary warnings (bit field).
Calibration Control	RW	6000	Uint16	Calibration control register. For complete restoration of calibration (pH and temperature): • 0x0001: Factory calibration • 0x0002: Last calibration
Factory calibration - Parameter	RW	6001	Uint16	Parameter index of the following calibration data (factory calibration): • 0x0000: pH • 0x0001: Temperature
Factory calibration - Offset	RW	6002	Float	Offset of the factory calibration to the selected parameter.
Factory calibration – Scaling	RW	6004	Float	Scaling factor of the factory calibration to the selected parameter.
Factory calibration – Square	RW	6006	Float	Square coefficient of the factory calibration to the selected parameter. Not used, always 0.
Factory calibration – Timestamp	RW	6008	Uint32	Time of factory calibration.
Active calibration - Parameter	RW	6010	Uint16	Parameter index of the following calibration data (active calibration): • 0x0000: pH • 0x0001: Temperature
Active calibration – Offset	RW	6011	Float	Offset of the active calibration to the selected parameter.
Active calibration – Scaling	RW	6013	Float	Scaling factor of the active calibration to the selected parameter.
Active calibration – Square	RW	6015	Float	Square coefficient of the active calibration to the selected parameter. Not used, always 0.
Active calibration – Timestamp	RW	6017	Uint32	Time of active calibration.

Last calibration - Parameter	RW	6019	Uint16	Parameter index of the following calibration data (last calibration): • 0x0000: pH • 0x0001: Temperature
Last calibration – Offset	RW	6020	Float	Offset of the last calibration to the selected parameter.
Last calibration – Scaling	RW	6022	Float	Scaling factor of the last calibration to the selected parameter.
Last calibration – Square	RW	6024	Float	Square coefficient of the last calibration to the selected parameter. Not used, always 0.
Last calibration – Timestamp	RW	6026	Uint32	Time of last calibration.

Errors and Warnings

Permanent errors indicate a defect of the sensor.

Description	Bitmask
General error	0x0001
ADC upper limit exceeded	0x0002
ADC lower limit not reached	0x0004

Permanent warnings

Description	Bitmask
n/a	n/a

Temporary errors provide information on the cause of questionable measured values (SQI) or calibration problems.

Description	Bitmask
ADC error	0x0001
ADC upper limit exceeded	0x0002
ADC lower limit not reached	0x0004
FSM invalid status	0x0010
FSM invalid transition	0x0020
FSM insufficient authentication	0x0040
FSM invalid parameter index	0x0100
FSM invalid calibration method	0x0200

Temporary warnings provide information on the cause of questionable measured values (SQI).

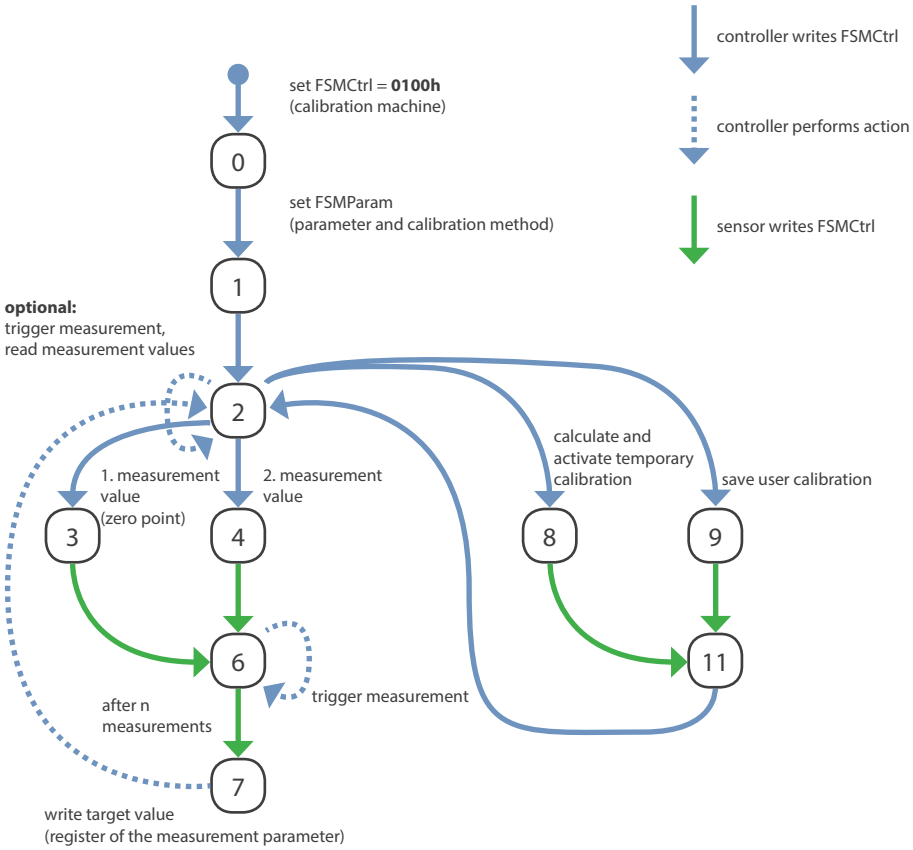
Description	Bitmask
Temperature outside 0 .. 65°C	0x0002
pH value outside 0.5 .. 12.5	0x0008
Reference voltage outside 0.3 .. 1.17V	0x0010

Report Server ID (0x11)

Returns the sensor name, the serial number and the firmware version number each as null-terminated ASCII string.

T	R	I	O	S	0x0	T	p	H	0x0	0	6	8	0	0	0	0	0	0x00	1	.	0	.	1	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 parameter. 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 acknowl-edges 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 prompted 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 meas-urement 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 calibration, 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 (see p. 28)	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 (poll until stable)	Check read FSM Status register until FSM Status gets 7 (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	Check read FSM Status register until FSM Status gets 2	0x03	5002		1	2	Integer	
Step 3								
Requirements:	Calibrate pH 10 or 4							
FSM Status 2	Start calibrate pH 10 or 4	0x06	5000	0x0104				
Insert buffer pH10 or 4								
Stable readings (poll until stable)	Check read FSM Status register until FSM Status gets 7	0x03	5002		1	7	Integer	
	Write specified value of standard solution	0x10	1000	IEEE 754 Float	2		IEEE 754 Float	

Requirements and notes	Functionality	Function code	Register	Value	Length	FSM Status	Type	Result
Notes:								
Use 4120 4120 (ph 10) or 4080 4080 (pH 4) if you can't write floats	Check read FSM Status register until FSM Status gets 2	0x03	5002		1	2	Integer	
Step 4								
Requirements:	Apply and check Calibration							
Calibration succeeded	Apply calibration and wait for FSM Status to get 11	0x06	5000	0x0108				
FSM Status 2								
	Check read FSM Status register until FSM Status gets 11	0x03	5002		1	11	Integer	
	Set FSM Status again to 2	0x06	5000	0x0102				
	Check read FSM Status register until FSM Status gets 2	0x03	5002		1	2	Integer	
Notes:								
Now poll readings to check if values satisfying.	Poll pH data	0x03	1000		2		IEEE 754 Float	
Calibration is not saved yet.								
If you leave calibration process or power down between step 1 and 6, the calibration is lost.								
Step 5								
Requirements:	Save Calibration							
Calibration process succeeded	Save Calibration and wait for FSM Status to get 11	0x06	5000	0x0109				
	Check read FSM Status register until FSM Status gets 11	0x03	5002		1	11	Integer	
	Set FSM Status again to 2	0x06	5000	0x0102				
	Check read FSM Status register until FSM Status gets 2	0x03	5002		1	2	Integer	
	Calibration is saved.							
Step 6								
Notes:	Leave Calibration process	0x06	5000	0x0000				
If done between calibration steps, calibration is aborted	Check read FSM Status register until FSM Status gets 0	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 (poll until stable)	Check read FSM Status register until FSM Status gets 7 (takes a little while)	0x03	5002		1	7	Integer	
	Write reference temperature value	0x10	1002	IEEE 754 Float	2		IEEE 754 Float	
Notes:	Check read FSM Status register until FSM Status gets 2	0x03	5002		1	2	Integer	
Step 3								
Requirements:	Apply and check Calibration							
Calibration succeeded	Apply calibration and wait for FSM Status to get 11	0x06	5000	0x0108				
FSM Status 2	Check read FSM Status register until FSM Status gets 11	0x03	5002		1	11	Integer	
	Set FSM Status to 2 again	0x06	5000	0x0102				
	Check read FSM Status register until FSM Status gets 2	0x03	5002		1	2	Integer	

Requirements and notes	Functionality	Function code	Register	Value	Length	FSM Status	Type	Result
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				
	Check read FSM Status register until FSM Status gets 11	0x03	5002		1	11	Integer	
	Set FSM Status to 2 again	0x06	5000	0x0102				
	Check read FSM Status register until FSM Status gets 2	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.	Check read FSM Status register until FSM Status gets 0	0x03	5002		1	0	Integer	LED gets green