pyroscience
sensor technology

AquapHOx Underwater Oxygen Sensor
APHOX-S-O$_2$

USER MANUAL
OPERATING INSTRUCTIONS

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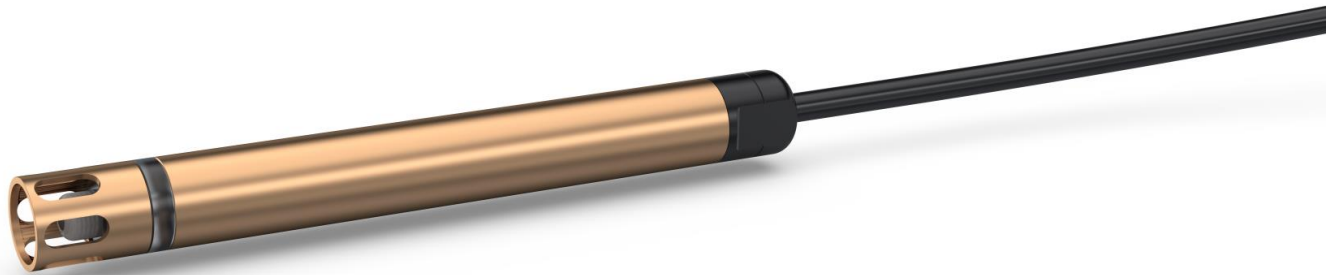
AquapHOx Underwater Oxygen Sensor
APHOX-S-O$_2$

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1 INTRODUCTION

The **APHOX-S-O2** is an underwater oxygen sensor. It combines the optical oxygen sensing technique of **PyroScience** with a corrosion and biofouling resistant pressure housing. The sensor can be used for underwater operation down to 50 m water depth. An internal NTC temperature sensor provides automatic temperature compensation of the oxygen sensor. Digital communication is possible via a RS485-Modbus RTU. Additionally, the sensor features voltage (0-5V) and current (4-20mA) outputs. These interfaces allow an easy integration in existing custom systems. The sensor comes with a factory calibration. If required, the user can perform a simple 1-point calibration or a 2-point calibration for increased accuracy at low oxygen concentrations

Depending on the customer's application and existing system there are different usage scenarios for operation:

Option A: The software **Pyro DeveloperTool** provides simple settings and calibration procedures. Furthermore, additional advanced settings provide full control of all features of the **APHOX-S-O2** (see chapter 3.1). For connection to a PC, the digital interface can be converted to USB via an USB adapter cable (item no. **APHOX-S-USB**)

Option B: The **APHOX-S-O2** features a standard RS485 interface with Modbus RTU protocol, supporting robust bus systems with up to 247 devices at a single bus. This very popular communication protocol allows easy integration of the **APHOX-S-O2** into third-party systems (see chapter 3.2).

Option C: The **APHOX-S-O2** also features 4 analog outputs (2x 0-5V and 2x 2-20mA). Configuration of the analog outputs, sample rate as well as calibration of the sensor can be performed by using the software **Pyro Developer tool** or the communication protocol (see chapter 3.3).

2   SPECIFICATIONS

Analytical performance

Optical sensor	Exchangeable screw cap (item no. **APHOX-S-OXCAP**)	
Measuring range Optimum Maximum	% air saturation (a.s.) 0 – 250% a.s. 0 – 500% a.s	mg/L (ppm) 0-22 mg/L 0-44 mg/L
Accuracy	±1%	±0.1 mg/L
Resolution	0.25% a.s.	0.025 mg/L
Detection limit	0.1% a.s.	0.01 mg/L
Response time	< 15s	
Drift	<1% rel. / 3 months	
Max. sample rate	1 s	
Temperature sensor Resolution Accuracy Typical response time	NTC-thermistor for automatic temperature compensation 0.01°C 0.1°C 20 s	

Environment

Temperature range during operation	-5°C – 40°C
Temperature range during storage	-10°C – 60°C
Maximum hydrostatic pressure	5 bar (50m)

Interface

Power	12V DC, 20mA (+ power consumption of analog output, if used)
Software	Pyro Developer Tool
Digital Interface	RS485 / Modbus-RTU PSUP protocol ('transparent mode')
Analog outputs	2x 0–5V and 2x4-20mA, 16bit, freely configurable

Mechanical

Dimension	20 x 226 mm
Weight-in-air	135 g
Housing Material	Corrosion and biofouling resistant copper alloy (CuNi10), polycarbonate, POM

Cable type and length	Shielded Cat5e, Ø7mm, seawater resistant PUR sheath Standard length: 8m, Custom lengths available
Max. cable length	55m

3 COMMUNICATION INTERFACES

3.1 Option A: Operating the underwater oxygen sensor with Pyro Developer Tool

The software **Pyro Developer Tool** offers simple settings and calibration procedures. Furthermore, additional advanced settings provide full control over all features of the module.

System requirements: PC with Windows 7/8/10 and min. 1000 MB free disk space.

Do not connect the USB adapter cable to your PC before the software has been installed! The software will automatically install the appropriate USB-drivers.

Installation steps:

- Download the **Pyro Developer Tool** from https://www.pyroscience.com/en/downloads/underwater-devices

- Unzip and start the installer and follow the instructions.

- Connect the Transmitter to your windows PC using the USB adapter cable.

- Start the **Pyro Developer Tool** software.

For more information on the software, please refer to the **Pyro Developer Tool** manual available at https://www.pyroscience.com/en/downloads/underwater-devices .

3.1.1 USB-interface cable

For the operation of **APHOX-S-O2** with a Windows PC, a coded USB interface cable (item no. **APHOX-S-USB**) is available from **PyroScience**. The cable enables to communicate with the module via the software **Pyro Developer Tool**. At the mounting adapter of the **APHOX-S-USB** cable, a label indicates the wire assignment.

3.2 Option B: RS485-Modbus interface

The RS485 interface of the module can be connected to a standard Modbus RTU bus. Up to 247 devices can be connected to a single bus consisting of the 4 wires required by the RS485 interface. The Modbus protocol is a popular industrial communication protocol reckoned by its simplicity and robustness. Modbus libraries are available for virtually any programming language. Numerous data logging systems support the Modbus protocol.

Please refer to chapter 5 for the electrical specifications and the wire assignment of the RS485-Modbus-interface.

3.2.1 Modbus RTU

An essential element of the Modbus protocol are slave addresses and registers. Every Modbus device possesses a configurable slave address (range 1-247) and a certain set of registers, which contain e.g., integer numbers. There exist read-write registers (e.g., temperature offset) and read-only registers (e.g. the result of a temperature measurement). The Modbus RTU protocol provides commands, allowing a "master device" (e.g., a PC or a PLC) to read or write specific registers from a device with a specific slave address.

The Modbus interface **APHOX-S-O2** is compatible with the Modbus RTU protocol as described in the official documentation "Modbus over serial line specification and implementation guide V1.02" and "Modbus application protocol specification V1.1b" provided by the Modbus Organization Inc. (https://modbus.org).

The **APHOX-S-O2** devices are delivered with slave address 1.

3.2.2 PyroScience Unified Protocol

All optical meters from **PyroScience** with firmware generation 4 (i.e., firmware version >= 4.0, introduced in 2020) comply to the so called **PyroScience Unified Protocol (PSUP)**. This communication protocol is based on registers and specific commands which are used to read and write the registers. All further details, including the Modbus register map, can be found in the reference manual **PyroScience Unified Protocol** available for download on the **PyroScience** website here:

https://www.pyroscience.com/en/downloads/underwater-devices

3.3   Option C: Read-out using the analog outputs

The **APHOX-S-O2** offers read-out using analog outputs. The settings for the analog outputs can be adjusted with the **PyroScience** software **Pyro Developer Tool** or the communication protocols.

Analog Output	2x 0-5V, 2x 4-20mA (16 bit each)

In the **Pyro Developer Tool** software the output parameter and the corresponding analog output can be selected. Further the so called "broadcast interval", which represents the sample interval of the measurements given at the analog outputs needs to be adjusted. For more information, please refer to the software manual **Pyro Developer Tool** (see link in chapter 3.1).

According to the Modbus-RTU communication protocol the analog outputs can be adjusted by writing the corresponding Modbus registers. For more information about the read-write Modbus registers please refer to the PSUP communication protocol, which explains also the Modbus registers. Alternatively, the registers can be adjusted with the **PyroScience** commands if the Modbus module is in transparent mode. Please refer to the **PSUP** communication protocol for more information about how to write and read the **PyroScience** registers (see link in chapter 3.2.2).

4 HANDLING INSTRUCTIONS

This chapter provides general handling instructions to operate the **APHOX-S-O2** successfully.

For in-depth information especially on sensor settings and sensor calibration, please refer to the respective **Oxygen Sensor Manual** available at https://www.pyroscience.com/en/downloads/underwater-devices .

4.1 Connecting the sensor screw cap

The sensor comes with a pre-calibrated sensor cap installed (item no. **APHOX-S-OXCAP)**. To replace the sensor cap, pull off the protection cap of the **APHOX-S-O2**, unscrew the old sensor cap, and screw on the new cap by hand. Please do not apply excessive force or use any tools to install the cap, as this might damage the sensor. Before calibration and measurement, please place the protective cap back on. The assembly is shown in Figure 1.
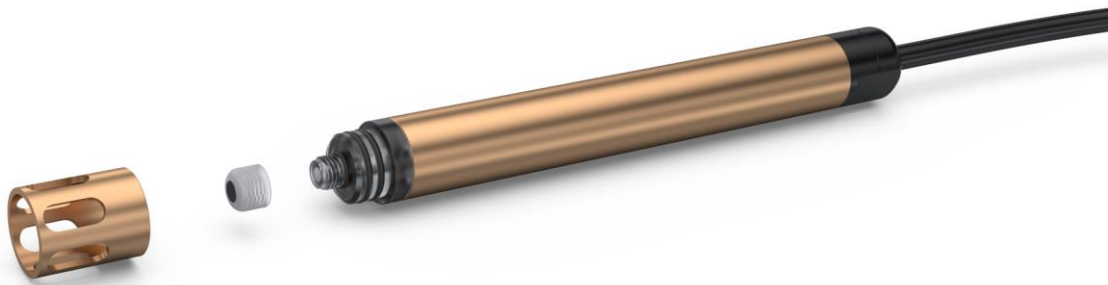

Figure 1: APHOX-S-O2, protective cap and oxygen screw cap before assembly

4.2 Calibration of Oxygen Sensors

The oxygen sensor can be calibrated with a 1-point or an optional 2-point calibration method. For the first calibration point, the sensor can be calibrated in air-saturated water or in air with 100% relative humidity (upper calibration). Optionally, the sensor can be calibrated in de-oxygenated water (0% calibration) to perform a 2-point calibration.

## 1-point calibration: Calibration in air saturated water

- For calibration in **air saturated water**, it is very important that the water is indeed 100% saturated with air. Fill an appropriate amount of water into a flask. Stream air through the water with an air stone connected to an air pump (available as commercial equipment for fish aquaria) for about 10 minutes. Alternatively, fill water into the flask leaving >50% air in the headspace, close it with a lid and shake the flask strongly for about 1 minute. Open the lid shortly for ventilating the headspace with fresh air. Close it again and shake the flask for 1 more minute

- Put the sensor in the liquid and enter all required parameters in the software or in the registers to perform a sensor calibration.

2-point calibration: Additional calibration in de-oxygenated water

- For **0% calibration**, use the 0% calibration capsules (item no.: **OXCAL**) from **PyroScience** according to the oxygen sensor manual. Please put the **APHOX-S-O2** in the solution and perform the 0% calibration by entering all required parameters in the software or writing the registers.

DO NOT use saline water (e.g. seawater) for this, but demineralized water. Saline water prevents proper dissolution of the reductant and can lead to false 0% sensor calibration.

5   MECHANICAL DIMENSIONS AND ELECTRICAL CONNECTOR
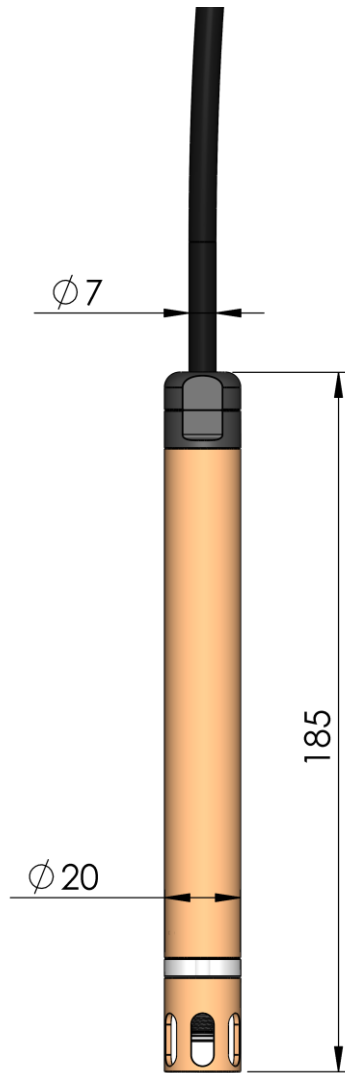
The wire assignment is as follows:

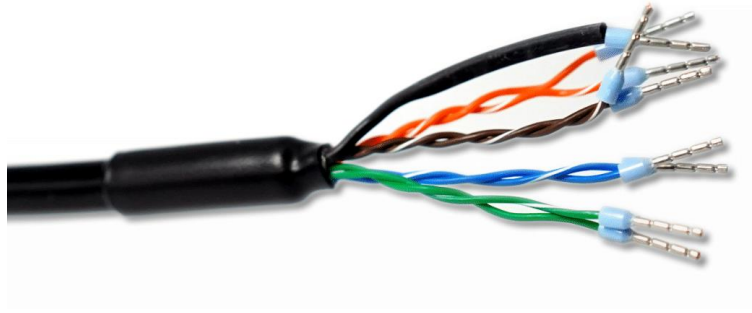| Name	Wire-color	Function
Shield	black	Cable shield
GND	blue	Ground
RS485A	orange	RS485 Data A
RS485B	orange/white	RS485 Data B
Vcc	Blue/white	Supply voltage
U1	brown	Analog voltage out 1 (0-5V)
U2	Brown/white	Analog voltage out 2 (0-5V)
I1	green	Analog current out 1 (4-20mA)
I2	Green/white	Analog current out 2 (4-20mA)

Figure 2: Wires at the end of the APHOX-S-O2 connection cable.

6   WARNINGS & SAFETY GUIDELINES

In case of problems or damage, disconnect the device and mark it to prevent any further use. Consult PyroScience **for advice! There are no serviceable parts inside the device. Please note that opening the housing will void the warranty.**

Follow appropriate laws and guidelines for safety in the laboratory, like EEC directives for protective labor legislation, national protective labor legislation, safety regulations for accident prevention and safety data-sheets from manufacturers of chemicals used during the measurements and of PyroScience buffer capsules.

Handle the sensors with care especially after removal of the protective cap! Prevent mechanical stress to the fragile sensing tip! Avoid strong bending of the fiber cable! Prevent injuries with needle-type sensors!

The sensors are not intended for medical or military purposes or any other safety-critical applications. They must not be used for applications in humans; not for in vivo examination on humans, not for human-diagnostic or any therapeutic purposes. The sensors must not be brought in direct contact with foods intended for consumption by humans.

The device and the sensors must be used by qualified personnel only, following the user instructions and the safety guidelines of the manual.

Handle the device with extreme care if there is any suspicion that it was flooded during deployment. Internal pressure might have built up as a consequence. Point the sensor side of the device away from people and material assets at all times, and carefully loosen the Subcon connector to relieve potential internal pressure before sending the instrument to PyroScience for service.

Keep the sensors and the device out of reach of children!

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