# OXYnor Series

SENSOR PROBES

## Instruction Manual

# OXYnorSeries

Specification:

## Electro-optical Module for Oxygen Measurements

Document filename: IM_OXYnor_dv6



Specifications may change without prior notice.

# Table of Contents

# List of Tables

# 1 Preface

You have chosen a new, innovative technology for measuring oxygen.

The OXYnor is a precise solution for oxygen measurements. The electro-optical module works with a chemical optical oxygen sensor.

OXYnor has several important features:

- It needs no polarization time.
- It is waterproof and can be submerged in water.
- It is integrated in a compact 12 mm stainless steel tube
- It is available with both, digital output (RS485 or RS232) and analog output (4 – 20 mA).

Therefore, the OXYnor is ideally suited for e. g. aquaculture, measurements in sewage, or environmental applications.

Please feel free to contact our service team to find the best solution for your application.

Your SENTEC Team

**PLEASE READ THE FOLLOWING INSTRUCTIONS CAREFULLY BEFORE WORKING WITH THIS DEVICE. WHEN DISREGARDING THESE INSTRUCTIONS THE SAFETY OF THE DEVICE CAN BE IMPAIRED.**

# 2 Safety Notes

! It is the customer's responsibility to validate the sensor and transmitter under end-user conditions according to safety precautions of the application to ensure that the use of the sensor is safe and suitable for the intended purpose.

SENTEC is explicitly not liable for direct or indirect losses caused by the application of these measurement systems. In particular it has to be considered that malfunctions can occur due to the naturally limited lifetime of the sensor depending on the respective application. The set-up of backup measurement stations is recommended when using the sensors in critical applications to avoid consequential losses. It is the customer's responsibility to install a suitable safety system in the event of sensor failure.

! Please note that the internal memory (flash) has a maximum of 10.000 write cycles. The device saves most settings to flash storage. Therefore, change settings only when necessary, otherwise the device will sustain permanent damage.

! Please note that after all write commands the device has to stay powered on for at least 150 or 200 ms (depending on the used protocol). Otherwise permanent data loss will occur.

! OXYnor does not conform to ATEX directives. Please do not use the device in ATEX environments.

! Make sure that the seals of the OXY nor are not in any way damaged. Do not use an OXYnor with damaged seals as this might damage the device.

! Make sure that the Optical Exchange Cap (OEC) is screwed tightly to the probe body and did not work loose while handling the probe.

! The temperature sensor is only to be used for temperature compensation of the OXYnor measurements and must not be used for controlling other processes.

# 3 Description of the OXYnor

The OXYnor is connected directly to a control unit. It combines an optical sensor and electro-optical module in one probe. OXYnor is integrated in a stainless steel housing with 12 mm diameter. Temperature compensation of oxygen measurements is realized with an integrated temperature sensor. As a digital interface it uses RS232 (SENTEC proprietary) or RS485 (SENTEC proprietary or Modbus RTU). It is also available with 4 – 20 mA analog output. A serial communication protocol is offered for data exchange between OXYnor and a PC or another host unit. For initial operation and adjustment of the 4 – 20 mA output the SENTEC STS software can be used. Its small outer dimensions (diameter: 12 mm, lengths from 81.4 mm to 135 mm) and low power consumption enable simple integration into custom monitoring and control systems. It is available with different cable lengths (standard length is 5 m).

The OXYnor WR is designed for wide range oxygen measurements with sensor type PSt3. The removable sensor cap (Optical Exchange Cap OEC) can easily be exchanged. It is waterproof and can be immersed completely into liquid, therefore, it is ideally suited for aquaculture, measurements in sewage, or environmental applications.

**Fig. 1** OXYnorWR-RS485 (left) and OXYnorWR-RS485M-2CS (right) with standard cable length of 5 m

**OXYnor features:**

- Maximum measurement range of 0 – 100 % $O_2$ (optimal 0 – 50 % $O_2$), detection limit of 0.03 % $O_2$ / 20 ppb.
- No polarization time
- Simple integration
- Communication via RS232 (SENTEC proprietary = human readable), via RS485 in two different protocols (SENTEC proprietary = human readable, or Modbus RTU), or via
  **4** – 20 mA output
- Integrated temperature sensor for temperature compensation
- Low power consumption
- Waterproof
- Configurable Baud rate (Modbus)

## 3.1 Scope of Delivery

The scope of supply will be customized according to your wishes. If you are using one of our optical oxygen probes for the first time, this is the equipment delivered:

- 1 x OXYnor (probe body – see list below) with standard 5 m cable (other lengths on request)
- 1 x Optical Exchange Cap OEC (compatible with probe body – see list below)
- 1 x EOM Starter Software (STS)

**Tab. 1** List of OXYnoroptions

<table>
<tr><th>PROBE BODY</th><th>PROBE LENGTH</th><th>COMPATIBLE OECs</th></tr>
<tr><td>OXYnorWR-RS232-Lx<br>(wide range, SENTEC proprietary)</td><td>81.4 mm</td><td rowspan="5">OEC-PSt3-NAU-YOP<br>OEC-PSt3-NAU-CAF<br>OEC-PSt3-NAU-PTFE<br>OEC-PSt3-NAU-OIW<br>OEC30-PSt3-NAU-YOP<br>OEC30-PSt3-NAU-CAF<br>OEC30-PSt3-NAU-PTFE<br>OEC30-PSt3-NAU-OIW</td></tr>
<tr><td>OXYnorWR-RS485-Lx<br>(wide range, SENTEC proprietary)</td><td>106 mm</td></tr>
<tr><td>OXYnorWR-RS485M-Lx<br>(wide range, Modbus RTU)</td><td>106 mm</td></tr>
<tr><td>OXYnorWR-RS485M-Lx-2CS<br>(wide range, Modbus RTU, current source 4 – 20 mA output for oxygen and temperature)</td><td>106 mm</td></tr>
<tr><td>OXYnorWR-RS485-4-20mA-Lx<br>(wide range, SENTEC proprietary, 4 – 20 mA)</td><td>135 mm</td></tr>
</table>

**Optional equipment (not supplied):**

- Connection adapter:
  - Adapter OXYnorRS232 v1 Set for OXYnorWR-RS232-Lx
  - Adapter CB-PGx-RS485-v1 Set for OXYnorWR-RS485-Lx / WR-RS485M- Lx / WR-RS485-4-20mA-Lx
  - Adapter CB-2CS-v1

**Additionally required equipment (not supplied):**

- PC / Notebook / Host Unit
- Optical Exchange Cap OEC (-PSt3) for replacement of a used sensor coating
- O-ring for OXYnor; the seal should be changed once year

## 3.2 Unit Definitions

The OXYnorconsists of a probe body and an OEC (optical exchange cap) with PSt3 oxygen sensor.

The electronic and optical components (LEDs, photodiodes and optical filters) are integrated in a stainless steel tube (diameter: 12 mm, length: 81.4 - 135 mm).

The oxygen sensor in the OEC connected to the probe body receives light impulses from the signal LED. The sensor response is then optically filtered, detected and forwarded to the electronic board for further processing. The oxygen exchange cap can be replaced if needed.

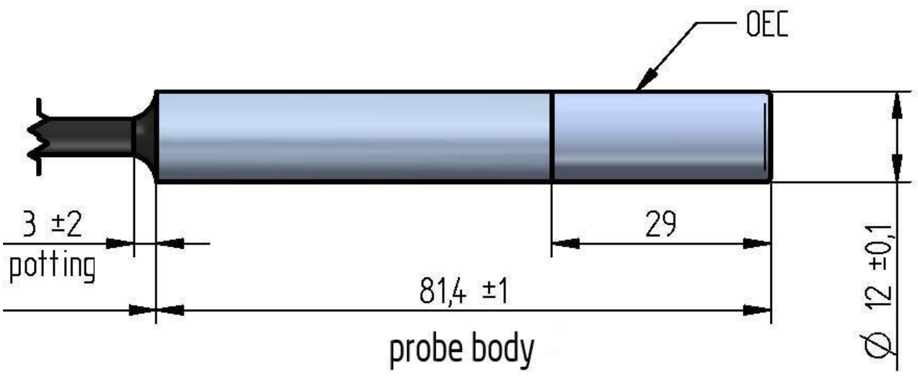



**Fig. 2** OXYnor WR-RS232-Lx (dimensions in mm)

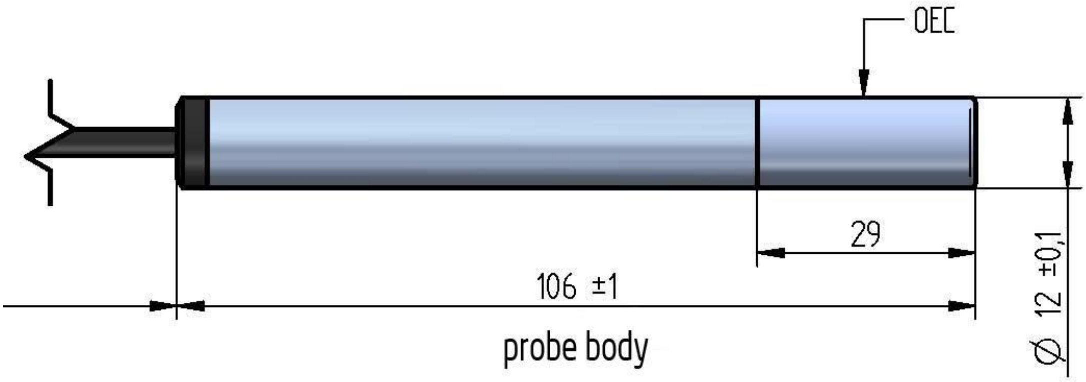



**Fig. 3** OXYnor WR-RS485-Lx / WR-RS485M-Lx / WR-RS485M-Lx-2CS (dimensions in mm)

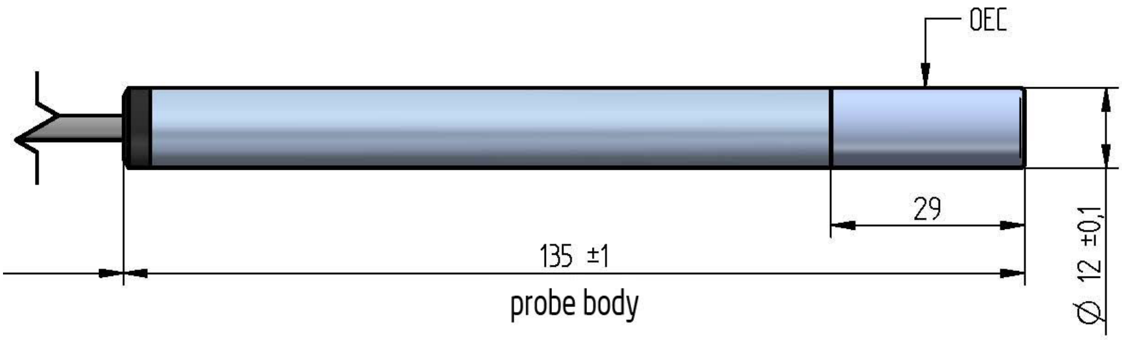



**Fig. 4** OXYnor WR-RS4854-20mA-Lx (dimensions in mm)

## 3.3 Optical Exchange Caps OECs

The probe body of an OXYnor WR can be combined with an OEC of compatible sensor type (WR = PSt3).These OECs are available in two designs and different variations (see table below).

The OEC30 with a tapered tip reduces air bubble formation on the sensor.

**!** Please note, that the OEC30 will add about 7 mm to the probe length. Keep this in mind when installing a probe with OEC30.

**Fig. 5** OEC for OXYnor

OEC30 (tapered tip) for OXYnor

**Tab. 2** List of OEC variants

| VARIATION | OEC | OEC30 |
|---|---|---|
| USP Class VI compatible | OEC-PSt3-NAU-YOP | OEC30-PSt3-NAU-YOP |
| Safe for Food Applications | OEC-PSt3-NAU-CAF | OEC30-PSt3-NAU-CAF |
| Hydrophobic Teflon overcoat | OEC-PSt3-NAU-PTFE | OEC30-PSt3-NAU-PTFE |
| Fast response time | OEC-PSt3-NAU-OIW | OEC30-PSt3-NAU-OIW |

In case you would like to try another OEC with your OXYnor and are not sure which one would suit your application best, please contact our service team at info@SENTEC.no.

## 3.4 Exchange of a Used OEC

When replacing an OEC please make sure to screw the new cap tightly to the probe body, so the black O-ring is no longer visible. If the OEC is not screwed on tightly the probe body might get damaged by entering liquid.

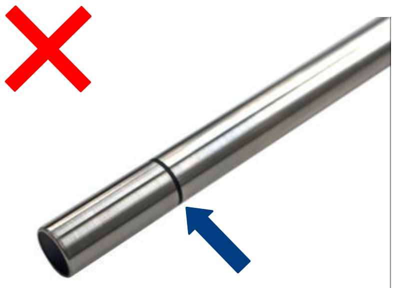
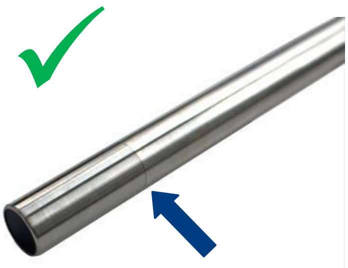


**Fig. 6** OEC attached too loosely



OEC properly attached

## 3.5 OXYnor-FTM (Metal Flow-through Cell)

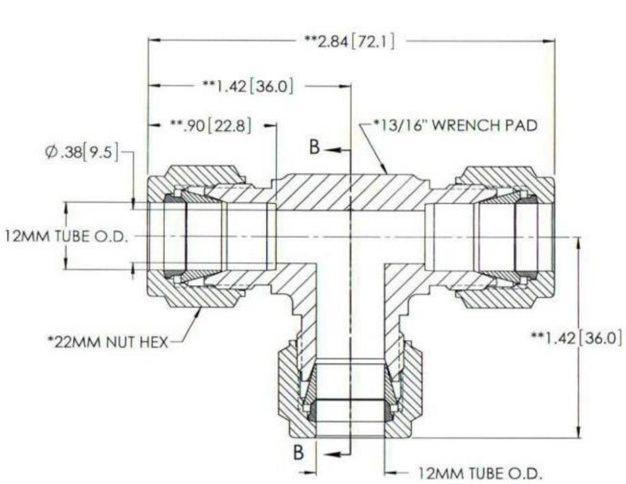



**Fig. 7** Schematic illustration of the OXYnor-FTM dimension in mm

OXYnormounted to the FTM all

The OXYnor can be mounted to a metal flow-through cell and integrated into steel tubes for perfusion monitoring of gasses and liquids.
(We also recommend to use the OXYnor-FTM as calibration chamber when calibrating the OXYnor with dry / humid gases.)

**Tab. 3** OXYnor-FTM specifications

| Specifications | |
|---|---|
| Material | Stainless steel SUS 316 L |
| Temperature range operation | -10 °C to + 50 °C |
| Max. pressure | 2 bar |

# 4 Pinning & Electrical Connections

Please note for all described device types:

! The supply voltage should not be exceeded as this will damage the device.

! In case you are not using the line adapter delivered by SENTEC the use of a power supply unit with limited power source is mandatory.

## 4.1 Pinning OXYnorWR-RS232

! The supply voltage must be within 5 V ± 0.5 V (Absolut Max Ratings).

**Tab. 4** OXYnorWR-RS232 pinning

| PIN CABLE COLOR | FUNCTION |
|---|---|
| brown | + 5 V |
| green | RxD |
| yellow | TxD |
| white | GND |
| transparent | cable shield / probe body |

## 4.2 Pining OXYnor WR-RS485(Modbus)

**!** Power supply of 5 – 30 VDC (Absolut Max Ratings). Ensure that the power supply is not < 5 VDC.

**Tab. 5** OXYnorWR-RS485(Modbus) pinning

| PIN CABLE COLOR | FUNCTION |
|---|---|
| yellow | RS485 B |
| green | RS485 A |
| white | GND |
| brown | 5 – 30 VDC |
| transparent | cable shield / probe body |

## 4.3 Pining OXYnor WR-RS485-4-20mA

**!** Power supply of 7 – 30 VDC (Absolut Max Ratings). Ensure that the power supply is not < 7 VDC.

**Tab. 6** OXYnorWR-RS485-4-20mA pinning

| PIN CABLE COLOR | FUNCTION |
|---|---|
| yellow | RS485 B |
| green | RS485 A |
| white | GND |
| brown | 7 – 30 VDC |
| grey | 4 … 20 mA (current sink) |
| transparent | cable shield |

## 4.4 Pining OXYnor WR-RS485M-4-20MA+TEMP

! Power supply of 6 – 30 VDC (Absolut Max Ratings). Ensure that the power supply is not < 6 VDC.

**Tab. 7** OXYnorWR-RS485M-4-20MA+TEMP pining

| PIN CABLE COLOR | FUNCTION |
|---|---|
| yellow | RS485 B |
| green | RS485 A |
| white | GND |
| brown | 6 – 30 VDC |
| grey | GNDA* |
| pink | 4 … 20 mA (current source) Iout1* (default: oxygen) |
| blue | GNDA* |
| red | 4 … 20 mA (current source) Iout2* (default: temperature) |
| transparent | cable shield / probe body |

*galvanic isolated

## 4.5 Grounding / Potential Equalization

! The OXYnor's device housing is made of stainless steel with high corrosion resistance (SUS 316 L). However, **electric potential differences** between the OXYnor and a tank or other peripherals in the tank can **cause immediate corrosion** through electrolysis. Therefore, please ensure to avoid electric potential differences between OXYnor and the surrounding environment.

! We recommend ALWAYS to connect the OXYnor to the protective ground at the installation site. Assign the device housing and cable shield to protective ground.

Especially the length of the cable can influence the ground connection quality.

If the OXYnor is installed in a fitting, which is connected to the protective ground, then the connection to the ground will be established via the OXYnor housing.

If the OXYnor is installed in a fitting, which is NOT connected to the protective ground (e.g. fitting made of plastic or glass), a ground connection should be attached to the OXYnorhousing.

## 4.6 Digital Connection to Desktop PC or Controller

### 4.6.1 OXYnor WR-RS232

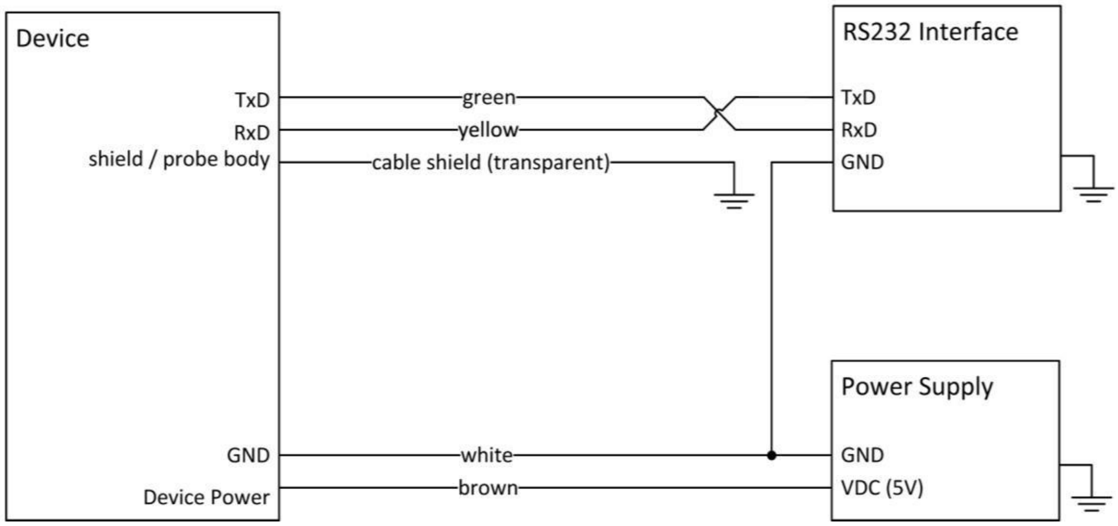



**Fig. 8** Schematic illustration of OXYnorWR-RS232 digital connection to PC or controller

### 4.6.2 OXYnor WR-RS485(Modbus) & WR-RS485-4-20mA & WR-RS485M-2CS

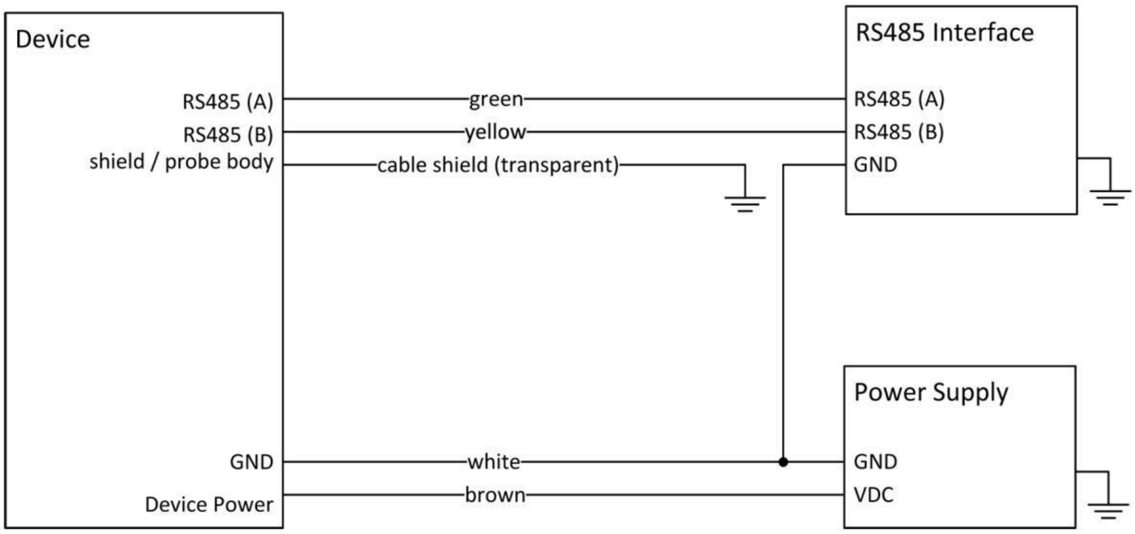



**Fig. 9** Schematic illustration of OXYnorWR-RS485(Modbus) & WR-RS485-4-20mA digital connection to PC or controller

## 4.7 Digital Connection to Laptop

In order to avoid high noise ratio in the oxygen measurements when an OXYnor is connected to a laptop, the device has to be rewired.

The stainless steel housing of the OXYnor is connected to the cable shielding, which has to be separated capacitively from the device electronics to avoid damage to the device when there is any kind of electrical discharge. This requires that the electrical potential of the device and any PC (or process controller) it is connected to is equal.

When connected to a laptop (with only decoupled DC supply or battery power) there is usually no protection conductor and therefore no equivalence between the potential of the device and laptop. A fluctuating potential can interfere with the oxygen measurements. To counter this problem the potential of the device (cable shielding) is left on the protective grounding and additionally connected to the power supply ground.

### 4.7.1 OXYnor WR-RS232

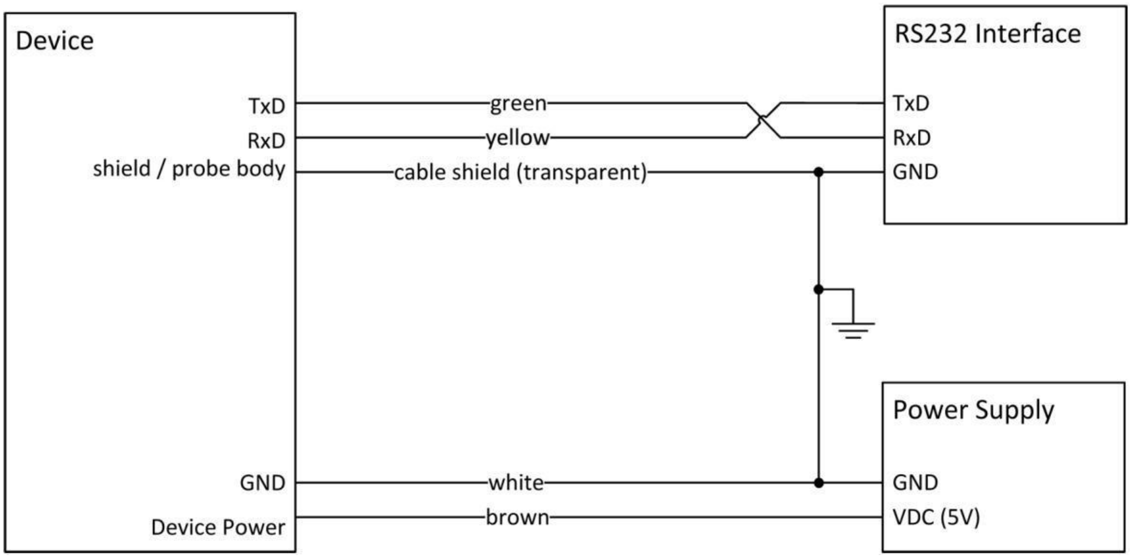



**Fig. 10** Schematic illustration of OXYnorWR-RS232 digital connection to laptop

### 4.7.2 OXYnor WR-RS485(Modbus) & WR-RS485-4-20mA & WR-RS485M-2CS

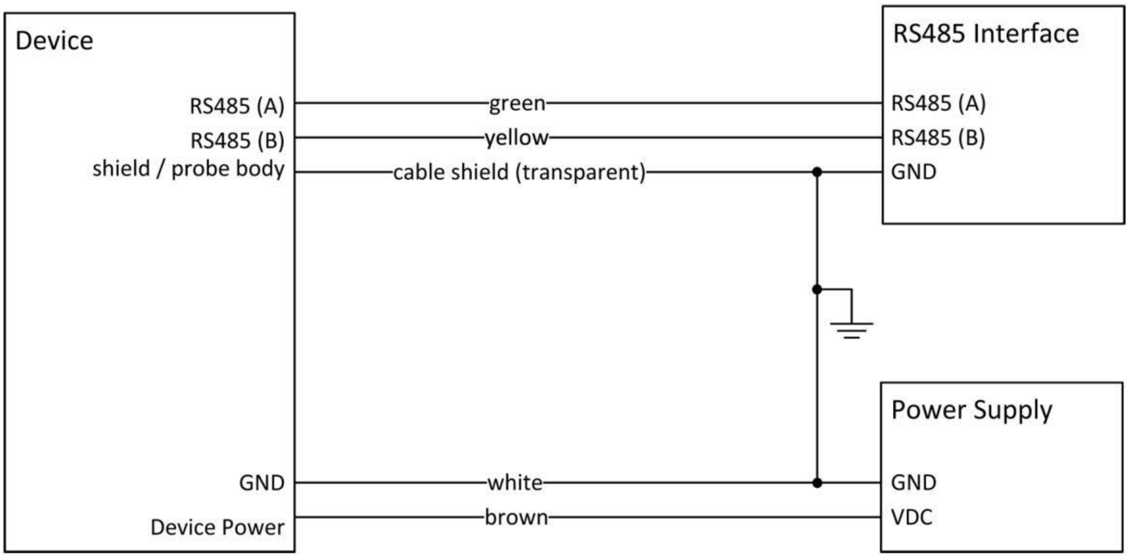



**Fig. 11** Schematic illustration of OXYnorWR-RS485(Modbus) & WR-RS485-4-20mA digital connection to laptop

## 4.8 Analog Connection (OXYnor WR-RS485-4-20mA only)

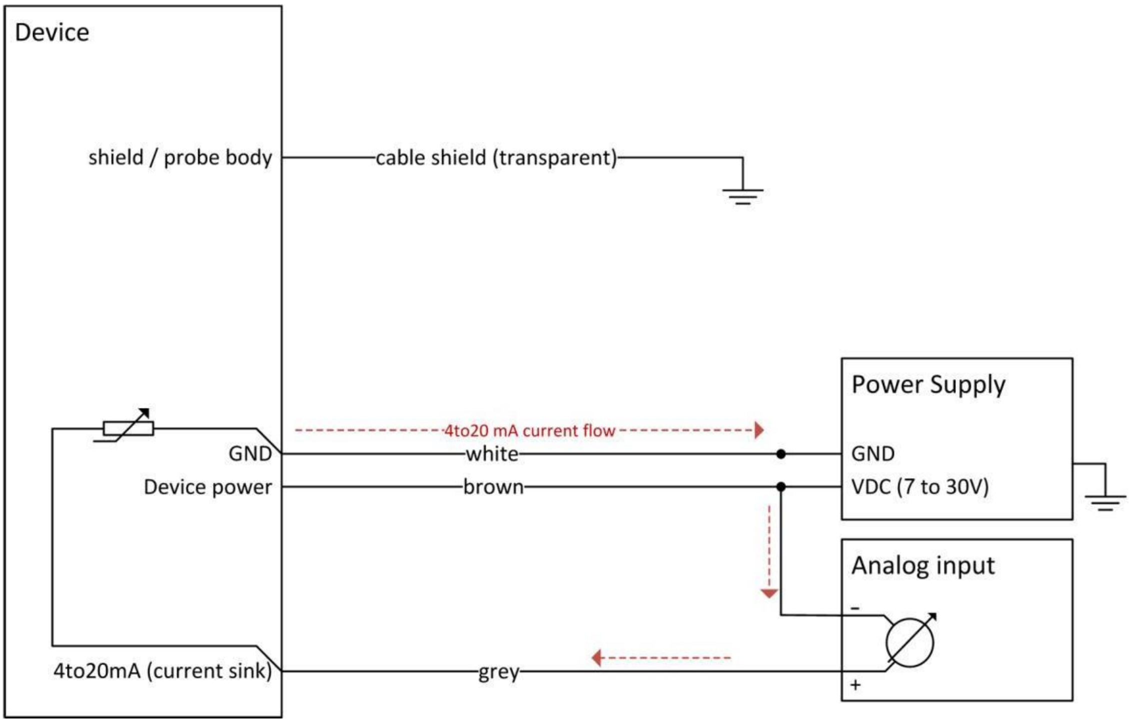



**Fig. 12** Schematic illustration of OXYnorWR-RS485-4-20mA analog connection

## 4.9 Analog & Digital Connection

### 4.9.1 OXYnor WR-RS485-4-20mA

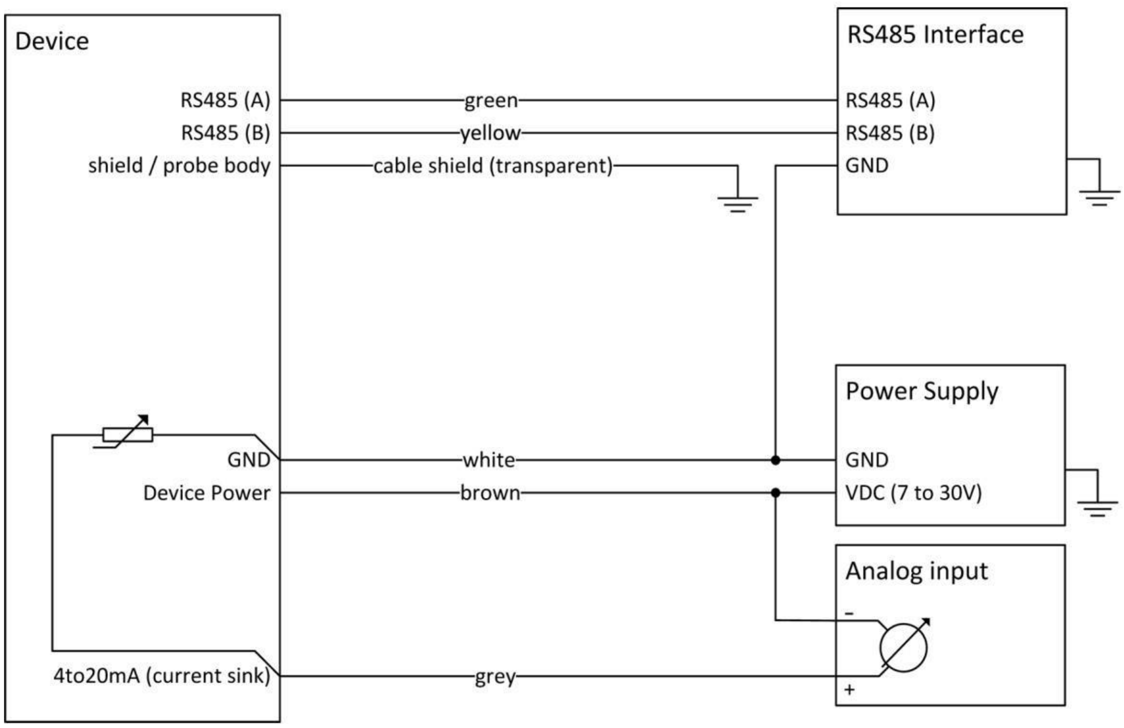



**Fig. 13** Schematic illustration of OXYnorWR-RS485-4-20mA analog and digital connection

### 4.9.2 OXYnorWR-RS485M-2CS

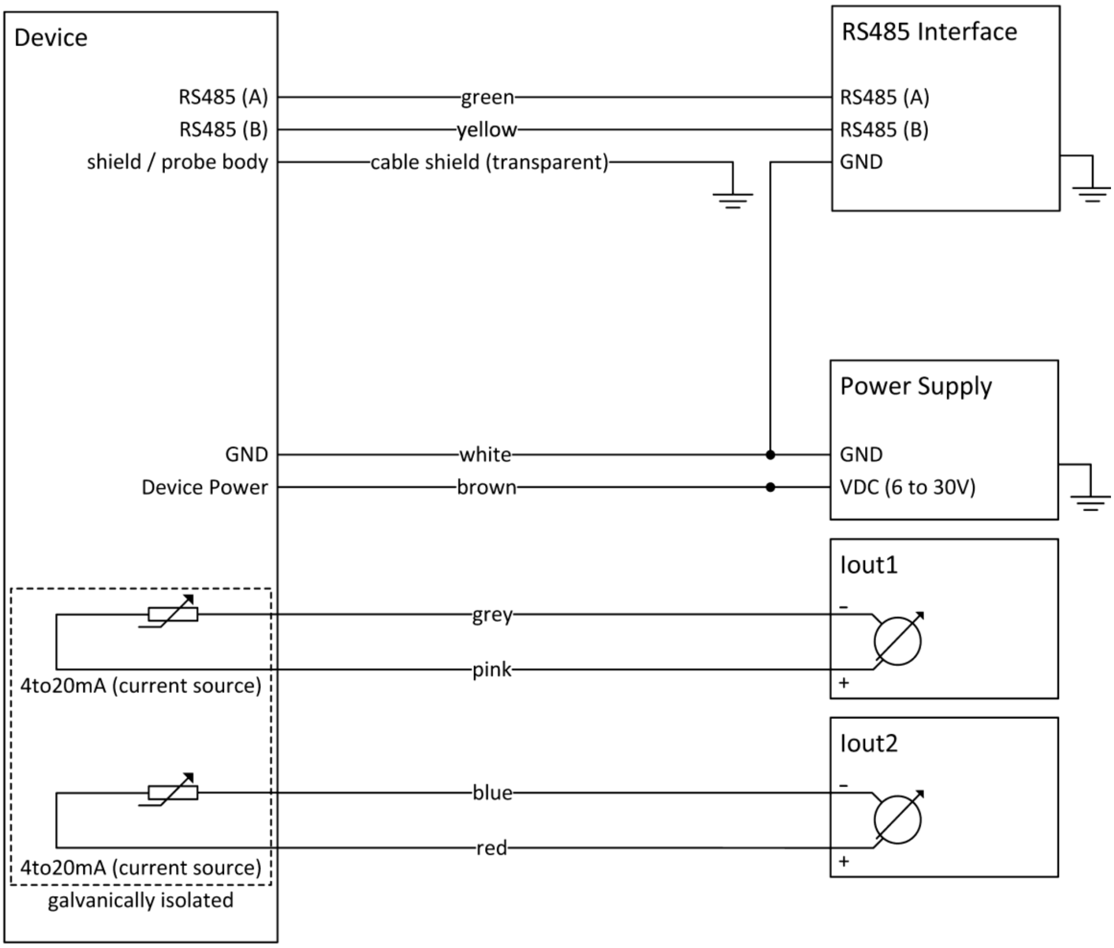



**Fig. 14** Schematic illustration of OXYnorWR-RS485M-2CS analog and digital connection

## 4.10 Daisy Chain (OXYnorWR-RS485(Modbus) & WR-RS485- 4-20mA & WR-RS485M-2CS)

To prevent reflections and therefore errors in digital communication in an RS485 daisy chain set-up we recommend to install a suitable termination. The need of these termination resistors depends on the position of the master interface, the distance between interfaces, and overall cable length. Typically, one termination resistor at the beginning and one the end of the daisy chain is used with R = 100 to 120 Ohm.

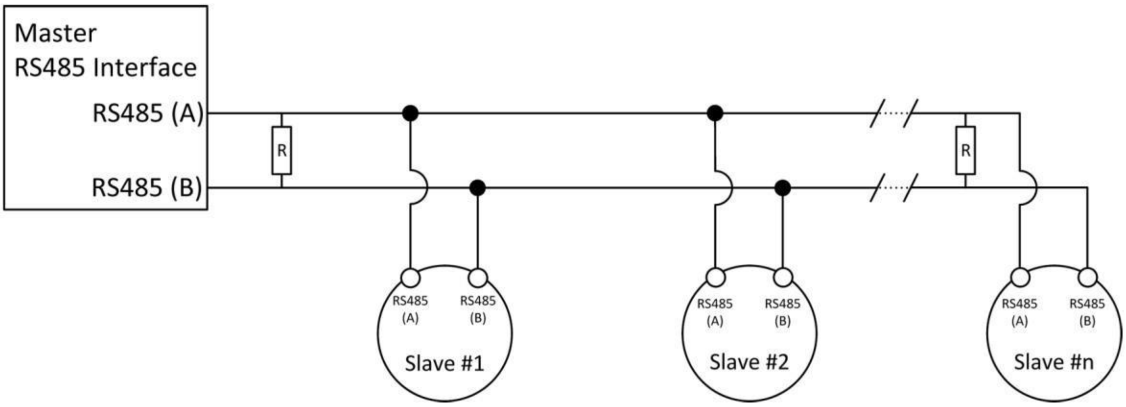



**Fig. 15** Schematic illustration of a daisy chain set-up: termination resistors are installed at the beginning and the end of the daisy chain.

# 5 Quick Start with Connection Adapter

The connection adapters (Adapter OXYnorRS232 v1 Set, Adapter OXYnorRS485 v1 Set, CB-PGx-RS485-v1 and CB-2CS-v1) allow easy connection of the OXYnor. This chapter describes how the adapters are used. Different power and communication options allow an individual set-up. Furthermore, SENTEC offers many accessories and supports you with individual solutions for a successful start with the OXYnor.
In case you have any questions, please contact our service team at info@sentec.no

## 5.1 Scope of Delivery

The Adapter OXYnorRS232 v1 Set is delivered with

- Terminal block
- USB-to-RS232 converter cable (USB-RS232-RJ4-4)

The Adapter CB-PGx-RS485-v1 and CB-2CS-v1 are delivered together with

- Terminal block (female terminal block permanently attached)
- USB-to-RS485 converter cable (USB-RS485-RJ4-4)
- Power supply (PAC-EU/US-L1.8-RJ11)


**Fig. 16** USB-to-RS485 converter cable


**Fig. 17** Power adapter PAC (PAC-EU/US-L1.8-RJ11)

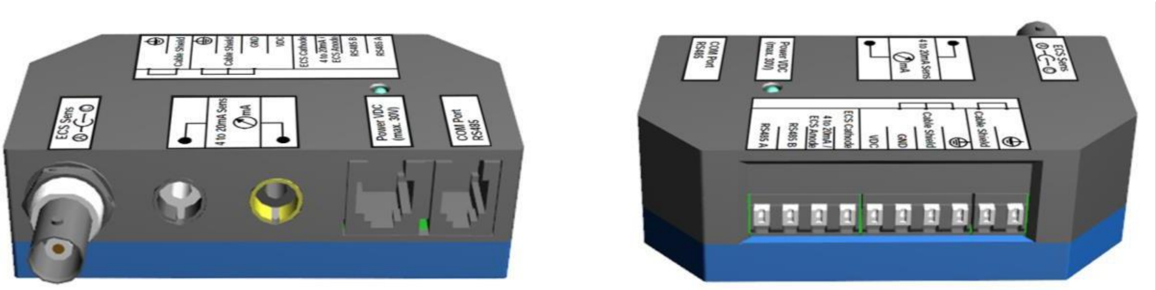


**Fig. 18** Adapter CB-PGx-RS485-v2

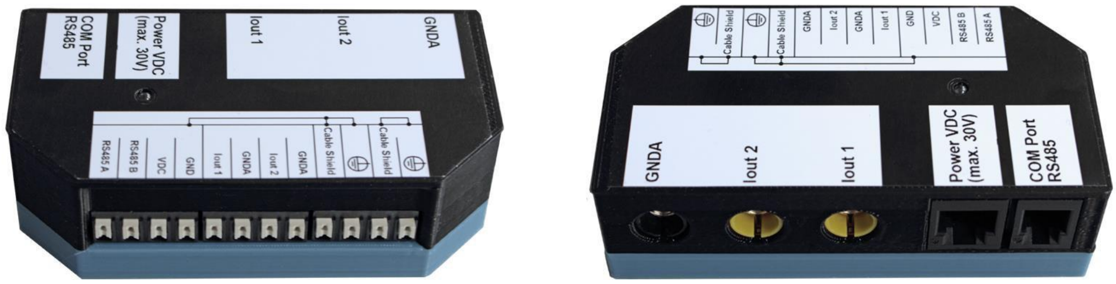



**Fig. 19** Adapter CB-2CS-v1

## 5.2 Start-Up of the OXYnor with the Connection Adapter

1. Connect the OXYnor cable with the open ends according to the Pin description (chapter 4) to the terminal block. (See also Fig. 20, Fig. 21, and Fig. 22.)
2. Connect the USB cable and plug it into a PC or other host unit.
3. Connect the power adapter and plug it to the power grid.

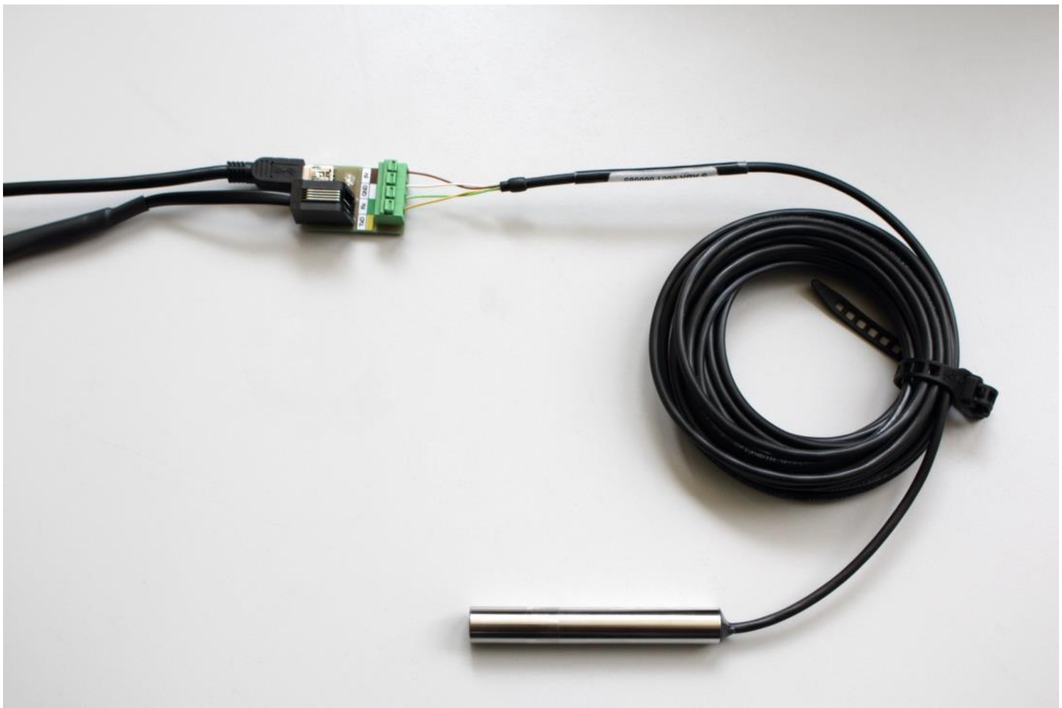


**Fig. 20** OXYnorWR-RS232 cable connected to the terminal block of the Adapter OXYnorRS232 v1

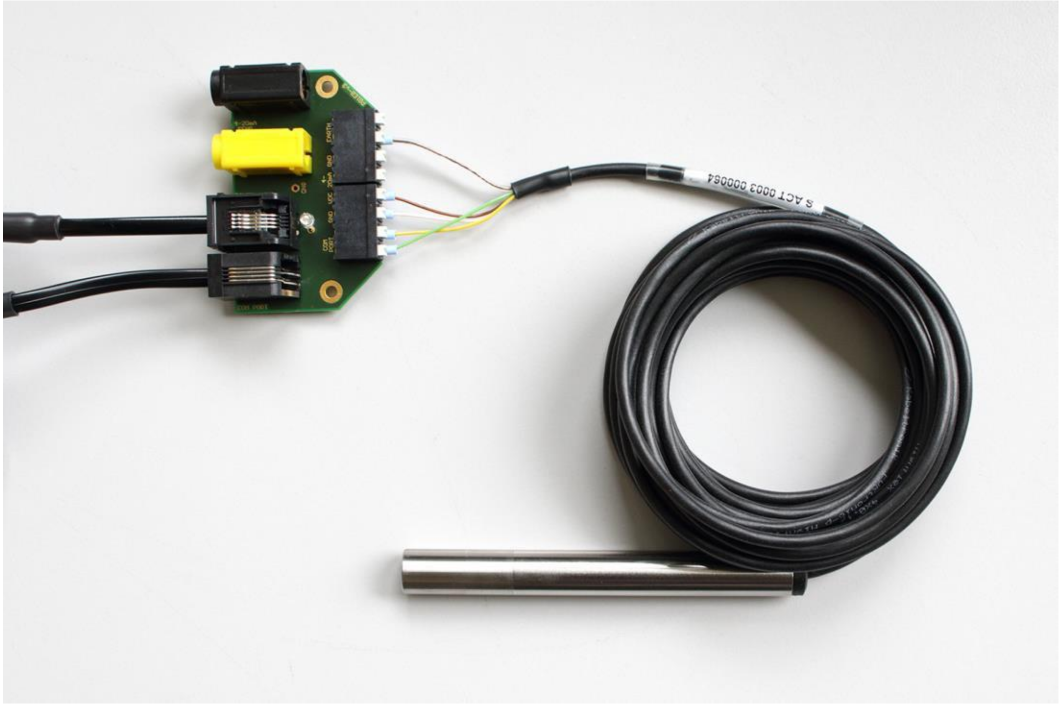


**Fig. 21** OXYnorWR-RS485 cable connected to the terminal block of the CB-PGx-RS485-v1

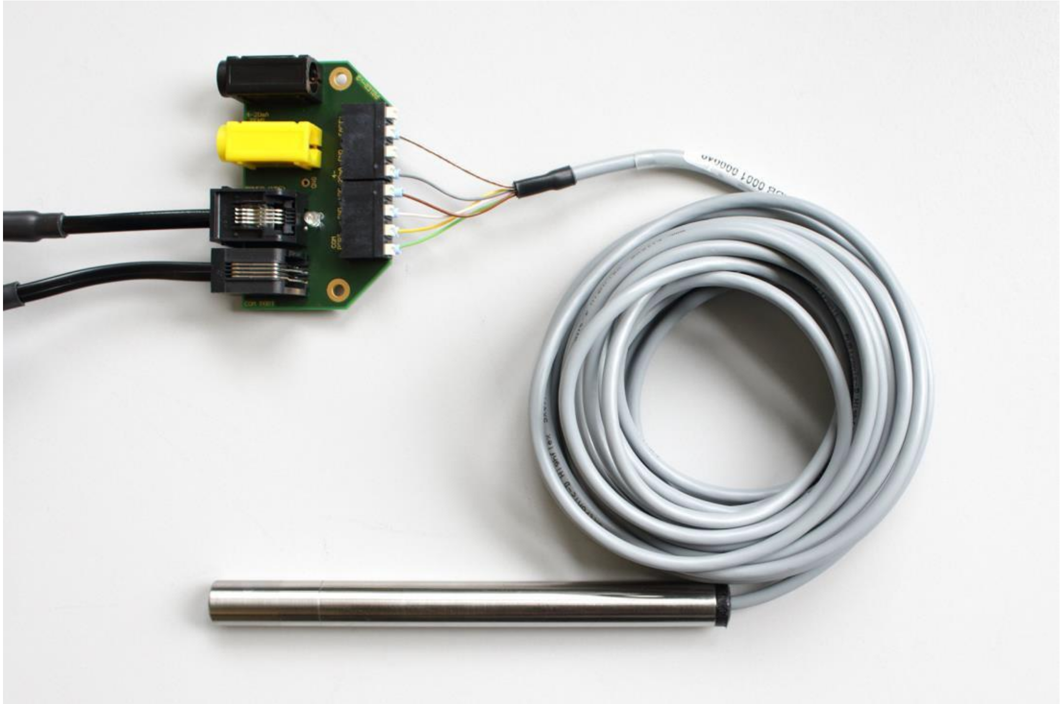


**Fig. 22** OXYnorWR-RS485-4-20mA cable connected to the terminal block of the CB-PGx-RS485-v1

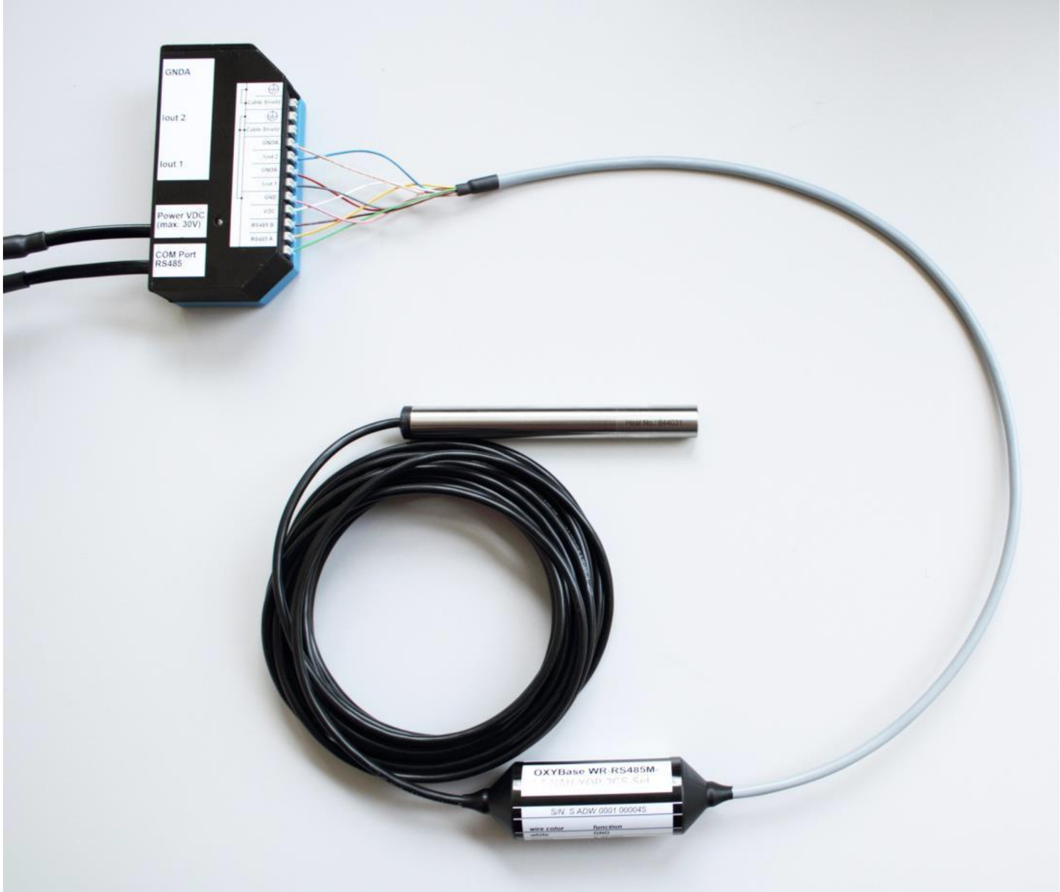



**Fig. 23** OXYnorWR-RS485M-4-20MA+TEMP cable connected to the CB-2CS-v1

Now you are able to communicate with the OXYnor

## 5.3 4 – 20 mA Sense Set-Up

The figure below shows how to connect a multimeter for 4 – 20 mA adjustment.

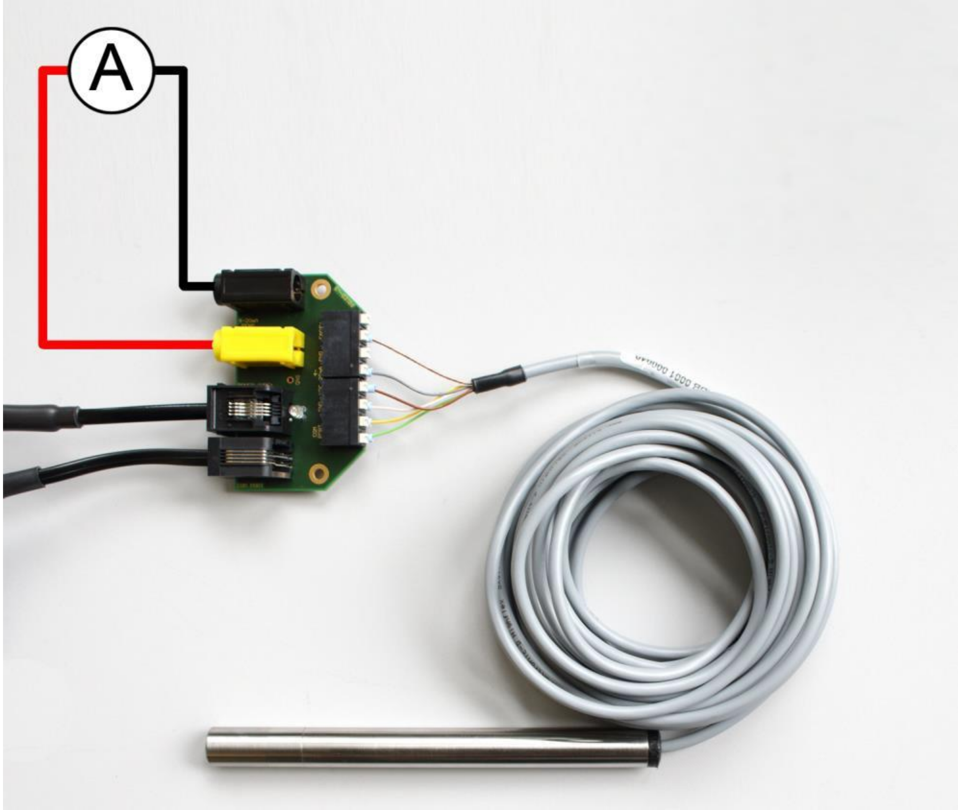



**Fig. 24** 4 – 20 mA Sense set-up for OXYnorWR-RS485-4-20mA

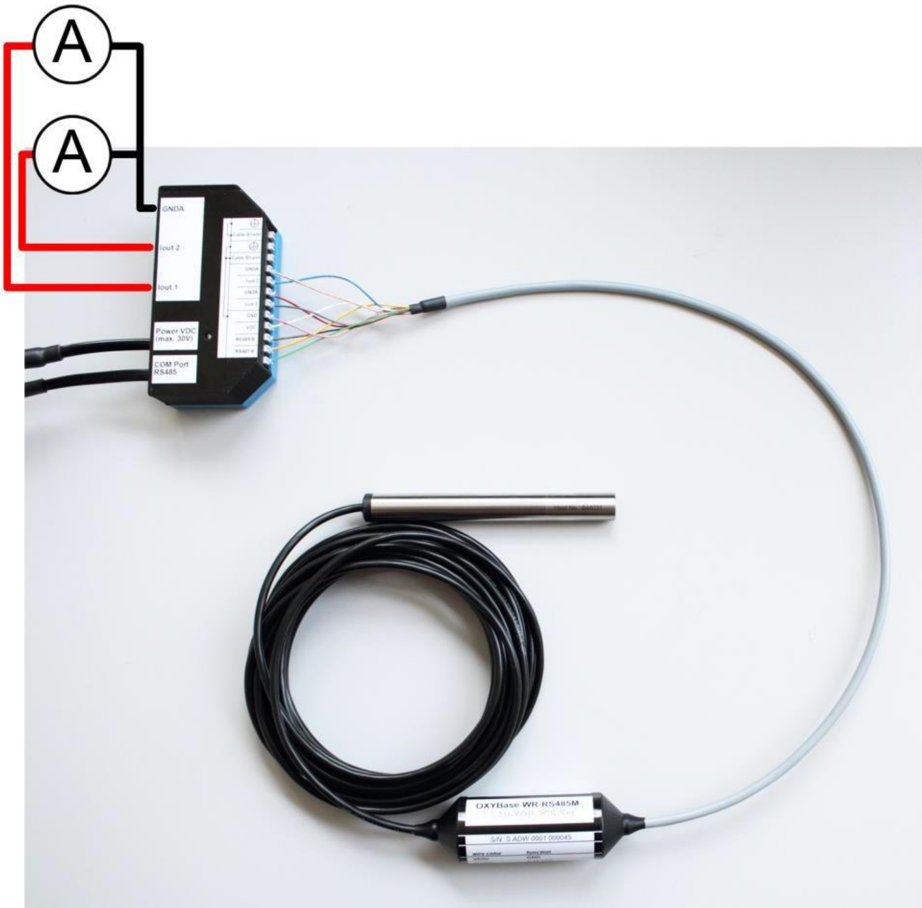



**Fig. 25** 4 – 20 mA Sense set-up for OXYnorWR-RS483-2CS

# 6 Connecting the OXYnor

## 6.1 Connection with STS Software

We recommend using the delivered STS software when connecting the OXYnor for the first time. Please refer to the STS software manual for detailed information.

1. Connect your OXYnor to the PC / notebook via the USB cable.
1. Please close all other applications as they may interfere with the software. Start the SENTEC STS software.
2. After successful initialization the **Devices** screen is displayed.

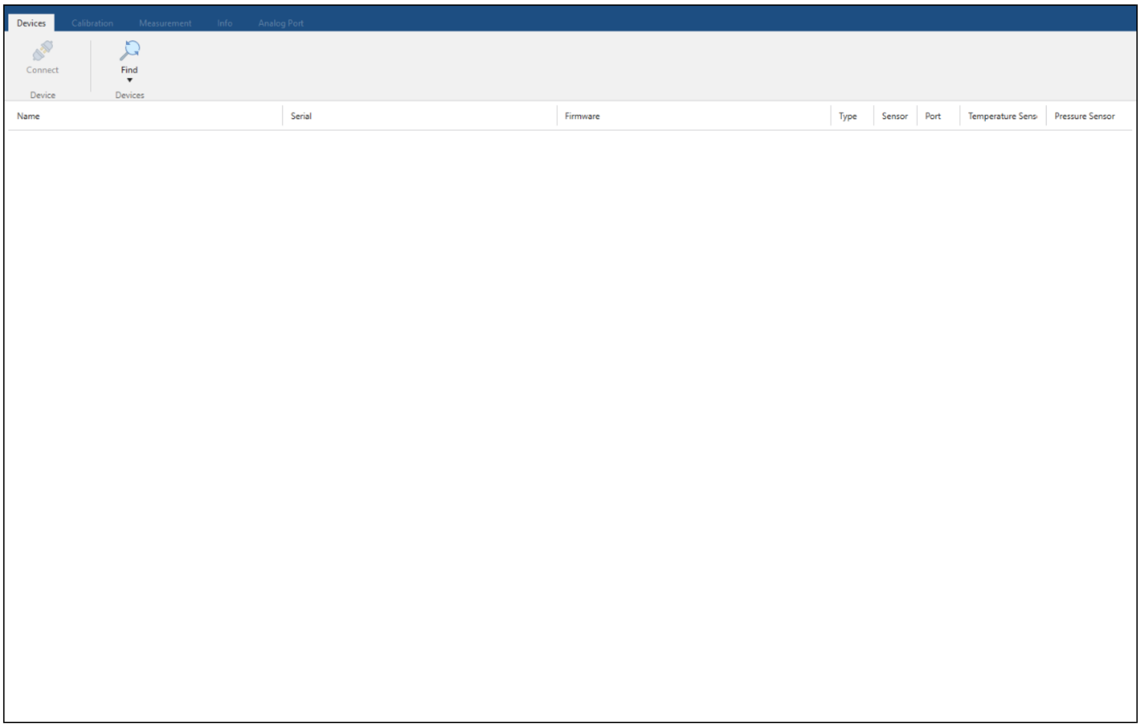



**Fig. 26** Initial screen: Devices

Use the **Find** button in the menu bar to initialize a software scan for all devices connected to the PC / notebook. Clicking on the  symbol will initiate a scan of all COM Ports for all device types.

**!** Scanning all COM Ports for all device types might take several minutes.

Click the arrow key below the  symbol and a drop-down menu will open where you can select COM Ports and device types you want to scan for by unchecking / checking the respective box. If you are not sure which COM Port your device is connected to, leave all COM Ports selected and click .

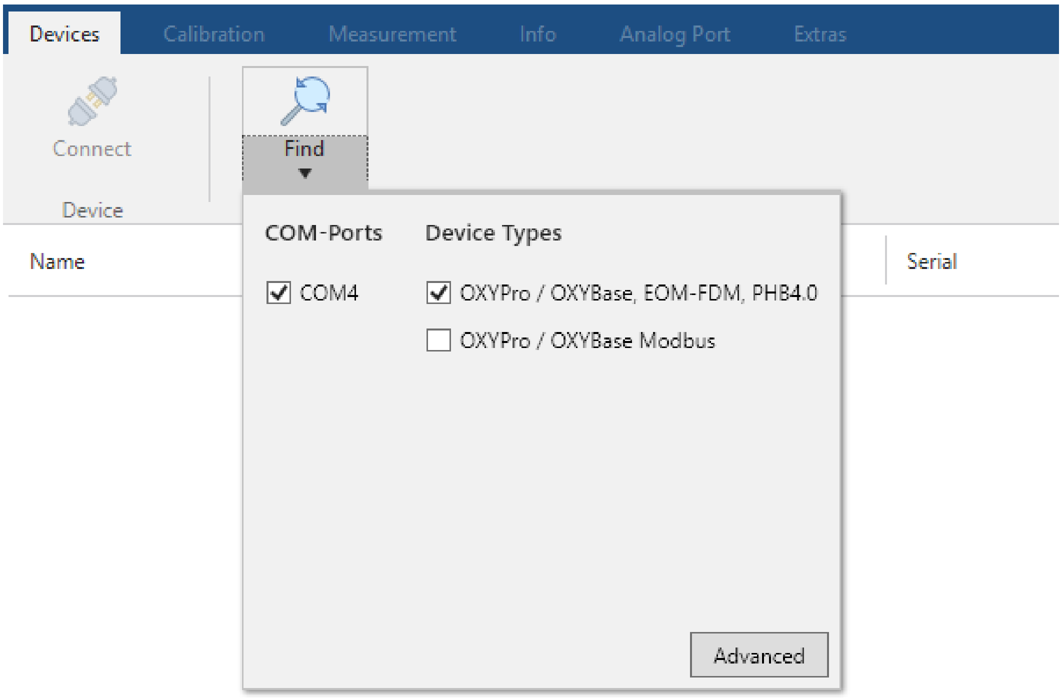



**Fig. 27** Select the COM Port and Device Type to speed up scanning for devices

After a successful scan the connected OXYnor will be displayed in a list on the main screen, along with its **Serial** number, **Firmware** version, the device **Type**, the connected **Sensor** type, the COM **Port** it is connected to, and whether there is a **Temperature** or **Pressure** sensor connected to it.

Click on the device name in the list so it is highlighted and press **Connect** in the menu bar. Wait while the software connects to the device and gathers device information. The display will automatically switch to the **Measurement** screen, when the device is ready for operation.

## 6.2 Connection with Terminal (SENTEC Proprietary Only)

The following chapter describe communication via HyperTerminal, alternatively other terminals like e. g. PuTTY can be used as well.

1. Open the HyperTerminal.
2. Enter a connection name and click **OK**.

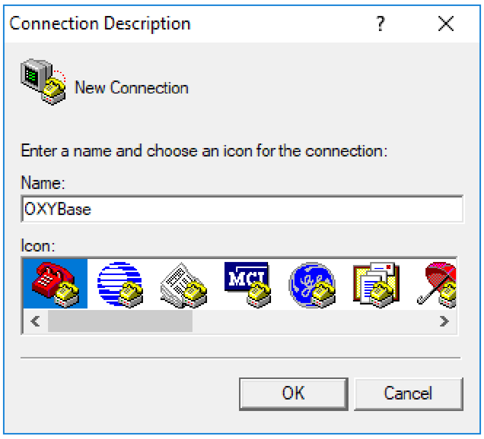



**Fig. 28** HyperTerminal – enter connection name

3. Select the correct COM Port and click **OK**. (If you are not sure about the COM Port number, open the **Device Manager** in the Control Panel of your PC / notebook. Look up the COM Port number of your device in the **Ports (COM & LPT)** directory.)

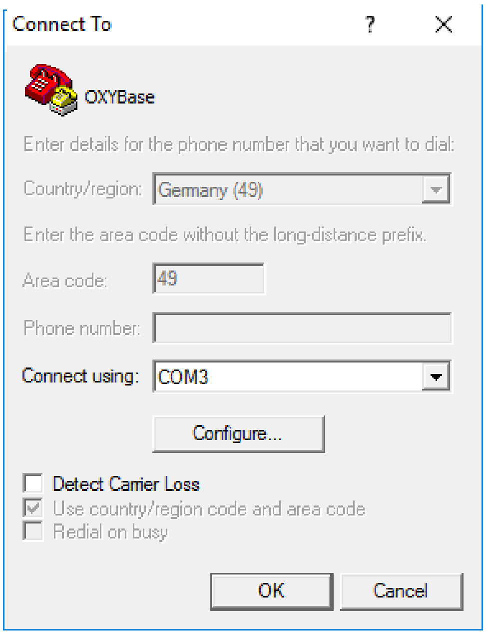



**Fig. 29** Select COM Port

4. The Port Properties window opens. Adjust the Port Settings as follows:

   **Bits per second** = 19200
   **Data bits** = 8
   **Parity** = None
   **Stop bits** = 1
   **Flow control** = None

   Confirm the settings by clicking **Apply** and then the **OK** button. Now you are ready to start communication with the OXYnor.

   Please note, that after a write process certain time consuming tasks are started, so a fixed timeslot of 200 ms after the transmitted response should be kept.

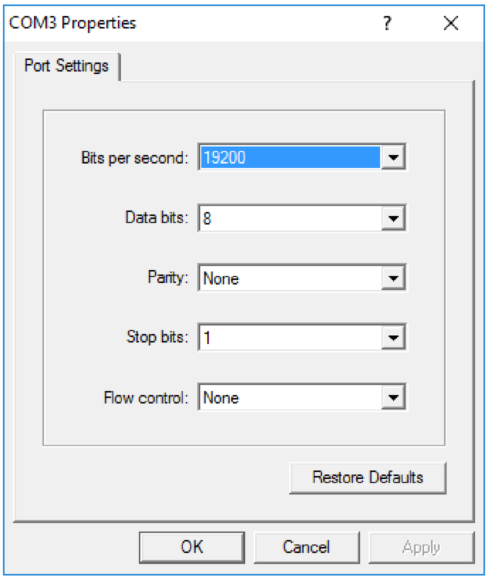


**Fig. 30** Port Settings

## 6.3 Connection with Modbus

The protocol is Modbus RTU conform according to Modbus Application Protocol V1.1b3.

It is a master-slave arrangement with the host controller acting as the master and each individual module as a slave.

Each module on the bus needs to have a unique device ID (see register 4095).

The default port settings are 19200 baud, 8 data bits, 2 stop bits, no parity (if you need other settings, please see register 4101 and 4107).

The device has no command buffer so the host must always wait until the command is processed.

- Read commands are fully processed after data transmission.

- After a write process certain time consuming tasks are started, so a fixed timeslot of 150 ms after the transmitted response should be kept.

RX Input Buffer is 256 bytes.

A CRC16 error checking method is implemented. Starting value is 0xFFF and polynomial type is 0xA001. For specification and further information see Ref. 1 in the Modbus RTU communication protocol.

**Data Formats**

- Float:
  Definition: Floating point according to IEEE 754 (Single Precision).

  This format requires two registers obtaining 32bit where each register contains the high byte in its first byte.

  Example: Float value of 0x12345678 (hexainteger) shall be written in two consecutive registers, where the first register is 3499. Therefore the value has to be transmitted in the following way:

  Register 3499, high byte 0x34
  Register 3499, low byte 0x12
  Register 3500, high byte 0x78
  Register 3500, low byte 0x56

- Integer:
  Definition: All integer values are 32bit wide and therefore also obtain 32bit. The example given above applies here as well.

- Character:
  Definition: 8bit ASCII Code table according to ISO-8859-1 (Latin-1 Western Europe)

  ! A register holds always exactly 2 characters. Unused bytes are filled with spaces (ASCII: 0x20).

- Boolean:
  Definition: Boolean registers are 16bit integer registers with only 0 and 1 as allowed values.

## 6.4 Multiplex

The following chapter describes how to set up the OXYnorin a bus environment via RS485.

To set up communication the following command codes are necessary:

2. Set the device number:
   All OXYnorare shipped with a default device ID of “0001”. Prior to entering multiplex bus mode, you must give each device a different device ID.

   **!** Make sure you can identify each device physically prior to entering multiplex bus mode. You can only communicate to a device with its correct device ID.

   Set the device ID: **idnoxxxx**
   Where: xxxx = “0001” … “0032”

3. Multiplexed bus mode:

   Set the multiplexed bus mode: **muxmxxx**
   Where: xxxx = “0000” (OFF) or “0001” (ON)

   Use this command to activate (0001) / deactivated (0000) the multiplexed bus mode. When setting it to ON, all following commands need to be sent with the correct device ID in every frame. The device will answer all queries with its device ID before the actual data.

   When setting OFF, all following commands need to be sent without a device ID.

   When the multiplexed bus mode is activated, the format string changes to the following format:

**Tab. 8** Format string in multiplexed bus mode

| Device ID (if multiplexed mode is ON) | Data | | Checksum (only if M2M is activated) | Delimiter |
|---|---|---|---|---|
| 2 Characters (00..32) | Command Code | Command dependent data | 2 bytes | CR |

Example (M2M Mode off):
Host: 01oxyu?<CR>
Target01: 010001<LF><CR>

Example (M2M Mode on):
Host: 01oxyu?[CS]<<CR>
Target01: 01ACK[CS]<LF><CR>
Target01: 010001[CS]<LF><CR>

**Example for a Multi-Device Environment:**

In this example we set up a connection with 6 devices without activation of M2M mode. Proceed in the following order:

**Tab. 9** Set-up of multi-device environment

| Step | Description | Host Command | Device Answer |
|---|---|---|---|
| 1 | Connect ONE device (this device will be called Target01 in this document) to the host. | | |
| 2 | Check connection with any command | idno?<CR> | 0001<LF><CR> |
| 3 | Assign device ID | idno0001<CR> | none |
| 4 | Check the device ID | idno?<CR> | 010001<LF><CR> |
| 5 | Activated multiplex bus mode | muxm0001<CR> | none |
| 6 | Check setup | 01idno?<CR> | 010001<LF><CR> |
| 8 | Connect ONE device (this will be called Target02 in this document) to the host. | | |
| 9 | Check connection with any command | idno?<CR> | 0001<LF><CR> |
| 10 | Assign device ID | idno0002<CR> | none |
| 11 | Check the device ID | idno?<CR> | 0002<LF><CR> |
| 12 | Activate multiplex bus mode | muxm001<CR> | none |
| 13 | Check setup | 02idno?<CR> | 020002<LF><CR> |
| 14 | Disconnect Target02 from the host | | |
| 15 …42 | Repeat steps 1 to 7 for the left 4 devices in the described manner, but increment the device ID with each step (idno0003, idno0004, idno0005, idno0006) | | |
| 43 | Connect all devices to the bus. You are now ready to communicate with each device individually via the device ID | | |

# 7 Calibration

## 7.1 Pre-Calibration Input

In case the Optical Exchange Cap screwed to the OXYnoris connected for the first time you can use calibration values of the factory pre-calibration.
You can find these values and sensor constants on the Final Inspection Protocol (FIP, see Fig. 31) delivered with your OEC. Use the values in the grey highlighted boxes of the FIP.

**Final Inspection Protocol**

| | |
|---|---|
| ***Type of sensor*** | Oxygen Exchange Cap |
| ***Ordering code*** | OEC-PSt3-NAU-YOP |
| ***Article number*** | 200001685 |
| ***Serial /Batch number*** | 170727-001_PSt3 |
| ***Production Date*** | 26 Jul 2017 |
| ***Reference device*** | SADB0001000001 |

***Dear customer,***
*Data are specific for the test instrumentation used in our laboratory. Your instrument in combination with the sensors might show different signal amplitude and phase angles.*

***Data***

**Atmospheric pressure:** 960 hPa
**Calibration Mode:** Humid

| | Phase signal | Valid range | Temperature | Valid range | Amplitude | QC-passed? |
|---|---|---|---|---|---|---|
| | [°] | [°] | [C°] | [C°] | [µV] | (ok / failed) |
| cal 0<br>0 % air-sat. | **60.13** | 58.00 - 62.00 | **19.2** | 18.0 - 22.0 | 303797 | OK |
| cal 2nd<br>100 % air-sat. | **26.97** | 25.00 - 29.00 | **19.2** | 18.0 - 22.0 | 128440.7 | OK |

**Response time [t90]:** < 60 s **Valid range:** < 60 s

*Please type in these values into the software for "manual calibration"*

***Sensor Constants***

| | | |
|---|---|---|
| f1 = 0.807 | dPhi1 = -0.06977 | dKSV1 = 0.000320 |
| m = 24.82 | dPhi2 = -0.00032 | dKSV2 = 0.000000 |

*Sensor is within the accepted tolerance window.*
*Sensor is visually inspected.*

**Fig. 31** Example for a Final Inspection Protocol for an OEC-PSt3

## 7.1.1 Pre-Calibration Input with STS Software

Go to the **Calibration** screen to perform a new sensor calibration.

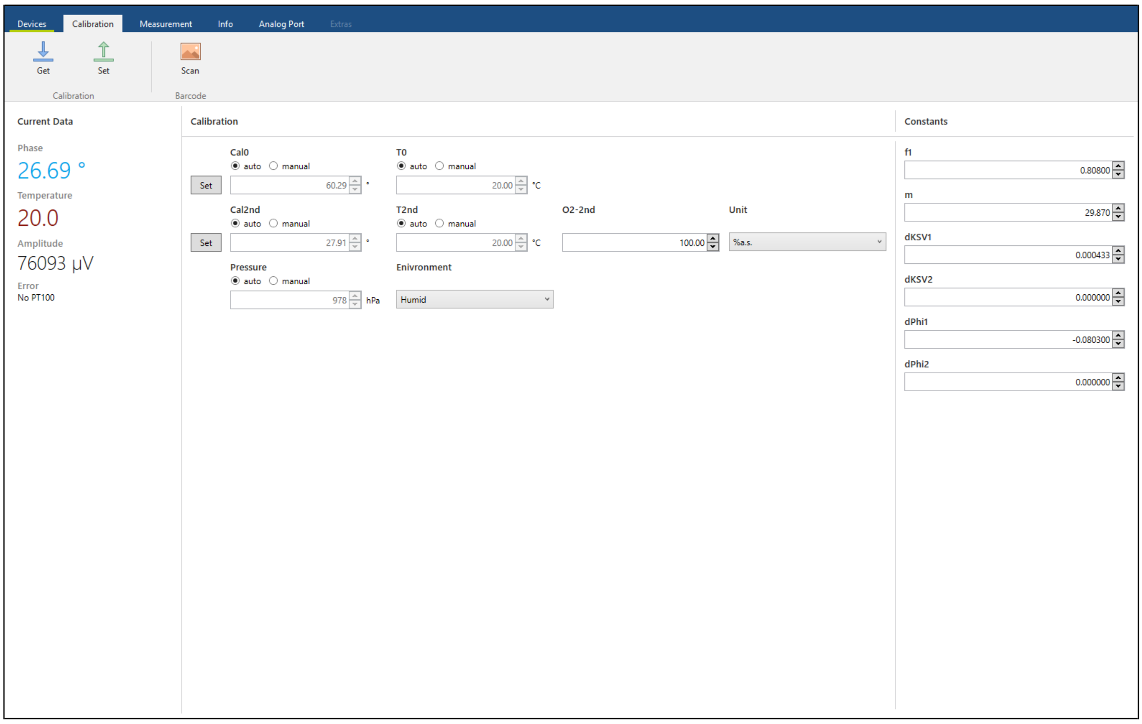



**Fig. 32** Calibration screen

With the **Get** button in the main menu bar the currently applied calibration data can be retrieved from the device and is then displayed in the respective fields on the main screen. By clicking the **Set** button new calibration data will be transferred to the device and applied for following measurements. In case you have a barcode scanner connected you can use the **Scan** button to read the sensor barcode and its calibration data.

On the left of the screen the currently measured **Phase**, **Temperature** (in case a temperature sensor is connected to or integrated in your device) and **Amplitude** are displayed. Furthermore, you will be informed in case any **Error** occurs during the measurement.

On the main screen the currently applied calibration values are displayed, while on the right of the screen the sensor constants are shown.

For pre-calibration input select **manual** above the respective parameter (**Cal0**, **T0**, **Cal2nd**, **T2nd**) and type the calibration values stated on the FIP (see Fig. 31) into the respective input fields. (If previously measured calibration values for the used oxygen sensor are available you can also use these values for the manual calibration.) Then change the **O2-2nd** and **Pressure** value and set the **Calibration Mode** (Dry - for measurements below 50 % humidity / Humid – for measurements above 50 % humidity and in liquids).

! Make sure to set the correct unit for the O2-2nd values.

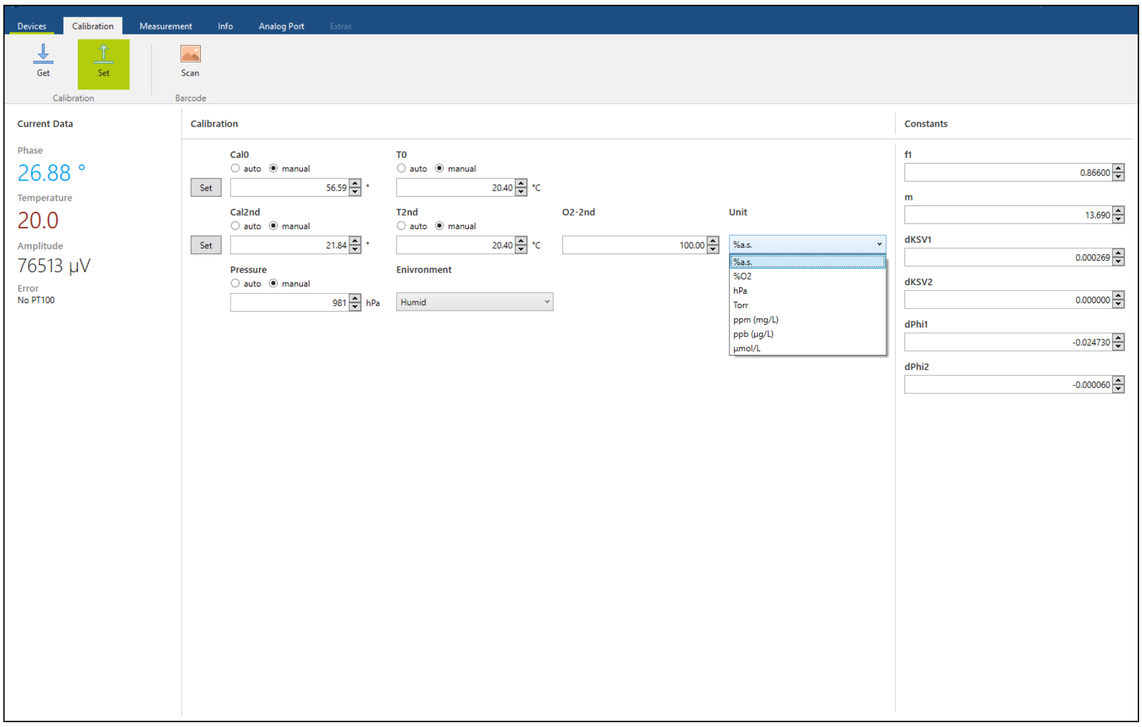


**Fig. 33** Calibration screen: Manual input of pre-calibration values; the correct unit for O2-2nd can be selected from a drop-down menu

Then change the sensor constants to the values stated on the FIP.

When you have finished editing the calibration values and sensor constants click the **Set** button in the main menu.

! Changes of the calibration values will only be stored by clicking the green highlighted **Set** button. If you move to another tab without clicking **Set** the previous calibration data will be applied.

## 7.1.2 Pre-Calibration Input with Terminal

1. Set the sensor constants with:

| | | |
|---|---|---|
| f1: | **scfo**xxxxxxxx | (example: scfo00086600 sets f1 = 0.866) |
| m: | **scmm**xxxxxxxx | (example: scmm00013690 sets m = 13.69) |
| dPhi1: | **scpo**-xxxxxxx | (example: scpo-0024730 sets dPhi1 = -0.02473) |
| dPhi2: | **scpt**-xxxxxxx | (example: scpt-0000060 sets dPhi2 = -0.00006) |
| dKSV1: | **scks**xxxxxxxx | (example: scks00000269 sets dKSV1 = 0.000269) |
| dKSV2: | **sckv**xxxxxxxx | (example: sckv00000000 sets dKSV2 = 0.0) |

2. Set the calibration type (whether calibration had been done in liquid or gas phase as stated in **Calibration Mode** on the FIP):

| | |
|---|---|
| humid: | **calt0000** |
| dry: | **calt0001** |

3. Set the measurement type (whether your measurement following calibration will be done in humid gas > 50 % humidity or liquid = humid, or in dry gases = dry):

| | |
|---|---|
| humid: | **malt0000** |
| dry: | **malt0001** |

4. Set the second calibration value ($O_2$ concentration used for cal2nd):

| | |
|---|---|
| for 100.0 % air sat.: | **clun0000, cloi0100, clof0000** |
| for 20.9 % oxygen: | **clun0001, cloi0020, clof0900** |

5. Set the 0 % oxygen phase value (cal0):

| | | |
|---|---|---|
| cal0: | **clzp**xxxx | (example: clzp5664 sets phase value cal0 = 56.64°) |

6. Set the 0 % temperature value (T0):

| | | |
|---|---|---|
| T0: | **clzt**xxxx | (example: clzt2000 sets temperature value T0 = 20.00°) |

7. Set the second phase value (cal2nd):

| | | |
|---|---|---|
| cal2nd: | **clhp**xxxx | (example: clhp2199 sets phase value cal2nd = 21.99°) |

8. Set the second temperature value (T2nd):

| | | |
|---|---|---|
| T2nd: | **clht**xxxx | (example: clht2000 sets temperature value T2nd = 20.00°) |

9. Set the atmospheric pressure for calibration (patm):

patm: **calp**xxxx (example: calp0981 sets atmosph. pressure patm = 981 hPa)

10. Set the measurement atmospheric pressure (= atmospheric pressure during measurements following the calibration):

mpatm: **walp**xxxx (example: walp0970 sets meas. pressure mpatm = 970 hPa)

This value will not be stored.

### 7.1.3 Pre-Calibration Input with Modbus

! All calibration values must be set or else the OXYnorwill show an oxygen value of '**- 5**'.

Use the grey highlighted values on the Final Inspection Protocol delivered with the OEC to perform the pre-calibration Input.
In the following description example values are used:

**Tab. 10** Pre-calibration input with Modbus

| Step | Description | Register(s) | Value (Example values) |
|---|---|---|---|
| 1 | Set the oxygen unit to '%O2' | 2089, 2090 | 16 (% O2) (integer) |
| 2 | Set the salinity value to '0.0' | 3115, 3116 | 0.0 (float) |
| 3 | Set the pressure value to '1013 hPa' | 3147, 3148 | 1013.0 (float) |
| 4 | Set the interval rate to '3 sec.' | 3497,3498 | 3 (integer) |
| | **Set all Calibration Values:** | | |
| 5 | Set the Calibration Mode to 'dry' | 5517, 5518 | 1 (dry) (integer) |
| 6 | Set Cal0 to '57,00 °' | 5521, 5522 | 57.00 (float) |
| 7 | Set T0 to '20.00 °C' | 5523, 5524 | 20.00 (float) |
| 8 | Set the O2-2nd value to '100' | 5527, 5528 | 100 (float) |
| 9 | Set the Cal2nd value to '22,00 °' | 5529, 5530 | 22.00 (float) |
| 10 | Set T2nd to '20.00 °C' | 5531, 5532 | 20.00 (float) |
| 11 | Set the calibration pressure pATM to '970 hPa' | 5533, 5534 | 970 (float) |
| 12 | Set the O2-2nd Unit to '% air saturation' | 5535, 5536 | 32 (% air sat.) (integer) |
| | **Set all Sensor Constants:** | | |
| 13 | Set f1 to '0.866' | 4911, 4912 | 0.866 (float) |
| 14 | Set dPhi1 to '- 0.02473' | 4913, 4914 | -0.02473 (float) |
| 15 | Set dPhi2 to '0.00006' | 4917, 4918 | 0.00006 (float) |
| 16 | Set dKSV1 to '0.000269' | 4919, 4920 | 0.000269 (float) |
| 17 | Set dKSV2 to '0.000000' | 4921, 4922 | 0.000000 (float) |
| 19 | Set the Control Alternative High Calibration value to '3' | 5339, 5340 | 3 (Use default calibration) (integer) |
| 20 | Set the Measurement Mode to 'humid' | 5703, 5704 | 0 (humid) (integer) |

## 7.2 Two-Point Calibration (Recalibration)

Best accuracy is achieved if the calibration temperature is about the same as the temperature during the following measurements.

### 7.2.1 Preparation of Calibration Standards

**For sensor type PSt3:**

1st Calibration Point HUMID:

- Oxygen-free water

  To prepare oxygen-free water dissolve 1 g of sodium sulfite ($Na_2SO_3$) and 50 µL cobalt nitrate ($Co(NO_3)_2$) standard solution (ρ(Co) = 1000 mg/L; in nitric acid 0.5 mol/L) in 100 mL water. Use a suitable vessel with a tightly fitting screw top and label it **cal 0**. Make sure there is only little headspace in your vessel. Due to a chemical reaction of oxygen with the $Na_2SO_3$ the water becomes oxygen-free. Additional oxygen, diffusing from air into the water, is removed by surplus $Na_2SO_3$. Close the vessel with the screw top and shake it for approximately one minute to dissolve $Na_2SO_3$ and to ensure that the water is oxygen-free. To prepare oxygen-free water you also can use sodium dithionite ($Na_2S_2O_4$).

  Fill the calibration solution **cal 0** in the vessel you have mounted the OXYnorin. Make sure the probe tip is covered completely with the liquid. To minimize the response time, you can slightly stir the solution. Then follow the instructions in chapter **7.2.2** - 7.2.4 respectively. After recording the first calibration point remove the calibration solution **cal 0**, fill the vessel with distilled water and stir it for 1 minute. Repeat this procedure at least 5 times to clean the OIM from sodium sulfite.

  For storing the calibration solution **cal 0** keep the vessel closed after calibration with a screw top to minimize oxygen contamination. The shelf life of **cal 0** is about 24 hours provided that the vessel has been closed with the screw top.

1st Calibration Point DRY:

- Nitrogen-saturated atmosphere

  As an alternative you can use nitrogen-saturated atmosphere as calibration standard **cal 0**. Use a commercially available test gas $N_2$ (5.0) (suppliers are e. g. Air Liquide, Linde, Westfalen AG).

  Lead the gas into a vessel filled with distilled water before introducing it in the calibration chamber or a flow-through cell with installed OXYnor(see Fig. 34). Then follow the instructions in chapter 7.2.2 - 7.2.4 respectively.

2nd Calibration Point HUMID:

- Air-saturated water
  Add 100 mL water to a suitable vessel and label it **cal 100**. To obtain air-saturated water, blow air into the water using an air-pump with a glass-frit (air stone), creating a multitude of small air bubbles, while stirring the solution. After 20 minutes, switch of the air-pump and stir the solution for another 10 minutes to ensure that the water is not supersaturated.

  Fill the calibration solution **cal 100** in the vessel you have mounted the sensor in. Make sure the sensor surface is covered completely with the liquid. To minimize the response time, slightly stir the solution. Then follow the instructions in chapter 7.2.2 - 7.2.4 respectively.

2nd Calibration Point DRY:

- Water vapor-saturated air
  As an alternative you can use water-vapor saturated air as calibration standard **cal 100**. Place wet cotton wool in a suitable vessel and close the vessel with a fitting screw top or lid. (For inserting the sensor into the vessel you might have to drill a hole in the lid.) Wait about 2 minutes to ensure that the air is water vapor-saturated.

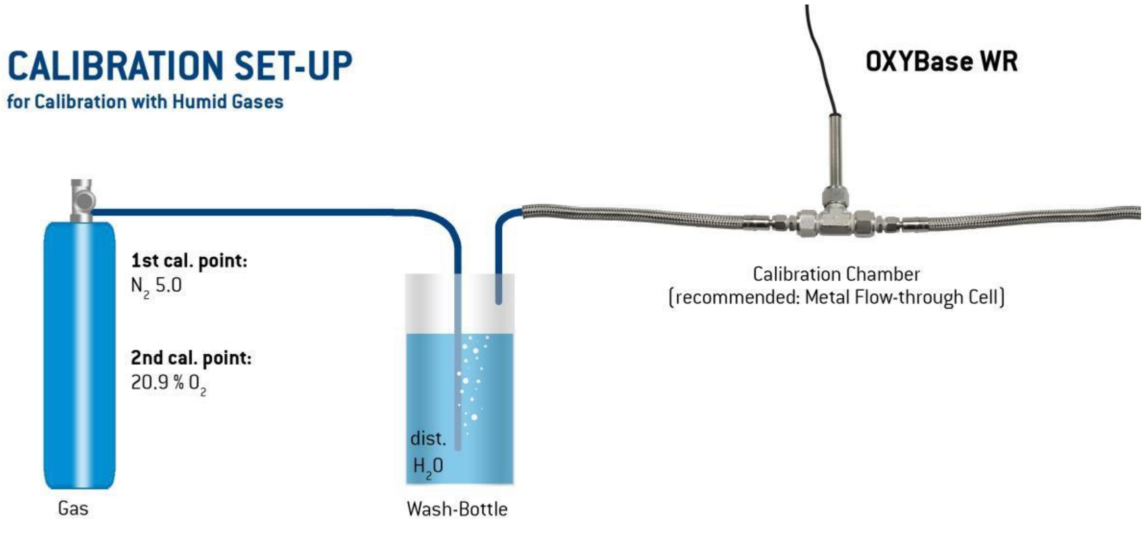



**Fig. 34** Schematic illustration of the calibration set-up when calibrating the OXYnorwith humid gases

## 7.2.2 Calibration Procedure with STS Software

Go to the **Calibration** screen to perform a new sensor calibration.

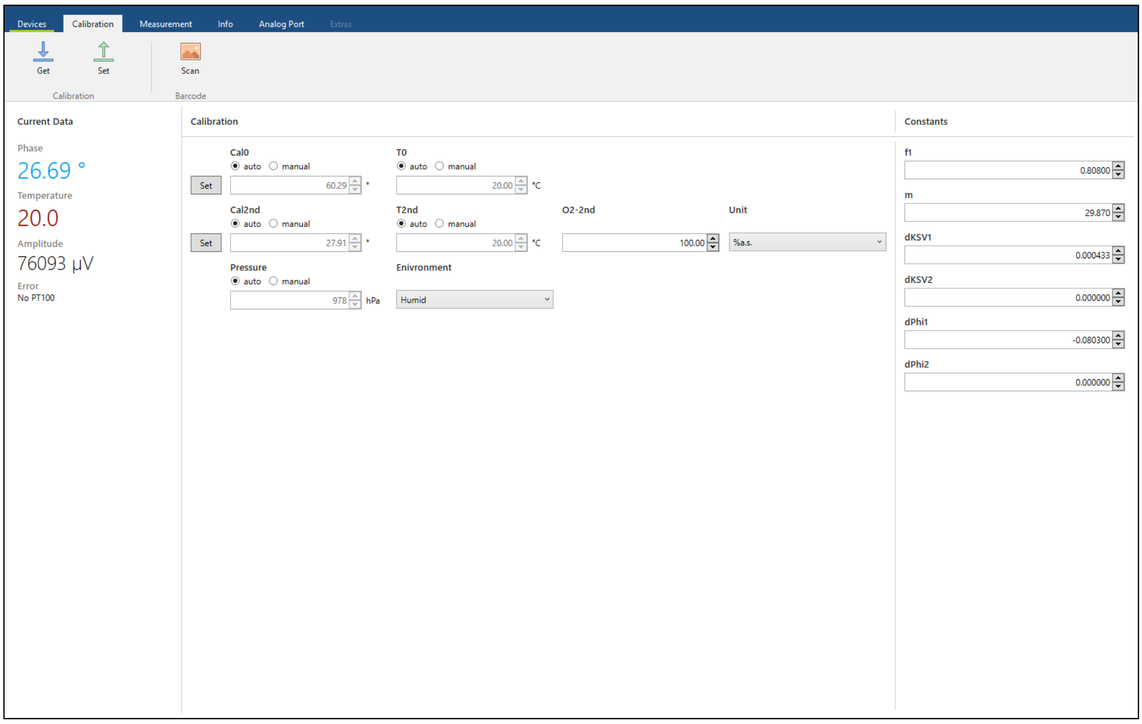



**Fig. 35** Calibration screen

With the **Get** button in the main menu bar the currently applied calibration data can be retrieved from the device and is then displayed in the respective fields on the main screen. By clicking the **Set** button new calibration data will be transferred to the device and applied for following measurements. In case you have a barcode scanner connected you can use the **Scan** button to read the sensor barcode and its calibration data.

On the left of the screen the currently measured **Phase**, **Temperature** (in case a temperature sensor is connected to or integrated in your device) and **Amplitude** are displayed. Furthermore, you will be informed in case any **Error** occurs during the measurement.

On the main screen the currently applied calibration values are displayed, while on the right of the screen the sensor constants are shown.

Select **auto** above the respective parameter (**Cal0**, **T0**, **Cal2nd**, **T2nd**).

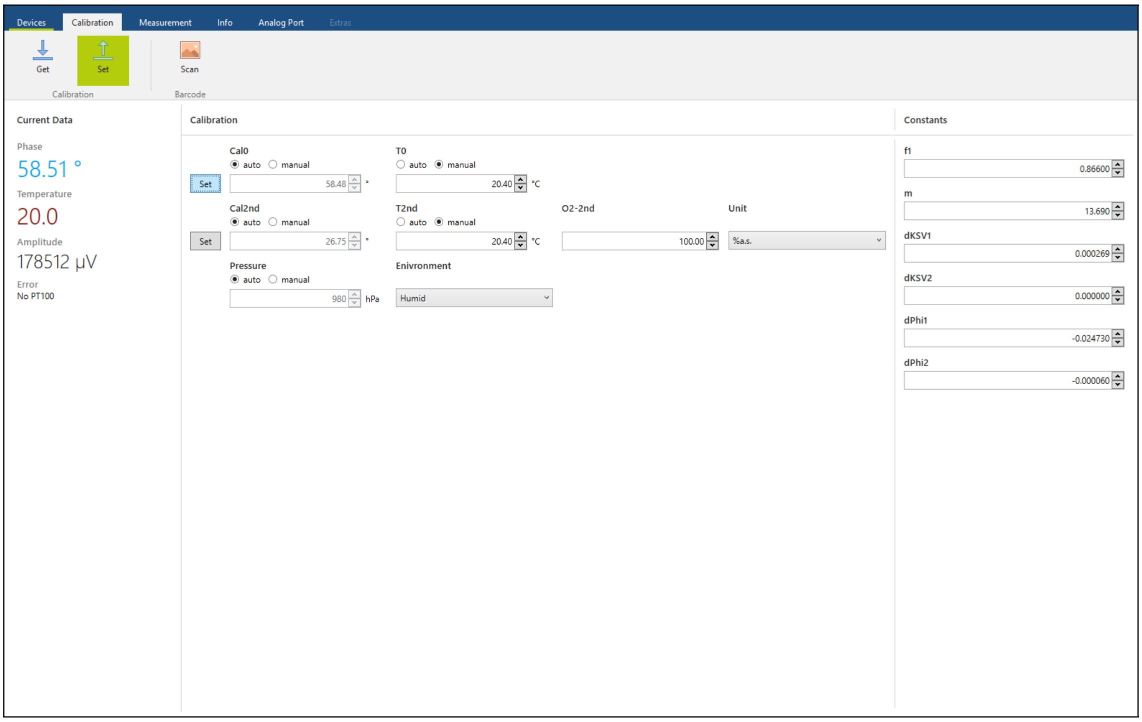



**Fig. 36** Two-point calibration with STS software – setting the first calibration point

Set the first calibration point **Cal0**:
Place the sensor in the medium for the first calibration point.
In the **Current Data** section on the left the currently measured **Phase** and **Amplitude** values of the oxygen sensor, and the current **Temperature** are displayed. Watch the displayed phase value; wait for about 3 minutes until the phase angle is constant (the variation of the phase angle should be smaller than ± 0.1° and the variation of temperature smaller than ± 0.1°C); click on the **Set** button left of the **Cal0** value and the new calibration values will be displayed in the **Cal0** and **T0** fields.

Set the second calibration point **Cal2nd**:
Place the sensor in the medium for the second calibration point.
Again watch the measured phase value; wait for about 3 minutes until the phase angle is constant (the variation of the phase angle should be smaller than ± 0.1° and the variation of temperature smaller than ± 0.1°C); click the **Set** button left of the **Cal2nd** value and the new calibration values for the second calibration point will be displayed in the **Cal2nd** and **T2nd** fields.

Then set the oxygen value of the second calibration standard **O2-2nd** in the respective oxygen unit, the atmospheric **Pressure** during calibration and the **Environment** in which the calibration is performed (Dry - for measurements below 50 % humidity / Humid – for measurements above 50 % humidity and in liquids).
Check the sensor constants and if necessary change them according to the values stated on the FIP (see Fig. 31).

When all values are set and entered click the **Set** button in the menu bar to transfer the new calibration data to the device.

**!** Changes of the calibration values will only be stored by clicking the green highlighted **Set** button. If you move to another tab without clicking **Set** the previous calibration data will be applied.

After successful calibration you can move to the Measurement tab and start oxygen measurements.

## 7.2.3 Calibration Procedure with Terminal

1. Set the calibration type (whether the calibration will be done in humid gases > 50 % humidity or liquid = humid, or in dry gases = dry):

   humid: **calt0000**
   dry: **calt0001**

2. Set the measurement type (whether your measurement following the calibration will be done in humid gases (> 50 % humidity) or liquid = humid, or in dry gases = dry):

   humid: **malt0000**
   dry: **malt0001**

3. Set the second calibration value ($O_2$ concentration used for cal2nd):

   for 100.0 % air sat.: **clun0000, cloi0100, clof0000**
   For 20.9 % oxygen: **clun0001, cloi0020, clof0900**

4. Set the first calibration point cal0 (0 % $O_2$ phase and temperature value):
   Place the OXYnorin the medium for the first calibration point, so the OEC with the PSt3 coating is completely inserted. Wait for about 3 minutes for the phase angle and temperature to adjust (the variation of the phase angle should be smaller than ± 0.1°, and the variation of temperature smaller than ± 0.1°C).

   Then set cal0 with the command: **calz**

5. Set the second calibration point cal2nd (second phase and temperature value):
   Place the OXYnorin the medium for the second calibration point, so the OEC with the PSt3 coating is completely inserted. Wait for about 3 minutes for the phase angle and temperature to adjust (the variation of the phase angle should be smaller than ± 0.1°, and the variation of temperature smaller than ± 0.1°C).

   Then set cal2nd with the command: **calh**

6. Set the measurement atmospheric pressure (= atmospheric pressure during measurements following the calibration):

mpatm: **malp**xxxx (example: malp0970 sets meas. pressure mpatm = 970 hPa)

### 7.2.4 Calibration Procedure with Modbus

For detailed information about calibration via Modbus please refer to the Modbus RTU communication protocol. Here two use cases are given as an example:

**Manual 1-Point Calibration of a PSt3 Sensor:**

Precondition: The sensor constants are set correctly and the sensor is placed in a low oxygen environment.

**Tab. 11** Manual 1-point calibration with Modbus

| Step | Description | Register(s) | Value |
|---|---|---|---|
| 1 | Read the error registers and check, if there are any errors. Only proceed, when no errors do occur. | 4907, 4908 | |
| 2 | Set the calibration values cal0 and T0. | 5521 to 5524 | 1st float: 55.27<br>2nd float: 21.98 |

**Automatic Low Point Calibration:**

**Tab. 12** Automatic low point calibration with Modbus

| Step | Description | Register(s) | Value |
|---|---|---|---|
| 1 | Read the error registers and check, if there are any errors. Only proceed, when no errors do occur. | 4907, 4908 | |
| 2 | The sensor is in a 0%O2 environment | / | |
| 3 | Set the sample rate to 3 s | 3499,3500 | Write: 3 (float) |
| 4 | Wait 30s | / | |
| 5 | Activate Low Calibration Point | 5161,5162 | Write: 0 (float) |
| 6 | Read the Low Calibration Point Status Register | 5157,5158 | Read: 0x80 (decimal)<br>Meaning: Phase not steady |
| 7 | Wait some more | / | |
| 8 | Activate Low Calibration Point | 5161, 5162 | Write: 0 (float) |
| 9 | Read the Low Calibration Point Status Register | 5157, 5158 | Read: 0x00 (decimal)<br>Meaning: No error, calibration process successful |

**Alternative High Point Calibration:**

**Tab. 13** Alternative high point calibration with Modbus

| Step | Description | Register(s) | Value |
|---|---|---|---|
| 1 | Read the error registers and check, if there are any errors. Only proceed, when no errors do occur. | 4907, 4908 | |
| 2 | The sensor is in an unknown environment. | / | |
| 3 | Set the sample rate to 3s | 3499,3500 | Write: 3 (float) |
| 4 | Wait 30s | / | |
| 5 | Initial measurement | 5339, 5340 | Write: 1 (decimal) |
| 6 | Extract a sample for further analysis to get the O2-2nd value. | / | |
| 7 | When the new O2-2nd value is known, transmit the value to assign the alternative calibration high point. | 5321, 5322 | Write: the new O2-2nd value (float) |
| 8 | Read the alternative high point calibration status register. | 5317, 5318 | Read: 0x14000000 (decimal) Meaning: Alternative high point calibration active and assigned. |

# 8 Start a Measurement with the OXYnor

## 8.1 Measurement with STS Software

Go to the **Measurement** tab in the software menu.

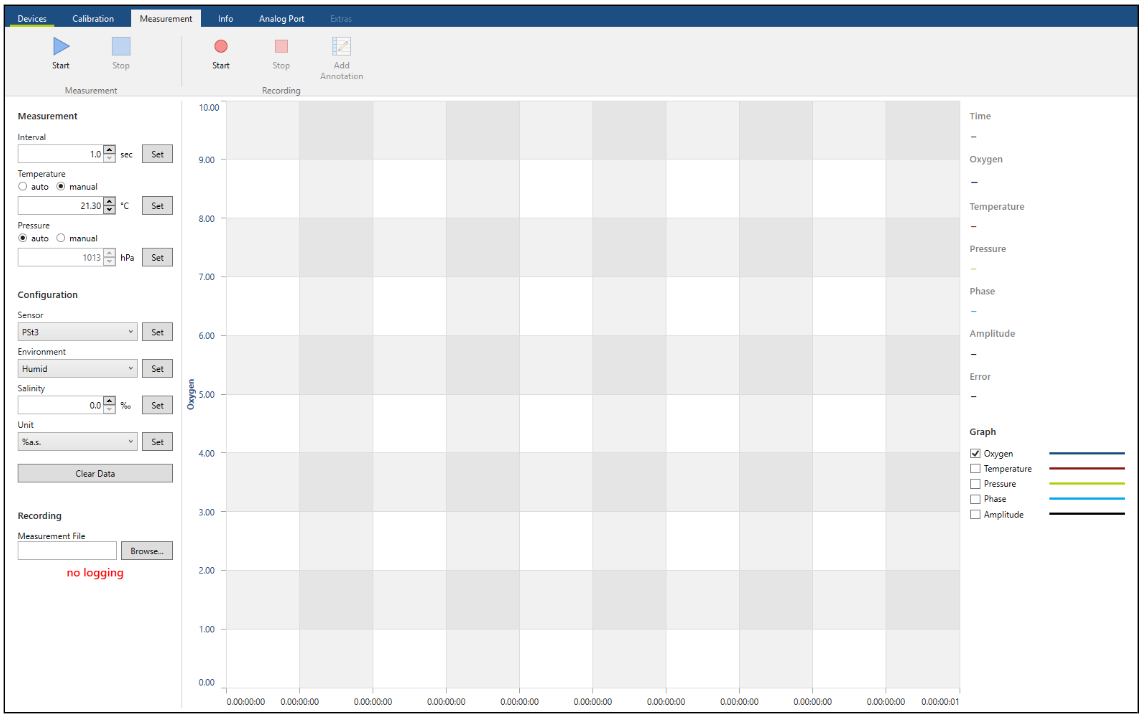
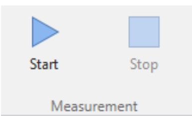


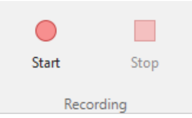
**Fig. 37** Initial Measurement screen

On the left of the Measurement screen you can select Measurement settings, while on the main screen the measurement data will be displayed in a graph. On the right the last measured **Oxygen**, **Temperature**, and **Pressure** values as well as the raw data values **Phase** and **Amplitude** are shown. Furthermore, you will be informed in case any **Error** occurs during the measurement.
In the lower right of the screen you can select which parameters should be displayed in the **Graph**.

The main menu offers following functions:



: Start or Stop a continuous measurement without data logging.




: Start or Stop data logging. Data recording can also be started during a running measurement.

In case data recording is stopped and then re-started during a running measurement the new data will be added to the previously recorded data.

Further details on how to work with the STS you can find in the STS software instruction manual which is delivered together with the OXYnor.

## 8.2 Measurement with Terminal

The following chapter describe communication via HyperTerminal, alternatively other terminals like e. g. PuTTY can be used as well.

1. Start communication with the board by pressing the dial icon, type in the command `**repo**´and press **ENTER** to get a status report.

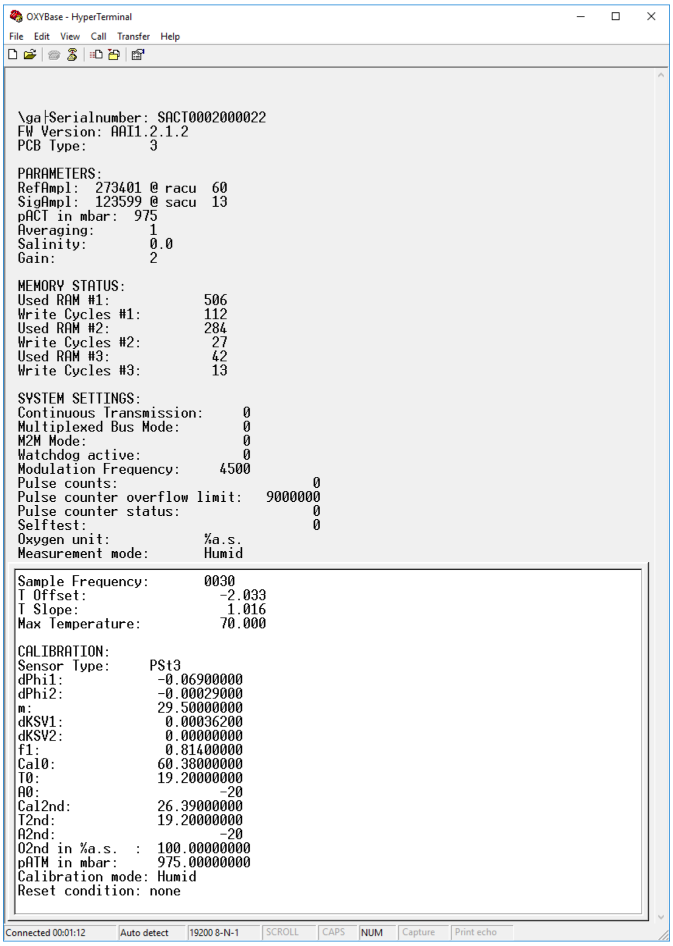



**Fig. 38** Status report

2. The device sends measurement data only on request with the command `**data**´. This will return one measurement data string.

**Measurement data string:**

Output data string:

**N** N0; **A** N1; **P** N2; **T** N3; **O** N4; **E** N5; <LF><CR>

| | |
|---|---|
| **N**: | start of **device address** N0 |
| N0: | byte value of device address, no decimal places |
| **A**: | start of amplitude value N1 |
| N1: | long value of amplitude, no decimal places |
| **P**: | start of **phase value** N2 |
| N2: | integer value of phase, two decimal places |
| **T**: | start of temperature value N3 |
| N3: | integer value of temperature, two decimal places |
| **O**: | start of **oxygen value** N4 |
| N4: | integer value of oxygen, decimal places 2 (standard) or 4 (only for oxygen unit mg/L and ppm gas) |
| **E**: | start of **error value** N5 |
| N5: | integer value of error code, no decimal places |

**!** Values for **P**, **T**, and **O** depend on stored calibration data. Refer to the next chapter for correct calibration.

**!** The measurement data string has fixed size for simple data extraction; the only exception is shown in example 2, where the oxygen unit is changed to mg/L.

**Data string example 1 (oxygen unit = % a. s.):**

**N**03;**A**0012941;**P**2507;**T**2150;**O**010210;**E**00000000;<LF><CR>

Output data interpretation:

| | |
|---|---|
| **N**03: | data string from device number 3 |
| **A**0012941: | 12941 µV (signal amplitude) |
| **P**2507: | 25.07 ° (signal phase shift) |
| **T**2150: | 21.5 °C (compensation temperature) |
| **O**010210: | 102.10 % a. s. (oxygen concentration by two decimal places) |
| **E**00000000: | No error |

**Data string example 2 (oxygen unit = mg/L):**

**N**03;**A**0012941;**P**2507;**T**2150;**O**00109061;**E**00000000;<LF><CR>

Output data interpretation:

| | |
|---|---|
| **N**03: | data string from device number 3 |
| **A**0012941: | 12941 µV (signal amplitude in) |
| **P**2507: | 25.07 ° (signal phase shift) |
| **T**2150: | 21.5 °C (compensation temperature) |
| **O**00109061: | 10.9061 mg/L (oxygen concentration by four decimal places) |
| **E**00000000: | No error |

You can find detailed information concerning the communication with the OXYnorin the communication protocol.

## 8.3 Measurement with Modbus

For detailed information about measurements and measurement settings please refer to the Modbus RTU communication protocol.

**!** Make sure the sensor constants and calibration values are already set correctly, before starting the measurement (see chapter 7.1.3 and 7.2.4).

Here a use case for continuous measurement is given as an example:

**Continuous measurement at 1 min intervals and manually set measurement temperature:**

**Tab. 14** Start of continuous measurement with Modbus

| Step | Description | Register(s) | Value |
|---|---|---|---|
| 1 | Set pressure to “1006.23” | 3147,3148 | 1006.23 (float) |
| 2 | Set temperature mode to “manual” | 5611 | 0 (boolean) |
| 3 | Set manual temperature to “20.56” | 2411, 2412 | 20.56 (float) |
| 4 | Set the interval rate to 1min (60s) | 3499,3500 | 60 (integer) |
| 5 | Wait 1s until the first measurement is executed | | |
| 6 | Read out the last measurement | 4897 to 4908 | See next table |
| 7 | Read out the oxygen unit | 2089,2090 | 1073741824 (integer, is 0x40000000 hex, meaning ppm gas) |

**Tab. 15** Measurement value registers description

| Register 4897 / 4898 | Register 4899 / 4900 | Register 4901 / 4902 | Register 4903 / 4904 | Register 4905 / 4906 | Register 4907/4908 |
|---|---|---|---|---|---|
| Float: Reference Amplitude in µV | Float: Oxygen Amplitude in µV | Float: Oxygen Phase shift in degrees | Float: Temperature in °C | Float: Calculated Oxygen Value in Unit | Integer: Error Register, see Table 9 Modbus RTU communication protocol. |
| 350000.00 | 10562.12<br>(Sensor and environment dependent value) | 44.32<br>(Sensor and environment dependent value) | 20.56 | 100<br>(Sensor and environment dependent value) | 0<br>(Error code. Should be 0 if a sensor is applied) |

# 9 Analog Output

The 4 – 20 mA outputs are factory calibrated and set to default values. With the STS software the outputs can easily be adjusted to your specific application.

## 9.1 Functional Principles

The OXYnorprocesses four working modes:

**Tab. 16** Analog output modes for OXYnorWR-RS485-4-20mA-Lx

| Parameter Value | Output Mode |
|---|---|
| 0 | off |
| 3 | linear |
| 4 | bilinear |
| 5 | fixed manual output |

In mode 0 the output is set to 0 mA and conversion is deactivated.

In mode 3 and 4 the last oxygen / temperature value will be converted to a current output within the range of given minimum and maximum values (see communication protocol, commands **cmin** and **cmax**).

In mode 5 the output is set to a fixed value, which is set with the **cset** command (see communication protocol).This mode is used for calibration and testing.

In mode 4 a bilinear conversion is used. Therefore, a value for the 12 mA output has to be defined with the command **cmid** (see communication protocol). These modes allow higher resolution in a certain range. Some examples are shown in the figure below.

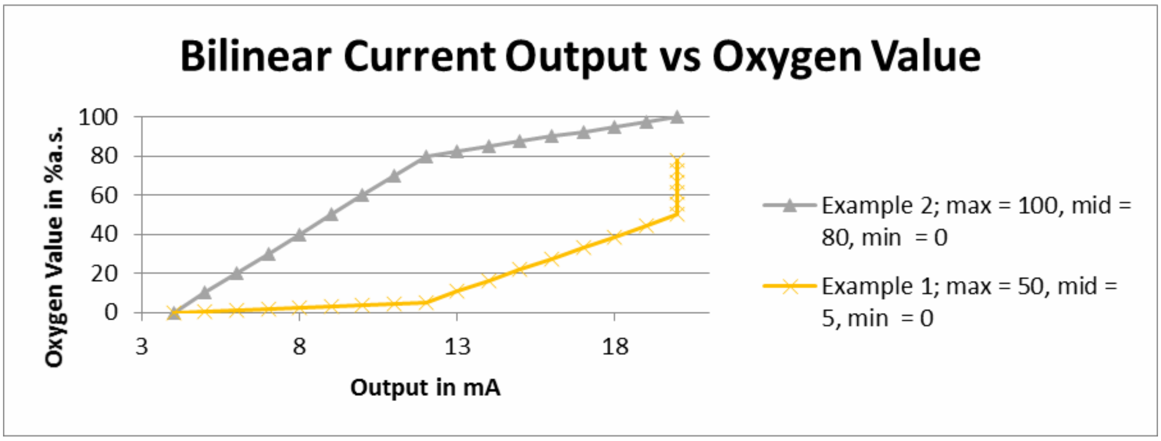



**Fig. 39** Bilinear current output. Example 1 shows high resolution in a low oxygen environment. Example 2 high resolution in high oxygen environment. Example 1 also shows the behavior for measurement values which lay outside the value range.

Furthermore, the analog output can indicate errors and warnings in different modes.

**Tab. 17** Error modes

| Parameter Value | Error Mode |
|---|---|
| 0 | off |
| 1 | alternating, error only |
| 2 | alternating, error and warning |
| 3 | continuous, error only |
| 4 | continuous, error and warning |

Alternating output: A square wave with +/-0.5mA amplitude and 8s period is added to the output (12 cycles), followed by 288s of the actual measurement value. Then, if error/warning is still present, the square wave is added again, etc.

! The actual measurement value will probably be changed if the measurement interval is less than 384s.

Continuous output: On an active error and/or warning the output is set to the error level (default: 22mA) or the warning level (default: 21mA) respectively until the error/warning vanishes. If there are errors and warnings present at the same time, the output will be set to the error level.

## 9.2 Use Cases

### 9.2.1 Interpreting the Current Value

To interpret the current value you will need to know the following settings:

- Mode
- Depending on the mode
  - In mode 0: none
  - In mode 3: minimum and maximum value (cmin, cmax)
  - In mode 4: minimum, maximum and middle value (cmin, cmax, cmid)
  - In mode 5: fixed manual out value
- Error / Warning mode

### 9.2.2 Linear Oxygen Mode with Constant Error

We assume now, the device is in mode 3 (channel oxygen) and the error / warning mode is mode 3 (continuous error output). The oxygen unit is % $O_2$, the maximum value = 21 and the minimum value = 10.

So the following current values could be read:

- 0 mA: The device is not powered or the 4 – 20 mA connection is not correct.
- 22 mA: There is an error. Read the error with the **cerr** command (see communication protocol) for further details.
- All values between 4 and 20 mA can be interpreted as valid oxygen values, calculated as this:
  Oxygen value = ((current – 4 mA) x (cmax – cmin) / (16 mA)) + cmin
  This is only valid for oxygen values between cmin and cmax. For lower or higher values the current will be 4 or 20 mA respectively.

  Further examples:
  4 mA → 10.00 % $O_2$ (or below)
  8 mA → 12.75 % $O_2$
  12 mA → 15.50 % $O_2$
  16 mA → 18.25 % $O_2$
  20 mA → 21.00 % $O_2$ (or above)

### 9.2.3 Bilinear Temperature Mode with Alternating Error

We assume now, the device is in mode 4 (channel temperature) and the error / warning mode is mode 1 (alternating error output). The maximum value = 60 °C, the minimum value = 0 °C and the middle value = 50 °C. As we are in the alternating error output it is reasonable to set the sampling rate to a value higher than 384 sec. (see communication protocol for details).

So the following current values could be read:

- 0 mA: The device is not powered or the 4 – 20 mA connection is not correct.
- If the current value is assumed to be constant within a period of 384 sec.:
  All values between 4 and 12 mA can be interpreted as valid temperature values, calculated as this:
  Temperature Value = ((current - 4 mA) x (cmid - cmin) / (8 mA)) + cmin

This is only valid for temperature values between cmin and cmid. For lower values the current will be 4 mA.

- All values between 12 and 20 mA can be interpreted as valid temperature values, calculated as this:
  Temperature Value = ((current - 12 mA) * (cmax - cmid) / (8 mA) ) + cmid

  This is only valid for temperature values between cmax and cmid. For high temperature values the current will be 20 mA.

Further examples:
4 mA → 0.00 °C (or below)
7 mA → 18.75 °C
10 mA → 37.50 °C
12 mA → 50.00 °C
15 mA → 53.75 °C
18 mA → 57.50 °C
20 mA → 60.00 °C

If the current values shows an alternating pattern with +/- 0.5 mA amplitude and 8 sec. period, followed by 288 sec. of constant value, there was an error, e.g. the oxygen value could not be detected due to low amplitude.

## 9.3 Activation of the 4 – 20 mA Output

By default OXYnoris delivered with deactivated 4 – 20 mA output. Reactivation can be done by changing the output mode.

### 9.3.1 Activation with STS Software

We recommend following procedure:

1. Start the STS software.
2. Choose the desired oxygen unit on the Measurement tab (e. g. % $O_2$).
3. Activate the Analog Port tab.
4. Change the port settings as in the figure below:

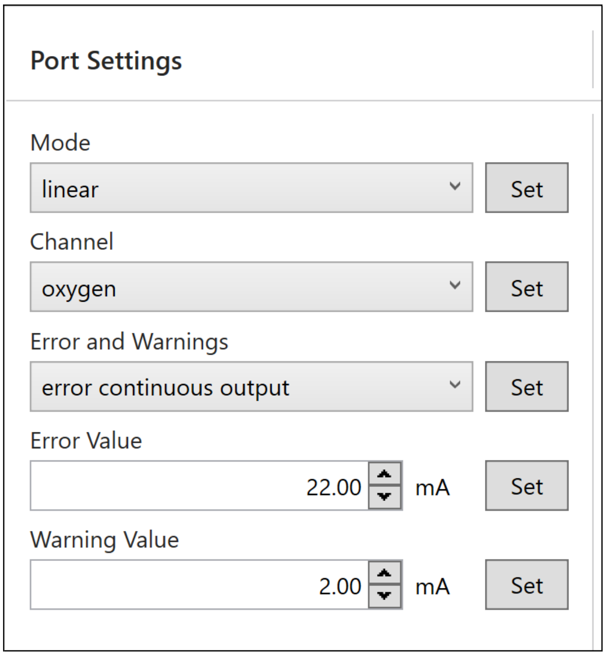



**Fig. 40** Change the port settings to these settings

In case an OXYnorWR-RS485M-4-20MA+TEMP with two analog outputs is connected to the software, a **Channel** selection field is displayed. Select one of the Analog Port channels to make settings for the respective analog output (see Fig. 41).

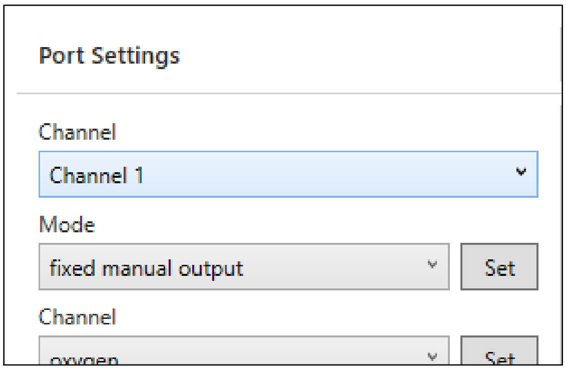



**Fig. 41** Setting the Analog Port Channel for OXYnorWR-RS485M-4-20MA+TEMP

5. Define the high and low value (e. g. high value 50 % $O_2$ equals 20 mA, and low value is always 0 % $O_2$ and equals 4 mA, see Fig. 42).

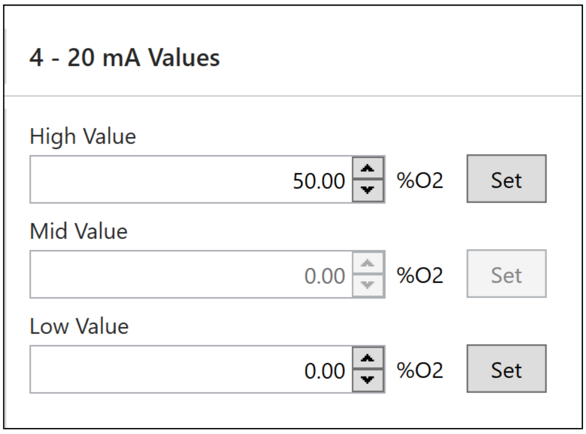



**Fig. 42** High and low value defined to 50 % $O_2$ and 0 % $O_2$

6. Then set the desired sampling rate on the Measurement tab (e. g. 10 sec.).
7. Start the measurement.
8. Now connect the OXYnorto a controller and receive the oxygen values via the analog outputs (white, brown and grey cable have to be connected).

### 9.3.2 Activation with Terminal (OXYnorWR-RS485-4-20mA only)

Precondition: Sensor constants and calibration values (PSt3) are already set correctly, the oxygen unit is % air saturation, and the 4 – 20 mA output is already in a calibrated state.

1. Set the output analyte to oxygen or temperature:

   **cout**xxxx (cout0001 = oxygen, cout0002 = temperature)

2. Set the mode to linear or bilinear mode:

   **cmod**xxxx (cmod0003 = linear, cmod0004 = bilinear)

3. Set the corresponding analyte value for the 4 mA output:

   **cmin**xxxx (example for $O_2$: cmin0000 = 0 % a. s. oxygen at 4 mA output)

4. (for BILINEAR mode only!) Set the corresponding analyte value for the 12 mA output:

   **cmid**xxxx (example for $O_2$: cmid0050 = 50 % a. s. oxygen at 12 mA output)

5. Set the corresponding analyte value for the 20 mA output

   **cmax**xxxx (example for $O_2$: cmax0100 = 100 % a. s. oxygen at 20 mA output)

6. Set the warning level:

   **cwrl**xxxx (example: cwrl2200 = 22 mA warning level)

7. Set the error level:

   **cerl**xxxx (example: cerl2450 = 24.5 mA error level)

8. Set the error / warning mode:

   **cewo**xxxx (example: cewo0004 = continuous, error and warning)

## 9.4 Analog Output Calibration

The OXYnoranalog output is delivered pre-calibrated. However, an experienced user may increase the precision in his specific process environment with a two-point calibration.

### 9.4.1 Analog Output Calibration with STS Software

Go to the **Analog Port** tab in the software.

In case an OXYnorWR-RS485M-4-20MA+TEMP with two analog outputs is connected to the software, a **Channel** selection field is displayed in the **Port Settings**. Select one of the Analog Port channels to calibrate it (see Fig. 43).

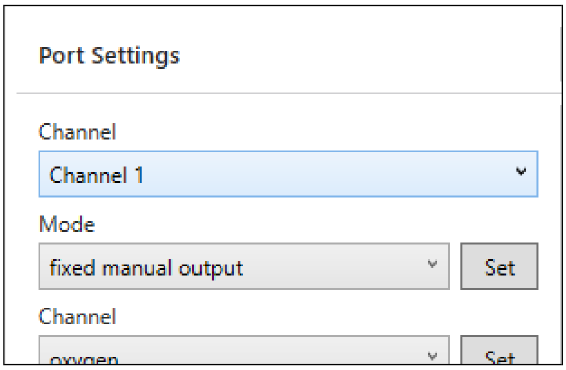



**Fig. 43** Setting the Analog Port Channel for OXYnorWR-RS485M-4-20MA+TEMP

In the **Calibration** input box you are able to perform the output calibration.

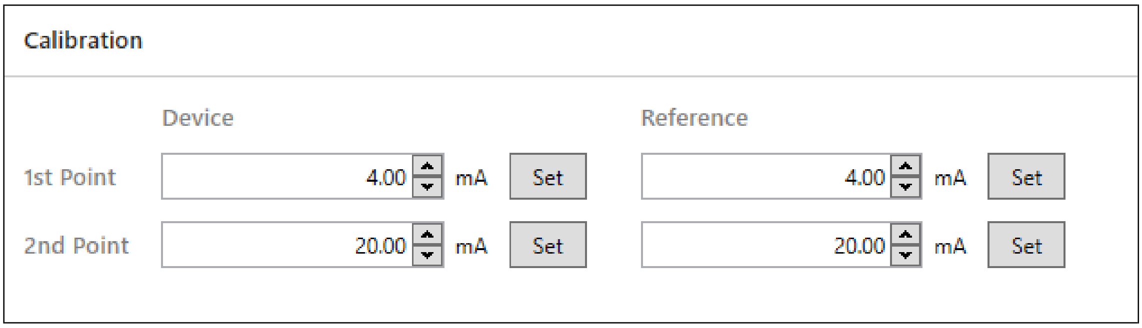



**Fig. 44** Analog Port Calibration

Workflow for calibration:

1. Connect a current measurement device to the OXYnor(see chapter 0). This will serve as your reference device.

2. Set the **1st Point** value in the **Device** column to any low value, e. g. 4.00 mA. Click the **Set** button and the current will be applied immediately.
3. Read the current value (e. g. 3.90 mA) shown on your reference device. Use the arrow keys or type this value in the **Reference** column next to the **1st Point** value to adjust the output values accordingly. Click **Set** to apply the change.
4. Set the **2nd Point** value in the **Device** column to any high value, e. g. 20.00 mA. Click the **Set** button and the current will be applied immediately.
5. Read the current value (e. g. 19.54 mA) shown on your reference device. Use the arrow keys or type this value in the **Reference** column next to the **2nd Point** value to adjust the output values accordingly. Click **Set** to apply the change.

With the **Reset Analog Calibration** button in the main menu bar any changes made in the **Calibration** section can be reset to default values.

### 9.4.2 Analog Output Calibration with Terminal (OXYnorWR-RS485-4-20mA only)

You need to be able to read the current mA value which is measured by your device.

1. Reset the existing calibration by writing the following commands:

   **ccal0000**
   **coff0000**

2. Set the mode to **fixed output** with:

   **cmod0005**

3. Set the current output to a low value, e. g. 4 mA with:

   **cset0400**

4. Read the current value on your device (e. g. 4.12 mA) and write it to the OXYnorwith:

   **coff0412** (according to this example)

5. Set the current output to a high value, e. g. 20 mA with:

   **cset2000**

6. Read the current value on your device (e. g. 20.36 mA) and write it to the OXYnorwith:

   **ccal2036** (according to this example)

# 10 Technical Data

## 10.1 Electrical Characteristics

### 10.1.1 DC Characteristics

**Tab. 18** DC characteristics

| ITEM | |
|---|---|
| Supply Voltage | OXYnorWR-RS232-Lx: 5 V ± 0.5 V<br>OXYnorWR-RS485-Lx: 5 – 30 VDC<br>OXYnorWR-RS485M-Lx: 5 – 30 VDC<br>OXYnorWR-RS485M-4-20MA+TEMP: 7 – 30 VDC<br>OXYnorWR-RS485-4-20mA-Lx: 7 – 30 VDC |
| Power consumption in active mode | max. 1 W |
| Power consumption in stand-by mode | < 0.15 W |

### 10.1.2 Timing Characteristics

**Tab. 19** Timing characteristics

| ITEM | UNIT | MIN | TYPICAL | MAX |
|---|---|---|---|---|
| Sampling rate | s | 0.2 | - | 599.9 |
| Sampling rate accuracy | ms | - | 3 | - |
| Initialization Time | s | - | 4.5 | - |
| Measurement time<br><br>It is defined by averaging filter length. Shortest filter (1) results in measurement time of 31 ms. | ms | 31 | - | 71 |

### 10.1.3 Serial Interface Characteristics

**Tab. 20** Serial interface characteristics

| DATA INTERFACE | RS485 SENTEC | RS485 Modbus |
|---|---|---|
| Baud rate | 19200 | default: 19200<br>configurable: 4800, 9600, 19200, 38400, 57600, 115200 |
| Data bits | 8 | 8 |
| Parity | No | default: none<br>configurable: even, odd, none<br>! When using even or odd parity the device will automatically use 1 stop bit. This is required due to Modbus standards. |
| Stop bits | 1 | default: 2<br>! When using even or odd parity the device will automatically use 1 stop bit. This is required due to Modbus standards. |
| Handshake | No | n. a. |
| Galvanic isolation | No | No |

## 10.2 External Characteristics

**Tab. 21** Probe dimensions & weight

| DIMENSIONS / WEIGHT | |
|---|---|
| Probe length | 81.4 mm (WR-RS232-Lx)<br>106 mm (WR-RS485-Lx, WR-RS485M-Lx & WR-RS485M-4-20MA+TEMP)<br>135 mm (WR-RS485-4-20mA-Lx) |
| Diameter | 12 mm |
| Weight | 100 g |

**Tab. 22** Probe housing materials

| MATERIALS | |
|---|---|
| Probe housing material | Stainless steel SUS 316 L |

## 10.3 Environmental Characteristics

**Tab. 23** Environmental Characteristics

| TEMPERATURE / PRESSURE | |
|---|---|
| Temperature range operation | Optimal: 0 °C to + 40 °C<br>Max.: - 10 °C to + 70 °C |
| Temperature range storage | Optimal: room temperature (+ 20 °C ± 5 °C)<br>Max.: 0 ° C to + 70 °C |
| Pressure resistance | 3 bar<br>(probe **with** attached OEC) |

## 10.4 Sensor Characteristics

**Tab. 24** Sensor characteristics

| OXYGEN EXCHANGE CAPS OEC-PSt3 | | | | |
|---|---|---|---|---|
| Cap type | OEC-PSt3-NAU-YOP | OEC-PSt3-NAU-CAF | OEC-PSt3-NAU-PTFE | OEC-PSt3-NAU-OIW |
| Measurement range* | Optimal: 0 – 50 % $O_2$, 0 – 500 hPa, 0 – 22.5 mg/L<br>Max.**: 0 – 100 % $O_2$, 0 – 1000 hPa, 0 – 45 mg/L | | | |
| Resolution* | 1 % $O_2$± 0.02 % $O_2$, 20.9 % $O_2$ ± 0.1 % $O_2$<br>0.4 mg/L ± 0.009 mg/L, 9 mg/L ± 0.04 mg/L | | | |
| Limit of detection* | 0.03 % $O_2$<br>0.3 hPa<br>0.020 mg/L | | | |
| Response time ($t_{90}$)<br>Gaseous $O_2$***:<br>Dissolved $O_2$****: | < 10 sec.<br>< 30 sec. | < 15 sec.<br>< 40 sec. | < 85 sec.<br>< 100 sec. | < 3 sec.<br>< 3 sec. |
| Cleaning procedure | 3 % $H_2O_2$, acidic agents (HCl, $H_2SO_4$) max. 4 – 5 %<br>cleaning agents containing $ClO_2$ at room temperature | | | |
| Compatibility | Aqueous solutions, ethanol, methanol | | | |
| No cross-sensitivity to | pH 1 – 14, $CO_2$, $H_2S$, $SO_2$, ionic species | | | |
| Cross-sensitivity to | Chlorine gas<br>Organic solvents such as pure acetone, toluene, chloroform or methylene chloride | | | |
| Calibration | Two-point calibration in oxygen free (e. g. nitrogen 5.0, 1 % sodium sulfite solution) and air-saturated environment (20.9 % oxygen, air-saturated water). | | | |
| Storage stability | 5 years provided the sensor material is stored at room temperature in dry conditions and in the dark | | | |
| Pressure resistance* | 3 bar | | | |
| Temperature range operation | Optimal: 0 °C to + 40 °C<br>Max.**: - 10 °C to + 90 °C | | | |
| Temperature range storage | Optimal: room temperature (+ 20 °C ± 5 °C)<br>Max.: 0 °C to + 70 °C | | | |
| | USP Class VI compatible | Safe for food application | Hydrophobic Teflon coating | Fast response time |

*at 20 °C, 960 – 980 hPa; humidified gas mixture

**after customized calibration

***determined changing from 20.9 % oxygen gas to nitrogen 5.0

****determined changing from air saturated water to a freshly prepared 1 % sodium sulfite solution

**Tab. 25** Temperature sensor characteristics

| TEMPERATURE SENSOR | |
|---|---|
| Sensor type | NTC sensor |
| Temperature performance | Accuracy below ± 1 °C |

# 11 Troubleshooting

1. The OXYnoris not responding:

    - Is the power adapter connected and working?
    - Is the digital interphase cable connected?
    - Is the COM Port number set correctly?
    - Are the Port settings correct? (SENTEC proprietary and Modbus protocol are different!)
    - Is the Baud rate set correctly?
    - Is the device ID set correctly?
    - Is the protocol / syntax correct?

2. The OXYnorcommunicates only sporadically:

    - Is the RS485 connected correctly?

3. The device measures temperature but no oxygen values:

    - Check the maximum temperature settings

4. The 4 – 20 mA output only gives a stable value:

    - Is the mode set to fixed?
    - Is this value the set error value?

# 12 Concluding Remarks

Dear Customer,

With this manual, we hope to provide you with an introduction to work with the OXYnor.

This manual does not claim to be complete. We are endeavored to improve and supplement this version.

We are looking forward to your critical review and to any suggestions you may have.

You can find the latest version at www.sentec.no

With best regards,

Your SENTEC

Team