Manual for SWAP soil Redox probes

Version: 2024-V1

Contents

About this manual

This manual is originally written in English. Versions in another language of this manual are a translation of the original instructions.

Safety and Information symbols
Symbols used in this manual:

⚠ **WARNING**
This symbol identifies a hazard that could lead to personal injury, including death.

⚠ **CAUTION**
This symbol identifies a hazard that could lead to damage to the machine, damage to other equipment and/or environmental pollution.

⚠ **ATTENTION**

Follow the instructions carefully to prevent errors or damage.

INSTRUCTION

Follow the instructions carefully to obtain optimal results and prevent errors.

Notices

Copyright

CE conformity
The SWAP soil ORP probe and SWAP soil ORP profile probes conform to EC regulations regarding electromagnetic emissions and susceptibility when used according to the instructions contained within this user manual, and is CE marked by SWAP instruments B.V.

Design change
SWAP instruments B.V. reserves the right to change designs, specifications and technical data of its products at any time without prior notification.

Disclaimer
SWAP instruments B.V. is not responsible and/or liable for any damage to the environment and goods and/or personal injury due to the (incorrect) use of the products. SWAP instruments B.V. is also not responsible for the outcome of the measurement results.

Intended use and application
SWAP probes are intended to be used solely in scientific applications performing environmental measurements. Every other use should be consulted and confirmed in writing by the manufacturer prior to operational use.

User qualification
Users should be physically and mentally fit, qualified and trained to use the equipment with respect to personal and environmental safety. The user should be equipped with all needed safety and wellbeing gear for both indoor as outdoor applications.

1. Introduction

Thank you for using our products. Much effort has been made to offer you these products, indented for high quality soil ORP measurements during its lifetime. We welcome your comments at SWAPinstruments.com.

The SWAP soil Redox probes measure soil Redox potential – also called Oxidation-Reduction Potential (ORP). The Redox sensitive electrodes are 99.99% Pt rings, that are embedded in an epoxy glass fibre shaft. Both analog and digital probes are available. The analog versions require special attention. A high impedance input of the readout equipment for these probes is required. The digital versions communicate by the SDI-12 protocol and have several advantages over the analog versions. All digital versions of the SWAP soil Redox probes have embedded electronics (high impedance input) and an integrated temperature sensor. The head and the tip of all soil Redox probes are made from POM-C. The tip contains the integrated double junction 3 M KCl gel Ag|AgCl reference electrode. It is a pointed tip for easily penetrating the probe into the soil. The PUR cable with a standard length a 5 meter leaves the head of the probe from the side and contains a M8 industry standard 4 pole waterproof plug. The plug can be connected to the SWI interface or a datalogger.

All probes are factory calibrated with Redox test solutions with known oxidation-reduction potentials and can be recalibrated by the user.

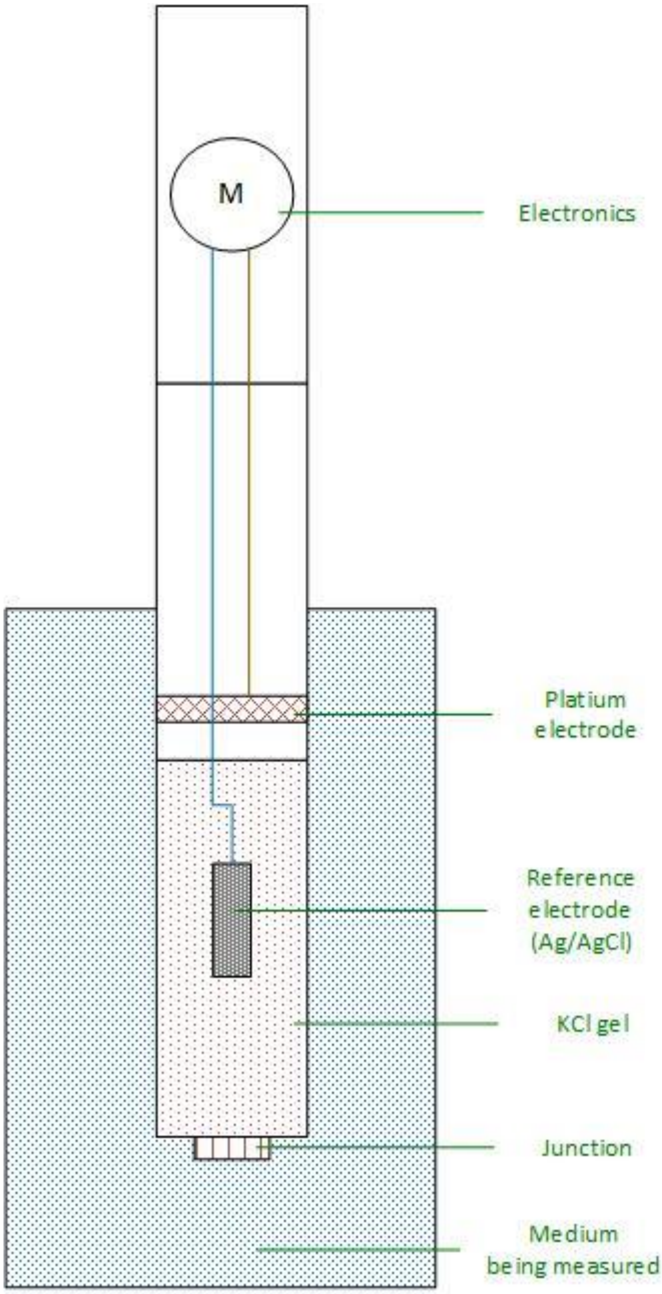
2. Working principle

The SWAP soil Redox probes are combined sensors with single or multiple measuring electrodes and a reference electrode. The measuring electrodes, made from 99.99 % Pt, detect changes in the Redox potential, while the reference electrode provides a stable comparison signal. The embedded electronics measures the signal accurately, applies calibration and converts it into a digital signal.

A Redox measurement reflects the ability of chemical species to oxidize or reduce other chemical species in solution. All redox active species present in solution contribute to the oxidation-reduction potential of that solution. Redox is measured as a single voltage in millivolts (mV). Oxidizers – like O_2, H_2O_2 and Cl_2 – have a positive Redox value, while reducers – like Fe, C and H_2S – have a negative Redox value.

For more information see (Background info)

https://www.swapinstruments.com/products/soil/documentation/



3. Care and safety

⚠ Before use, remove the protection and storage bottle (with 3 M KCl gel) from the tip (of the reference electrode) before inserting it into the soil. The tip of a SWAP soil Redox probe is pointed to ease soil insertion. Care must be taken, and handling precautions followed. Only insert SWAP soil Redox probes into soils and sediments.

⚠ Take care when attaching cables to ensure that the connectors are clean, undamaged and properly aligned before pushing the parts together.

⚠ Do not pull a SWAP soil Redox probes out of the soil by its cable.

⚠ If you feel strong resistance when inserting a SWAP soil Redox probe into soil, it is likely you have encountered a stone. Stop pushing and re-insert at a new location.

⚠ Use the SWAP pre-drills for easy soil insertion and to avoid damaging the probe(s).

4. Product overview

4.1 Features

- ✓ Redox potential accurate to 5 mV (Hanna ORP test solution 240 mV at 25 °C)
- ✓ Temperature accurate to ± 0.2 °C for 0 – 20 °C
- ✓ Excellent stability
- ✓ Minimal soil disturbance
- ✓ Easy installation at depth in holes augered with the SWAP pre-drill
- ✓ PUR cable, waterproof connector to IP67
- ✓ Rugged, weatherproof and can be buried.
- ✓ Good electrical immunity

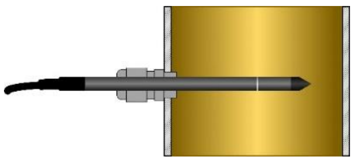
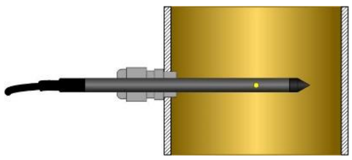
4.2 Technical specifications

For more information about the technical specifications visit swap-soil-redox-probes-technical-specs-1.pdf (swapinstruments.com)

5. Parts list

Your shipment with soil Redox probes may include the following:

SWAP Soil Redox probes (analog)	
	**ORP 30-1-B** ✓ 1 x Redox electrode (99.99 % Pt): at 30 cm from probe top side ✓ Analog output (mV ORP) ✓ 3-meter PUR cable screened with open wire ends ✓ Length 36.5 cm, diameter 1.4 cm, weight 0.12 kg
	**ORP 40-4-B** ✓ 4 x Redox electrode (99.99 % Pt): at 10, 20, 30 and 40 cm from probe top side ✓ Analog output (mV ORP) ✓ 3-meter PUR cable screened with open wire ends ✓ Length 46.5 cm, diameter 1.4 cm, weight 0.18 kg
	**ORP 80-4-B** ✓ 4 x Redox electrode (99.99 % Pt): at 20, 40, 60 and 80 cm from probe top side ✓ Analog output (mV ORP) ✓ 3-meter PUR cable screened with open wire ends ✓ Length 86.5 cm, diameter 1.4 cm, weight 0.26 kg
	**ORP 30-1-A** ✓ 1 x Redox electrode (99.99 % Pt): at 30 cm from probe top side ✓ 1 x Temperature electrode (NTC): at 29 cm from probe top side ✓ Integrated reference electrode: Ag/AgCl, 3 M KCl gel, double junction ✓ Analog output (mV ORP) ✓ 3-meter PUR cable screened with open wire ends ✓ Length 39 cm, diameter 1.4 cm, weight 0.15 kg
	**ORP 40-4-A** ✓ 4 x Redox electrode (99.99 % Pt): at 10, 20, 30 and 40 cm from probe top side ✓ 1 x Temperature electrode (NTC): at 29 cm from probe top side ✓ Integrated reference electrode: Ag/AgCl, 3 M KCl gel, double junction ✓ Analog output (mV ORP) ✓ 3-meter PUR cable screened with open wire ends ✓ Length 49 cm, diameter 1.4 cm, weight 0.22 kg

SWAP Soil Redox probes (analog)	
	**ORP 80-4-A** ✓ 4 x Redox electrode (99.99 % Pt): at 20, 40, 60 and 80 cm from probe top side ✓ 1 x Temperature electrode (NTC): at 29 cm from probe top side ✓ Integrated reference electrode: Ag/AgCl, 3 M KCl gel, double junction ✓ <u>Analog output (mV ORP)</u> ✓ 3-meter PUR cable screened with open wire ends ✓ Length 89 cm, diameter 1.4 cm, weight 0.30 kg
	**ORP 30-1-BNC** ✓ 1 x Redox electrode (99.99 % Pt): at 30 cm from probe top side ✓ Integrated reference electrode: Ag/AgCl, 3 M KCl gel, double junction ✓ <u>Analog output (mV ORP)</u> ✓ 1.2-meter PUR cable screened with BNC connector ✓ Length 39 cm, diameter 1.4 cm, weight 0.20 kg
	**ORP-10-1-C** ✓ Ideal for column experiments ✓ Also suitable for field measurements ✓ 1 x Redox electrode (99.99 % Pt): at 10 cm from probe top side ✓ <u>Analog output (mV ORP)</u> ✓ 3-meter PUR screened cable with open wire ends ✓ Length 14.5 cm, diameter 0.8 cm **Price: 150.00 Euro**
	**TMP-10-1-C (temperature probe)** ✓ Ideal for column experiments ✓ Also suitable for field measurements ✓ 1 x Temperature electrode (NTC): at 10 cm from probe top side ✓ <u>Analog output</u> (resistance 10Kohm@25°C) ✓ 3-meter PUR screened cable with open wire ends ✓ Length 14.5 cm, diameter 0.8 cm **Price: 150.00 Euro**

SWAP Soil Redox probes (analog)	
Custom made probe	**ORP-custom made** ✓ x-number of Redox electrodes (99.99 % Pt): at specified distances from probe top side: ✓ Maximum number of Redox electrodes: • Option 1: Max. 4 Pt electrodes (no NTC and no integrated reference electrode) • Option 2: With integrated reference electrode, max. 3 Pt electrodes • Option 3: With integrated temperature electrode (NTC), max. 2 Pt electrodes • Option 4: With integrated reference electrode and integrated temperature electrode, max. 1 Pt electrode ✓ 1 x Temperature electrode (NTC): at specified distance from probe top side ✓ Integrated reference electrode: Ag/AgCl, 3 M KCl gel, double junction ✓ Analog output (mV ORP) ✓ x-meter PUR screened cable (max. 245 meter) with open wire ends or BNC connector ✓ Specified probe length ✓ Diameter 1.4 cm

SWAP Soil Redox probes (SDI-12)	
	**ORP-30-1-D** ✓ 1 x Redox electrode (99.99 % Pt): at 30 cm from probe top side ✓ 1 x Temperature electrode (NTC): at 29 cm from probe top side ✓ Integrated reference electrode: Ag/AgCl, 3 M KCl gel, double junction ✓ SDI-12 output ✓ 5-meter PUR cable with moulded connector IP67 ✓ Length 39 cm, diameter 1.4 cm, weight 0.17 kg
	**ORP-40-4-D** ✓ 4 x Redox electrode (99.99 % Pt): at 10, 20, 30 and 40 cm from probe top side ✓ 1 x Temperature electrode (NTC): at 25 cm from probe top side ✓ Integrated reference electrode: Ag/AgCl, 3 M KCl gel, double junction ✓ SDI-12 output ✓ 5-meter PUR cable with moulded connector IP67 ✓ Length 49 cm, diameter 1.4 cm, weight 0.22 kg
	**ORP-80-4-D** ✓ 4 x Redox electrode (99.99 % Pt): at 20, 40, 60 and 80 cm from probe top side ✓ 1 x Temperature electrode (NTC): at 50 cm from probe top side ✓ Integrated reference electrode: Ag/AgCl, 3 M KCl gel, double junction ✓ SDI-12 output ✓ 5-meter PUR cable with moulded connector IP67 ✓ Length 89 cm, diameter 1.4 cm, weight 0.30 kg
Custom made probe	**ORP-custom made** ✓ x-number of Redox electrodes (99.99 % Pt): at specified distances from probe top side (maximum of 4 Pt electrodes) ✓ 1 x Temperature electrode (NTC): at specified distance from probe top side ✓ Integrated reference electrode: Ag/AgCl, 3 M KCl gel, double junction ✓ SDI-12 output ✓ 5-meter PUR cable (max. 50 meter) with moulded connector IP67 ✓ Specified probe length ✓ Diameter 1.4 cm

SWAP Soil Redox probe drill sets	
	**PRE-50** ✓ Suitable for Soil Redox probes ORP-30-1-B, ORP-30-1-BNC, ORP-30-1-A, ORP-30-1-D and ORP-40-4-D ✓ Length 50 cm, diameter 1.2 cm weight 0.1 kg ✓ Including non-recoil hammer ✓ Length 32 cm, width 10 cm, weight 0.82 kg
	**PRE-100** ✓ Suitable for Soil Redox probes ORP-30-1-B, ORP-30-1-BNC, ORP-30-1-A, ORP-30-1-D, ORP-40-4-D and ORP-80-4-D ✓ Length 100 cm, diameter 1.2 cm, weight 0.2 kg ✓ Including non-recoil hammer ✓ Length 32 cm, width 10 cm, weight 0.82 kg

SWAP Soil Redox probe accessories	
	**REF-12-0-A** ✓ Ag/AgCl, 3 M KCl gel, double junction ✓ Analog output (mV ORP) ✓ 3-meter PUR cable with open wire ends ✓ Length 17.5 cm, diameter 1.4 cm, weight 0.24 kg
	**Electrolyte-100** ✓ 3.0 M KCl gel ✓ 100 ml ✓ For > 30 refills ✓ Including refilling syringe ✓ Length 4 cm, width 4 cm, height 10 cm, weight 0.13 kg
	**CEX-10** ✓ Extension PUR cable per 10 meter ✓ Male / female connectors (IP67) ✓ Custom lengths upon request ✓ Weight 0.27 kg

6. Getting started

6.1 Calibration

The SWAP soil Redox probes (mV ORP) are delivered uncalibrated. It is possible to establish an external calibration by measuring 1 (offset) or more (calibration line) Redox/ORP test solutions with specified Redox/ORP values. See chapter 7 (Maintenance) for more information.

6.2 Cable connections

- ✓ Ensure that the connectors of the cables, probes, wireless interfaces and loggers are clean, undamaged and properly aligned **before** pushing / screwing the parts together.
- ✓ To ensure watertight connections, the connectors must be screwed firmly together.
- ✓ The recommended maximum length of the extensions cables is 50 meter.

6.3 Installation

It is **recommended** to use the SWAP pre-drill to pre-form a hole (12 mm in diameter) before inserting the SWAP soil Redox probes (14 mm in diameter) to the desired installation depth. This is especially essential for dry soils and for inserting the longer version ORP probes (e.g., ORP-40-4-D and ORP-80-4-D).

- ✓ Remove stones and large object.
- ✓ Push or hammer the SWAP pre-drill in the soil. Use the SWAP non-recoil for hammering. If you feel strong resistance, you have probably hit a stone. Stop, and pre-drill a hole at a new location.
- ✓ Push or hammer the SWAP soil Redox probe in the pre-formed hole. Use the SWAP non-recoil for hammering. If you feel strong resistance, you have probably hit a stone. Stop, and pre-drill a hole at a new location. Push or hammer the SWAP soil Redox probe in the new pre-formed hole.
- ✓ Make sure the Pt rings are fully inserted and that they make good soil contact.

6.4 Connecting to a readout unit or datalogger

Readout unit

The analog SWAP soil Redox probes (e.g., ORP-30-1-A) can be connected to a mV/pH meter, for example with a BNC connector. The input impedance or resistance of such an instrument should be at least 10 Giga Ohm, preferable higher. Connection to instruments should kept clean and dry to maintain the input resistance. Please follow the instruction of such a mV/pH meter.

The SDI-12 SWAP soil Redox probes can be connected to the SWAP Wireless Interface (SWI). The standard versions of the SDI-12 SWAP soil Redox probes have an industry standard M8 waterproof 4 contact connector (see 6.4. M8 connector for details). Other connectors or pinning can be used too. Always consult the specifications of the manufacturer.

With the SWI it is possible to read the measured data, to send the data to a cloud service and to calibrate the Redox electrodes using the SWAP SWI app. Consult the SWI operation manual for further instructions.

Datalogger

All SWAP soil Redox probes can be connected to a datalogger.

For analog probes, the input impedance or resistance a datalogger should be at least 10 Giga Ohm, preferable higher. Connection to instruments should kept clean and dry to maintain the needed input resistance. Poor isolation can result into false or slow measurements.

The digital probes connect to SDI-12 input as popular communication standard. The standard versions of the SDI-12 SWAP soil Redox probes have an industry standard M8 waterproof 4 contact connector (see 6.4. M8 connector for details). Other connectors or pinning can be used too. Always consult the specifications of the manufacturer.

The following guidelines are applicable when connecting SWAP instruments probes to a third-party SDI-12 logger:

- Appropriate fusing is recommended.
- The equipment should be secured against overvoltage according to the SDI-12 standard hardware protection suggestions.
- The probes can be on continuous power or powered only when measurements are performed. The probes use 4 mA as supply current.

ORP-D type probes with M8 connector

The digital probes use a M8 connector for waterproof connection to the equipment. Figure 1 shows the pin view (male) of the M8 connector. A table with the pin description is given below (Table 1).

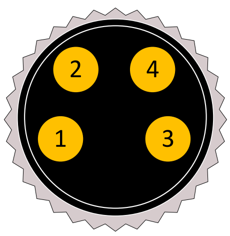


Figure 1. Pin view (male) of the M8 connector.

Table 1. Pin description of the M8 connector of the ORP-D type probes.

Function	Wire colour	Connector pin	Comment
Power supply	Brown	1	+12 volt
Ground	Black	4	0 volt
Data	White	2	SDI-12 communication
Reference	Blue	3	spare

ORP-B type probes with open wires

The analog B type soil Redox probes have Pt electrodes, no temperature sensor and no integrated reference electrode. An external reference electrode (e.g. the REF-12-0-A) should be connected to perform mV measurements. Figure 2 shows an example of an ORP-B type soil Redox probe (ORP-30-1-B). The wire scheme is given in Table 2.

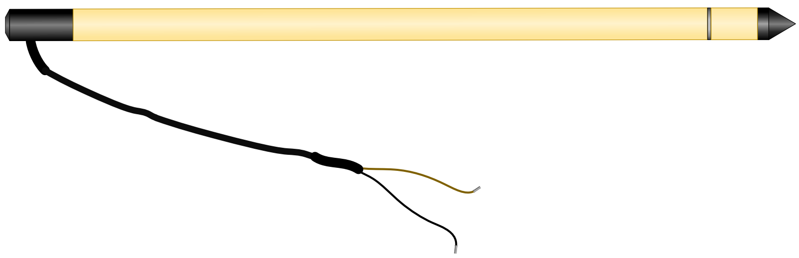


Figure 2. ORP-30-1-B (B type soil Redox probe).

Table 2. Wire scheme of the ORP-B type probes

Function	Wire colour	Comment
Electrode 1	Brown	Top
Electrode 2	Blue	optional electrode
Electrode 3	White	optional electrode
Electrode 4	Black	Bottom
Cable screen	Yellow/Green	

ORP-A type probes with open wires

The analog A type soil Redox probes have a single Pt electrode, a temperature sensor and an integrated reference electrode. Figure 3 shows an example of an ORP-A type soil Redox probe (ORP-30-1-A). The wire scheme is given in Table 3.

Figure 3. ORP-30-1-A (A type soil Redox probe).

Table 3. Wire scheme of the ORP-A type probes

ORP 30-1-A			ORP-40-4-A and ORP 80-4-A		
Function	**Wire colour**	**Comment**	**Function**	**Wire colour**	**Comment**
Pt electrode 1	Brown	-	Pt electrode 1	Brown	-
-	-	-	Pt electrode 2	Red	-
-	-	-	Pt electrode 3	Pink	-
-	-	-	Pt electrode 4	Yellow	-
Reference	Blue	-	Reference	Blue	-
Thermistor	White	NTC (Table 4)	Thermistor	White	NTC (Table 4)
Thermistor	Black		Thermistor	Grey	
Cable screen	Yellow/ green	-	Cable screen	Yellow/ green	-

Table 4. NTC (thermistor specifications)

Temp.°C	Ohms	Temp.°C	Ohms	Temp.°C	Ohms	Temp.°C	Ohms	Temp.°C	Ohms
-20	97006	0	32651	20	12493	40	5325	60	2487
-19	91553	1	31031	21	11943	41	5116	61	2399
-18	86439	2	29500	22	11420	42	4916	62	2315
-17	81641	3	28054	23	10923	43	4724	63	2234
-16	77138	4	26687	24	10450	44	4542	64	2157
-15	72911	5	25395	25	10000	45	4367	65	2082
-14	68940	6	24172	26	9572	46	4200	66	2011
-13	65209	7	23016	27	9165	47	4040	67	1942
-12	61703	8	21921	28	8777	48	3887	68	1876
-11	58405	9	20885	29	8408	49	3741	69	1813
-10	55304	10	19903	30	8056	50	3601	70	1752
-9	52385	11	18973	31	7721	51	3467		
-8	49638	12	18092	32	7402	52	3339		
-7	47050	13	17257	33	7097	53	3216		
-6	44613	14	16465	34	6807	54	3098		
-5	42317	15	15714	35	6530	55	2985		
-4	40151	16	15001	36	6266	56	2877		
-3	38110	17	14324	37	6014	57	2773		
-2	36184	18	13682	38	5774	58	2674		
-1	34366	19	13073	39	5544	59	2579		

Thermistor specification
Resistance @ 25 deg. C = 10,000 Ohm
Tolerance 0-60 deg.C = 0.2 deg.C
Beta value 25/85 = 3976 K

SDI-12 communication

SDI-12 is a well-known communication standard for a variety of sensors used for environmental monitoring. SDI-12 is a digital communication protocol connected by a 3-wire connection: supply, ground and communication (data). As the analog signals are converted to digital signals in the sensor itself, (electromagnetic) interferences are avoided.

SDI-12 sensors are command operated. To perform measurements, commands need to be sent to the sensor.

SWAP instruments supplies you with the instrumentation to get sensor data without bothering the technical SDI-12 knowledge (expected Q2 and Q3 2021). Readout instruments like the SWI interface and the SWAP instruments logger family in combination with the app, know how to 'talk to an SDI-12 probe'. Also, various dataloggers like the Delta-T Devices GP2 datalogger and Campbell Scientific dataloggers communicate without problems. The SWAP instruments probes are equipped with SDI-12 communication version 1.3. For a full explanation of the SDI-12 commands please go to:

http://www.sdi-12.org/archives_folder/SDI-12_version1_3%20January%2028,%202016.pdf

Manual communication with a probe may be needed, for example, when connecting to a third-party datalogger. The basic commands for communication with SDI-12 sensors are straightforward. When sensors have unique addresses, sensor cables can be combined to mutual inputs.

Table 5 shows some SDI-12 functions, commands and responses. 'a' is always the first character in a command. It denotes the sensor address and can be any character from 0-9, a-z or A-Z. Address 0 is reserved for new sensors (from the factory). It can be changed by the user. When multiple sensors are connected to the same communication line, each sensor needs its own individual address. All sensor commands end with the '!' sign. All sensor answers are followed by non-visible control characters <CR><LF> forcing a new line.

Table 5. Examples of basic SDI-12 functions, commands and responses.

FUNCTION	COMMAND	RESPONSE	COMMENT
Address acknowledge	a!	a	sensor is available
change address A to b	aA,b!	b	sensor address is now b
Sensor identification	aI!	a13SWAPINSTREDOXA11321032001	SDI-12 version 1.3
		a13SWAPINSTREDOXA11321032001	manufacturer
		a13SWAPINSTREDOXA11321032001	sensor model
		a13SWAPINSTREDOXA11321032001	sensor version
		a13SWAPINSTREDOXA11321032001	serial number
measurement	aM!	aM000025	in 2 seconds data available
		aM000025	5 measurements available
data register	aD0!	a-1.3-6.3+7.9-2.8+20.6	channel 1 measure = -1.3
		a-1.3-6.3+7.9-2.8+20.6	channel 2 measure = -6.3
		a-1.3-6.3+7.9-2.8+20.6	channel 3 measure = +7.9
		a-1.3-6.3+7.9-2.8+20.6	channel 4 measure = +2.8
		a-1.3-6.3+7.9-2.8+20.6	temperature °C = +20.6

6.5 De-installation

It is **recommended** to carefully dig out the installed SWAP soil Redox probes. This is especially essential for dry soils and for the longer version ORP probes (e.g., ORP-40-4-D and ORP-80-4-D).

- ✓ Carefully dig out the SWAP soil Redox probe.
- ✓ Do not pull out the SWAP soil Redox probe using the electrical cable.
- ✓ Pull by holding the glass-fiber enforced epoxy shaft with both hands.
- ✓ Clean the SWAP soil Redox probe before re-installing into a soil. See chapter 7 (Maintenance) for further details.

6.6 Temperature correction

Redox measurements are influenced by temperature, but in general cannot be compensated for this effect. Redox measurements reflect all oxidation and reduction reactions taking place at the surface of the Redox electrode. Since many chemical species can be involved in these reactions - each with their own temperature dependency - it is not possible to define a single temperature compensation equation.

However, if a sample consists of a single or dominant (high poise) redox species, temperature compensation can be applied. For example, Redox test (calibration) solutions often consist of a chemical species with a high poise. The temperature influence of Consort ORP test solution 358 mV, for example, is established at approximately -1.2 mV/°C (between 5 and 40 °C). Also, Redox measurements in chlorinated water can be corrected for the influence of temperature.

The temperature correction factor can be established as follows:

1) Measure the Redox potential and temperature of a sample (e.g., Redox test solution or soil sample) at varying temperatures.

2) Plot the temperature on the x-axis and the measured Redox potential on the y-axis (see Figure 4: example of the T effect on Hanna ORP test solution 240 mV). Perform a linear regression analysis. The slope is the temperature correction factor (T_factor).

3) The equation for the temperature correction is as follows:

Eh_T_compensated (at 25 °C) = Eh_measured + T_factor x (25 - T_measured)

In which,
Eh_T_compensated = Temperature compensated Redox potential (in mV)
Eh_measured = Measured Redox potential (in mV)
T_factor = temperature correction factor
T_measured = measured temperature (in °C)

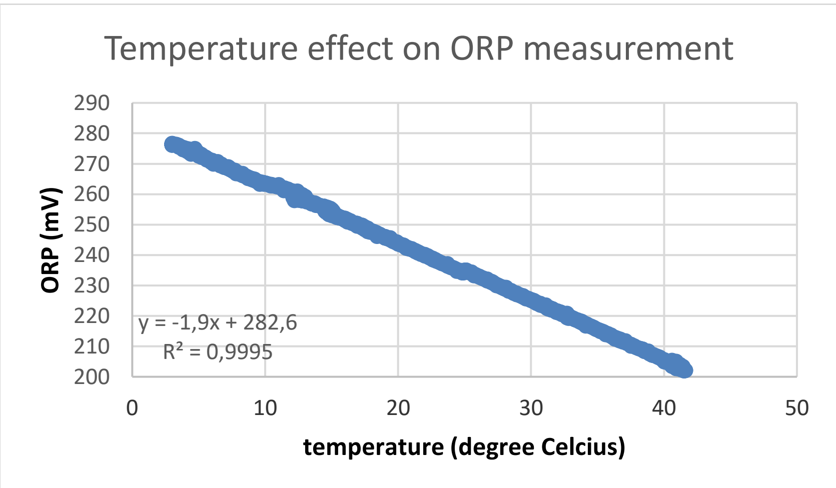


Figure 4. Temperature effect on the ORP measurement of Hanna ORP test solution 240 mV. Measured with SWAP ORP-30-1-D (vs. 3 M KCl gel Ag|AgCl reference electrode).

7. Maintenance

7.1 Calibration

The SWAP soil Redox probes are delivered uncalibrated. It is possible to establish an external calibration by measuring 1 (offset) or more (calibration line) Redox/ORP test solutions with specified Redox/ORP values. This can be done with any suitable Redox test solution (e.g., Zobell's Solution, Quinhydrone Solutions and/or tap water). There are also ORP test solutions on the market that contain/consist of sulphuric acid with acidities as low as pH < 1. We do not recommend these test solutions since they can dissolve the glass fibre epoxy housing of the SWAP soil Redox probes.

External calibration can be performed as follows:

<u>Materials:</u>

- SWAP soil Redox probe
- readout unit or datalogger
- Redox calibration / test solutions

<u>External calibration</u>

1) Connect the SWAP soil Redox probe (clean the probe before calibration) to the readout unit or datalogger.

2) Place the probe in a beaker filled with the Redox calibration / test solution. Make sure that the reference electrode, the Redox electrode (Pt ring) and temperature sensor of the SWAP soil Redox probe are fully immersed in the solution. Register/save/store the measured Redox potential and temperature (when the signal is stable).

3) Repeat step 2 for every Redox calibration / test solution. Rinse (with demi water) and dry your probe before inserting into a new Redox calibration / test solution.

4) For calibration / test solutions with a high 'Redox strength' (poise) the mV reading should be stable within 30 seconds. When a calibration / test solution with a low poise is used - like tap water - it might take an hour before the mV reading is stable. In general, Redox species in tap water react slowly with Pt.

5) Determine the offset when 1 calibration / test solution is used or the slope, intercept and correlation coefficient of the calibration line when at least 2 calibration / test solutions are used.

Note: the mV reading depends on the calibration / test solution used, the type of reference electrode used and temperature.
SWAP soil Redox probes have integrated 3.0 M KCl gel Ag|AgCl reference electrodes.

<u>Uncontrolled quality</u>

When the calibration data show deviating values from the quality criteria, the error can, for example, be caused by:

1) A contaminated or expired calibration / test solution.

Check the expiry date of the calibration / test solution. Use for every calibration fresh solution to avoid contamination.

2) A fouled Redox electrode (Pt ring).

See chapter 7.2 (Cleaning the Redox electrodes) for more details.

3) Problems with the reference electrode.

See chapter 7.3 (Maintenance of the SWAP reference electrode) for more details.

4) Problems with the readout unit or datalogger.

Check the wiring of the readout unit or datalogger.

Example 3-point calibration

An example of a 3-point calibration is given in Appendix A.

7.2 Cleaning the Redox electrodes

Maintenance of the Redox electrode(s) - Pt ring(s) - of the SWAP soil Redox probes is relatively simple. They should always be cleaned before use and whenever retrieved from the soil. Use the following materials:

- ✓ Piece of cotton cloth.
- ✓ Water and soap, ethanol and/or mild acid (e.g., 0.1 M HCl)
- ✓ Distilled water.
- ✓ Waterproof abrasive paper: P1200 grit or higher

Clean the Redox electrodes with a piece of cotton cloth using the general cleaning agents: water and soap, ethanol and/or mild acid (e.g. 0.1M HCl). Wear protective gloves when using a mild acid. Do not use chemicals that are more aggressive than necessary. Rinse with distilled water after cleaning. Dry afterwards with a piece of cotton cloth.

Probes applied in oxidising environments may respond slowly when subsequently used in reducing environments. Probes may be 'poised' when they have been in contact with sulfides: a thin layer of PtS may have formed that influences the Redox measurements. Polishing the Pt surface with abrasive paper P1200 grit or higher may solve these problems, since this generates a fresh Pt surface.

⚠ **Caution:** always wet polish as contact with fiberglass dust from the probes is undesirable.

7.3 Maintenance of the SWAP reference electrode

SWAP instruments offers both integrated (e.g., in SWAP soil redox probes) and stand-alone reference electrodes. These are all 3.0 M KCl gel Ag|AgCl double junction reference electrodes. Although, SWAP reference electrodes are designed for long-term monitoring, the liquid junction can get clogged (e.g., with soil particles) and the KCl concentration of the internal solution (gel) can change during use. Therefore, regular maintenance is strongly advised (preferably monthly).

Use the following **materials** for maintenance:

- ✓ Piece of cotton cloth
- ✓ Water and soap
- ✓ Distilled water (in laboratory wash bottle)
- ✓ SWAP Electrolyte-100 (3.0 M KCl gel)
- ✓ SWAP tools for emptying and refilling the reference electrode

1) Clean the SWAP probe containing an integrated reference electrode or the SWAP stand-alone reference electrode with water and soap using a piece of cotton cloth. Rinse the probe with distilled water. Dry with a piece of cotton cloth.

2) Open the reference electrode - preferably in a clean workspace to avoid contamination of the inside of the reference electrode.

3) Unscrew the external sealing cap of the reference electrode. Remove the internal solution (gel) from the main chamber with the SWAP syringe.

4) Unscrew the internal sealing cap of the small chamber of the reference electrode. Remove the internal solution (gel) from the small chamber with the SWAP syringe.

5) Hold the SWAP probe or stand-alone reference electrode with the reference electrode upward and the cable top downward.

6) Flush and fill the small chamber completely with 3.0 M KCl gel using the SWAP syringe (make sure the syringe is clean and doesn't contain old internal solution (gel)). Screw the internal sealing cap on the small chamber (hand tight).

7) Flush and fill the main chamber completely with 3.0 M KCl gel using the SWAP syringe (make sure the syringe is clean and doesn't contain old internal solution (gel)). Screw the external sealing cap on the main chamber (hand tight).

8) Remove remnants of the gel from the outside of the probe or stand-alone reference electrode using distilled water.

Calibration and testing

After maintenance of an integrated reference electrode (e.g., in a SWAP soil Redox probe), recalibrate the probe.

See chapter 7.1 (Calibration) for more details.

After maintenance of a stand-alone SWAP reference electrode, it can be tested versus another reference electrode that is known to function properly.

See chapter 7.4 (Testing of the SWAP stand-alone reference electrode) for more details.

7.4 Testing of the stand-alone SWAP reference electrode

To determine if the SWAP (stand-alone) reference electrode (still) functions according to specifications, it can be tested (calibrated) against another reference electrode that is known to be working properly. To ascertain this, this other reference electrode should only be used for calibration purposes. The reference electrode should be the same type of reference electrode (Ag|AgCl) with the same internal solution (3 M KCl gel) as the SWAP (stand-alone) reference electrode.

Use the following **materials** for testing:

- ✓ Beaker with tap water
- ✓ SWAP (stand-alone) reference electrode
- ✓ Reference electrode for calibration purposes
- ✓ mV meter

1) Clean the SWAP (stand-alone) reference electrode with water and soap using a piece of cotton cloth. Rinse the probe with distilled water. Dry with a piece of cotton cloth.

2) Connect the SWAP (stand-alone) reference electrode to one input of the mV meter and the other reference electrode to the other input of the mV meter.

3) The readout, difference between the two reference electrodes, should ideally be 0 mV. In practise, ± 5 mV is good for soil redox measurements.

4) If the readout is > 5 mV, this can be caused by a) the KCl concentration of the internal solution has changed, b) the liquid junction is blocked, c) the reference electrode for calibration purposes or the mV meter doesn't work properly.

Ad a) Refill the reference electrode with fresh internal solution and repeat the test procedure.

See chapter 7.3 (Maintenance of the SWAP reference electrode) for details.

Ad b) Clean the liquid junction of the SWAP (stand-alone) reference electrode according to 1) and repeat the test procedure.

Ad c and d) Make sure that the reference electrode for calibration purposes and/or mV meter work properly.

8. Technical support

8.1 Conditions of Sale

Our Conditions of Sale (see https://www.swapinstruments.com/conditions-of-sale// for the latest version) set out the legal obligations of SWAP instruments on these matters. The following paragraphs summarise the position of SWAP instruments, but reference should always be made to the exact terms of our Conditions of Sale, which will prevail over the following explanation.

1) SWAP instruments warrants that the goods will be free from defects arising out of the materials used or poor workmanship for a period of two years from the date of delivery.

2) SWAP instruments shall be under no liability in respect of any defect arising from fair wear and tear, and the warranty does not cover damage through misuse or inexpert servicing, or other circumstances beyond their control.

3) If the buyer experiences problems with the goods they shall notify SWAP instruments (or SWAP instruments' local distributor) as soon as they become aware of such problem. SWAP instruments may rectify the problem by replacing faulty parts free of charge, or by repairing the goods free of charge at the premises of SWAP instruments in The Netherlands during the warranty period.

4) If SWAP instruments requires that goods under warranty be returned to them from abroad for repair, SWAP instruments shall not be liable for the cost of carriage or for customs clearance in respect of such goods. However, SWAP instruments requires that such returns are discussed with them in advance and may at their discretion waive these charges.

5) SWAP instruments shall not be liable to supply products free of charge or repair any goods where the products or goods in question have been discontinued or have become obsolete, although SWAP instruments will endeavour to remedy the buyer's problem.

6) SWAP instruments shall not be liable to the buyer for any consequential loss, damage or compensation whatsoever (whether caused by the negligence of the SWAP instruments, their employees or distributors or otherwise) which arise from the supply of the goods and/or services, or their use or resale by the buyer.

7) SWAP instruments shall not be liable to the buyer by reason of any delay or failure to perform their obligations in relation to the goods and/or services if the delay or failure was due to any cause beyond the reasonable control of SWAP instruments.

8.2 Service and repairs

Users in countries that have a SWAP instruments distributor or technical representative should contact them in the first instance.

Please contact our service department if one of our products or systems is damaged:

support@swapinstruments.com

Spare parts for our products and systems can normally be supplied within a few working days of receiving an order. Spare parts and accessories for products not manufactured by SWAP instruments may have to be obtained from one of our suppliers. This may result in longer delivery times.

We aim to complete repairs within 10 working days of the customer giving their consent for us to proceed with the repair at the quoted price. In case the products or systems cannot be repaired by SWAP instruments, external specialists will be involved. This may result in longer repair times.

No goods or equipment should be returned SWAP instruments without first obtaining the return authorisation from SWAP instruments or our distributor.

8.3 Technical support

SWAP instruments provides free technical support on all our products and systems. Please contact our service department and we will contact you within one working day.

support@swapinstruments.com

Users in countries that have a SWAP instruments distributor or technical representative should contact them in the first instance.

8.4 Contact details

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Appendix A. Example of a 3-point calibration

This is an example how to calibrate your SWAP soil Redox pobe with 3 calibration / test solutions. The details of the test solutions are given in Table 6. The calibration data are given in Table 7. Figure 5 shows the calibration graph.

Table 6. Specifications of the 3 calibration / test solutions (versus 3.0 M KCl gel Ag|AgCl reference electrode).

Temperature (°C)	**Consort ORP test solution 124 mV[#1]**	**Consort ORP test solution 358 mV[#1]**	**Hanna ORP test solution 240 mV[#2]**
	Data in this table are vs. 3.0 M KCl Ag|AgCl reference electrode		
2	142	-	-
4	139	-	-
5	-	370	273
6	136	-	-
8	133	-	-
10	130	365	263
12	127	-	-
14	125	-	-
15	-	359	254
16	123	-	-
18	121	-	-
20	119	353	244
22	116	-	-
24	114	-	-
25	113	347	235
26	112	-	-
28	114	-	-
30	111	341	225
32	109	-	-
34	106	-	-
35	-	335	215
36	104	-	-
38	101	-	-
40	88	329	205
T effect	~ -1.1 mV/°C	~ -1.2 mV/°C	~ -1.9 mV/°C
Source	Consort data sheet (adjusted for reference electrode used: -11 mV)	Consort data sheet (adjusted for reference electrode used: -11 mV)	SWAP instruments data (adjusted for reference electrode used: -5 mV)

[#1] =versus saturated KCl Ag|Ag Cl reference electrode at 25 °C.
[#2] =versus 3.5 M KCl Ag|Ag Cl reference electrode at 25 °C.

Table 7. Calibration data of the 3 calibration / test solutions measured with a SWAP ORP soil Redox probe (versus 3.0 M KCl gel Ag|AgCl reference electrode).

ORP test solution	**Certified value (mV) according specs.**	**Adjusted certified value (mV) vs 3.0 M KCl at 25 °C**	**Measured value (mV) vs 3.0 M KCl at 25 °C**	**Calibrated value (mV) vs 3.0 M KCl at 25 °C**
Consort 124 mV (vs. saturated KCl at 25 °C)	124	113	129	113
Consort 358 mV (vs. saturated KCl at 25 °C)	358	347	343	347
Hanna 240 mV (vs. 3.5 M KCl at 25 °C)	240	235	240	235

The calibration results in this example are as follows:

Slope = 0.9167

Intercept = 24.998 mV

R^2 = 1.00

Based on this calibration graph, measured soil Redox values can be recalculated using equation 1.

Eh_calibrated = (Eh_measured – 24.998) / 0.9167

In which,

Eh_calibrated = calibrated Redox potential

Eh_measured = measured Redox potential (uncalibrated)

Note: The calibration line is only valid for the Redox potential range that is tested. In case of the above example, the calibration line is valid in the range of 113 to 347 mV (vs 3.0 M KCl Ag|AgCl at 25 °C).

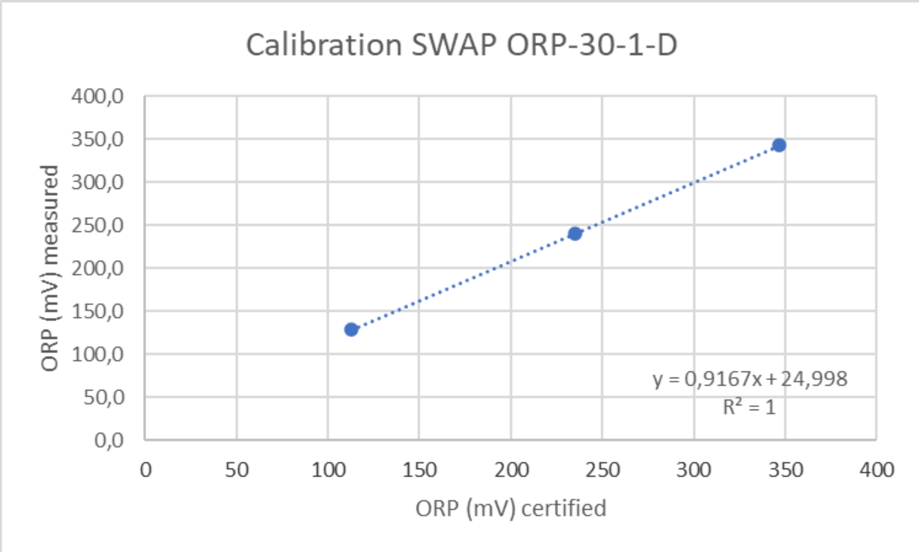
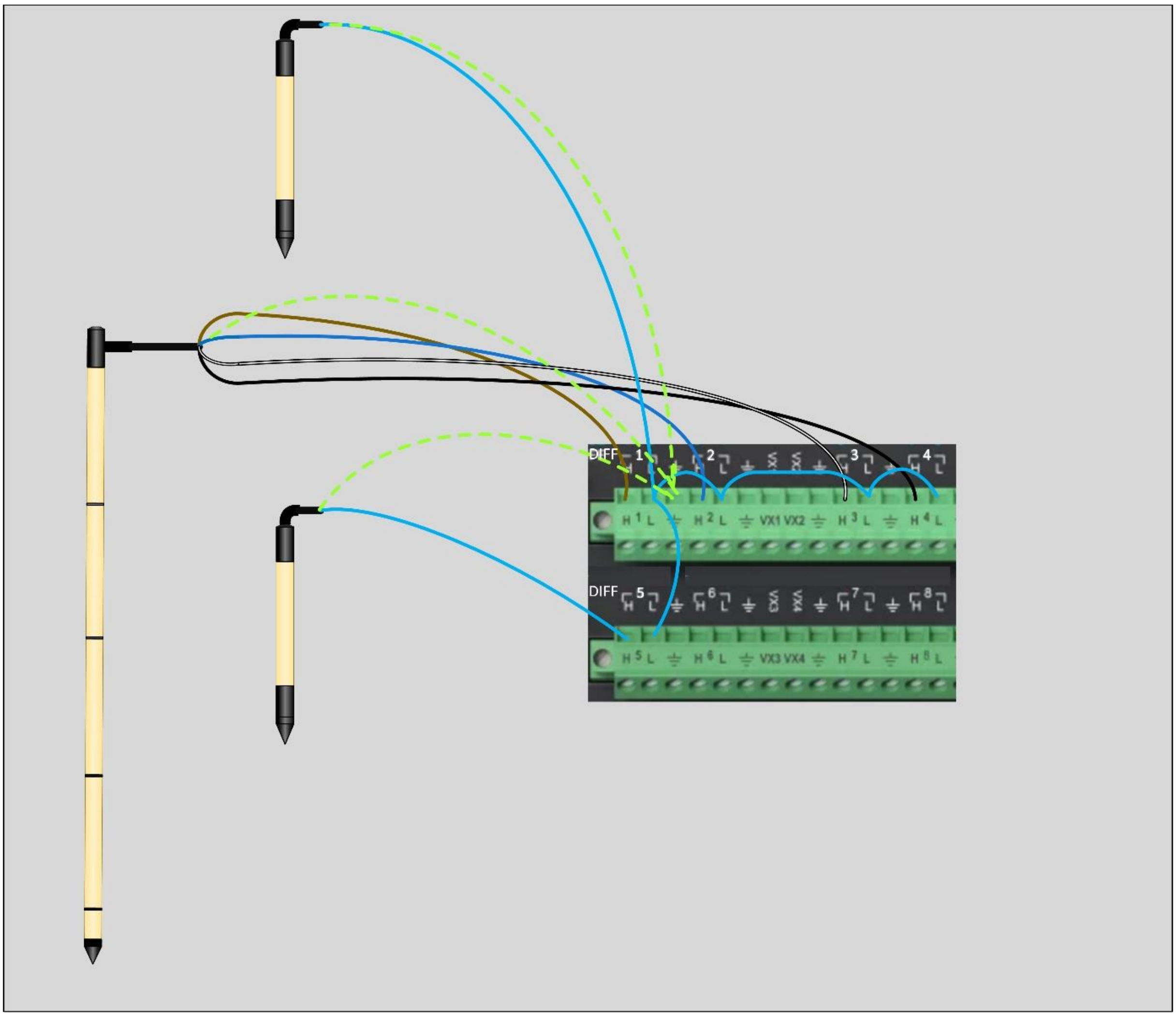


Figure 5. Calibration graph of the measured ORP values vs. the certified ORP values of 3 redox test solutions (vs. 3 M KCl gel Ag|AgCl reference electrode at 25 °C).

Appendix B. Suggestions for datalogger connections

Suggestions for wiring the analog ORP probes in Differential (DIFF) Mode to a logger:

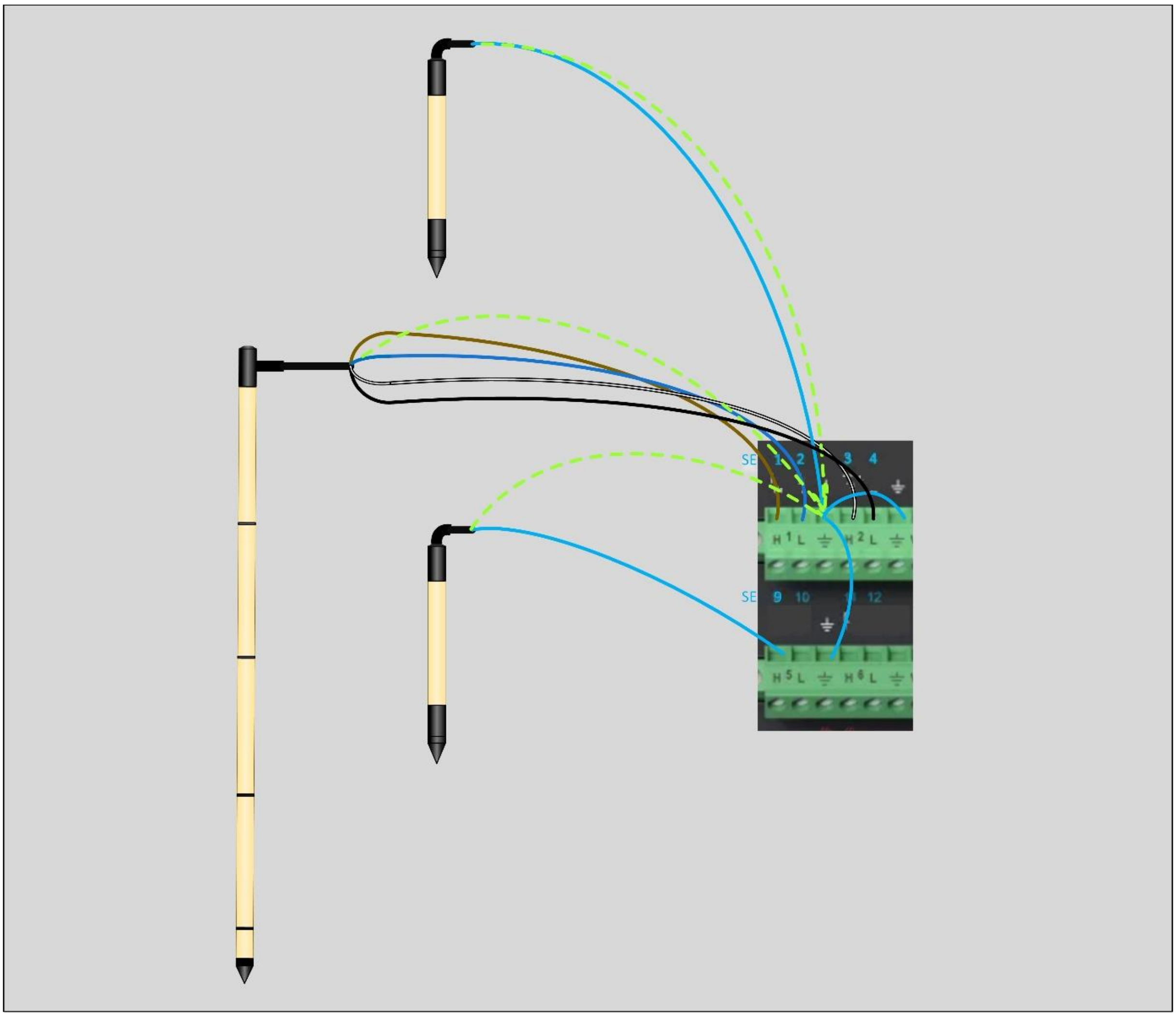
- Connect each individual Pt electrode to a DIFF channel 1..4 H input.
- Connect the reference electrode to all DIF channel 1..5 L inputs.
- Optional: connect a back-up reference as a reference check to DIFF channel 5 H (if the difference voltage rises above 5-10 mV refresh the KCL gel).
- Connect all green-yellow cable screen wires to a common ⏚ signal ground input (only for electromagnetic interference protection).



Suggestions for wiring the analog ORP probes in Single Ended (SE) Mode to a logger:

Beware!
The signal ground terminal ⏚ is not isolated from the logger shielding ground.
Therefore, the logger and his power supply must be isolated from earth!
Place the logger in a plastic enclosure and do not use other sensors or telecom with earth connections!

- Connect each individual Pt electrode to a SE channel 1..4 input.
- Connect the reference electrode to all used SE ⏚ signal ground inputs.
- Optional: connect a back-up reference as a reference check to Channel SE 9 (if the difference voltage rises above 5-10 mV refresh the KCL gel).
- Connect all green-yellow cable screen wires to a common ⏚ signal ground input (only for electromagnetic interference protection).

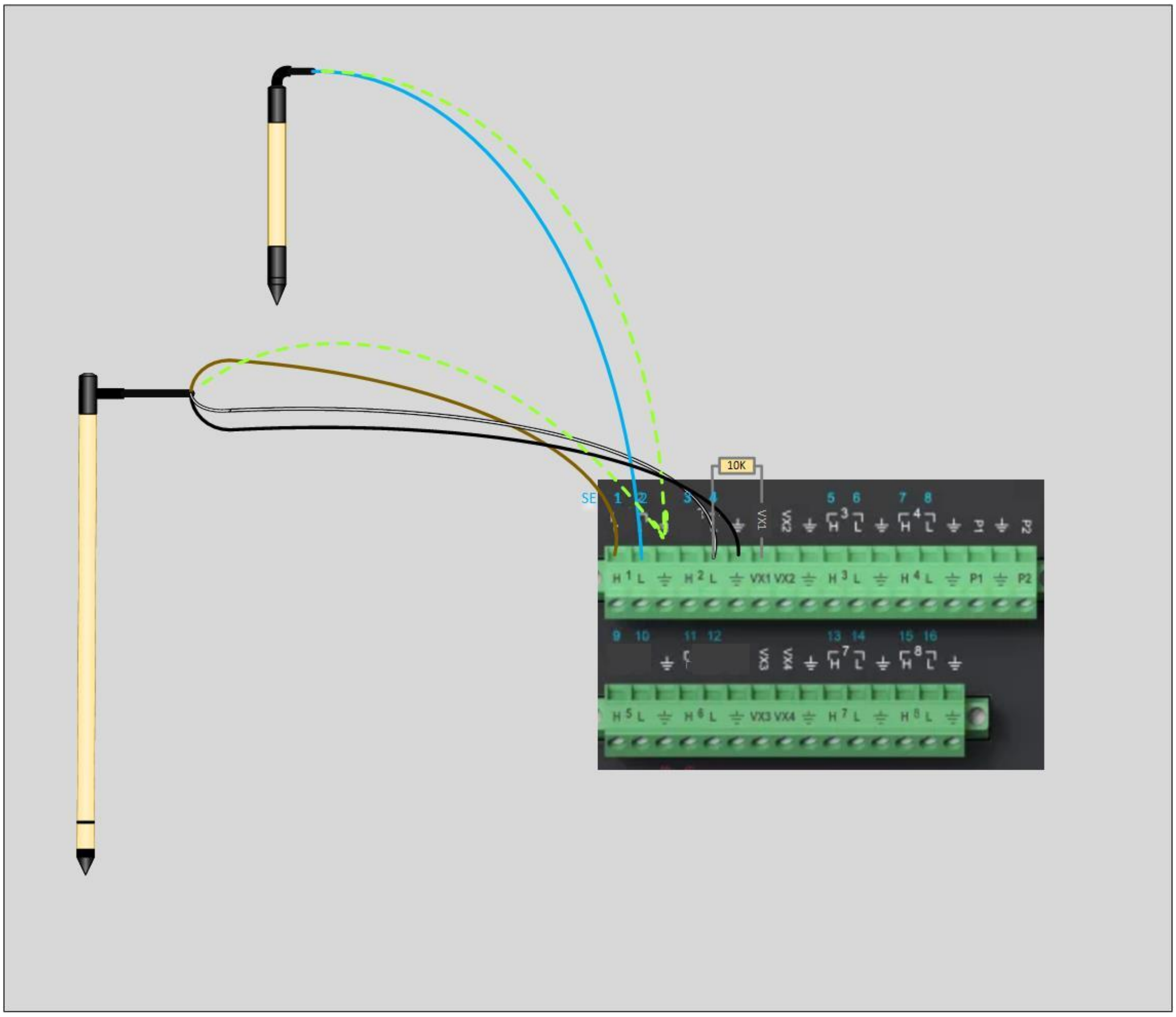


Suggestions for wiring the ORP probes temperature sensor to a logger in single-ended (SE) mode:

The temperature measurement can be done by connecting the probe thermistor sensor (NTC) to the logger. The logger excitation voltage at VX1 with a 10K precision resistor* in series is used to make a voltage divider in combination with the thermistor. Due to the temperature-resistance relation of the thermistor, the divided voltage has a relation to the temperature. This voltage is measured by the logger and converted mathematically to temperature.
Cable length influence on the measured values can be ignored for cables with a maximum length of 100 m.

*Value 10 Kohm, acc. 0.1 % , TC=15 ppm/°C.
[YR1B10KCC - Neohm - Te Connectivity - Through Hole Resistor, 10 kohm, R (farnell.com)]

- Connect a resistance 10,000 Ohm (10Kohm) from the VX1 excitation voltage output to the SE 4 temperature measurement input channel (i.e., channel 4)
- Connect the white wire to terminal 4
- Connect the black wire to terminal ⏚
- Connect all green-yellow cable screen wires to a common ⏚ signal ground input (only for electromagnetic interference protection)



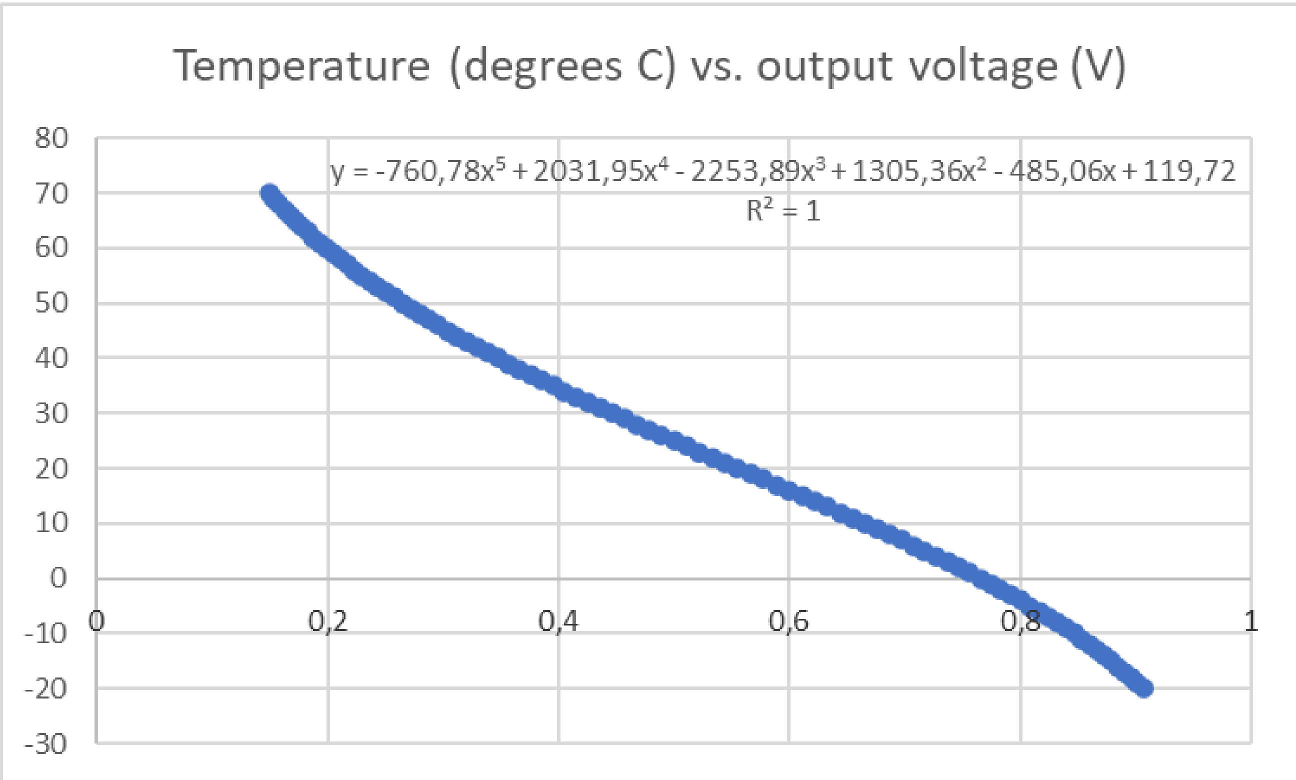
The output voltage, measured with a datalogger, can be calculated based on the following equation:

$U_{output} = U_{excitation} \times R_{thermistor} / (R_{serial} + R_{thermistor})$

In which,
U_{output} = output voltage in V
$U_{excitation}$ = excitation voltage in V
$R_{thermistor}$ = thermistor resistance in Ohm (see Table 4)
R_{serial} = serial resistance in Ohm

Example:

In the Figure below, the temperature is plotted as a function of the output voltage (U_{output}). The output voltage (U_{output}), in this example, is calculated based on an excitation voltage ($U_{excitation}$) of 1 V and a serial resistance (R_{serial}) of 10,000 Ohm. Based on the polymonial function, shown in the Figure below, the temperature can be calculated based on the measured output voltage ((U_{output})).



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