SMP Series Smart Pyranometers

Operational Manual

0374212 | 02-1025

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1 Scope of supply

The following items are included with SMP series pyranometers:

- Smart pyranometer
- Sun shield
- Optional cable, pre-wired with 8-pins connector or connector only for customer cable
- Calibration certificate
- Instruction sheet
- Pyranometer fixing kit SMP3:
  - 2 stainless steel screws each: M5 x 30 mm, M5 X 40 mm and M5 x 50 mm
  - Nuts and flat washers
- Pyranometer fixing kit SMP6:
  - 2 stainless steel screws M5 x 80 mm
  - Nuts and flat washers
  - Nylon insulation ring

2 Order numbers and variant code

2.1 Product variants

Variant	Order number
SMP3	0374900
SMP6	0374920

2.2 Accessories and spare parts

Accessories

Item	Order number
CVF 4 Ventilation Unit, no plug, no cable	0378910-000
CMF1 Mounting Fixture for 1 or 2 unventilated radiometers	0362700
CMF4 Mounting Fixture	0362703
Glare Screen Kit for downwards facing unventilated radiometers	0305722
Glare Screen Kit for downwards facing ventilated radiometers	0305725
AMPBOX signal amplifier, standard gain setting	0365900
METEON Irradiance Meter and Data Logger	0365910
METEON 2.0 Smart Irradiance Meter	0388900
LogBox SE Data Logger	3303096
Fixed Feet	0362705
CMP3 Albedometer Rod	0338720
CM121B Shadow Ring for unventilated radiometers	0346900
CM121C Shadow Ring for ventilated radiometers	0346901
Smart Powered Hub, for up to 6 smart instruments, with integrated AC to 24 V DC power supply	0382440
Smart Hub, for up to 6 smart instruments, for external DC power	0382445
PMU485 Smart Set Hub	0382460

For SMP3, SMP6

Item	Order number
Waterproof 8-pin plug only	2523146
10 m cable, pre-wired with waterproof 8-pin plug	0362621
25 m cable, pre-wired with waterproof 8-pin plug	0362623
50 m cable, pre-wired with waterproof 8-pin plug	0362624
100 m cable, pre-wired with waterproof 8-pin plug	0362625

3 About this manual

3.1 Other applicable documents

The following documents contain further information on installation, maintenance and calibration:

- Smart Explorer Software Manual

3.2 General signs and symbols

The signs and symbols used in the operational manual have the following meaning:

Practical tip

i This symbol indicates important and useful information.

Action

✓ Prerequisite that must be met before performing an action.

▸ Step 1

⇨ Intermediate result of an action

▸ Step 2

⇨ Result of a completed action

List

- List item, 1st level
  - List item, 2nd level

3.3 Explanation of warnings

To avoid personal injury and material damage, you must observe the safety information and warnings in the operating manual. The warnings use the following danger levels:

⚠ WARNING

WARNING

This indicates a potentially hazardous situation. If the hazardous situation is not avoided, it may result in death or serious injuries.

⚠ CAUTION

CAUTION

This indicates a potentially hazardous situation. If the hazardous situation is not avoided, it may result in moderately serious or minor injuries.

NOTICE

NOTE

This indicates a situation from which damage may arise. If the situation is not avoided, products may be damaged.

4 General safety instructions

4.1 Intended use
The pyranometer is used to measure and report the solar radiation.

4.2 Potential misuse
Any use of the product that does not comply with the intended use, be this intentional or negligent, is forbidden by the manufacturer.

- Use the product only as described in the operational manual.

4.3 Personnel qualification
The equipment described in this manual must be installed, operated, maintained and repaired by qualified personnel only.

- Obtain training from OTT HydroMet if necessary.

4.4 Operator obligations
The installer is responsible for observing the safety regulations. Unqualified personnel working on the product can cause risks that could lead to serious injury.

- Have all activities carried out by qualified personnel.
- Ensure that everybody who works on or with the product has read and understood the operational manual.
- Ensure that safety information is observed.
- File the operational manual together with the documentation of the entire system and ensure that it is accessible at all times.

4.5 Personnel obligations
To avoid equipment damage and injury when handling the product, personnel are obliged to the following:

- Read the operational manual carefully before using the product for the first time.
- Pay attention to all safety information and warnings.
- If you do not understand the information and procedure explanations in this manual, stop the action and contact the service provider for assistance.
- Wear the necessary personal protective equipment.

4.6 Risk of burns due to hot surfaces
If the ambient temperature is too high, the metal parts of the housing may heat up (> 60 °C). Touching the housing can cause burns.

- Do not touch the housing.
- Wear protective gloves during installation and maintenance.

4.7 Correct handling
If the product is not installed, used and maintained correctly, there is a risk of injury. The manufacturer does not accept any liability for personal injury or material damage resulting from incorrect handling.

- Install and operate the product under the technical conditions described in the operational manual.
- Do not change or convert the product in any way.
- Do not perform any repairs yourself.

- Get OTT HydroMet to examine and repair any defects.
- Ensure that the product is correctly disposed of. Do not dispose of it in household waste.

4.8 Certification

CE (EU)
The equipment meets the essential requirements of EMC Directive 2014/30/EU.

FCC (US)
FCC Part 15, Class "B" Limits

This device complies with part 15 of the FCC Rules. Operation is subject to the following two conditions:

1. This device may not cause harmful interference.
2. This device must accept any interference received, including interference that may cause undesired operation.

IC (CA)
Canadian Radio Interference-Causing Equipment Regulation, ICES-003, "Class B"

This Class B digital apparatus meets all requirements of the Canadian Interference-Causing Equipment Regulations.

5 Product description

5.1 Design and function

The SMP series instruments are radiometers designed for measuring short-wave irradiance on a plane surface (radiant flux, W/m^2) which results from the sum of the direct solar radiation and the diffuse sky radiation incident from the hemisphere above the instrument.

SMP pyranometers feature a 2-wire smart interface with RS-485 Modbus® (RTU) protocol for connection to programmable logic controllers (PLC's), inverters, digital control equipment and data loggers.

All models are available in two versions. One has an analog voltage output of 0 to 1 V, the other has an analog current output of 4 to 20 mA.

Digital signal processing provides faster response times and, with an integrated temperature sensor, corrects for the temperature dependence of the detector sensitivity. An additional pressure and humidity sensor provides confirmation that the detector remains in stable working condition.

To achieve the required spectral and directional characteristics SMP pyranometers use thermopile detectors and glass domes. The thermopile responds to the total energy absorbed by black surface coating, which is spectrally non-selective. The thermopile warms up and the heat generated flows through a thermal resistance to a heat-sink, the pyranometer housing.

The rise of temperature in the thermopile is easily affected by wind, rain and thermal radiation losses to the environment and the delicate black coating must be protected. Therefore the detector is shielded by domes. These domes allow equal transmittance of the direct solar radiation component for every position of the sun in the hemisphere above the detector. The internal desiccant prevents condensation on the inner sides of the domes, which can cool down considerably on clear windless nights. The pressure and humidity sensor enables desiccant monitoring to clarify that desiccant is not saturated.

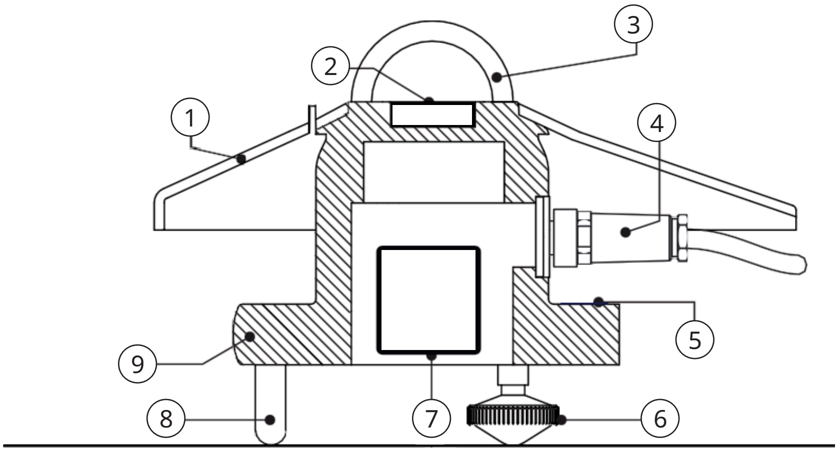
The pyranometers have built-in bubble levels and adjustable leveling feet. Snap-on sun shields reduce solar heating of the housings. The waterproof connectors have gold-plated contacts.

Albedometers are constructed using two pyranometers, an albedometer mounting rod, and a glare screen to prevent direct sunlight from below the horizon entering the lower pyranometer.

Two pyranometers can be used as albedometers. The upper measures incoming global solar radiation and the lower measures solar radiation reflected from the surface below, when the two signal outputs have been converted to irradiance in W/m^3, the albedo can be simply calculated.

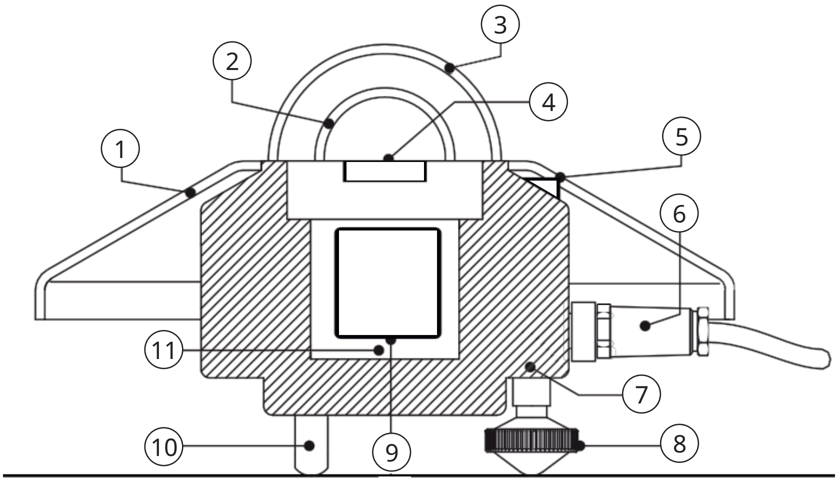
The pyranometer can be delivered with an optional waterproof plug pre-wired to a signal cable. Cables are available in 10 m, 25 m, or 50 m lengths. The instruments can also be ordered with a plug only, for the user to fit their own cable.

5.2 Product overview



SMP3 pyranometer

1	Sun shield	6	Adjustable leveling feet
2	Thermopile detector	7	Smart interface
3	Glass dome	8	Fixed foot
4	Connector	9	Housing
5	Bubble level		



SMP6 pyranometers

1	Sun shield	7	Housing
2	Inner glass dome	8	Adjustable leveling feet
3	Outer glass dome	9	Smart interface
4	Thermopile detector	10	Fixed foot
5	Bubble level	11	Internal desiccant
6	Connector		

6 Transport, storage, and unpacking

6.1 Transport

- Transport the product always in its original packaging.
- Ensure that the product is not mechanically stressed during transport.

6.2 Storage

- Store within specified temperature ranges.
- Store in dry area.
- Store in original box where possible.

6.3 Unpacking

- Carefully remove the product from the packaging.
- Check that the delivery is complete and undamaged.
- If you find any damage or if the delivery is incomplete, then immediately contact your supplier or manufacturer.
- Keep the original packaging for any further transportation.

7 Installation

7.1 Planning installation

For the solar irradiation to be measured in the entire photovoltaic system, it is necessary to position several pyranometers in the system. The number of pyranometers required depends on the system's performance and ambient conditions.

The minimum number of sensors required for a Class A system is defined as follows:

- 1 sensor for each monitoring point to measure the following values:
  - In-plane irradiance (POA)
  - Global horizontal irradiance
- In addition, the following sensors are used for bi-facial performance monitoring:
  - 1 horizontal albedo sensor
    or
  - 3 in-plane rear-side irradiance sensors

The number of monitoring points depends on the system size, as seen in the table below:

System size (AC) in MW	Number of monitoring points	Number of pyranometers
< 40	2	6 to 10
≥ 40 to < 100	3	9 to 15
≥ 100 to < 300	4	12 to 20
≥ 300 to < 500	5	15 to 25
≥ 500 to < 700	6	18 to 30
≥ 700	7, plus 1 for every further 200 MW	21+ to 35+

7.2 Mechanical installation

7.2.1 Preparatory work

- If using the digital output, then set the Modbus® address before visiting the site. Otherwise a computer and RS-485 / USB converter is required during installation.

7.2.2 Required tools and aids

The following tools and aids are required:

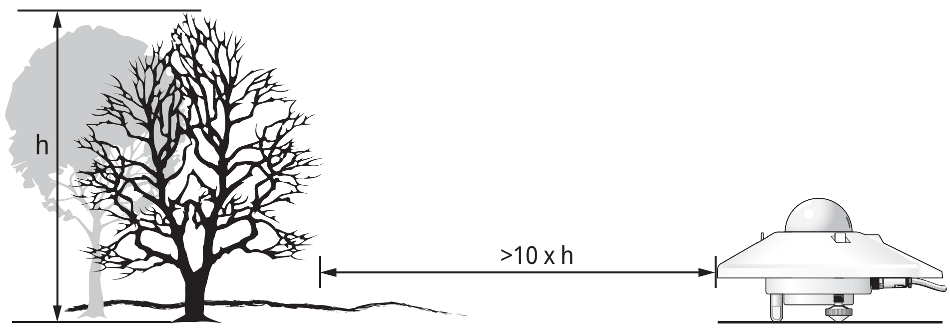
- Allen key, 4 mm
- wrench, 8 mm
- open-ended wrench, 16 mm or ⅝"

7.2.3 Installation for measuring global radiation

7.2.3.1 Choosing a site

There should be no obstructions in the field of view above the instrument's sensor element. If this is not possible, the location of the instrument must be chosen to ensure that obstacles do not rise by more than 5 degrees above the azimuth range between sunrise after the shortest night and sunset on the longest day.

The 5 degrees correspond to a minimum distance from the instrument to the obstacle of 10 times the height of the obstacle:

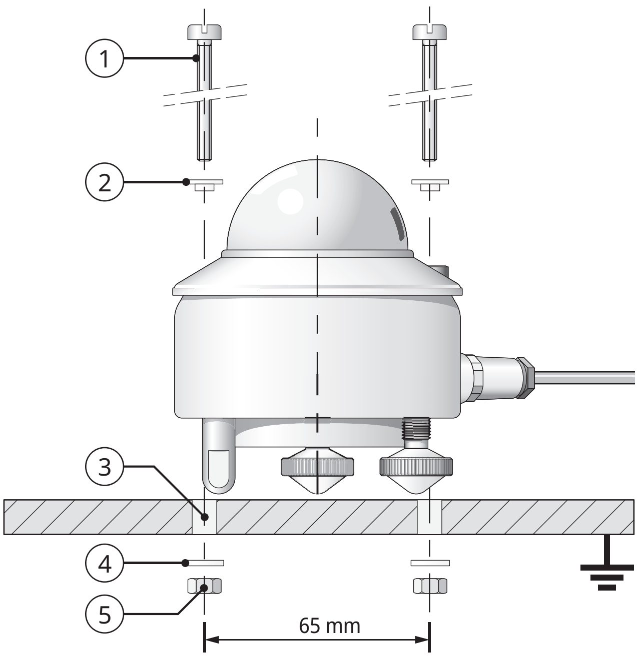


Minimum distance from instrument to obstacle

The minimum distance is important for measuring the direct radiation. The diffuse solar radiation is not so affected by obstacles near the horizon. An obstacle to the field of view that rises 5 degrees over the entire azimuth range of 360 degrees reduces the diffuse radiation directed downwards by only 0.8 %.

- Position the instrument in such a way that no shadows fall on it, for instance from masts.
- Avoid hot exhaust gases with a temperature of over 100 °C in the proximity of the instrument. It can cause measurement deviations.
- Do not position the instrument in front of light-colored walls or any other objects that reflect the sunlight or emit short-wave radiation.

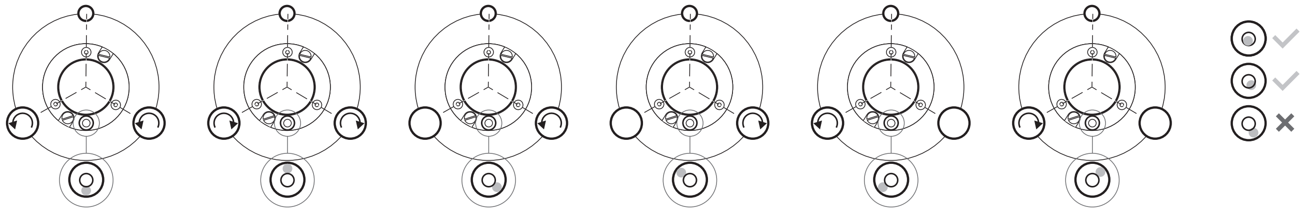
7.2.3.2 Mounting instrument



1	2x M5 x 80 mm screws	4	2x flat washers
2	2x nylon insulating rings	5	2x nuts
3	2x Ø 5.2 mm		

- To insulate the instrument against the temperature of the mounting plate, place the instrument on the adjustable foot and the two leveling feet.

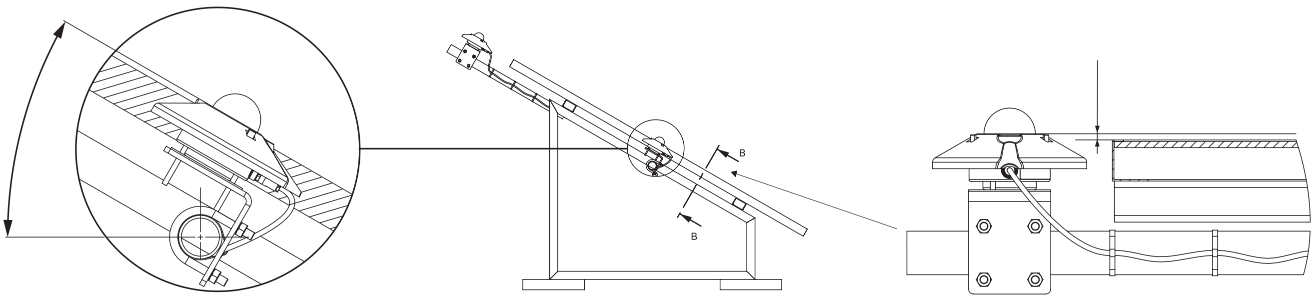
- Position the instrument in such a way that the nuts are located at a distance of 2 to 3 mm from the mounting plate.
- Ensure that the instrument is fixed.
- Ensure that the instrument is not in the shade.
- When installed horizontally, point the cable connector towards the nearest pole to reduce the UV exposure on the cable.
- In order to align the instrument horizontally, rotate the leveling feet until at least half the spirit level bubble is in the inner ring.



- Fix the instrument with the screws, ensure that the instrument retains the correct alignment.
- To prevent corrosion between the screws and the instrument housing, ensure that the nylon insulating rings are fixed.
- Insert the connector with the cable into the instrument's connection socket.
- Tighten the locking ring hand tight.
  NOTICE! The seal may be damaged by overtightening!
- Fix the cable in such a way that the cable doesn't move or cast a shadow on the instrument.
- Fix the sun shield.

7.2.4 Installation for measuring global radiation on sloping surfaces

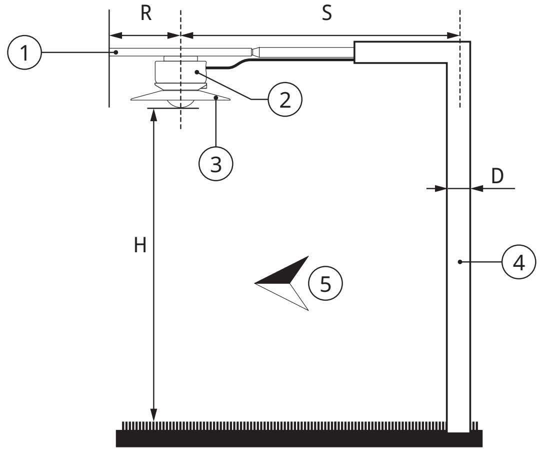
In a photovoltaic system, the pyranometer can be installed at the same angle as the modules. The pyranometer can be mounted using the adjustable leveling feet or using a set of fixed feet that are suitable for mounting on sloping surfaces.



- Place the pyranometer on a horizontal surface.
- Ensure that the leveling feet protrude as far as the adjustable foot.
- Level the pyranometer.
- Label the pyranometer with a note stating that the feet have been set.
- Alternatively, remove the leveling feet and mount the fixed feet.
- Label the pyranometer with a note stating that the fixed feet are suitable for sloping installation.
- Fix the pyranometer on the sloping surface.
- Point the cable connector downwards to reduce moisture exposure around the connector.

7.2.5 Installation for measuring reflected radiation

In inverted position the pyranometer measures the reflected global radiation.



1 Mounting plate
2 Pyranometer
3 Glare screen
4 Mast
5 Equator

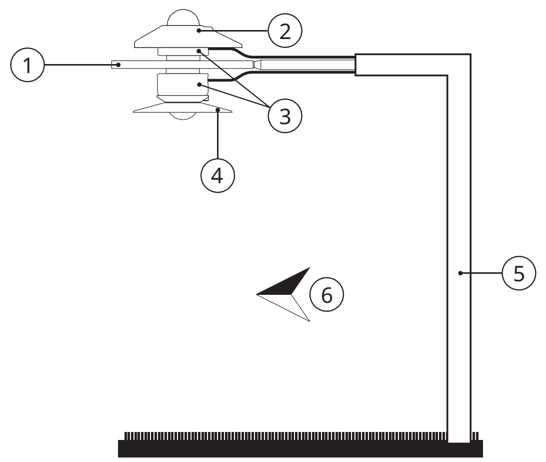
The mounting plate prevents the pyranometer from being heated by solar radiation. The optional glare screen has an angle of 5 degrees and prevents direct radiation on the glass dome during sunrise and sunset.

The mounting device must not excessively disrupt the pyranometer's field of vision. The mast in the illustration absorbs the radiation reflected by the earth's surface with a fraction of D/2πS. In the worst case (sun at its zenith), the pyranometer shadow reduces the signal by a factor of R^2/H^2. As a rule of thumb, a black shadow under the pyranometer with a radius of 0.1 x H reduces the signal by 1%. 99% of the signal comes from a range with a radius of 10 x H.

- Level the mounting plate well, as the pyranometer will be mounted without feet.
- Fix the pyranometer to the mounting plate at a height of between 1 and 2 meters above an even surface such as short grass.

7.2.6 Installation for measuring albedo

An albedometer consists of two identical pyranometers that measure the incident radiation and the radiation reflected by the surface below. Albedo is the ratio of the two radiation measurements and varies from 0 (dark) to 1 (bright).

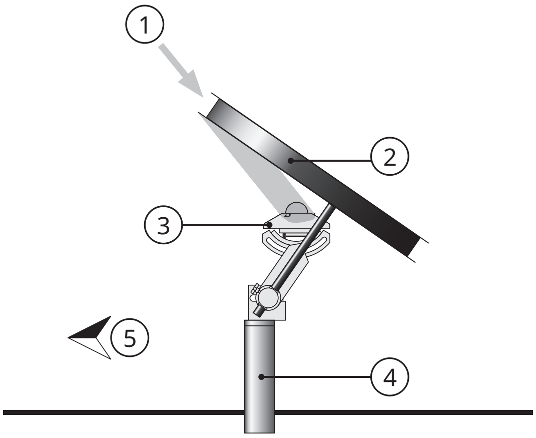


1 Albedo mounting plate
2 Sun shield
3 Pyranometer
4 Glare screen
5 Mast
6 Equator

- Mount the upper pyranometer.
- Mount the lower pyranometer.

7.2.7 Installation for measuring diffuse radiation

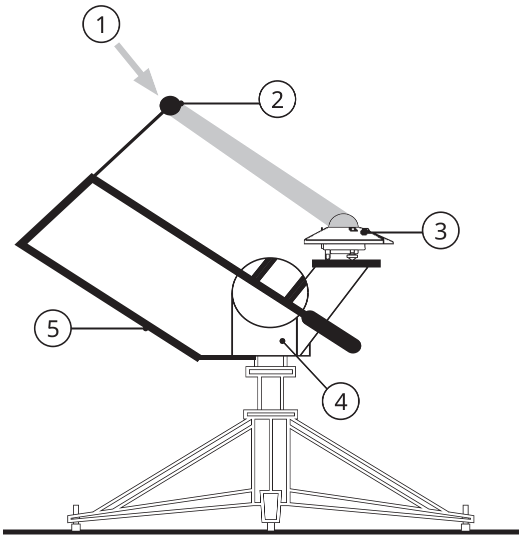
For the diffuse radiation to be measured, the direct radiation on the pyranometer's glass dome must be blocked. The direct radiation can be blocked using a static shadow ring or a two-axis automatic sun tracker.



1 Sun
2 Shadow ring
3 Pyranometer
4 Mounting bracket
5 Equator

Mounting static shadow ring

Because the sun moves across the sky, the static shadow ring interrupts part of the diffuse radiation and needs to be regularly adjusted. At times the shadow ring intercepts a significant proportion of the diffuse sky radiation. Therefore, the recorded data must be revised.



1 Sun
2 Shadow ball
3 Pyranometer
4 Sun tracker
5 Shading assembly

Mounting automatic sun tracker

The automatic sun tracker uses the information regarding its location and the time to calculate the position of the sun. This allows the tracker to be oriented exactly towards the sun whatever the weather. Using a shadowing fixture on the tracker, the pyranometer's glass dome can be shaded all year round without any need for adjustment.

7.3 Electrical installation

7.3.1 Electrical connections

SMP pyranometers can be supplied with a waterproof connector pre-wired to 10 m, 25 m or 50 m of high quality yellow cable with 8 wires and a shield covered with a black sleeve.

> i Longer cable more than 100 m will affect quality of the RS-485 digital signal. It is recommended to minimize the cable length to ensure reliable communication.

7.3.2 Protective grounding for pyranometer

The shield of the cable is connected to the aluminium pyranometer housing through the connector body.

- Secure the pyranometer with its leveling screws on a metal support (i.e. the instrument mount).
- Ensure there is secure contact between the pyranometer housing and the metal support. The preferred method for protective grounding is to connect the metal support to a local protective ground point (e.g. by using a lightning conductor) and do not connect the cable shield at the readout end.
- If there is no good local protective ground connection at the pyranometer, connect the cable shield to a protective ground point at the readout equipment. Lightning can induce high voltages in the shield but these will be led off at the pyranometer or readout equipment, depending on the connection methodology.

7.3.3 Power connection

The minimum power supply voltage for the instrument is 5 V DC. 5-volt-power can only be used with a short cable, maximum 10 m. To ensure reliable performance, a minimum voltage of 12 V DC is recommended. It is advised to protect the input of the pyranometer with a fast acting overcurrent protection device with a maximum rating of 250 mA.

7.3.4 Power consumption

Typical power consumption SMP-V for maximum output (1 V)

Voltage on the pyranometer (V DC)	Current (mA)	Power (mW)
5	10.0	50
12	4.5	55
24	2.5	60

- Maximum power consumption 65 mW at the highest input voltage.
- Maximum input current 12.5 mA at the lowest input voltage.
- Maximum inrush current 200 mA.

Typical power consumption SMP-A for max output (20 mA)

Voltage on the pyranometer (V DC)	Current (mA with 100 Ω load resistor)	Power (mW)
5	28	77
12	24	83
24	6	100

The above Megawatt values represent the dissipation within the SMP-A. For the total power the energy in the load resistor has to be added.

For supply voltages below 12 Volts or above 20 Volts use a load resistor of less than 500 Ω to keep the power consumption as low as possible.

7.3.5 Analog voltage output

The SMP-V (voltage output versions) have been factory set such that an output of 0 Volts represents -200 W/m^2 (this will never be reached in practice), and the full-scale output of 1 Volt represents 2000 W/m^2. The voltage output range in W/m^2 can be changed with the supplied PC software.

The measurement range must start from a negative value in order to show (small) negative readings, for example night-time offsets, because the analog output itself cannot go negative. For the default setting of 0 to 1 Volt representing -200 to 2000 W/m^2 the range is actually 2200 W/m^2 with a zero offset of 200 W/m^2.

The irradiance value ($E_{\downarrow solar}$) for the default setting can be calculated as shown below:

$E_{\downarrow solar}$=	(V x 2200) - 200
$E_{\downarrow solar}$=	Solar radiation
[W/m^2] V =	Output of radiometer [Volt]

If the pyranometer is used in atmospheric conditions it is advised to keep the range as factory set.

7.3.6 Analog current output

The SMP-A (current output versions) have been factory set such that an output of 4 mA represents 0 W/m^2 and the full-scale output of 20 mA represents 1600 W/m^2. The current output range in W/m^2 can be changed with the supplied PC software. The maximum recommended irradiance for the SMP3 and SMP6 are 2000 W/m^2 and for the SMP10 and SMP22 are 4000 W/m^2.

Negative inputs will make the output go below 4 mA and no zero offset is needed. For the default setting of 4 to 20 mA representing 0 to 1600 W/m^2, each mA represents 100 W/m^2.

The irradiance value ($E_{\downarrow solar}$) for the default setting can be calculated as shown below:

$E_{\downarrow solar}$=	(mA - 4) x 100
$E_{\downarrow solar}$=	Solar radiation
[W/m^2] mA =	Output of radiometer [mA]

7.3.7 Wiring information

NOTICE

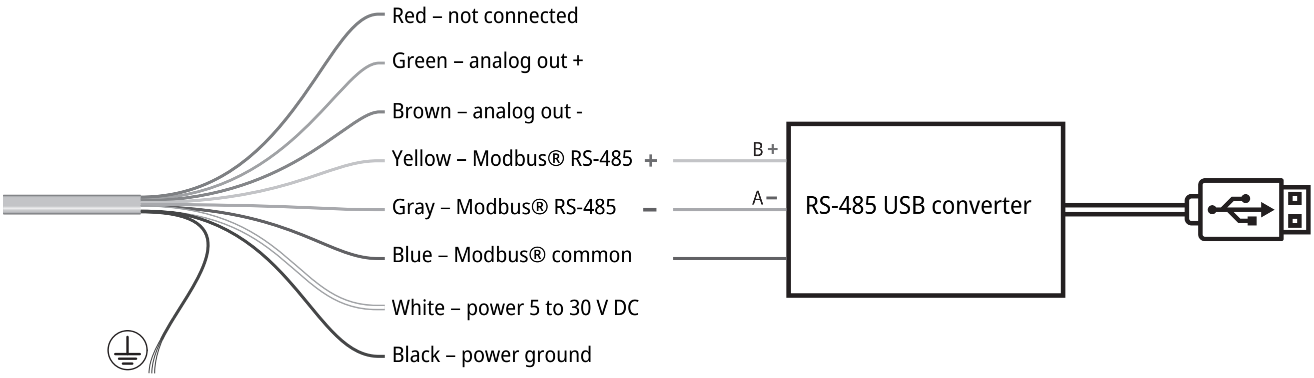
Damage due to lack of insulation!

The power supply units of portable computers such as laptops can generate large voltage peaks.

- Ensure that the RS-485 USB converter has galvanic isolation between the inputs and outputs.

The maximum differential between either of the Modbus® RS-485 lines (yellow and grey) and the power ground / RS-485 common line (black) is 70 V DC.

The instrument must be connected to a computer via an RS-485 converter with a USB port.

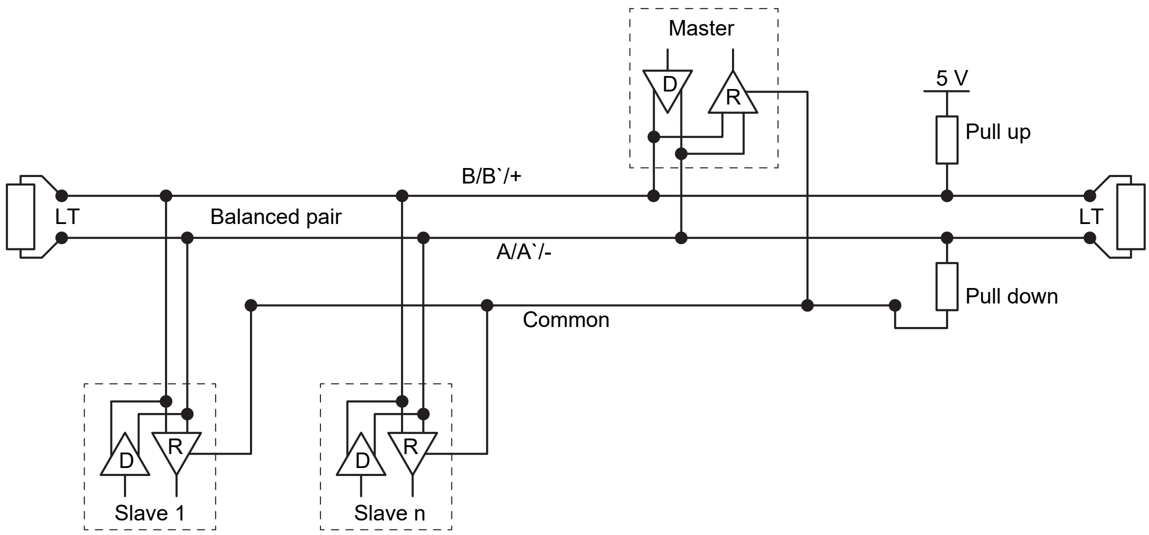


Connection to RS-485 converter

- When connecting the sensor, ensure that the power supply is switched off.
- Connect the white wire and black wire on the power supply unit.
- Connect the yellow, gray and blue wires to the RS-485 converter.
- Isolate and seal the red wire and any other wires when they are not in use.
- Align the indentation on the connector with the indentation on the instruments's connection socket.
- Plug the connector into the connection socket.
- Turn the locking ring clockwise and tighten it hand tight to secure the connector.
  NOTICE! The seal may be damaged by overtightening!
- Switch on the power supply.
- Switch on the computer.

i It may take three hours for the pyranometer to reach a stable temperature. During this time, the irradiation measurements may deviate from the final measurements.

The digital interface can be connected to a 2-wire RS-485 network as shown below.



Connection to a RS-485 network

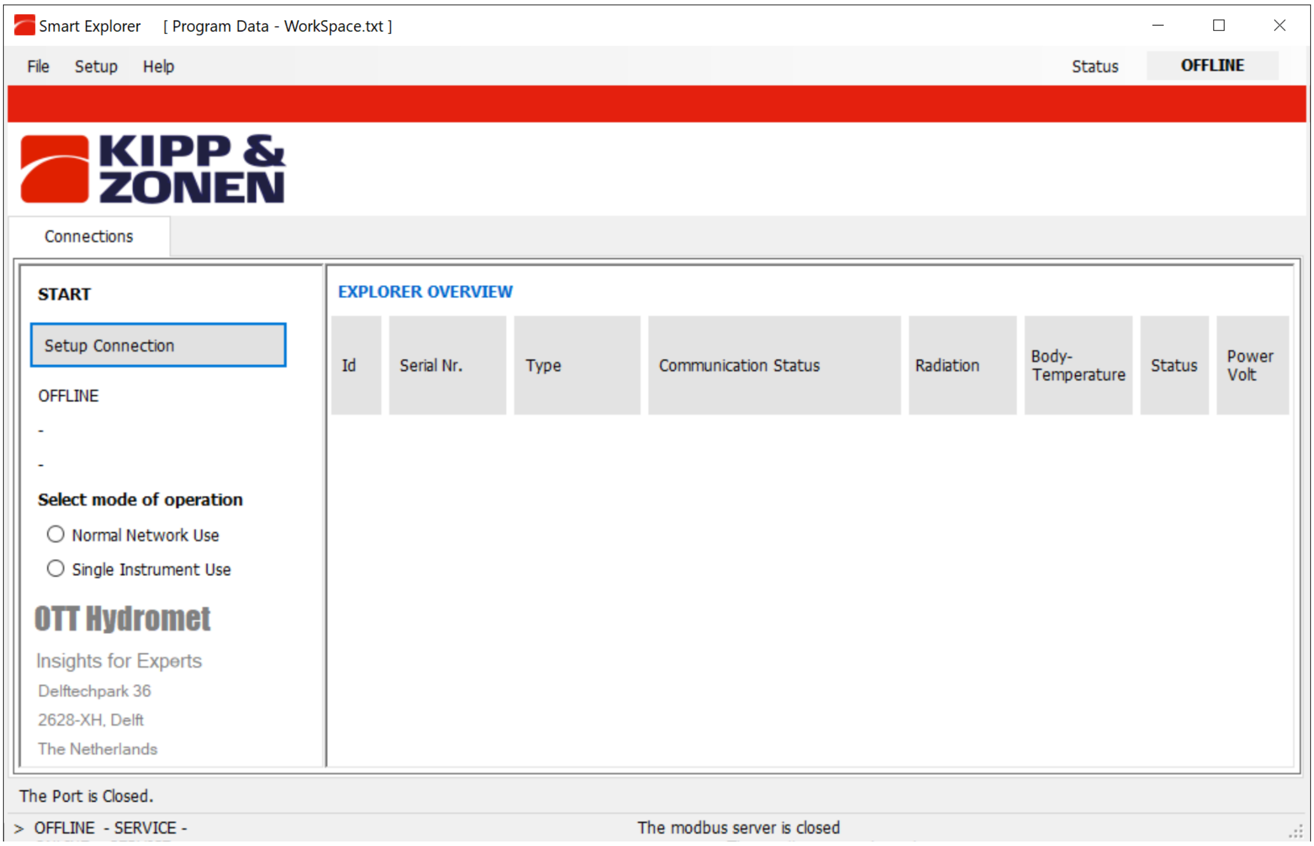
The slaves and master may be a SMP pyranometer or other devices.

- If a SMP pyranometer is the last device on the network, connect a line terminator (LT), consisting of a 120 Ω or 150 Ω resistor, between terminals A/A`/- and B/B`/+.
- Never place this line termination on the derivation cable.
- Install the pull up and pull down resistors as shown, with values between 650 Ω and 850 Ω.

8 Commissioning

8.1 Instrument set-up

The Smart Explorer software allows to configure a smart sensor and to collect real-time data.



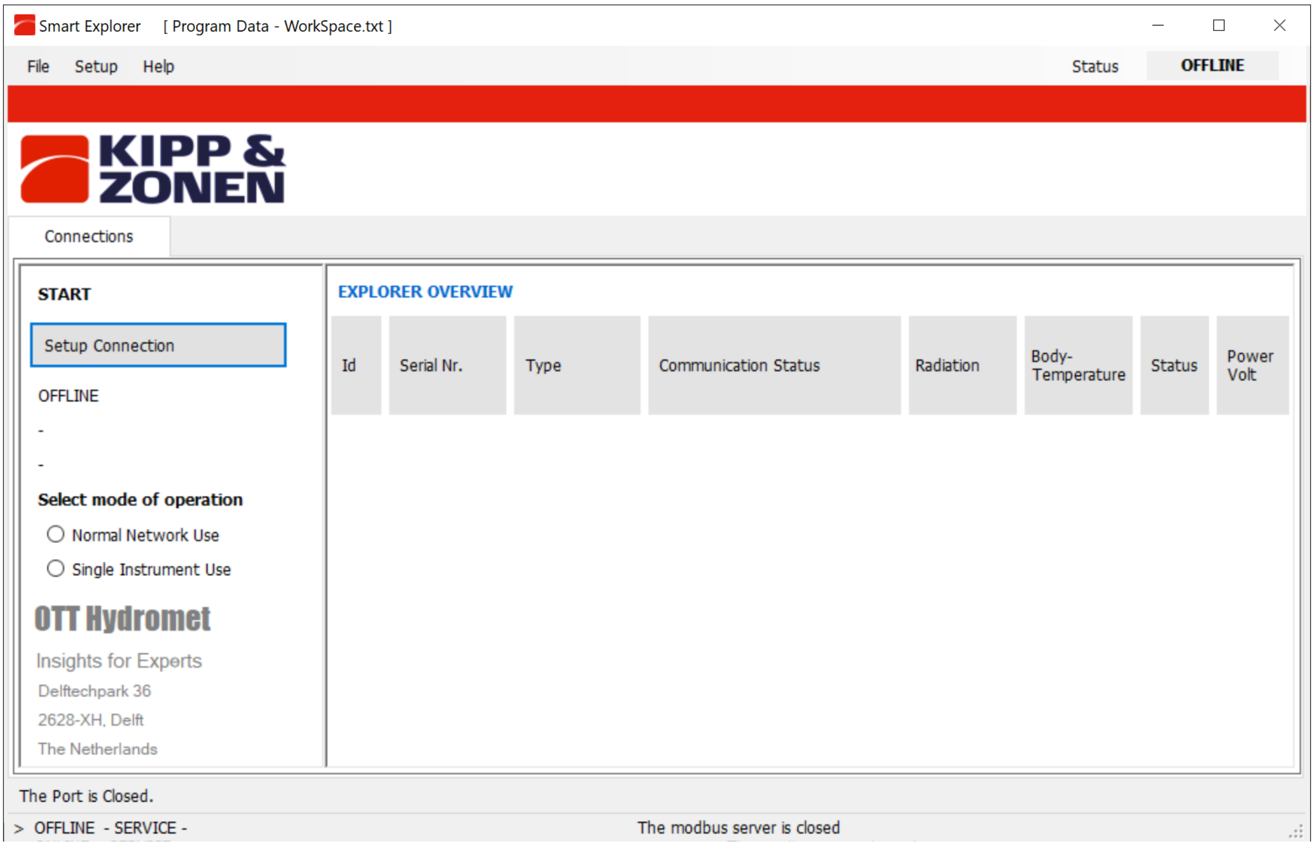
The factory default communication parameters are as follows:

- Modbus® baud rate: 19200
- Parity: even
- Data bits: 8
- Stop bits: 1
- Address: 1

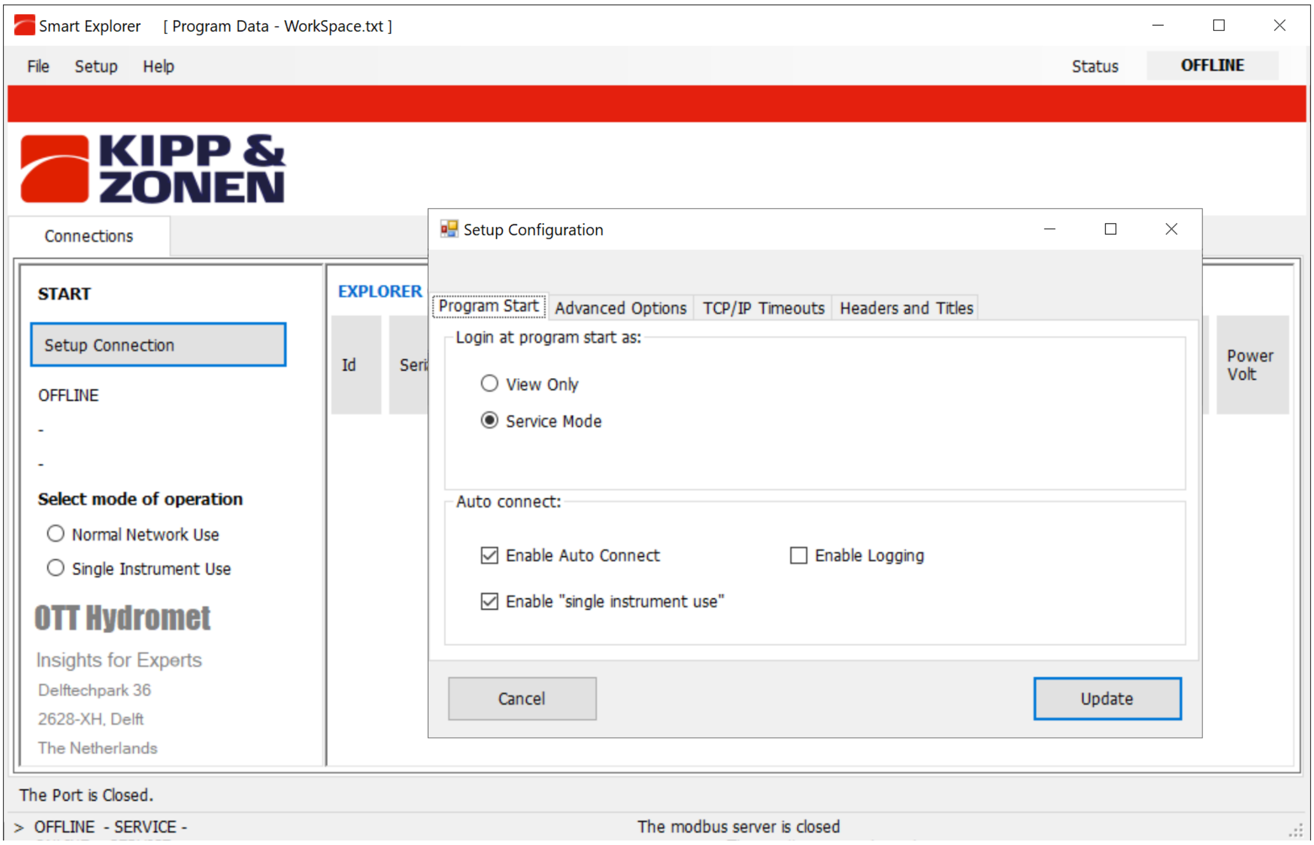
- If using the software on-site, ensure that the software is already installed on the laptop.
- For detailed information about setup, monitoring, and data logging, see the Smart Explore software manual.
- Download the Smart Explorer software and the manual at the following address: www.otthydromet.com

8.1.1 Starting the Smart Explorer Software

- Start the Smart Explorer Software:



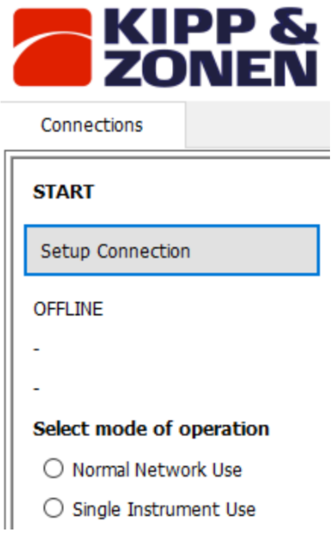
- Click on the *Setup* menu and check whether the following settings are activated:



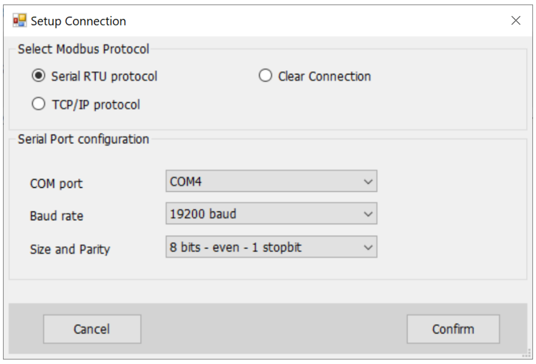
- Adjust the settings if necessary.
- Click on the **Update** button to save the settings.

8.1.2 Establishing connections

- To establish a connection to the instrument, click on the **Setup Connection** button.



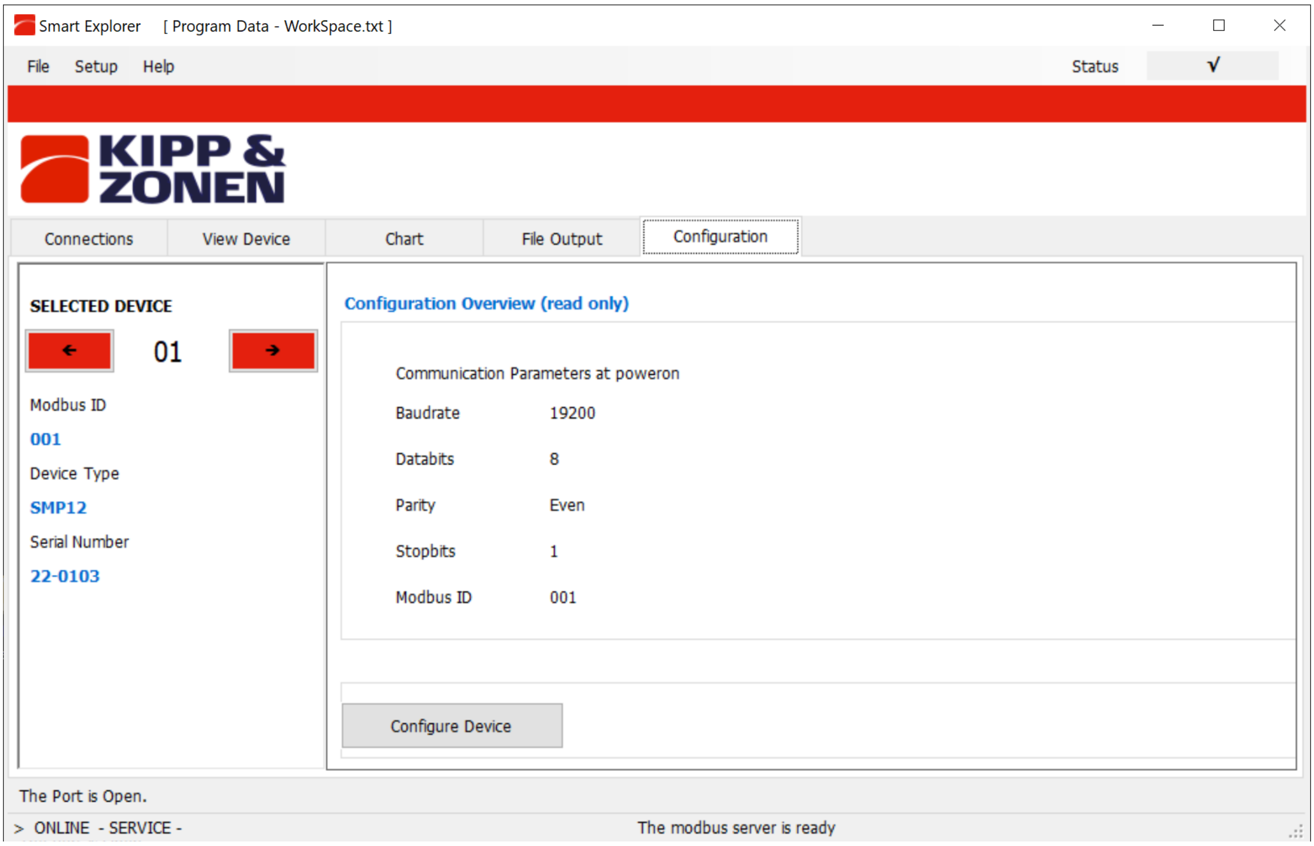
- Activate the *Serial RTU protocol* to establish the direct RS-485 connection.



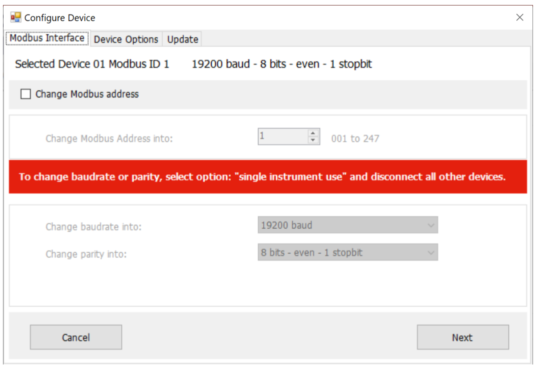
- Select the COM port (see Windows Device Manager).
- Leave the other factory settings unchanged.
- Click on the **Confirm** button to save the settings.

8.1.3 Adjusting the communication parameters

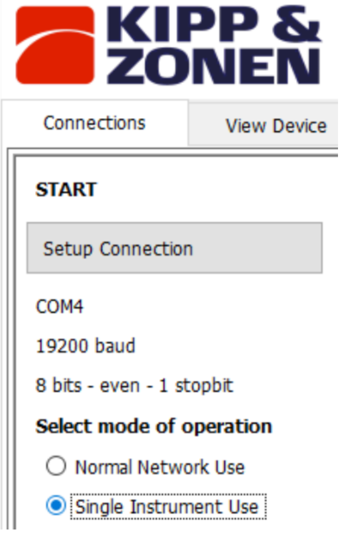
- Click on the *Configuration* tab to access the current communication parameters.



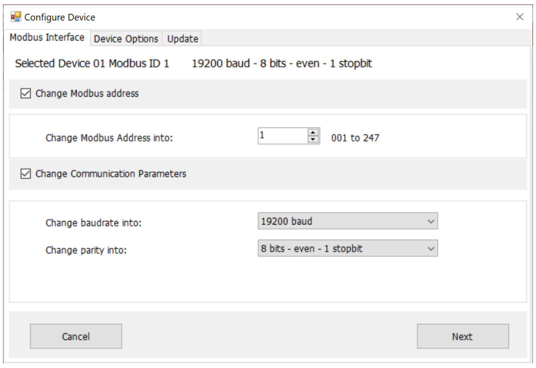
- To change the parameters, click on the **Configure Device** button.
  - ⇨ The following warning appears:



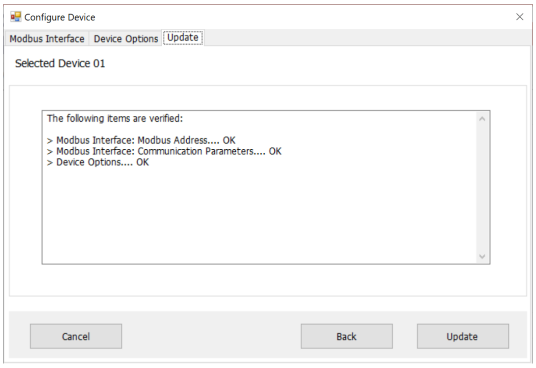
- To change the Modbus address, the baud rate and the parity, close the window and activate the *Single Instrument Use* operating mode on the *Connections* tab. The Modbus address can also be changed in the *Normal Network Use* operating mode.



- Go to the *Configuration* tab and click on the **Configure Device** button again.
- Activate the *Change Modbus address* checkbox and set the new address.



- Activate the *Change Communication Parameters* checkbox and select the baud rate and parity.
- Click on the **Next** button.
  - ⇨ The *Update* tab appears:



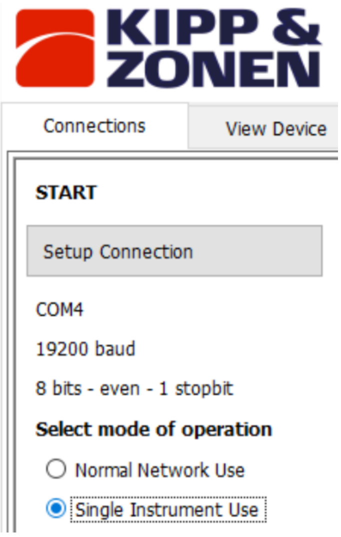
- Click on the **Update** button to save the settings.

⇨ Following the update, the instrument is reset and is ready for operation again after approximately 1 minute.

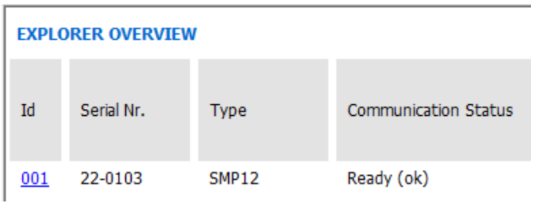
⇨ The communication parameters are changed and the *Connections* tab appears.

8.1.4 Finding an instrument with unknown communication parameters

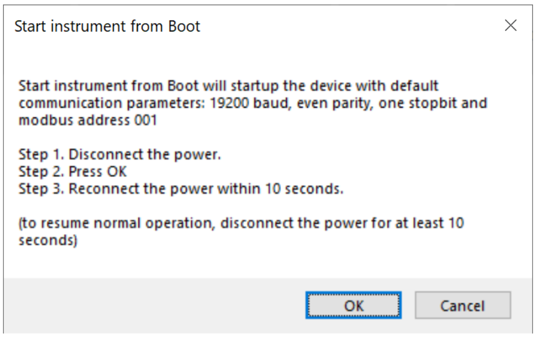
- Activate the *Single Instrument Use* operating mode on the *Connections* tab.



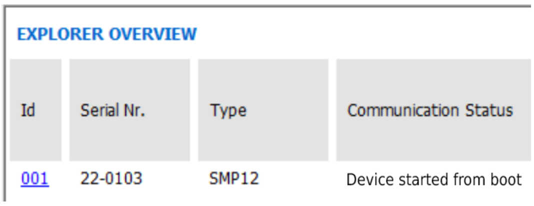
- If only the Modbus address is unknown, click on the **Send Broadcast** button.
  - ⇨ The connected instrument is displayed:



- If no instrument is found, click on the **Start From Boot** button.
  - ⇨ The following window appears:



- Follow the instructions in the window.
  - ⇨ The connected instrument is displayed:



  - ⇨ After approximately 1 minute, reliable measurement results appear on the *Connections* tab.
- Check the communication parameters on the *Configuration* tab.
- Switch off the instrument and switch it back on after 10 seconds to restore normal operation.

9 Operation

9.1 Making and saving measurements

The instruments require suitable sources of power and radiation (light) to operate and make measurements.

- To save the measurements, connect the instrument to a readout or data storage device. The instrument has no internal data memory.

9.2 Collecting data

An optimal setting for the data interval is to sample every second and store one minute averages.

- For setting up the combination of the instrument and data storage read the manual of the data collection device.
- Take care when using the analog output to match the output range of the instrument closely to the input range of the data collection device to maximise the available resolution and minimise noise.
- To do this, determine the maximum analog output of the instrument and the minimum input range of the data collection device.

10 Maintenance

10.1 Maintenance schedule

CAUTION

Risk of burns due to hot surface at high ambient temperature!

The metal parts of the device housing can become very hot at high ambient temperatures (> approx. +60 °C). This can result in burns.

- Do not touch the housing.
- Wear protective gloves during installation and maintenance.

The frequency of cleaning is dependent upon the local weather and environmental conditions. Ideally, the dome of the instrument should be cleaned every morning before sunrise. The frequency of cleaning can be reduced by the use of a ventilation unit (not available for the SMP3), with the heaters switched on when necessary.

The following maintenance intervals are recommended:

Interval	Activity	Performed by
Twice a week	▸ Clean the dome using a dry and lint-free cloth. ▸ For persistent soiling, use additional distilled water. If the soiling is servere, pure alcohol can be used. ▸ Ensure that no streaks or deposits are left on the dome.	Operator
Monthly	▸ Check that the instrument is standing horizontally or at the correct angle. Adjust the instrument if required. ▸ Check that the sun shield is fixed tightly.	Operator
Annually	▸ Check all electrical connections: Unscrew the plugs, clean the plugs if necessary and reconnect. ▸ Check all cables for damage. ▸ Check fastenings and basic supports. ▸ Clean the sun shield if dirty.	Operator
5 years	▸ Check sensitivity or have a recalibration performed.	OTT HydroMet
10 years	▸ Replace the desiccant in the instrument.	OTT HydroMet

11 Troubleshooting

11.1 Fault elimination

Fault	Possible cause	Measures
Output signal not available or incorrect	Pyranometer does not work properly	‣ Check that the cables are correctly connected to the readout equipment. ‣ Check the power supply (12 V DC recommended). ‣ Check that the instrument has a unique Modbus® address. ‣ Compare the digital and analog outputs to see if the problem is only on one output. ‣ Check the location for obstacles that block the direct solar radiation. ‣ Check the glass dome for contamination. Carry out maintenance work as required. ‣ For analog outputs, check the data logger or integrator input offset so that a signal of 0 V or 4 mA gives a "zero" reading. ‣ Check that the leveling is correct. ‣ Report any malfunctions or damage to the representative of OTT HydroMet.

12 Repair

12.1 Customer support

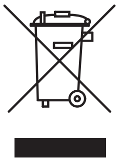
- Have repairs carried out by OTT HydroMet service personnel.
- Only carry out repairs yourself, if you have first consulted OTT HydroMet.
- Contact your local representative: www.otthydromet.com/en/contact-us
- Include the following information:
  - instrument model
  - instrument serial number
  - firmware version (only for devices used with ConfigTool.NET)
  - details of the fault or problem
  - examples of data files
  - readout device or data acquisition system
  - interfaces and power supplies
  - history of any previous repairs or modifications
  - pictures of the installation
  - overview of the local environment conditions

OTT HydroMet repair service

13 Notes on disposing of old devices

Member States of the European Union

In accordance with the German Electrical and Electronic Equipment Act (ElektroG; national implementation of EU Directive 2012/19/EU), OTT HydroMet takes back old devices in the Member States of the European Union and disposes of them in the proper manner. The devices that this concerns are labeled with the following symbol:



- For further information on the take-back procedure contact OTT HydroMet:

OTT HydroMet B.V.
Service & Technical Support
Delftechpark 36
2628 XH Delft
The Netherlands
phone: +31 15 2755 210
email: solar-info@otthydromet.com

All other countries

- Dispose of the product in the proper manner following decommissioning.
- Observe the country-specific regulations on disposing of electronic equipment.
- Do NOT dispose of the product in household waste.

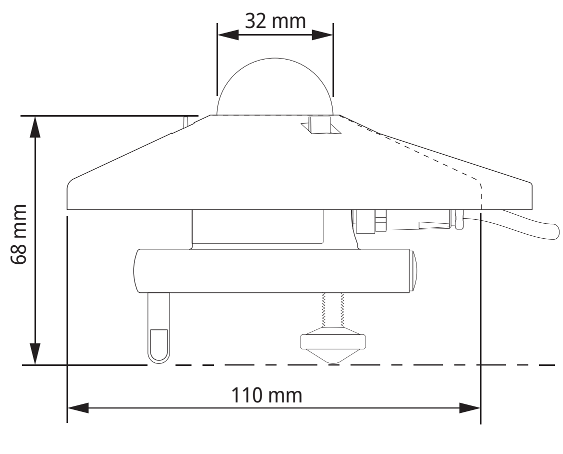
14 Technical data

14.1 Optical and electrical data

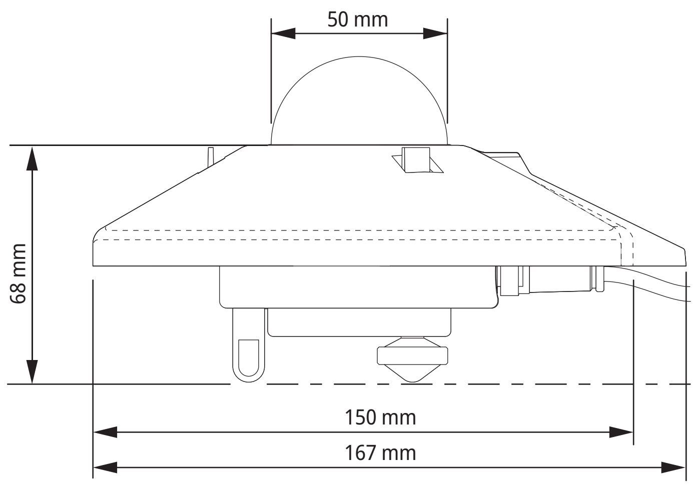
Specification	SMP3	SMP6
Classification to ISO 9060:2018	Spectrally flat Class C	Spectrally Flat Class B
Analog output , V-version	0 to 1 V	0 to 1 V
Analog output range, V-version	-200 to 2000 W/m^2	-200 to 2000 W/m^2
Analog output , A-version	4 to 20 mA	4 to 20 mA
Analog output range, A-version	0 to 1600 W/m^2	0 to 1600 W/m^2
Serial output	RS-485 Modbus®	RS-485 Modbus®
Serial output range	-400 to 2000 W/m^2	-400 to 2000 W/m^2
Response time (63 %)	< 1.5 s	< 1.5 s
Response time (95 %)	< 12 s	< 12 s
Spectral range (20 % points)	285 to 3000 nm	270 to 3000 nm
Spectral range (50 % points)	300 to 2800 nm	285 to 2800 nm
Zero offset:		
a) thermal radiation (at 200 W/m^2)	< 15 W/m^2	< 8 W/m^2
b) temperature change (5 K/h)	< 5 W/m^2	< 2 W/m^2
c) total zero offset (a, b and other sources)	< 20 W/m^2	< 10 W/m^2
Additional signal processing errors	< 3 W/m^2	< 2 W/m^2
Non-stability (change/year)	< 1 %	< 1 %
Non-linearity (100 to 1000 W/m^2)	< 3 %	< 1 %
Directional response (up to 80° with 1000 W/m^2 beam)	< 20 W/m^2	< 15 W/m^2
Temperature response	< 3 % (-20 °C to +50 °C) < 4 % (-40 °C to +70 °C)	< 2 % (-10 °C to +40 °C) < 4 % (-40 °C to +70 °C)
Clear sky GHI spectral error	< 0.2 %	< 0.1 %
Spectral selectivity (350 to 1500 nm)	< 3 %	< 3 %
Tilt response (0° to 180° at 1000 W/m^2)	< 1.5 %	< 1 %
Field of view	180°	180°
Accuracy of bubble level	< 0.2°	< 0.1°
Power consumption (at 12 V DC)	V-version: 55 mW A-version: 100 mW	V-version: 55 mW A-version: 100 mW

Specification	SMP3	SMP6
Software, Windows™	SmartExplorer software, for configuration, test and data logging	SmartExplorer software, for configuration, test and data logging
Supply voltage	5 to 30 V DC	5 to 30 V DC
Detector type	Thermopile	Thermopile
Operating temperature range	-40 °C to +70 °C	-40 °C to +70 °C
Storage temperature range	-40 °C to +80 °C	-40 °C to +80 °C
Humidity range (non-condensing)	0 to 100 %	0 to 100 %
MTBF (Mean Time Between Failures)	> 10 years	> 10 years
Ingress Protection (IP) rating	67	67
Recommended applications	Economical solution for efficiency and maintenance monitoring of PV power installations, routine measurements in weather stations, agriculture, horticulture and hydrology	Good quality measurements for Solar Monitoring, hydrology networks, greenhouse climate control

14.2 Dimensions and weight



SMP3



SMP6

Specification	SMP3	SMP6
Instrument weight	300 g	600 g
Dimensions unpacked (diameter x height)	11 x 8.4 cm	15 x 9.3 cm
Packaging dimensions	29 x 21 x 10 cm	22,5 x 19 x 15 cm
Weight of 10 m cable	400 g	

15 Appendix

15.1 Commonly used Modbus® commands

The commands are all according to the Modbus RTU protocols described in the document: 'Modbus® over serial line V1.02' and 'Modbus application protocol V1.1b' available from the Modbus® organization (www.modbus.org). The commands can be tested using software tools, such as the program 'Modbus Poll' from www.modbustools.com.

The following commands are implemented:

Function	Sub function	Description
0X01	N/A	Read coils
0X02	N/A	Read discrete inputs
0X03	N/A	Read holding registers
0X04	N/A	Read input register
0X05	N/A	Write single coil
0X06	N/A	Write holding register
0X10	N/A	Write multiple registers

The SMP series devices do not make a difference between a "coil" and a "discrete input". The only difference is that a discrete input is read only. The SMP series devices do not make a difference between a holding register and an input register. The only difference is that an input register is read only.

15.2 Input registers overview

Input registers are read only.

Real-time processed data

PDU address	Parameter	R/W	Type	Mode	Description
0	IO_DEVICE_TYPE	R	U16	All	Device type of the sensor
1	IO_DATAMODEL_VERSION	R	U16	All	Version of the object data model
2	IO_OPERATIONAL_MODE	R	U16	All	Operational mode: normal, service, calibration, and factory
3	IO_STATUS_FLAGS	R	U16	All	Device status flags
4	IO_SCALE_FACTOR	R	S16	All	Scale factor for sensor data (determines number of decimal places)
5	IO_SENSOR1_DATA	R	S16	N, S	Temperature compensated radiation in W/m^2 (Net radiation for SGR) (1)
6	IO_RAW_SENSOR1_DATA	R	S16	N, S	Raw, non-linearized and non-temperature compensated radiation(1)
7	IO_STDEV_SENSOR1	R	S16	N, S	Standard deviation IO_SENSOR1_DATA
8	IO_BODY_TEMPERATURE	R	S16	N, S	Body temperature in 0.1 °C
9	IO_EXT_POWER_SENSOR	R	S16	N, S	External power voltage
10	IO_SENSOR2_DATA	R	S16	N, S	Temperature compensated long wave down radiation in W/m^2 (only for SGR) (1)

PDU address	Parameter	R/W	Type	Mode	Description
11	IO_RAW_SENSOR2_DATA	R	S16	N, S	Long wave down radiation in W/m^2 (only for SGR) [(1)]
12	IO_STDEV_SENSOR2	R	S16	N, S	Not used, always 0
13	IO_TEMP_SENSOR_1_K	R	U16	N, S	Body temperature in 0.01 °K (only for SGR)
14	IO_TEMP_SENSOR_2_K	R	U16	N, S	Panel temperature in 0.01 °K (only for DustIQ and RT1)
15	IO_TILT	R	U16	N, S	Tilt of the sensor in the horizontal plane in 0.1° (only for SMP12)
16	IO_RH	R	U16	N, S	Internal relative humidity of the sensor in 0.1 % (only for SMP12)
60	IO_DAC_OUTPUT_VOLTAGE	R	U16	N, S	DAC output voltage or current (actual voltage or current)
61	IO_SELECTED_DAC_INPUT	R	U16	N, S	DAC selected input voltage

[(1)] The scale factor defines the format and number of decimal places

R = Read only | U16 = 16-bit unsigned integer | S16 = 16-bit signed integer | N = available in normal mode | S = available in service mode

Real-time data A/D counts

PDU address	Parameter	R/W	Type	Mode	Description
18	IO_ADC1_COUNTS	R	S32	All	Input voltage sensor 1 in 0.01 µV
19	–	–	–	–	(R18=MSB, R19=LSB)
20	IO_ADC2_COUNTS	R	S32	All	Not supported, always 0
21	–	–	–	–	–
22	IO_ADC3_COUNTS	R	S32	All	Input voltage body temperature sensor in 0.01 µV
23	–	–	–	–	(R22=MSB, R23=LSB)
24	IO_ADC4_COUNTS	R	S32	All	Input voltage power sensor in 0.01 µV
25	–	–	–	–	(R24=MSB, R25=LSB)

R = Read only | S32 = 32-bit signed integer | All = available in normal and service mode

Error reports

PDU address	Parameter	R/W[(2)]	Type	Mode	Description
26	IO_ERROR_CODE	R	U16	All	Most recent/actual error code
27	IO_PROTOCOL_ERROR	R	U16	All	Protocol error/communication error
28	IO_ERROR_COUNT_PRIO1	R	U16	All	Priority 1 error count
29	IO_ERROR_COUNT_PRIO2	R	U16	All	Priority 2 error count
30	IO_RESTART_COUNT	R	U16	All	Number of controlled restarts
31	IO_FALSE_START_COUNT	R	U16	All	Number of uncontrolled restarts
32	IO_SENSOR_ON_TIMEH	R	U16	All	On time in seconds (MSB word)
33	IO_SENSOR_ON_TIMEL	R	U16	All	On time in seconds (LSB word)

PDU address	Parameter	R/W[2]	Type	Mode	Description
41	IO_BATCH_NUMBER	R	U16	All	Production batch number = year in YY
42	IO_SERIAL_NUMBER	R	U16	All	Serial number
43	IO_SOFTWARE_VERSION	R	U16	All	Software version
44	IO_HARDWARE_VERSION	R	U16	All	Hardware version
45	IO_NODE_ID	R	U16	All	(Modbus®) device address RS-485

[2] Writing any value to input registers 26-33 will reset the contents of the registers

R = Read only | U16 = 16-bit unsigned integer | All = available in normal and service mode

Real time floating data points

PDU address	Parameter	R/W[2]	Type	Mode	Description
10000	U_DEVICE_TYPE	R	U16	All	Device type of the sensor (see register IO_DEVICE_TYPE)
10001	U_OPERATIONAL_MODE	R	U16	All	Operational mode (see register IO_OPERATIONAL_MODE)
10002	U_ERROR_CODE	R	U16	All	Most recent/actual error code (see register IO_ERROR_CODE)
10003	U_STATUS_FLAGS	R	U16	All	Device status flags (see register U_STATUS_FLAGS)
10004	U_BATCH_NR	R	U16	All	Production Batch number (see register IO_BATCH_NUMBER)
10005	U_SERIAL_NR	R	U16	All	Serial number (see register IO_SERIAL_NUMBER)
10006	FL_SENSOR1_DATA	R	F32	All	Temperature compensated radiation 1 in W/m^2 with decimal point set by scale factor
10008	FL_STDEV_SENSOR1	R	F32	All	Standard deviation sensor 1 with decimal point
10010	FL_ SENSOR2_DATA	R	F32	All	Temperature compensated radiation sensor 2 or long wave down with decimal point.
10012	FL_STDEV_SENSOR2	R	F32	All	Not used. Always 0
10014	FL_BODY_TEMPERATURE	R	F32	All	Body temperature in ° Kelvin with decimal point.
10016	FL_EXT_POWER_SENSOR	R	F32	All	External power voltage with decimal point
10018	F_PVPANEL_TEMP_K	R	F32	All	PV panel temperature in ° Kelvin
10020	FL_TILT	R	F32	All	Tilt of the sensor in the horizontal plane in °
10022	FL_RH	R	F32	All	Internal relative humidity of the sensor in %

R = Read only | U16 = 16-bit unsigned integer | F32 = 32-bit floating point | All = available in normal and service mode

Real time floating data points

PDU address	Parameter	R/W	Type	Mode	Description
20000	FL_TILT_ROLL[1]	R	F32	All	Roll of the sensor in °
20002	FL_TILT_PITCH[1]	R	F32	All	Pitch of the sensor in °

[(1)] Registers only available for SMP12 pyranometer

PDU address	PDU Address + 1 = Modbus® register number		

Parameter	Name	Name of the register	
R/W	Read Write	R	Read only
		R/W	Read/write
Type	Type and size	U16	16-bit unsigned integer
		S16	16-bit signed integer
		S32	32-bit signed integer
		F32	32-bit floating point
Mode	Operation mode	N	Available in normal mode
		S	Available in service mode
		ALL	Available in all modes

15.3 Holding registers overview

PDU address	Parameter	R/W	Type	Mode	Description
34	IO_DEF_SCALE_FACTOR	R/W	S16	All	Default scale factor
35 ~ 40	Factory use only	–	–	–	–

R/W = Read/Write | S16 = 16-bit signed integer | All = available in normal and service mode

15.4 Discrete inputs overview

Status indicators

Input	Parameter	R/W	Default	Mode	Description
0	IO_SENSOR1_DISCONNECTED	R	0	All	Sensor 1 disconnected
1	IO_SENSOR2_DISCONNECTED	R	0	All	Sensor 2 disconnected
2	IO_VOID_DATA_FLAG	R	0	All	Void signal, 1 = unstable signal, temperature too low or too high
3	IO_OVERFLOW_ERROR	R	1[(1)]	All	Overflow, signal out of range
4	IO_UNDEFLOW_ERROR	R	1[(1)]	All	Underflow signal out of range
5	IO_ERROR_FLAG	R	1[(1)]	All	General hardware error (set if one of the H/W error flags is set)
6	IO_ADC_ERROR	R	1[(1)]	All	Hardware error A/D converter
7	IO_DAC_ERROR	R	1[(1)]	All	Hardware error D/A converter
8	IO_CALIBRATION_ERROR	R	1[(1)]	All	Calibration checksum error
9	IO_UPDATE_FAILED	R	1[(1)]	All	Update parameters stored in nonvolatile memory failed

[(1)] Set if an error occurred at power on, otherwise cleared.

A discrete input can be true or false. A discrete input is read only and can be read in all modes.

15.5 Discrete coils overview

Device control

Coil	Parameter	R/W	Default	Mode	Description
10	IO_CLEAR_ERROR	R/W	0	All	Select normal operation and clear error (1 = clear error)
11 TO 17	Factory use only	–	–	–	–
18	IO_RESTART_MODBUS	R/W	0	All	Restart the device with Modbus® protocol
19	Factory use only	–	–	–	–
20	IO_ROUND	R/W	1	S, N	Enable rounding of sensor data
21	IO_AUTO_RANGE	R/W	0	S, N	Enable auto range mode (0 = no auto range)
22	IO_FASTRESPONSE	R/W	0	S, N	Enable fast response filter (0 = no filter)
23	IO_TRACKING_FILTER	R/W	1	S, N	Enable tracking filter (0 = no filter)

R/W = Read/Write | N = available in normal mode | S = available in service mode | All = available in normal and service mode
A coil can be read, but some can't be written in normal mode or service mode.

i The default values of the device options are stored in non-volatile memory. The default values can be overruled during operation. However, at power-on the default values are restored and the smart sensor will start up with the default values stored in the non-volatile memory.

Input PDU Address + 1 = Modbus® register number

Input	Discrete input	Modbus® discrete input 0 is the first discrete input	
Coil	Modbus coil	A coil can be read or written	
Parameter	Name	Name of the register	
R/W	Read write	R	Read only
		R/W	Read/write
Def	Default value		Default value at power on (0,1, or undefined)
Mode	Operation mode	N	Available in normal mode
		S	Available in service mode
		ALL	Available in all modes

Inputs can be read in all modes but some coils cannot be written to in normal or service mode

15.6 Input register details

Many of the registers and controls are for remote diagnostics. In this chapter only the most relevant registers and controls are described.

Register	Parameter	Description		
0	IO_DEVICE_TYPE	The device type defines which device is connected. This register can be used to check the type of the connected device. IO_datamodel_version 107 supports the following type of sensors:		
		Sensor type	*Value*	*# of sensors*

Register	Parameter	Description		
		SMP3 (volt version)	601	1
		SMP3 (current loop version)	602	1
		SMP6 (volt version)	619	1
		SMP6 (current version)	620	1
		SMP10 (volt version)	617	1
		SMP10 (current version)	618	1
		SMP11 (volt version)	603	1
		SMP11 (current loop version)	604	1
		SMP12 (volt version)	633	1
		SMP21 (volt version)	605	1
		SMP21 (current loop version)	606	1
		SMP22 (volt version)	607	1
		SMP22 (current loop version)	608	1
		SGR3 (volt version)	609	2*
		SGR3 (current loop version)	610	2*
		SGR4 (volt version)	611	2*
		SGR4 (current loop version)	612	2*
		SHP1 (volt version)	613	1
		SHP1 (current loop version)	614	1
		SUV5 (volt version)	615	1
		SUV5 (current loop version)	616	1
1	IO_DATAMODEL_VERSION	The data-model describes the functions supported by the smart sensor. This document is valid for data-model version: 107. A different implementation of the Modbus® protocol (with new features) could result in a different data model 'that is' or 'that is not' compatible with the older version. The value of this register must be >=107. If you receive another value, then you should read an older or newer version of this document and check the differences.		
2	IO_OPERATIONAL_MODE	The operation mode defines the state of the smart sensor. The operational modes are:		
		1	Normal mode	
		2	Service mode	
		3	Calibration mode	
		4	Factory mode	
		5	Error mode	
		After power on the normal mode (1) is set. When the IO_CLEAR_ERROR is set then the smart sensor always returns to the normal mode (1). When the error mode (5) is set, then there is a fatal error.		
3	IO_STATUS_FLAGS	This register defines the status of the smart sensor and the validity of the data. Each bit has a special meaning. Bit 0 is the first (least significant) bit.		
		Bit #	*Individual bit representation*	*Remark*
		0	Quality of the signal	see IO_VOID_DATA_FLAG

Register	Parameter	Description		
		1	Overflow	see IO_OVERFLOW_ERROR
		2	Underflow	see IO_UNDERFLOW_ERROR
		3	Error flag	see IO_ERROR_FLAG
		4	ADC error	see IO_ADC_ERROR
		5	DAC error	see IO_DAC_ERROR
		6	Calibration error	see IO_CALIBRATION_ERROR
		7	Update EEPROM error	see IO_UPDATE_FAILED
		8	Power failure error	see POWER_FAILED_FLAG
		9	Tilt sensor error	see IO_TILT_ERROR
		10	Relative humidity sensor error	see IO_RH_ERROR
		11	Relative humidity threshold warning	see IO_RH_THRESHOLD
		12	Body temperature sensor error	see IO_BODY_TEMP_ERROR
4	IO_SCALE_FACTOR	The scale factor defines the number of fractional digits, the range and the position of the decimal point for the following registers: IO_SENSOR1_DATA, IO_SENSOR2_DATA, IO_RAW_SENSOR1_DATA and IO_RAW_SENSOR2_DATA. The scale factor is read only. The default value of the scale factor is a copy of register 34 IO_DEF_SCALE_FACTOR, made during power up. If the register IO_SCALE_FACTOR is not set to 0 then you must multiply or divide the data of the above mentioned four IO_SENSOR registers.		
		Scale factor	*Calculation*	
		2	floating point result = integer register X / 100	
		1	floating point result = integer register X / 10	
		0	floating point result = integer register X	
		-1	floating point result = integer register X * 10	
5	IO_SENSOR1_DATA	This register holds the actual data (solar radiation) measured by the sensor. The solar radiation is measured in W/m^2. If the register IO_SCALE_FACTOR is not set to 0 then you must multiply or divide the data as described under register 4. The raw data from the sensor is calibrated, linearized; temperature compensated and filtered.		
6	IO_RAW_SENSOR1_DATA	The raw sensor data is calibrated but not linearized and temperature compensated. If the register IO_SCALE_FACTOR is not set to 0 then you must multiply or divide the data as described under register 4, IO_SCALE_FACTOR.		
7	IO_STDEV_SENSOR1	This register is used to calculate the standard deviation over the signal. When the register is read, the data is sent to the computer and at the same time a new calculation is started. The next time register 7 is read the standard deviation over the last period is sent to the computer and a new calculation is started. If the poll frequency is quite high (for example 1 poll per second) then the standard deviation will be zero or almost zero, but if the poll frequency is very low then the standard deviation can be quite high, indicating that the data in register 5 or 6 changed dramatically since the last		

Register	Parameter	Description
		poll. The standard deviation is measured in 0.1 W/m^2. To convert the data to a floating point, make the following calculation: floating point result = integer register (IO_STDEV_SENSOR1) / 10
8	IO_BODY_TEMPERATURE	The body temperature sensor measures the temperature of the body in 0.1 °C. To convert the data to a floating-point number, make the following calculation: floating point result = integer register (IO_BODY_TEMPERATURE) / 10
9	IO_EXT_POWER_SENSOR	The external power sensor measures the external voltage applied to the chassis socket in 0.1 Volt. To convert the data to a floating-point number, make the following calculation: floating point result = integer register (IO_EXT_POWER_SENSOR) / 10
15	IO_TILT	The tilt sensor measures the tilt of the sensor in the horizontal plane in 0.1°. To convert the data to a floating-point number, make the following calculation: floating point result = integer register (IO_TILT) / 10
16	IO_RH	The RH sensor measures the internal relative humidity of the sensor in 0.1 %. To convert the data to a floating-point number, make the following calculation: floating point result = integer register (IO_RH) / 10

15.7 Holding register details

Register	Parameter	Description
34	IO_DEF_SCALE_FACTOR	The default scale factor is set in the factory mode or service mode and is stored in non-volatile memory. The default scale factor stored in non-volatile memory is always set after a power-on. However, it is possible to change the default setting during operation by writing a value to the register 34. Note: This value is not stored in non-volatile memory and is overwritten with the default value at power on. The following values are valid: • Scale factor = 2 • Scale factor = 1 • Scale factor = 0 • Scale factor = -1

15.8 Discrete inputs details

Input	Parameter	Description
0	IO_SENSOR1_DISCONNECTED	0 = true, 1 = false
1	IO_SENSOR2_DISCONNECTED	0 = true, 1 = false
2	IO_VOID_DATA_FLAG	The void data flag is raised when the data in register IO_SENSOR1_DATA or IO_RAW_SENSOR1_DATA is not valid, because the body temperature of the sensor is too low or too high, when there is an internal overflow condition, because a calculation is out of range or a division by zero occurred, the

Input	Parameter	Description
		reference voltage of the ADC is not stable, or the digital filter is not stable. When the IO_VOID_DATA_FLAG is set, bit 0 in the IO_STATUS_FLAGS is also set. The IO_VOID_DATA_FLAG and bit 0 of the IO_STATUS_FLAGS are cleared when the IO_VOID_DATA_FLAG is read by the computer.
3	IO_OVERFLOW_ERROR	This discrete input is raised when an out-of-range condition occurs and the sensor data (see IO_SENSOR1_DATA) is above the maximum value specified by the calibration program or above 29,999. The typical maximum value is 4000 W/m^2. When the IO_OVERFLOW_ERROR is set, bit 1 in the IO_STATUS_FLAGS is also set. The IO_OVERFLOW_ERROR and bit 1 of the IO_STATUS_FLAGS are cleared when the IO_OVERFLOW_ERROR is read by the computer.
4	IO_UNDERFLOW_ERROR	This discrete input is raised when an underflow condition occurs and the sensor data (see IO_SENSOR1_DATA) is below the minimum value specified by the calibration program or below -29,999. The typical minimum value is -400 W/m^2. When the IO_UNDERFLOW_ERROR is set, bit 2 in the IO_STATUS_FLAGS is also set. The IO_UNDERFLOW_ERROR and bit 2 of the IO_STATUS_FLAGS are cleared when the IO_UNDERFLOW_ERROR is read by the computer.
5	IO_ERROR_FLAG	The error flag is raised when there is a (fatal or correctable) hardware error or software error such as: ADC error, DAC error, calibration error or when the update of the calibration data failed. When the IO_ERROR_FLAG is raised the error code is copied to the register IO_ERROR_CODE (see register 26). The error flag is cleared when a true condition is written to the coil: 'IO_CLEAR_ERROR'. This has no effect when the error is fatal or not resolvable such as a calibration error. The error flag is always set after a power up, this is to indicate the power went off, or a restart occurred. The computer should raise the IO_CLEAR_ERROR to reset the error flag.
6	IO_ADC_ERROR	This flag is raised when the A/D converter responsible for the conversion of the analogue signals to digital signals detected a failure (hard or software). The ADC error flag is cleared when a true condition is written to the coil: 'IO_CLEAR_ERROR' and the error produced by the ADC, is not fatal.
7	IO_DAC_ERROR	This flag is raised when the D/A converter responsible for the conversion of the digital signal to the analogue output signal detected a failure (hard or software). The DAC error flag is cleared when a true condition is written to the coil: 'IO_CLEAR_ERROR' and the error produced by the DAC, is not fatal.
8	IO_CALIBRATION_ERROR	The calibration error flag is raised when the sensor was not calibrated, or a checksum error was detected in the calibration data. This flag can't be cleared unless the sensor is sent back to the manufacturer or dealer for a re-calibration.
9	IO_UPDATE_FAILED	The update failed is raised when data is written to the non-volatile memory and the update failed. This can happen in calibration mode when calibration data in written to non-volatile memory or in the service mode when device options are written to the non-volatile memory. If this error is set, you should retry the last update action. If the error does not disappear then there could be a hardware problem with the non-volatile memory (EEPROM).

15.9 Discrete coils details

Coil	Parameter	Description
10	IO_CLEAR_ERROR	Setting this coil will clear the error only when the error is a non-fatal error. Reading this coil will always return a 0. The coil IO_CLEAR_ERROR can be used to select the normal mode (see IO_OPERATIONAL_MODE). The smart sensors will always start-up in the normal mode. Note: Use IO_CLEAR_ERROR to return to the normal mode.
18	IO_RESTART_MODBUS	–
20	IO_ROUNDOFF	Setting this coil enables rounding of the data presented in IO_SENSOR1_DATA and IO_RAW_SENSOR1_DATA. If not set, then the customer should round off the received data before processing the data. The default value after power on is ON. If IO_ROUNDOFF is cleared, then the sensor is not calibrated and could produce more digits, than there are significant digits.
21	IO_AUTO_RANGE	Setting this coil enables the auto-range feature. The auto-range feature increases the number of digits for small signals. The default value after power on is OFF. If IO_AUTO_RANGE is set then the sensor is not calibrated and could produce more digits, than there are significant digits.
22	IO_FASTRESPONSE	Setting this coil enables the fast response filter. This filter increases the step response of the sensor. Disabling the fast response give the SMP pyranometers the same response time as the CMP equivalents. The default value after power on is ON.
23	IO_TRACKING_FILTER	Setting to this coil enables the tracking filter. The tracking filter reduces the noise of the signal. However, when the filter is on, the step response on a sudden signal change is decreased. The smart sensor uses variable filter constants to minimize the effect on the step response. The default value after power on is OFF.

15.10 Requesting serial number

Register	Parameter	Description
41	IO_BATCH_NUMBER	The batch number defines the production year of the smart sensor, 20=2020, 21=2021 etc.
42	IO_SERIAL_NUMBER	Register 42 defines the 4 digits serial number of the smart sensor. Only the combination of the batch number and serial number is unique.

15.11 Demonstration program

The simple ‘C’ program below will show how to read the sensor data and how to deal with errors. The program will read the registers: ‘operational mode, status flags, scale factor, and sensor data’ from Modbus® device with address 2 into registers uOperationMode, uStatusFlags, iScaleFactor and iSensorData. Then the program will check the operation mode (must be ‘normal’) and if there are no errors flags set in iStatusFlags. If there is an error, then set the IO_ERROR_FLAG.

```
UInt16	uOperationalMode = 0;
UInt16	uStatusFlags = 0;
Int16	iScaleFactor = 0;
Int16	iSensorData = 0;
float	fSensorData = 0;

int main (void)
{
	while (true)
	{
		// Send MODBUS request 0x04 Read input registers to slave 2
		// Get modus data will wait for the answer and copies the data to registers
		// uOperationalMode, uStatusFlags, iScaleFactor and iSensorData

		SendModbusRequest (0x04, 2, IO_OPERATIONAL_MODE, 4);
		WaitModbusReply ();
		GetModbusData ();

		If (uOperationalMode != 1)
		{
			// Send MODBUS request 0x05 write single coil to slave 2
			SendModbusRequest (0x05, 2, IO_CLEAR_ERRROR, true);
			WaitModbusReply ();
		}
		else if (uStatusFlags != 0)
		{
			SendModbusRequest (0x05, 2, IO_CLEAR_ERRROR, true);
			WaitModbusReply ();
		}
		switch (iScaleFactor)
		{
			case 2: fSensorData = (float)(iSensorData) / 100.0;
			case 1: fSensorData = (float)(iSensorData) / 10.0;
			case 0: fSensorData = (float)(iSensorData);
			case -1: fSensorData = (float)(iSensorData) * 10.0;
			default: fSensorData = 0.0;
		}
		// wait 1 second
		Delay (1000);
	}
}
```

Contact Information