

Instruction Manual

SUV series • Smart UV Radiometer

Important user information

Dear customer, thank you for purchasing a Kipp & Zonen instrument. It is essential that you read this manual completely for a full understanding of the proper and safe installation, use, maintenance and operation of your new SUV series radiometer.

We understand that no instruction manual is perfect, so should you have any comments regarding this manual we will be pleased to receive them at:

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Declaration of Conformity



Kipp & Zonen B.V.

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P.O. Box 507, 2600 AM Delft
The Netherlands

declares under our sole responsibility that the product

SUV-A, SUV-B, SUV-E and SUV5 Smart UV Radiometer

to which this declaration relates, is in conformity with European Harmonised Standards
as published in the Official Journal of the EU, based on the following standard

[EMC - Emissions] **EN 61326-2-3:2013**

[EMC - Immunity] **EN 61326-2-3:2013**

[Environmental Affairs] **EN 50581:2012**

following the provisions

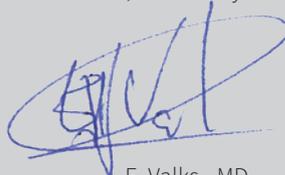
EMC-directive **2014/30/EU**

RoHS Directive **2011/65/EU**

also, this device complies to

[EMC - FCC] **Title 47CFR part 15**

Delft, 1 February 2018



E. Valks - MD

Kipp & Zonen B.V.

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Throughout this manual the following symbols are used to indicate to the user important information.



General warning about conditions, other than those caused by high voltage electricity, which may result in physical injury and/or damage to the equipment or cause the equipment to not operate correctly.

Note

Useful information for the user

1.1

Product overview

The UV radiometers SUV series is designed to measure global UV irradiance in the different UV bands.

SUV-A covers the range between 315 and 400 nm

SUV-B covers the range between 280 and 315 nm

SUV-E is designed to match the sensitivity of the human skin with regard to the ISO 1766:1999 / CIE S 007 / E-1998.

The UV-Index can be calculated from the SUV-E output

SUV5 covers the range between 280 and 400 nm

The radiometers are designed for continuous outdoor use in routine monitoring applications with the sun as a source. It can also be used in indoor applications, bearing the specifications of the source (generally a lamp) and of the radiometer in mind.

SUV radiometers feature internal digital signal processing and interface optimized for industrial data acquisition and control systems. Kipp & Zonen has developed a smart interface that features RS-485 Modbus® data communication for connection to programmable logic controllers (PLC's), inverters, digital control equipment and the latest generation of data loggers. Amplified analog outputs are also included for devices that have high-level analogue inputs or current loop interfaces.

The SUV-A, SUV-B, SUV-E and SUV5 have an output of 0 to 1 V, only SUV5 is also available with an analogue current output of 4 to 20 mA. They all have a 2-wire RS-485 interface with Modbus® (RTU) protocol.

Digital signal processing and an integrated temperature sensor, corrects for the temperature dependence of the detector sensitivity.

This manual, together with the SmartExplorer manual and instruction sheet, provides information related to the installation, maintenance, calibration, product specifications and applications of the SUV radiometers.

If any questions should remain, please contact your local Kipp & Zonen representative or e-mail the Kipp & Zonen customer and product support department at: support@kipazonen.com

Please go to www.kipazonen.com for information about other Kipp & Zonen products, or to check for any updates to this manual or software.

1.1.1

The SUV Radiometers

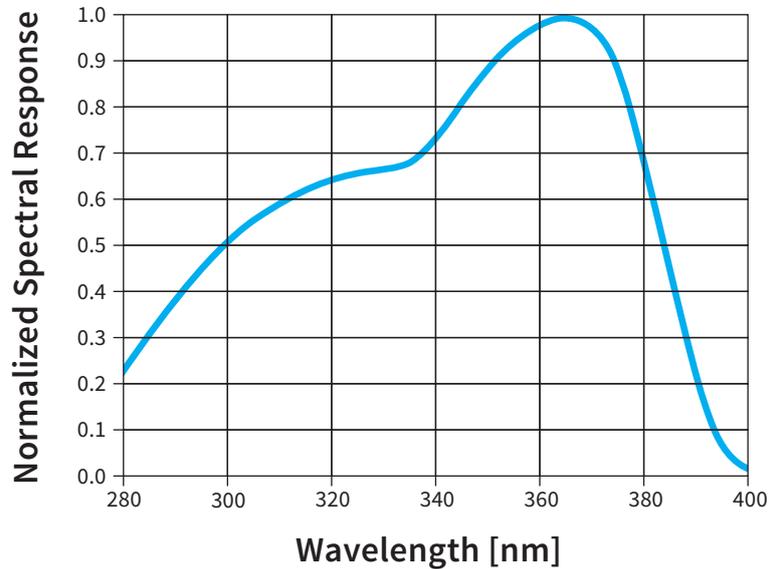
The SUV5 radiometer can measure UV-radiation of extended spectra of radiation as from solar radiation and incandescent lamps.

Customer must be aware that: a feature of broadband radiometry is that very different spectra can yield the same integrated irradiances in the bandwidth of the radiometer as long as the spectral response curve of the latter is rectangular (ideal). The bandwidth of a radiometer with a non-rectangular shape of the spectral response is determined by its half power wavelengths. For the SUV5 radiometer the nominal pass band so becomes 315 to 378 nm (the overall spectral range is 280 to 400 nm). In principle the SUV5 radiometer measures global irradiance within this wavelength interval.

Due to the non-rectangular spectral response curve of the SUV, it will not weigh UV radiation of different wavelength equally in this band. Different spectra with the same irradiance in the SUV passband will give different output voltages and consequently each spectra needs its own sensitivity figure ($\mu\text{V}/\text{W}/\text{m}^2$).

1.1.2 Spectral response of SUV5 radiometer

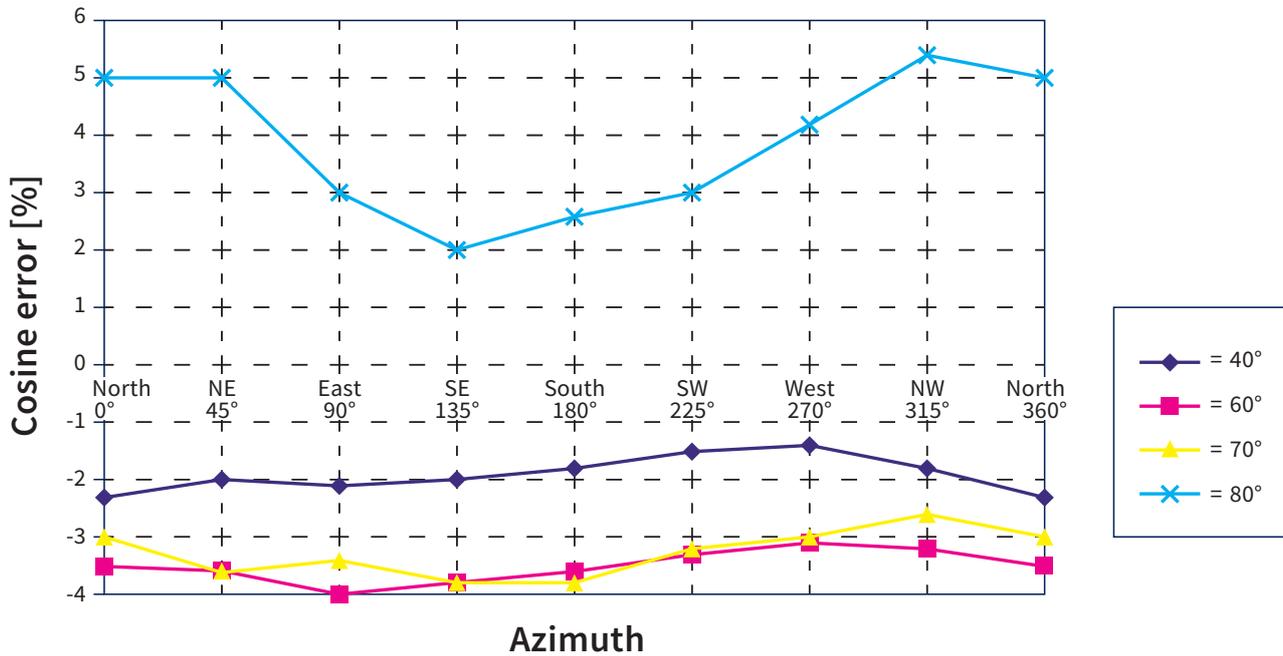
The accuracy of the SUV radiometers is mainly determined by the properties of the band pass filter. The figure below shows the spectral response of a SUV5 on a logarithmic scale. A linear plot of the SUV5 relative spectral response attached to the calibration certificate.



SUV5 relative spectral response (relative units)

By definition global radiation G is the downward irradiance, both direct and diffuse, on a horizontal surface. In other words, G represents the downward vertical component of the radiation field. Especially the accurate measurement of the vertical component of the direct radiation requires a detector with a so-called cosine response. In pyranometers with thermal detectors a good cosine response is reached with flat black absorber paint and proper domes. For measurement of weak UV-signals in small wavelength - intervals photoelectric detectors are more attractive. However photodiodes and the interference filter needed cannot accept radiation with large incidence angles. A diffusor is necessary which accepts radiation from at least a full angle of 170° . The dimensions of the diffusor ensure a good cosine response but due to tolerances in diffusor and protecting dome each UV radiometer has its own individual directional response. To ensure that the response at 90° incidence angle is zero ($\cos. 90^\circ = 0$) a shadow of a rim shades off the diffusor side for angles $>85^\circ$.

The diagram is only given as qualitative information. The diffuse radiation undergoes the same cosine errors but of course 'weighted' over all zenith and azimuth angles. From some parts of the sky strongly polarized diffuse radiation is received. However the diffusor depolarizes this radiation.



Cosine error versus azimuth of SUV5 REF 1 at different sun's zenith (cable pointing North)

To achieve the required spectral and directional characteristics SUV radiometer use a photo-diode detector filter and quartz dome. It has a built-in bubble levels and adjustable levelling feet. Snap-on sun shields reduce solar heating of the housings. The waterproof connectors have gold-plated contacts.

The SUV radiometers can be delivered with a waterproof plug pre-wired to a high quality signal cable, typically this is 10 m long but other lengths are available. The instruments can also be ordered without a cable or with a plug only, for the user to fit their own cable.

The SUV radiometers have an internal desiccant that is guaranteed for 10 years.

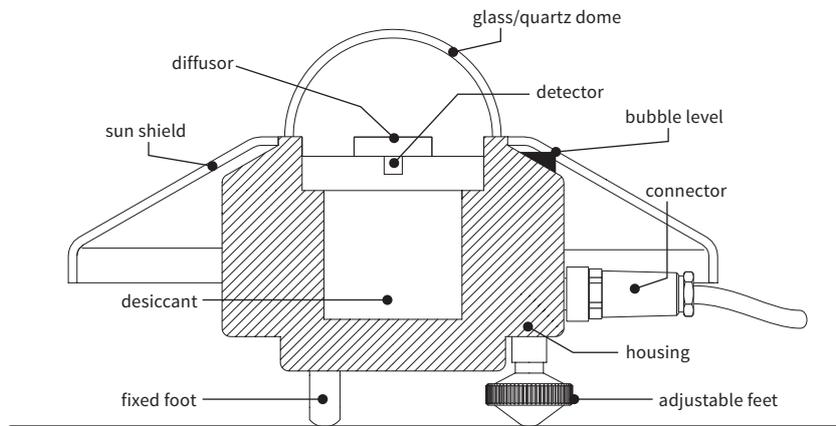
1.1.3 The SUV Radiometers

The SUV-A, SUV-B and SUV-E get a spectral calibration, which is supplied with the instruments.

This data can be used in combination with the UVIATOR software to optimize the data accuracy using satellite data.

See chapter 3 and the separate UVIATOR manual for further details.

1.2 Key parts of the SUV radiometers



2

Installation

Please follow the instructions in this section carefully for the mechanical and electrical installation of the SUV series radiometers.

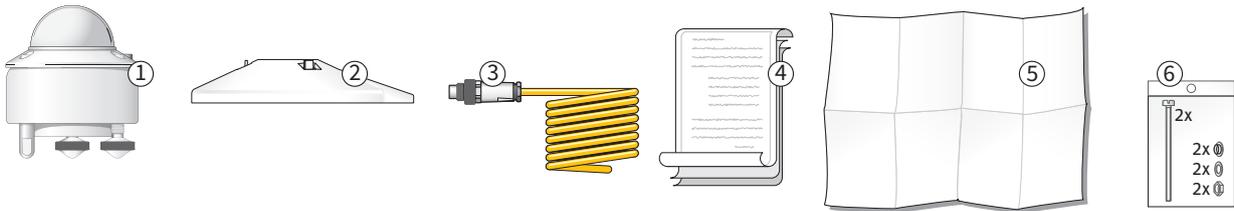
2.1 Included with the product

Check the contents of the shipment for completeness (see below) and note whether any damage has occurred during transport. If there is damage, a claim should be filed with the carrier immediately. In the case of damage and/or the contents are incomplete, contact your local Kipp & Zonen representative or e-mail the Kipp & Zonen customer and product support department at: support@kippzonen.com

Although the SUV radiometers are weather-proof and suitable for use in harsh environmental conditions, they have some delicate mechanical parts. Please keep the original packaging for safe transport of the radiometer to the measurement site, or for use when returning the radiometer for calibration.

The following items are included with SUV radiometers:

- ① Smart UV Radiometer
- ② Sun screen
- ③ Optional cable, pre-wired with 8-pins connector or connector only for customer cable
- ④ Calibration certificate
- ⑤ Instruction sheet
- ⑥ Radiometer fixing kit; 2 each of stainless steel M5 x 80 mm screw, nut, flat washer, nylon insulation ring
- ⑦ Spectral calibration information on included USB memory stick



2.2 Tools required

The tools required to fix an SUV radiometer to a support are a 4 mm (M5 socket head screw) Allen key and a 8 mm (M5 nut) wrench / spanner.

2.3 Location and support

The instruction sheets contain all the outline information necessary for the correct installation of the radiometers. Further detail for specific types of installation and application are given later in this section.

The SUV radiometer has an internal desiccant that is operational for 10 years after the last calibration date as mentioned on the instrument label and calibration certificate.

2.4 Installation for measurement on a horizontal plane

The following steps must be carefully taken for optimal performance of the instrument.

2.4.1 Location

Ideally, the site for the radiometer should be free from any obstructions to the hemispherical view from the plane of the detector. If this is not possible, the site should be chosen in such a way that any obstruction over the azimuth range between earliest sunrise and latest sunset should have an elevation not exceeding 5° (the apparent sun diameter is 0.5°).

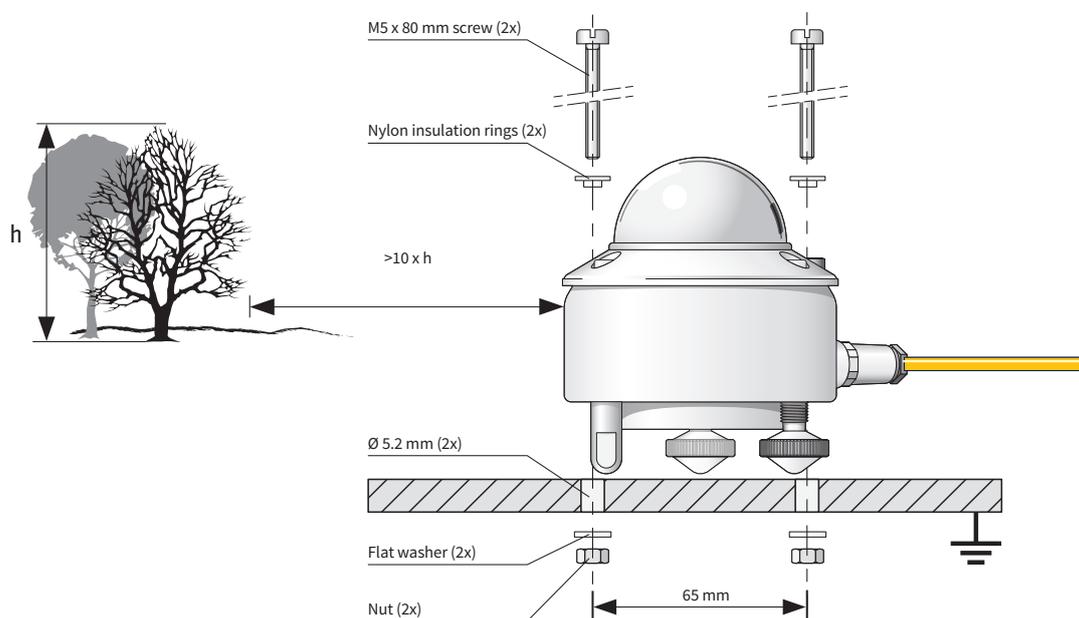
It is evident that the radiometer should be located in such a way that a shadow will not be cast upon it at any time (for example by masts or ventilation ducts). The radiometer should be distant from light-coloured walls or other objects likely to reflect sunlight onto it, or emitting short-wave radiation.

The radiometer should be readily accessible for cleaning the outer dome, checking that it is level.

2.4.2 Mounting

The SUV radiometer is provided with two holes for 5 mm bolts. Two nylon insulation rings and two each of stainless steel bolts, washers and nuts are provided in the fixing kit. The radiometer should first be secured lightly with the bolts to a solid and stable mounting stand or platform as shown below. The nylon insulators are important to prevent corrosion between the screws and the radiometer housing.

Ensure that there is a good electrical contact with the ground to conduct away currents in the cable shield induced by lightning.



Note After recalibration and/or reinstallation ensure that the nylon insulators are refitted.

2.4.3 Orientation

In principle no special orientation of the instrument is required, although the World Meteorological Organization (WMO) recommends that the signal lead (connector) is pointed towards the nearest pole, to minimize heating of the electrical connections. This is also where any mounting pole, or other support, should be located in order that shadows do not fall on the instrument.

2.4.4 Levelling

Accurate measurement requires proper levelling of the detector surface. Level the instrument by turning the two adjustable feet to bring the bubble of the spirit level centrally within the marked ring.

Note It is ideal that the bubble should be completely within the marked ring. However, in fact, the radiometer is level within the specified accuracy when the bubble is at least half within the ring.

2.4.5 Securing

Secure the radiometer tightly with the two stainless steel bolts. Use the two nylon insulators to avoid contact between the aluminum body and the steel screws. Ensure that the radiometer maintains the correct levelled position when it is tightened.

2.4.6 Fitting the connector and cable

Locate the plug correctly in the radiometer socket, it only fits one way, and push it in. Screw the plug locking ring hand-tight. Over-tightening may damage the waterproof seal. Secure the cable so that it cannot blow in the wind or cause a shadow on the instrument.

Note The cable should be arranged with a curve below the instrument so that water drips off, rather than running along the cable up to the connector.

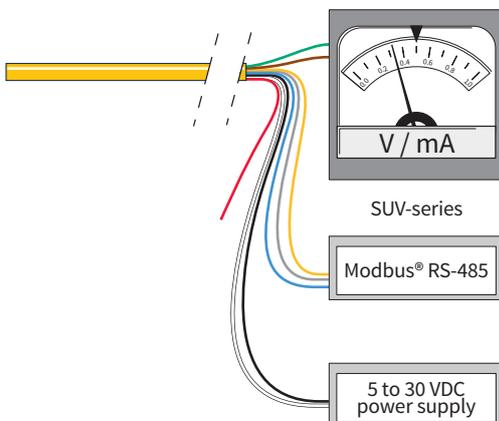
2.4.7 Fitting the sun shield

Finally, clip on the sun shield to prevent excessive heating of the radiometer body. The bubble level is visible through the top of the sun shield for routine checks and the shield 'tail' helps to protect the connector.

2.5 Electrical connections

The SUV radiometers use an 8-wire cable with pre-wired waterproof connector. Cables are available at different lengths. The color code of the wires and the connector pin numbers are shown below and on the instruction sheet.

Special attention is needed to prevent power or ground loops when connecting the SUV radiometer to multiple readout devices. Connecting the RS-485 to a grounded circuit and the analogue output to a floating circuit can cause unacceptable ground loops. This may cause differential voltages outside the SUV radiometer specifications and will damage the unit. We recommend using either the analogue or the digital output but not both. The maximum differential between either of the Modbus® RS-485 lines (yellow and grey) and the power ground / RS-485 common line (blue) is 70 VDC. Only the SUV5-A has a 4 to 20 mA output.



Radiometer Connection		
Wire	Function	Connect with
3 Green	Analogue out	V+/4-20 mA(+)
6 Brown	Analogue ground	V-/4-20 mA(-)
4 Yellow	Modbus® RS-485	B/B/+
5 Grey	Modbus® RS-485	A/A/-
7 White	Power 5 to 30 VDC (12V recommended)	
8 Black	Power ground / RS-485 Common	
1 Red	None	Not connected
2 Blue	Modbus® common / Ground	
Shield	Housing	Ground *

* Connect to ground if radiometer not grounded



First connect all wires before plugging into the radiometer



The shield of the cable is connected to the aluminum radiometer housing through the connector body. Preferably, secure the radiometer with its levelling screws on a metal support with a good connection to ground (e.g. by using a lightning conductor) and do not connect the cable shield at the readout end.



If there is no good ground connection at the radiometer, the shield at the cable end should be connected to ground at the readout equipment. Lightning can induce high voltages in the shield but these will be led off at the radiometer or readout equipment.

Note

Long cables may be used, but the cable resistance must be smaller than 0.1 % of the impedance of the readout equipment for the analogue outputs and may affect the baud rate of the RS-485 digital connection.

2.5.1 Power connection

The minimum power supply voltage for the SUV radiometers is 5 VDC. However, for optimal performance it is advised to use 12 VDC, especially when long cables are used. 5-Volt power can only be used in combination with a short cable, maximum 10 m.

It is advised to protect the output of the power supply with a fast blowing fuse of maximum 250 mA rating.

Typical power consumption SUV-V for maximum output (1 V)		
5 VDC	50 mW	(approx. 10.0 mA)
12 VDC	55 mW	(approx. 4.5 mA)
24 VDC	60 mW	(approx. 2.5 mA)

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 SUV5-A for max output (20 mA)		
5 VDC	77 mW	(approx. 28 mA with 100 Ω load resistor)
12 VDC	83 mW	(approx. 24 mA with 100 Ω load resistor)
24 VDC	100 mW	(approx. 6 mA with 100 Ω load resistor)

The above mW values represent the dissipation within the SUV5-A. For the total power the energy in the load resistor has to be added.

Using the SUV5-A with supply voltages below 12 Volts or above 20 Volts it is advised to use a load resistor of less than 500 Ω to keep the power consumption as low as possible.

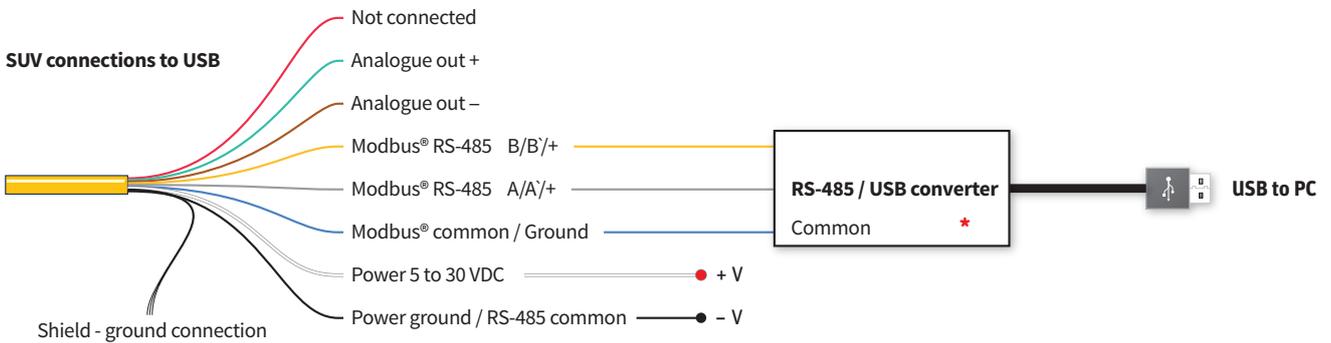
2.5.2 Data connection

Connection to a Personal Computer by Universal Serial Bus (USB)

The connection depends on the use of a RS-485 to USB converter.

The converter must have galvanic isolation between the inputs and outputs to prevent possible damage to the SUV radiometer digital interface. This is particularly an issue with portable computers (laptops, etc.) in which the power supplies can generate large voltage spikes.

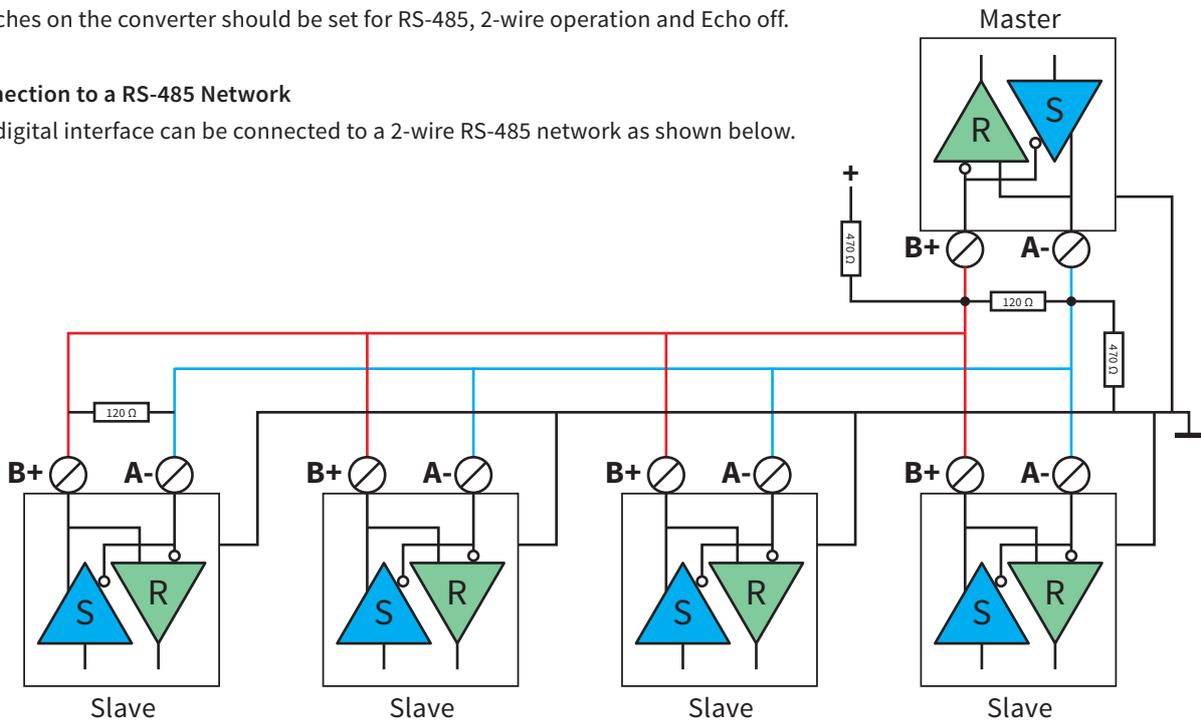
A suitable converter is the model USOPTL4 from B & B Electronics. One end has the USB connector to the PC the other end has a connector with screw terminals for the instrument wires. This RS-485 converter is powered from the USB interface, so no additional power adaptor is necessary.



***Note** Switches on the converter should be set for RS-485, 2-wire operation and Echo off.

Connection to a RS-485 Network

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



The slaves may be a SUV radiometer or any other Modbus® devices. If a SUV radiometer is the last device on the network a line terminator (LT), consisting of a 120 Ω to 150 Ω resistor, must be connected between terminals A/A'/- and B/B'+. Never place this line termination on the derivation cable. It is also required to install the pull up and pull down resistors as shown. The value of these resistors must be between 470 Ω and 850 Ω.

2.5.3 Analogue voltage output

The SUV radiometer (voltage output) have been factory set such that an output of 0 Volts represents -100 W/m^2 (this will never be reached in practice), and the full-scale output of 1 Volt represents 400 W/m^2 .

The voltage output range in W/m^2 can be changed by the user with the supplied PC software. The maximum recommended irradiance for the SUV radiometer is 400 W/m^2 .

The measurement range must start from a negative value because the analogue output itself cannot go to zero or go negative. For the SUV5 and SUV-A the default setting of 0 to 1 Volt representing -100 to 400 W/m^2 the range is actually 500 W/m^2 with a zero offset of 100 W/m^2 . For the SUV-B and SUV-E ranges see the specification table.

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

2.5.4 Analogue current output

The SUV5-A (current output) 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 400 W/m^2 .

The current output range in W/m^2 can be changed by the user with the supplied PC software. The maximum recommended irradiance for the SUV5-A is 400 W/m^2 .

2.5.5 Recommended cable types

Where cables need to be extended, or the customer prefers to provide their own cables, they should be suitable for outdoor used and UV resistant.

Recommended types	
RS-485	Ethernet CAT 5 shielded twisted pair (STP)
0 to 1 V	Shielded 2-core signal cable
4 to 20 mA	Shielded twisted pair control cable

3 Calibration and UVIATOR software

From late 2007 the specially developed Kipp & Zonen UVIATOR software is available for all UVS / SUV radiometers (except for CUV5 and SUV5). The use of the UVIATOR is explained in the UVIATOR manual. In this chapter the benefits and the principles are explained.

Why use UVIATOR software

To improve the quality and relevance of measured UV irradiance data from UV radiometers by taking into account the spectral properties of the radiometer and of the atmosphere at the time and location of the measurement.

Theoretical Background

Atmospheric ultraviolet radiation measurements are difficult to perform due to the drastic decrease of UV-B irradiance towards shorter wavelengths, caused by the strong stratospheric Ozone absorption. Besides the extinction of UV radiation due to Ozone, Rayleigh scattering also affects the radiation, especially in the UV-B spectral region.

As UV radiation represents only a small portion of the solar spectrum, broadband UV radiometers contain filters and use signal amplifiers to measure the UV irradiance in the appropriate spectral region. Filters are used to measure the UV irradiance in the UV-A or UV-B spectral region, or to match as closely as possible a specific theoretical weighting function, such as UV-E.

As the actual radiometer spectral response functions do not correspond exactly to the theoretical weighting functions, even for the radiometers measuring only UV-A or UV-B irradiances, the measurements are affected by a systematic error caused by spectral mismatch.

The SUV Series is suitable for the measurement of UV irradiance according to theoretically defined UV-A, B and E spectra. In general all broadband filter instruments have limited performance due to the intrinsic spectral mismatch of each sensor with respect to the theoretical definitions of UV-A, B and E.

By knowing the spectral mismatch in detail, one can compensate the instrument effects for different measurement conditions. Kipp & Zonen has developed a unique software program for post-processing and analysis of UV data. The UVIATOR program performs automatically a number of UV measurement corrections and thereby improves the measurement quality significantly.

The spectral mismatch error correction is based on the correction method described in the WMO Report No. 141 [Ref. 2]. Further explanations and discussions of the spectral mismatch error are presented in a number of publications listed at the end of this section.

3.1 UV radiometer calibration and correction method

To achieve the most accurate measurement result with broadband UV radiometers, the raw signals must be transformed into UV irradiances using two 'Calibration Steps' (A and B), and an 'Adjustment Step'.

Calibration Step A:

The raw signal of the instrument (in units of Volts) has to be transformed into an irradiance (in units of W/m²). To achieve this transformation a so-called 'radiometric calibration factor', denoted as ρ (in units of V/W/m²), has to be determined.

Calibration Step B:

The irradiances have to be corrected for the spectral mismatch error with 'conversion factors', denoted as γ (no units). These conversion factors are determined using modelled UV irradiances as a function of various total Ozone column densities and solar zenith angles.

Adjustment Step:

The corrected UV measurements are obtained by multiplying the raw UV radiometer reading under outdoor measurement conditions with an appropriate 'adjustment factor', χ , defined as $1/(\rho \cdot \gamma)$. The appropriate adjustment factor has to be chosen according to the measurement conditions at the time of the UV radiometer reading.

The Adjustment Step which provides the final, corrected, UV irradiance (in units of W/m^2) is carried out by the UVIATOR program for each individual SUV radiometer reading. Before the broadband SUV radiometer can be used in the field, it must be factory calibrated according to Calibration Steps A and B, which provide the calibration and correction factors for a particular instrument.

The next two paragraphs describe Calibration Steps A and B as they are performed at Kipp & Zonen. The first paragraph of this chapter describes the Adjustment Step as implemented in the UVIATOR program.

3.1.1 Calibration Step A: determination of the radiometric calibration factor

The radiometric calibration of the broadband SUV radiometers is performed with a Xenon lamp, a monochromator and a calibrated Silicon photo-diode detector. The photo-diode and the test SUV radiometer are mounted behind the exit slit of the monochromator.

They are exposed to spectral irradiances between 280 nm and 400 nm (step increments 1 nm, slit width 2 nm at FWHM). The spectral measurements are performed sequentially as the monochromator has one exit slit only. Nevertheless, identical monochromator output signals can be achieved for the photo-diode and the SUV radiometer by positioning the sensitive surfaces of both detectors at the same distance from the exit slit.

A calibration factor is defined as the ratio between the radiometer output and the radiation input, i.e. the radiometer reading divided by the UV irradiance. To obtain the radiometric calibration factor, ρ , in the laboratory, the UV radiometer output and the UV irradiance input are determined using the monochromatic measurements.

The broad-band UV radiometer output can be calculated according to:

$$U_{SUV} = \int u_{SUV}(\lambda) \cdot d\lambda$$

where $u_{SUV}(\lambda)$ are the spectrally measured test SUV readings. $u_{SUV}(\lambda)$ is also referred to as the spectral response function. The index SUV denotes the variable of a broad-band SUV radiometer. The radiometer-weighted UV irradiance input, can be calculated as:

$$E_{SUV} = \frac{\int e_{Si}(\lambda) \cdot s_{SUV}(\lambda) \cdot d\lambda}{A_{eff}}$$

where $e_{Si}(\lambda)$ is the irradiance (in units of W/nm) of the monochromator output (measured with the photo-diode), $s_{SUV}(\lambda)$ is the normalized spectral response function of the test SUV radiometer (i.e. $u_{SUV}(\lambda)/\max(u_{SUV}(\lambda))$), and A_{eff} is the effective area (in m^2) of the SUV radiometer detection surface. Finally, the radiometric calibration factor is obtained from the two monochromator-based measurements (U_{SUV} and E_{SUV}) according to $\rho = U_{SUV} / E_{SUV}$. The units of ρ are $V/(W/m^2)$.

3.1.2 Calibration Step B: determination of the conversion factor table

Without any measurement correction, a broadband UV radiometer can provide results that deviate by a factor of 2 or more from the true values. The magnitude of the deviation depends mainly on the extent of the spectral mismatch and the measurement conditions.

The measurement conditions for which correction factors are calculated are obtained by varying the solar zenith angle, Θ_0 , and the total Ozone column density, $[O_3]$ in the radiative transfer model TUV [Ref. 3]. Other atmospheric parameters affecting UV irradiances, such as extinction due to aerosols, are not explicitly included as they are assumed to be comparatively small.

The modelled UV spectra are used to determine the conversion factors, $\gamma(\Theta_0, O_3)$, which are defined as:

$$\gamma = T_{SUV} / T_{SUX}$$

where T_{SUV} and T_{SUX} denote the normalized spectral response function-weighted irradiance and the ‘true’ irradiance, respectively:

$$T_{SUV}(\Theta_0, O_3) = \int e_{TUV}(\lambda, \Theta_0, O_3) s_{SUV}(\lambda) d\lambda$$

and

$$T_{SUX}(\Theta_0, O_3) = \int e_{TUV}(\lambda, \Theta_0, O_3) s_{SUX}(\lambda) d\lambda$$

where $e_{TUV}(\lambda, \Theta_0, O_3)$ denotes the TUV modelled irradiance as a function of the variable input parameters Θ_0 and O_3 . Note, that the ‘true’ irradiance, TUVX, represents the modelled irradiance weighted with a theoretical spectral response function, $s_{SUX}(\lambda)$. Such a theoretical spectral response function could be the Erythemal weighting function CIE-1987 [Ref. 4]. The conversion factors calculated with the Erythemal weighting function provide the corrections for the SUV-E-T radiometer.

The solar zenith angles, Θ_0 , are varied between 0° and 85° (using steps of 5°) and the Ozone column densities, $[O_3]$ are varied between 200 Dobson Units (DU) and 500 DU (using steps of 10 DU), yielding $18 \times 31 = 558$ conversion factors. If UV irradiances have to be measured with broadband UV radiometer under exceptional conditions, it is recommended to calculate new conversion factors using model parameters that are representative for the exceptional condition (e.g. snow-covered land surface at a location which is mostly snow-free).

3.2 Adjustment Step: UVIATOR correction method

To obtain the most accurate UV irradiances using broad band UV radiometers, the readings ('raw radiometer output') must be multiplied with the adjustment factor, χ . This is a combined correction factor, composed of the radiometric calibration factor, ρ , and the conversion factor, γ , i.e. $\chi = 1 / (\rho \cdot \gamma)$.

The UVIATOR program performs the required selection of the appropriate conversion factor automatically and corrects an instantaneous SUV measurement according to the conditions at the time and location of the measurement. For the selection of the conversion factor, the parameters Θ_0 and O_3 have to be determined according to the measurement conditions at the time of the UV radiometer reading.

The UVIATOR program calculates the solar zenith angle, Θ_0 , for each measurement as a function of the measurement location (latitude and longitude) and the GMT of the reading. The total Ozone column density, O_3 , is automatically retrieved from the OMI or TOMS satellite data archives. Note, that TOMS data are daily mean values only. UVIATOR offers plug-ins to allow the use of other Ozone column observation data, such as from the Kipp & Zonen Brewer.

Finally, the UVIATOR program corrects the UV measurements using the appropriate solar zenith angles and Ozone column densities and makes a new data file.

References:

- [1] WMO/GAW Report No. 120: WMO - UMAP Workshop on Broad-Band UV Radiometers, Garmisch-Partenkirchen, Germany, 1996. WMO TD - No. 894
- [2] WMO/GAW Report No. 141: Report of the LAP/COST/WMO Intercomparison of Erythemat Radiometers, Thessaloniki, Grece, 1999. WMO TD - No. 1051 [3] TUV discrete ordinate radiative transfer model, Madronich et al. 1998, www.acd.ucar.edu
- [4] McKinley, A.F. and B.L. Diffey, 1987: A reference action spectrum for ultraviolet induced erythema in human skin. CIE J., 6, 17-22.
- [5] Schreder, J., J. Gröbner, A. Los, and M. Blumthaler, 2004: Intercomparison of monochromatic source facilities for the determination of the relative spectral response of erythemat broadband filter radiometers. Optics Letters, 29(13).

4

Accessories

Below is a brief description of the accessories available for SUV radiometers. Detailed information can be found on our website, where the brochures and manuals for these accessories can be viewed and downloaded.

4.1 Ventilation

To further improve measurement accuracy of the SUV radiometers the CVF4 ventilation unit can be used. CVF4 has a tachometer output to monitor the fan speed and 5 or 10 Watt heater. The advantages of a CVF4 are:

- No precipitation or condensation on the dome
- Less dirt on the dome
- Frost, snow or ice can be melted
- Less frequent cleaning required

4.2 Mountings

For mounting radiometers the following plates and brackets are available:

- CMF1 mounting fixture with rod for mounting one unventilated SUV radiometer
- CMF4 mounting plate with rod for mounting one ventilated SUV radiometer
- CMB1 mounting bracket to fix and adjust a mounting rod to a mast, pole or wall
- Adjustable Tilt Radiometer mounting kit for mounting a radiometer at a zenith angle from 0° to 90°

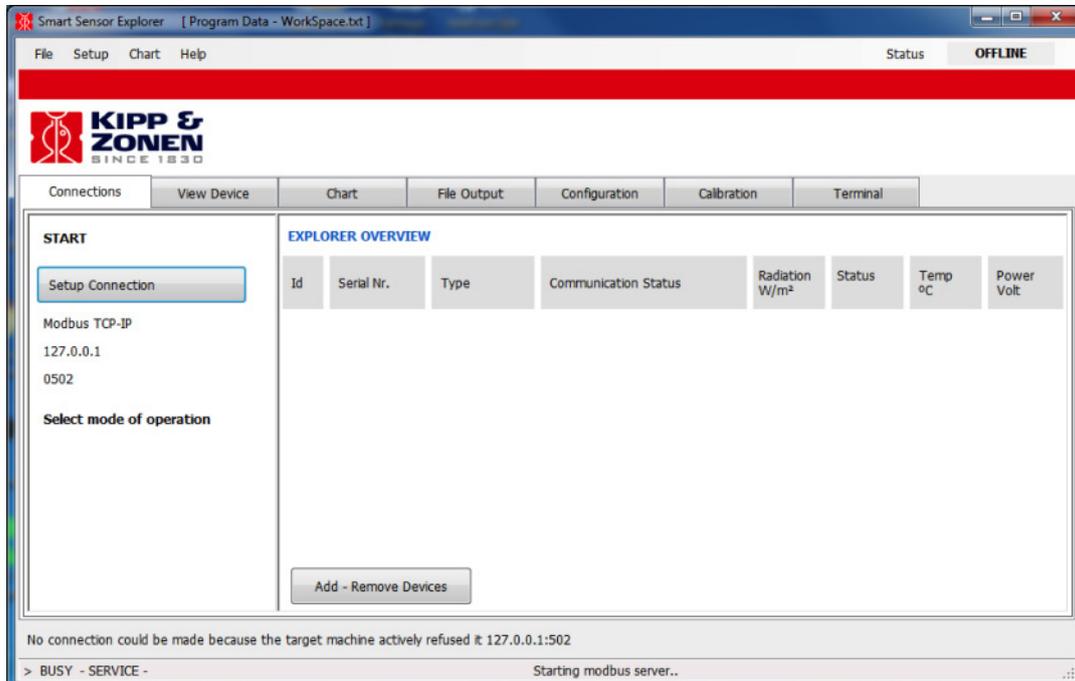
4.3 Cables

For the SUV radiometers different cable lengths are available with a pre-wired waterproof connector plug. Also a loose connector can be ordered for you to fit to your own cable.

- 10 m cable with connector
- 25 m cable with connector
- 50 m cable with connector
- Loose connector without cable

SmartExplorer software and Modbus® communication

The SmartExplorer software allows you to configure a smart sensor and to collect real-time data. SmartExplorer runs on a PC with Windows Vista, 7, 8 or 10 and when installing downloads the .NET 4.5 frame work from the Microsoft Server. When using the software on site, make sure the software is already installed on your laptop.



To connect a smart radiometer to a PC, a RS-485 to USB converter is required. Recommended is using an isolated version like the 'USOPTL4' from B&B for safety and protection of the PC.

- Configuration makes it possible to configure a smart sensor 'out of the box' and test the smart sensor before the sensor is used in an operational network.
- The SmartExplorer software can use a RS-485 to USB or Ethernet interface to connect to a PC
- Collecting data makes it possible to store data from the smart sensor in a comma separated file. The comma separated file is created at the beginning of every new day or at the beginning of the first day of the week.
- The SmartExplorer software can also be used to monitor and/or log up to 10 instruments simultaneously and works with all smart radiometers (SMP, SHP, SGR, SUV, RT1).

Please check the separate SmartExplorer manual for detailed information about the set-up, monitoring and data logging of the smart sensors. The latest version of the manual can be downloaded the from the relevant product page under the tab 'Download' from our website.

The factory default communication parameters for all Smarts are:

- The factory default Baud rate of a smart sensor is '19200 baud'
- The factory default Size and Parity is '8 bits - even - 1 stopbit'
- The factory default Modbus® address is 1

6 Operation and measurement

SUV radiometers only require suitable sources of power and radiation to operate and make measurements. However, it is necessary to connect them to some sort of readout or data storage device in order to save the measurements, there is no internal data memory.

6.1 Data collection

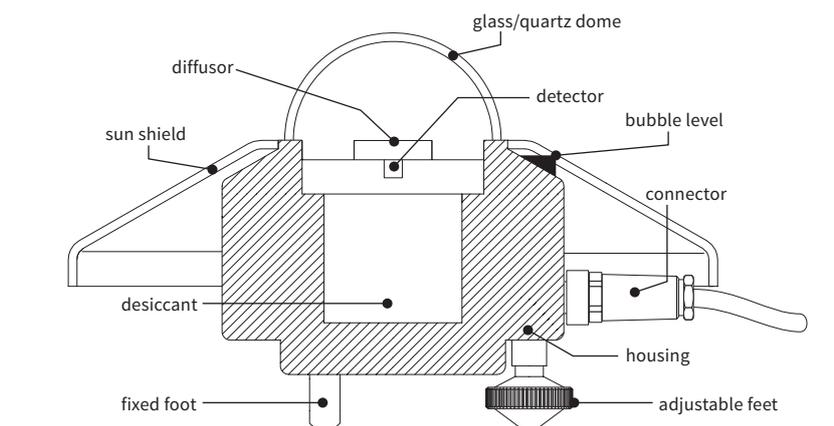
An optimal setting for the data interval is to sample every second and store one minute averages. For setting up the combination of radiometer and data storage please refer to the manual of the data collection device.

Take care when using the analogue output to match the output range of the radiometer closely to the input range of the data collection device to maximise the available resolution and minimise noise.

This can be done by determining the maximum expected analogue output of the radiometer in your application and taking the minimum input range of your data collection device that can just handle that signal.

6.2 Key parts of the SUV radiometer

The detector of the SUV radiometer is a photo diode with a white diffusor on top. This is covered with a glass dome to protect it. The dome is made of a special glass type that transmits sufficient UV light in the UV-A/UV-B range. The photo diode is read by the Smart interface as well as its temperature. The output signal, both digital and analog are temperature corrected values.



The SUV radiometers have a sealed construction with a non-replaceable internal drying cartridge. The internal desiccant lasts for 10 years.

6.2.1 Dome

The material of the radiometer dome is glass or quartz. The UV irradiance can come from any direction within the hemisphere above the radiometer and therefore the dome is designed to minimize errors in measurement at all incident angles (the directional response).

6.2.2 Detector

The measuring element in a SUV radiometer is a photo diode. The photodiode, filter and dome give the SUV radiometers their spectral response. The diffusor in combination with the dome give the SUV radiometers the correct cosine response.

6.2.3 Housing

The radiometer housing accommodates all the key parts of a SUV radiometer. The anodized aluminum parts are lightweight and give high mechanical and thermal stability to the instrument. The stainless steel fixings are isolated where necessary to prevent electrolytic corrosion.

Due to fine mechanical construction SUV radiometers are virtually sealed and comply with international standard IP 67. SUV radiometer can be levelled with two adjustable feet using the bubble level, situated next to the dome of the instrument. For ease of maintenance the bubble level is visible from above without removing the snap-on white sun shield. The sun shield acts to protect all the external parts and to reduce solar heating of the housing.

6.2.4 Desiccant

To keep the detector and electronics dry and to prevent condensation forming inside the domes with temperature changes a desiccant is used to absorb humidity within the radiometer. For the SUV radiometers this desiccant is internal and lasts for 10 year. The desiccant will be exchanged when these instruments comes back to a Kipp & Zonen service location for recalibration.

6.2.5 Cable and connector

For ease of installation and replacement during recalibration of the radiometer, they can be supplied with a waterproof cable socket fit to the radiometer housing. The matching waterproof plug is normally supplied pre-wired to a very high quality yellow cable selected for low noise, very wide temperature range and UV resistance.

Cables come pre-wired to the connector plug in a range of lengths, 10 m is standard. 25 m, 50 m and 100 m lengths are also available. The connector plug can also be supplied loose for the user to fix to their own cable.

7 Maintenance and recalibration

SUV radiometers are simple to maintain and do not require any special tools or training. There are no service items requiring scheduled replacement.

7.1 Daily maintenance

Depending upon the weather conditions dew, glazed frost or hoar frost can be precipitated on the top of the dome and can stay there for several hours in the morning. An ice cap on the dome is a strong diffuser and affects the radiometer signal. Snow may completely cover the dome.

The frequency of cleaning is highly dependent upon the local weather and environmental conditions, such as dust, airborne pollutants or salt spray in marine environments. Ideally, the dome of the radiometer should be cleaned every morning before sunrise. In all cases the frequency of cleaning can be reduced by the use of a ventilation unit, with the heaters switched on when necessary.

Note Clean the dome using pure alcohol or distilled water and a lint-free cloth. Ensure that no smears or deposits are left on the dome.

7.2 Monthly maintenance

Check that the radiometer is level and adjust if necessary.

Check that the sun shield is firmly clipped on.

Check that dome is dry and clean.

7.3 Yearly maintenance

Check all the electrical connections. Unscrew the plugs, clean if necessary and then reconnect.

Check cables for damage caused by accident or by rodents.

Check the instrument mountings and any base supports are secure.

7.4 Calibration

An ideal radiometer gives an output that is proportional to the absolute irradiance level. This relationship can be expressed as a constant ratio called 'sensitivity'. SUV radiometers are very stable instruments, but they do change very slightly with time. Recalibration is recommended every two years. Normally this is carried out at the Kipp & Zonen factory or at an authorized calibration facility.

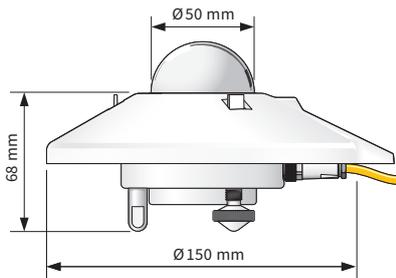
Kipp & Zonen reserves the right to make changes to specifications and other product documentation without prior notice.

8.1 Optical and electrical

Specifications	SUV5	SUV-A	SUV-B	SUV-E
Response time (95%)	< 1%			
Spectral range (overall)	280 to 400 nm	315 to 400 nm	280 to 315 nm	ISO 17166:1999
Measurement range	400 W/m ²	90 W/m ²	9 W/m ²	0.9 W/m ²
Non-stability (change/year)	< 5%	< 5%	< 5%	< 5%
Non-linearity (0 to 400 W/m ²)	< 1%	< 1%	< 1%	< 1%
Directional response (up to 70° with 1000 W/m ² beam)	< 5 W/m ²	< 5 W/m ²	< 5 W/m ²	< 5 W/m ²
Temperature response (-20 °C to +50 °C)	< 2%	< 2%	< 2%	< 2%
Spectral selectivity	< 20%	< 20%	< 20%	< 20%
Field of view	180°	180°	180°	180°
Accuracy of bubble level	< 0.1°	< 0.1°	< 0.1°	< 0.1°
Power consumption (at 12 VDC)	55 mW	55 mW	55 mW	55 mW
Power consumption SUV5-A	100 mW	100 mW	100 mW	100 mW
Software, Windows™	Smart Sensor Explorer Software, for configuration, test and data logging			
Supply voltage	5 to 30 VDC	5 to 30 VDC	5 to 30 VDC	5 to 30 VDC
Detector type	Photodiode with filter	Photodiode with filter	Photodiode with filter	Photodiode with filter
Operating temperature range	-40 °C to +60 °C	-40 °C to +60 °C	-40 °C to +60 °C	-40 °C to +60 °C
Storage temperature range	-40 °C to +80 °C	-40 °C to +80 °C	-40 °C to +80 °C	-40 °C to +80 °C
Humidity range	0 to 100%	0 to 100%	0 to 100%	0 to 100%
Ingress Protection (IP) rating	67	67	67	67
Analogue output • V-Version	0 to 1 V	0 to 1 V	0 to 1 V	0 to 1 V
Analogue output range	-100 to 400 W/m ²	-10 to 90 W/m ²	-1 to 9 W/m ²	-10. to 0.9 W/m ²
Analogue output • SUV5-A	4 to 20 mA	N/A	N/A	N/A
Serial output	RS-485 Modbus®	RS-485 Modbus®	RS-485 Modbus®	RS-485 Modbus®
Serial output range	0 to 400 W/m ²	0 to 400 W/m ²	0 to 400 W/m ²	0 to 400 W/m ²
Weight	600 g	600 g	600 g	600 g

Note: The performance specifications quoted are worst-case and/or maximum values

8.2 Dimensions and weight



Weight without cable: 0.6 kg

There are no user-serviceable parts within the SUV radiometer and it must not be opened without the agreement and instruction of Kipp & Zonen.

9.1 Output signal not present or incorrect

The following contains a procedure for checking the instrument in case it appears that it does not function correctly:

1. Check the SUV radiometer cable wires are properly connected to the readout equipment.
2. Check the power supply (12 VDC recommended).
3. Check that the instrument has a unique Modbus® address.
4. Compare the digital and analogue outputs to see if the problem is in one output only.
5. Check the instrument location. Are there any obstructions that cast a shadow on the instrument by blocking the direct sun during some part of the day?
6. Check the dome, it should be clear and clean.
7. For analogue outputs check the data logger or integrator input offset such that a signal of 0 Volt or 4 mA (as appropriate) gives a 'zero' reading.
8. Check levelling. The bubble should be at least half inside the marked ring of the level.
9. If water, frost or ice is deposited on the dome, clean it. Probably water droplets will evaporate in less than one hour under sunlight.

Any malfunction or visible damage should be reported to your Kipp & Zonen representative, who will suggest the appropriate action.

9.2 Frequently Asked Questions

The most frequently asked questions are listed below. For an update or further information refer to our website at www.kippzonen.com

Q: Is the radiometer calibration affected by the length of the signal cable?

A: With longer cable lengths the impedance increases, however it does not affect the radiometer sensitivity for the following reason. For the SUV Voltage output, the impedance of the voltage measurement device is at least 1000 times more than the impedance of the radiometer plus cable (> 1 MOhm). Then the current that goes through the readout cable is negligible and won't generate an offset.

For the SUV5-A current versions the cable length is limited by the power supply voltage and voltage drop over the cable.

The digital RS-485 output can operate over cable lengths up to 1000 m, depending on the baud-rate used.

If you require any support for your Kipp & Zonen product please contact your local representative in the first instance. The information can be found in the 'Contact' section (home tab) of our website at www.kippzonen.com

Alternatively, you can contact us directly at www.kippzonen.com/support

Please include the following information:

- Instrument model
- Instrument serial number
- Details of the fault or problem
- Examples of data files
- Readout device, data acquisition system and operating system
- Interfaces and power supplies
- History of any previous repairs or modifications
- Pictures of the installation
- Overview of the local environment conditions

Kipp & Zonen guarantees that your information will not be shared with other organisations.

A Appendices

A. Modbus®

A.1 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 SUV series does not make a difference between a 'coil' and a discrete input. The only difference is that a discrete input is read only.

The SUV series do not make a difference between a holding register and an input register. The only difference is that an input register is read only.

A.2 Input registers

Input registers are read only

Real-time Processed Data						
PDU address	Parameter	Name	R/W	Type	Mode	Description
0	IO_DEVICE_TYPE	DevType	R	U	All	Device type of the sensor
1	IO_DATAMODEL_VERSION	DataSet	R	U	All	Version of the object data model
2	IO_OPERATIONAL_MODE	DevMode	R	U	All	Operational mode: normal, service, calibration and so on
3	IO_STATUS_FLAGS	Status	R	U	All	Device Status flags
4	IO_SCALE_FACTOR	Range	R	S	All	Range and scale factor sensor data (determines number of decimal places)
5	IO_SENSOR1_DATA	Sensor1	R	S	N,S	Temperature compensated radiation in W/m ² (Net radiation for SGR)
6	IO_RAW_SENSOR1_DATA	RawData1	R	S	N,S	Radiation (sensor 1) in W/m ²
7	IO_STDEV_SENSOR1	StDev1	R	S	N,S	Standard deviation IO_SENSOR1_DATA
8	IO_BODY_TEMPERATURE	BodyTemp	R	S	N,S	Body temperature in 0.1 °C
9	IO_EXT_POWER_SENSOR	VSupply	R	S	N,S	External power voltage
10	IO_SENSOR2_DATA	Sensor2	R	S	N,S	Temperature compensated long wave down radiation in W/m ² (only for SGR)
11	IO_RAW_SENSOR2_DATA	RawData2	R	S	N,S	Long wave down radiation in W/m ² (only for SGR)
12	IO_STDEV_SENSOR2	StDev2	R	S	N,S	Not used, always 0
13	IO_BODY_TEMP_K	BodyTempK	R	U	N,S	Body temperature in 0.01 °K (only for SGR)
14	IO_AUX_INPUT2	Aux2	R	S	N,S	Not used, always 0
15	IO_AUX_INPUT3	Aux3	R	S	N,S	Not used, always 0
16	IO_DAC_OUTPUT_VOLTAGE	VDAC	R	U	N,S	DAC output voltage or current (actual voltage or current)
17	IO_SELECTED_DAC_INPUT	DacInp	R	U	N,S	DAC selected input voltage

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

Note

Panel temperature and Power sensor need to be divided by 10.

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 μ V
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 μ V
23					(R22=MSB, R23=LSB)
24	IO_ADC4_COUNTS	R	S32	All	Input voltage power sensor in 0.01 μ V
25					(R24=MSB, R25=LSB)

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_PRI01	R	U16	All	Error code priority 1
29	IO_ERROR_COUNT_PRI02	R	U16	All	Error count priority 2
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_TIME	R	U16	All	On time in seconds (MSB word)
33	IO_SENSOR_ON_TIME_L	R	U16	All	On time in seconds (LSB word)
 					
41	IO_BATCH_NUMBER	R	U16	All	Production batch number
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®/SMA) device address RS-485

⁽²⁾ Writing any value to input registers 26-33 will reset the contents of the registers

Legend

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 (MSB first, LSB last)
Mode	Operation mode N available in normal mode S available in service mode C available in calibration mode (not for users) F available in factory mode (not for users) All available in all modes

A.3 Holding registers

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

A.4 Read input register

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

Register 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 102 supports the following type of sensors.

Real-time Processed Data					
Parameter name	Register	R/W	Initial Val	Mode	Description
IO_DEVICE_TYPE	R0	R	65535	All	Selected device type of the sensor
Parameter	Value	# of sensors	1/Sensitivity	Type	
SMP3 (volt version)	601	1		Pyranometer	
SMP3 (current loop version)	602	1		Pyranometer	
SMP6 (volt version)	619	1		Pyranometer	
SMP6 (current version)	620	1		Pyranometer	
SMP10 (volt version)	617	1		Pyranometer	
SMP10 (current version)	618	1		Pyranometer	
SMP11 (volt version)	603	1		Pyranometer	
SMP11 (current loop version)	604	1		Pyranometer	
SMP21 (volt version)	605	1		Pyranometer	
SMP21 (current loop version)	606	1		Pyranometer	
SMP22 (volt version)	607	1		Pyranometer	
SMP22 (current loop version)	608	1		Pyranometer	
SGR3 (volt version)	609	2*		Pyrgeometer	
SGR3 (current loop version)	610	2*		Pyrgeometer	
SGR4 (volt version)	611	2*		Pyrgeometer	
SGR4 (current loop version)	612	2*		Pyrgeometer	
SHP1 (volt version)	613	1		Pyrheliometer	
SHP1 (current loop version)	614	1		Pyrheliometer	
PR1 (volt version)	621	1		Pyranometer	
PH1 (volt version)	623	1		Pyrheliometer	
SUV-A (volt version)	625	1		UV-A Radiometer	
SUV-B (volt version)	627	1		UV-B Radiometer	
SUV-E (volt version)	629	1		UV-E Radiometer	
SUV5 (volt version)	615	1		UV Broadband Radiometer	
SUV5 (current loop version)	616	1		UV Broadband Radiometer	
RT1 (volt version)	631	1		Rooftop sensor	

Register 1 IO_DATAMODEL_VERSION

The data-model describes the functions supported by the smart sensor. This document is valid for data-model version: '100' and '101'. 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 ≥ 102 . If you receive another value then you should read an older or newer version of this document and check the differences.

Register 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 and 5 = Error mode. The standby mode (mode 0) is not supported.

After power on the operation mode (1) is set. When the IO_CLEAR_ERROR is set then the smart sensor always returns to the normal mode. When the Error mode (5) is set, then there is a fatal error.

Register 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 0	Quality of the signal	see IO_VOID_DATA_FLAG
Bit 1	Overflow	see IO_OVERFLOW_ERROR
Bit 2	Underflow	see IO_UNDERFLOW_ERROR
Bit 3	Error flag	see IO_ERROR_FLAG
Bit 4	ADC Error	see IO_ADC_ERROR
Bit 5	DAC Error	see IO_DAC_ERROR
Bit 6	Calibration Error	see IO_CALIBRATION_ERROR
Bit 7	Update EEPROM error	see IO_UPDATE_FAILED

Register 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 set during calibration mode or it can be changed during operation (see register IO_DEF_SCALE_FACTOR and coil IO_AUTO_RANGE).

If the register IO_SCALE_FACTOR is not set to 0 then you must multiply or divide the data of register (X), whereas X is one of the above mentioned registers.

Scale factor = 2 (floating point) result = (integer) register (X) / 100.0
 Scale factor = 1 (floating point) result = (integer) register(X) / 10.0
 Scale factor = 0 (floating point) result = (integer) register(X)
 Scale factor = -1 (floating point) result = (integer) register(X) * 10.0

The default value of register IO_SCALE_FACTOR is 0. However, this value can be set to a different value if the coil IO_AUTO_RANGE is set or a different value is written to the register IO_DEF_SCALE_FACTOR (set default scale factor).

Register 5 IO_SENSOR1_DATA

This register holds the actual data (solar radiation) measured by the sensor. The solar radiation is measured in W/m².

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 using 2 different kinds of filters (See IO_FAST_RESPONSE and IO_TRACKING_FILTER).

Register 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.

Register 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 poll. The standard deviation is measured in 0.1 W/m². To convert the data to a floating point, make the following calculation:

(floating point) result = (integer) register (IO_STDEV_SENSOR1) / 10.0

Register 8 IO_BODY_TEMPERATURE

The body temperature sensor measures the temperature of the body in 0.1 °C.

The convert the data to a floating point number, make the following calculation:

(floating point) result = (integer) register (IO_BODY_TEMPERATURE) / 10.0

Register 9 IO_EXT_POWER_SENSOR

The Ext power sensor measured the external voltage applied to the sensor in 0.1 Volt.

The convert the data to a floating point number, make the following calculation:

(floating point) result = (integer) register (IO_EXT_POWER_SENSOR) / 10.0

Example

Read registers: 'operational mode to external power' from Modbus® device with address 1.

Tx transmitted data to the smart sensor

Rx received data from the smart sensor

SendModbusRequest (0x04, 1, IO_OPERATIONAL_MODE, 8);

Tx 01 04 00 02 00 08 50 0C

Rx 01 04 10 00 01 00 00 00 03 E5 03 E5 00 00 00 F8 00 EA 66 12

Explanation of the received bytes:

- 01 = MODBUS address
- 04 = read input registers
- 10 = number of received data bytes
- 00 01 = operational mode (mode 1)
- 00 00 = status flags (none)
- 00 00 = scale factor = 0 = 1x
- 03 E5 = 997 decimal = sensor 1 data in W/m²
- 03 E5 = 997 decimal = raw sensor 1 data in W/m²
- 00 00 = 0 = standard deviation sensor 1
- 00 F8 = 248 = 24.8°C.
- 00 EA = 234 = 23.4 Volt
- 66 12 = MODBUS checksum (CRC16)

A.5 Discrete inputs

A discrete input can be true or false. A discrete input is read only; a coil can be read or written.

Status indicators					
Input	Parameter	R/W	Def.	Mode	Description
0	IO_FALSE	R	0	All	Always false (for testing only)
1	IO_TRUE	R	1	All	Always true (for testing only)
2	IO_VOID_DATA_FLAG	R	*	All	Void signal, 1=unstable signal, temperature too low or too high
3	IO_OVERFLOW_ERROR	R	*	All	Overflow, signal out of range
4	IO_UNDEFLOW_ERROR	R	*	All	Underflow signal out of range
5	IO_ERROR_FLAG	R	*	All	General hardware error (set if one of the H/W error flags is set)
6	IO_ADC_ERROR	R	*	All	Hardware error A/D converter
7	IO_DAC_ERROR	R	*	All	Hardware error D/A converter
8	IO_CALIBRATION_ERROR	R	*	All	Calibration checksum error
9	IO_UPDATE_FAILED	R	*	All	Update calibration parameters failed

Legend

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 C available in calibration mode (not for users) F available in factory mode (not for users) All available in all modes

Inputs can be read in all modes but some coils can't be written in normal mode or service mode.

A.6 Coils

Device control					
Coil	Parameter	R/W	Def.	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_ROUNDOFF	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)

Note 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.

ADC CONTROL					
Coil	Parameter	R/W	Def.	Mode	Description
24 to 34	Factory use only				

A.7 Read write holding registers

Register 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

Scale factor 0 is the default value. See also input register 4 IO_SCALE_FACTOR.

A.8 Read discrete inputs

Discrete input 0 IO_FALSE This discrete input is always false

Discrete input 1 IO_TRUE This discrete input is always true

Discrete input 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 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.

Discrete input 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/m².

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.

Discrete input 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/m².

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.

Discrete input 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** in order to reset the error flag.

Discrete input 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.

Discrete input 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.

Discrete input 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 recalibration.

Discrete input 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 is 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).

A.9 Read write discrete coils

Coil 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.

Coil 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.

Coil 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.

Coil 22 **IO_FASTRESPONSE**

Setting this coil enables the fast response filter. This filter increases the step response of the sensor.

The default value for SUV radiometers is OFF.

Coil 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.

A.10 Requesting serial number

Register 41 **IO_BATCH_NUMBER**

The batch number defines the production year of the smart sensor, 11 = 2011, 12=2012 etc.

Register 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.

A.11 A.11 Simple 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 uOperationalMode, 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 modbus data will wait for the answer and copies the data to registers
        // uOperationalMode, uStatusFlags, iScaleFactor and iSensorData

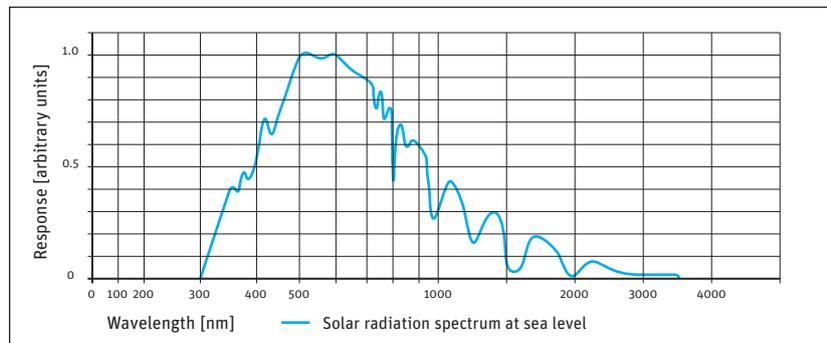
        SendModbusRequest (0x04, 2, IO_OPERATIONAL_MODE, 4);
        WaitModbusReply ();
        GetModbusData ();

        If (uOperationalMode != 1)
        {
            // Send MODBUS request 0x05 write single coil to slave 2
            SendModbusRequest (0x05, 2, IO_CLEAR_ERROR, true);
            WaitModbusReply ();
        }
        else if (uStatusFlags != 0)
        {
            SendModbusRequest (0x05, 2, IO_CLEAR_ERROR, 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);
    }
}
```

Radiometer physical properties

B.1 Spectral range

The spectrum of the solar radiation reaching the Earth's surface is in the wavelength range between 280 nm and 4000 nm, extending from ultraviolet (UV) to the far infrared (FIR). Due to the excellent physical properties of the glass dome and black absorber paint, Kipp & Zonen SUV radiometers are equally sensitive in a wide spectral range. 97 - 98 % of the total energy will be absorbed by the thermal detector.



B.2 Sensitivity

For the SUV radiometers the physical sensitivities are converted to a digital and analogue output. The SUV radiometers all have an analogue output of 0 to 1 Volt for -100 to 400 W/m^2 . Only the SUV5-A has a 4 to 20mA output is for 0 to 400 W/m^2 .

B.3 Response time

Any measuring device requires a certain time to react to a change in the parameter being measured. The radiometer requires time to respond to changes in the incident radiation. The response time is normally quoted as the time for the output to reach 95 % (sometimes $1/e$, 63 %) of the final value following a step-change in irradiance. It is determined by the physical properties of the thermopile and the radiometer construction.

B.4 Non-linearity

The non-linearity of a radiometer is the percentage deviation in the sensitivity over an irradiance range from 0 to 1000 W/m^2 compared to the sensitivity calibration irradiance of 500 W/m^2 . The non-linear effect is due to convective and radiative heat losses at the black absorber surface which make the conditional thermal equilibrium of the radiometer non-linear.

B.5 Temperature dependence

The sensitivity change of the radiometer with ambient temperature change is related to the thermo-dynamics of the radiometer construction and the used detector type. The temperature dependence is given as percentage deviation with respect to the calibrated sensitivity at $+20 \text{ }^\circ\text{C}$. The SUV radiometers have an integrated temperature sensor and use a fourth-order polynomial function to actively correct for temperature errors over a $-40 \text{ }^\circ\text{C}$ to $+70 \text{ }^\circ\text{C}$ range.

B.6 Tilt error

This is the deviation from the sensitivity at 0° tilt (exactly horizontal) over the range from 0° to 90° tilt under 1000 W/m^2 normal incidence irradiance. The tilt response is proportional to the incident radiation. The error could be corrected for, in applications where it is necessary to install the radiometer on an inclined surface, but is usually insignificant.

B.7 Operating temperature

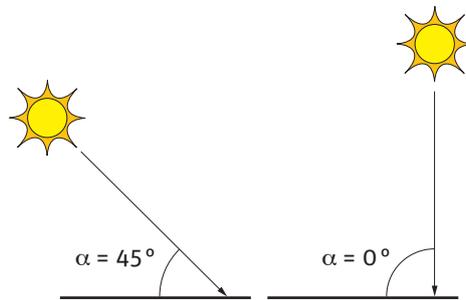
The operating temperature range of the radiometer is determined by the physical properties of the individual parts. Within the specified temperature range Kipp & Zonen radiometers can be operated safely. Outside this temperature range special precautions should be taken to prevent any physical damage or performance loss of the radiometer. Please contact your Kipp & Zonen representative for further information regarding operation in unusually harsh temperature conditions.

B.8 Field of view

The field of view is defined as the unobstructed open viewing angle of a radiometer. ISO and WMO require that a radiometer for the measurement of global solar radiation has a field of view of 180° in all directions (i.e. a hemisphere). The inherent field of view of the instrument should not be confused with the clear field of view of the installation location.

B.9 Directional response

Radiation incident on a flat horizontal surface originating from a point source with a defined zenith position (such as the sun) will have an intensity value proportional to the cosine of the zenith angle of incidence. This is sometimes called the 'cosine-law' or 'cosine-response' and is illustrated below.



Ideally a radiometer has a directional response which is exactly the same as the cosine-law. However, in a radiometer the directional response is influenced by the detector and by the quality, dimensions and construction of the dome(s). The maximum deviation from the ideal cosine-response of the radiometer is given up to 80° angle of incidence with respect to 1000 W/m^2 irradiance at normal incidence (0° zenith angle).

B.10 Maximum irradiance

The maximum irradiance is defined as the total irradiance level beyond which the output is no longer linear and out of specifications. The analogue output for the SUV radiometers is set to 400 W/m^2 , which is sufficient under normal atmospheric conditions.

B.11 Non-stability

This is the percentage change in sensitivity over a period of one year.

Kipp & Zonen recommends recalibration every two years. However, for quality assurance purposes some institutes, companies or networks may require more or less frequent recalibration. Please read the chapter on the calibration procedure for radiometers for more information.

B.12 Environmental

The SUV radiometers are intended for outdoor use under all expected weather conditions. The radiometers comply with IP 67 and their solid mechanical construction is suitable to be used under all environmental conditions within the specified ranges.

Customer Services

Kipp & Zonen stands for quality and our instruments are known around the world for their accuracy, reliability and durability. We invest a lot of care and effort into providing you with the best products available on the market, at a range of price and performance points.

Our instruments have an impressively long operating life when properly maintained. We offer a variety of

services to support and assist you in optimising the use of our instruments.

Resources include our Customer Support System, Download Center and Knowledge Center with FAQ's.

Please go to **www.kippzonen.com** to find your preferred customer support resource.

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