

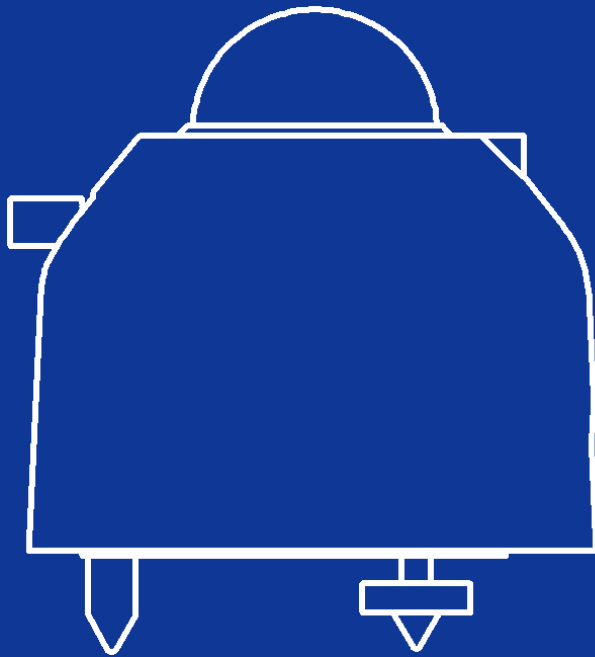
Instruction Manual

Pyranometer

ISO9060: 2018 Class B

Sub-category "Spectrally flat"

MS-60 MS-60S



EKO

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2. Important User Information

Thank you for using EKO Products

Reading this manual is recommended prior to installation and operation of the product. Keep this manual in a safe and handy place for whenever it is needed. For any questions, please contact us at below:

2-1. Contact Information

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2-2. Warranty and Liability

For warranty terms and conditions, please contact EKO Instruments or your distributor for further details.

EKO guarantees that the product delivered to customer has been tested to ensure the instrument meets its published specifications. The warranty included in the conditions of delivery is valid only if the product has been installed and used according to the instructions provided in this operating manual.

In case any manufacturing defect[s] occurs, the defected part[s] will be repaired or replaced under warranty; however, the warranty will not be applicable if:

- Any modification or repair has been done by other than EKO service personnel.
- The damage or defect is caused by disrespecting the specifications mentioned on the product brochure or instruction manual.
- Spirit level
- Discoloration of the pyranometer body, sun screen, and cable within a range that does not affect the function and performance.

2-3. About Instruction Manual

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This manual was issued: Jun. 10, 2021
Version Number: 5

2-4. Environment

1. WEEE Directive 2002/96/EC [Waste Electrical and Electronic Equipment]



In August of 2005, the European Union [EU] implemented the EU WEEE Directive 2002/96/EC and later the WEEE Recast Directive 2012/19/EU requiring Producers of electronic and electrical equipment [EEE] to manage and finance the collection, reuse, recycling and to appropriately treat WEEE that the Producer places on the EU market after August 13, 2005. The goal of this directive is to minimize the volume of electrical and electronic waste disposal and to encourage re-use and recycling at the end of life.

EKO products are subject to the WEEE Directive 2002/96/EC. EKO Instruments has labeled its branded electronic products with the WEEE Symbol [figure Trash bin] to alert our customers that products bearing this label should not be disposed of in a landfill or with municipal or household waste in the EU.

If you have purchased EKO Instruments branded electrical or electronic products in the EU and are intending to discard these products at the end of their useful life, please do not dispose of them with your other household or municipal waste. Disposing of this product correctly will help save valuable resources and prevent any potential negative effects on human health and the environment, which could otherwise arise from inappropriate waste handling.

2. RoHS Directive 2002/95/EC

EKO Instruments has completed a comprehensive evaluation of its product range to ensure compliance with RoHS Directive 2002/95/EC regarding maximum concentration values for substances. As a result, all products are manufactured using raw materials that do not contain any of the restricted substances referred to in the RoHS Directive 2002/95/EC at concentration levels in excess of those permitted under the RoHS Directive 2002/95/EC, or up to levels allowed in excess of these concentrations by the Annex to the RoHS Directive 2002/95/EC.

2-5. ISO/IEC 17025

EKO Instruments Co. Ltd. calibration laboratory is accredited by Perry Johnson Laboratory Accreditation, Inc. [PJLA] to perform pyranometer and pyrhelimeter calibrations in accordance with the requirements of ISO/IEC17025, which are relevant to calibration and testing.

EKO is a manufacturer who can offer calibration service for pyranometers and pyrhelimeters in-house. Based on the applied calibration methods EKO provides the best quality solar sensor calibrations compliant to the international standards defined by ISO9847 [Indoor method] and ISO9059 [Outdoor method] [Certification: L13-94-R2 / www.pjilabs.com]

ISO/IEC17025 provides a globally accepted basis for laboratory accreditation that specifies the management and technical requirements. With calibrations performed at the EKO Instruments laboratory we enable our customers to:

- Clearly identify the applied calibration methods and precision
- Be traceable to the World Radiation Reference [WRR] through defined industrial standards:
 - ISO9846 Calibration of a pyranometer using a pyrhelimeter
 - ISO9847 Calibration of field pyranometer by comparison to a reference pyranometer
 - ISO9059 Calibration of field pyrhelimeters by comparison to a reference pyrhelimeter
- Obtain repeatable and reliable calibration test results through consistent operations

Our clients will obtain highly reliable data by using an ISO/IEC17025 calibrated sensor. Our Accredited lab is regularly re-examined to ensure that they maintain their standards of technical expertise.

2-6. CE Declaration



IMPORTANT USER INFORMATION



DECLARATION OF CONFORMITY

We: EKO INSTRUMENTS CO., LTD
1-21-8 Hatagaya Shibuya-ku,
Tokyo 151-0072 JAPAN

Declare under our sole responsibility that the product:

Product Name: Pyranometer
Model No.: MS-60

To which this declaration relates is in conformity with the following
harmonized standards of other normative documents:

Harmonized standards:

EN 61326-1:2006 Class A (Emission)
EN 61326-1:2006 (Immunity)

Following the provisions of the directive:

EMC-directive: 89/336/EEC
Amendment to the above directive: 93/68/EEC

Date: June 30, 2017

Position of Authorized Signatory: Deputy General Manager of Quality Assurance Dept.

Name of Authorized Signatory: Shuji Yoshida

Signature of Authorized Signatory: *Shuji Yoshida*

**DECLARATION OF CONFORMITY**

We: EKO INSTRUMENTS CO., LTD
1-21-8 Hatagaya Shibuya-ku,
Tokyo 151-0072 JAPAN

Declare under our sole responsibility that the product:

Product Name: Pyranometer
Model No.: MS-60S

To which this declaration relates is in conformity with the following harmonized standards of other normative documents:

Harmonized standards:

EN 61326-1:2013 Class A (Emission)
EN 61326-1:2013 (Immunity)

Following the provisions of the directive:

EMC-directive: 2014/30/EU

Date: Feb. 25, 2021

Position of Authorized Signatory: Manager of Quality Assurance Div.

Name of Authorized Signatory: Minoru Kita

Signature of Authorized Signatory: 

3. Safety Information

EKO Products are designed and manufactured with consideration for safety; however, please make sure to read and understand this instruction manual thoroughly to be able to operate the instrument safely in the correct manner.



WARNING CAUTION

Attention to user; pay attention to the instructions given on the instruction manual with this sign.



HIGH VOLTAGE WARNING

High voltage is used; pay special attention to instructions given on this instruction manual with this sign to prevent electric leakage and/or electric shocks.



3-1. General Warnings

1. Setup

- The installation base or mast should have enough load capacity for the instrument to be mounted. Fix the pyranometer securely to the base or mast with bolts and nuts; otherwise, the instrument may drop due to a gale or an earthquake, which may lead to unexpected accidents.
- Make sure to install the instrument and cables in a suitable location and avoid submersion in water.
- When connecting this product to a measuring instrument for measurement, connect the shield wire of the output cable to signal ground (SG) for MS-60 and to ground earth for MS-60S. Noises may be included in the measurement data.
- Although this product is tested to meet EMC Directive compliance requirements, it may not fully satisfy its primary specification/performance when using this product near following locations where strong electromagnetic wave is generated. Please pay attention to the installation environment.
 - Outdoor: High voltage power line, power receiver/distribution facility, etc.
 - Indoor: Large-size chiller, large rotation device, microwave, etc.
- Do not use this product in the environment where corrosive gas, such as ammonia and sulfurous acid gas, are generated. It may cause malfunction.
- Do not install in the area that cause salt damages. It may cause malfunction by paint peeling off or corrosion. When installing in the area with risk of salt damages, make sure to take following measures:
 1. Wrap the connector with self-fusing tape
 2. Change the fixing screw to bolt screw made of aluminum
 3. Run the cables in a plastic or metal pipe treated with salt-resistant paint such as molten zinc plating
 4. Periodically clean.
- Do not use this instrument in the vacuum environment.
- For proper grounding use the original cable provided.

- If the cable and sensor are in risk for getting damaged by birds and small animals, protect the cable and the sensor by using:
 1. Reflective tape
 2. Repellent
 3. Cable duct
 4. Installing bird-spike
- When using the configurable 0-1V output from MS-60S, please use a precision shunt resistor 100Ω. The settings can be changed with the 485 / USB conversion cable and dedicated software.

2. Handling

- Be careful when handling instruments with glass domes. Strong impact to this part may damage the glass and may cause injuries by broken glass parts.
- When carrying any MS-60 model with the sun screen attached, always hold the instrument from the bottom. Holding only the sun screen part may lead to dropping the sensor as it comes off from the sun screen.

3. Signal Cable [MS-60S]

- Make sure to ground the signal cable. When grounding is insufficient, it may cause not only measurement error due to noise, but also cause electric shock and leakage accidents or damage to the electronics.
- Check the voltage and types of specified power supply before connecting this instrument. When improper power supply is connected, it may cause malfunction and/or accident.
- Use this instrument with 0.5A fuse connected to the power supply line in series. Without connecting the fuse, it has risks of generating heat and fire due to large-current flowing by the power supply when internal damage of the electronics occurs.

4. About RS-485 Modbus connection [MS-60S]

- This product supports communication through the RS-485 Modbus RTU protocol.
- It is recommended to use the optional EKO converter cable when connecting MS-60S to a PC.
- Depending on the USB-RS485 converter type, an additional termination resistor (120Ω) and/or pull-up/pull-down resistor (680Ω) may be required for proper communication.
- When connecting to a RS-485 (Modbus) master peripheral device, an additional termination resistor (120Ω) and/or pull-up/pull-down resistor (680Ω) may be required for proper communication.

4. Introduction

The International Industrial Standard ISO9060 was revised in 2018 to the second edition, and with this the pyranometers will be classified as "Class A" "Class B" and "Class C" in order descending performance classification. For the pyranometers that meet the criteria of response time and spectral selectivity, "fast response" and "spectrally flat" respectively are accompanied as subcategories of grades.

MS-60 is a ISO9060:2018 pyranometer that is classified as Class B and meets the subcategory "spectrally flat".

Alumite-treated, robust, lightweight aluminum body with double-glass dome provides a well-balanced product of cost performance and quality.

MS-60/MS-60S is sensitive to the 285 to 3,000nm wavelengths required for measuring solar irradiance, and is capable of measuring in temperatures as severe as -40°C to +80°C.

The S-Series offers advanced measuring capabilities with a variety of industrial signaling outputs (MODBUS 485 RTU, SDI-12, 4-20mA, 0-1V which is in combination with precision shunt resistors 100Ω) and on-board sensors for remote diagnostics of relative-humidity and tilt angle.

MS-60/MS-60S is continuously ventilated in combination with an optional MV-01 (fan + heater unit) to reduce condensation, dust, and snow accumulation on the glass dome.

Main features

- Lightweight aluminum body
- Dual glass dome reduces zero offset
- Ventilation unit with heater can be mounted (optional)
- Supports several output formats (analogue output (mV), MODBUS 485RTU, SDI-12, 4-20mA, And 0-1V (external 100 Ω precision shunt resistor)

All MS-60/MS-60S are manufactured by EKO, and calibration is traceable to the Global Standards for Radiation (World Radiometric Reference) controlled by the World Radiation Center (PMOD/WRC*).

The calibration method of EKO pyranometers is ISO/IEC 17025 accredited and conducted in accordance with the international standard ISO9847 (indoor calibration).

Accredited calibration facilities undergo periodic reviews and maintain the highest levels of calibration standards and technical expertise.

This instrument is warranted for a period of 5 years and a recommended recalibration period of 2 years.

(*) PMOD/WRC: Physikalisch-Meteorologisches Observatorium Davos/World Radiation Center

4-1. About the Pyranometer Series

All MS-60 sensors give excellent durability. The sensor is airtight and can be deployed with little maintenance since the desiccant is incorporated inside. Solar sensors are applied outdoors, hence the detector black surface, optical components and sensor mechanics are constantly exposed to solar radiation, temperature and pressure differences. UV radiation known as harmful radiation to materials can change the chemical properties of substances irreversibly. In the case of the MS-60, the detector is totally isolated below the sensor optics surface, which is sealed, and can't be affected by a high dose of UV, moisture or pressure differences.

Besides, EKO provides a unique calibration service for pyranometers compliant to the international standards defined by ISO9847 [indoor method]. When an ISO/ IEC17025 calibrated sensor is purchased, EKO provides a calibrated sensor with a consistently low calibration uncertainty. The Accredited lab is regularly re-examined to ensure that they maintain their standards of technical expertise.

A setting report is provided with all parameters which were set and tested during manufacturing (current range settings, digital output communication settings, tilt position calibration, relative humidity and sensor temperature).

In case of MS-60, MS-60S, with combination of optional MV-01 [ventilator + heater unit], reduces the dew condensation and accumulation of dusts and snow on glass dome by continuously blowing heated air. The ventilation unit with heater is recommended when the sensor is deployed with a chance of occurrence of condensation, snow and ice. IEC 61724-1 Class B monitoring systems should use the MS-60 series pyranometer with the MV-01 which has a minimum <2W power consumption.

In the following paragraphs, the types are described individually.

1. MS-60

The analog MS-60 pyranometer can be used for optimal performance throughout the day.

Category of ISO9060: 2018

“Spectrally flat pyranometer of class B”

2. MS-60S

The MS-60S with smart sensor technology and onboard diagnostic functions. 4 different output types can be selected, which is a great benefit for system integrators who work with various industrial standards. This new Smart transducer will also have additional features such as internal temperature and humidity sensors and a tilt sensor for remote sensor diagnostics. These additional internal sensors will help the user to monitor the stability of the irradiance sensors as well as to ensure its proper installation and maintenance practices.

Up to 31 smart sensors per one Master can be connected in one network. The signal converter settings can be changed using the optional RS485 / USB converter cable and the configurator software.

Category of ISO9060: 2018

“Spectrally flat pyranometer of class B”

Key features:

- Outputs (**Modbus 485 RTU**, configurable **SDI-12**, **4-20mA**, configurable **0-1V** with external 100Ω precision shunt resistor)
- Low power consumption
- Wide voltage-supply input range [5 to 30 VDC]
- With built-in tilt / roll sensor to check the sensor position over time.
- Humidity and temperature sensor to monitor the sensor temperature and condition of the drying agent (silica gel) inside the sensor body.

4-2. Field applications

The MS-60 analog sensor is well suited to be used in traditional meteorological networks where analog sensors are still common. The MS-60S with digital (Modbus 485 RTU / SDI-12) can be used in a multi sensor network for onsite monitoring of large PV plants. Digital sensor can be easily configured, With the MS-60S, users can connect using a standard laptop and 'Hibi'; a new, custom built programme developed by EKO to give users real-time access to the internal diagnostics, custom settings, and data on irradiance, humidity, internal temperature and tilt angle from the sensor. This data can also be acquired when the pyranometer is connected through the data logger digital serial communication port. Each pyranometer has it own unique communication address. This way multiple pyranometers can be connected in a network.

The MS-60S builds on the revolutionary qualities of the original MS-60 by adding a new internal diagnostics system, giving users remote visibility over body temperature, internal humidity, tilt and roll angle; helping them to ensure optimum performance without the need for regular physical checks. Coupled with the 2-year recalibration interval, the internal diagnostic capabilities of the MS-60S makes it an ideal solution for complex networks, hard to reach locations, and monitoring stations with restricted access.

4-3. Application to the standards

MS-60/MS-60S models are qualified to be used within any application which refers to an international standard according to:

- ISO9060: 2018 Spectrally flat pyranometer class B (Pyranometer classification)
- IEC 61724-1:2017 Class B (PV monitoring system requirement)
- ASTM 2848-11 (Test Method for Reporting Photovoltaic Non-Concentrator System Performance)
- WMO-No. 8, seventh edition 2018 Good quality pyranometer (Meteorological system requirement)
- ISO/TR 9901:1990 (Solar energy field pyranometers recommended practice for use)
- ASTM G183 - 05 (Standard Practice for Field Use of Pyranometers)

MS-60/MS-60S models comply to the international standards for calibration and traceable to the WRR:

- ISO 9847 Calibration of field pyranometers by comparison to a reference pyranometer
- ISO 9846 Calibration of a pyranometer using a pyrhelimeter
- ISO/IEC 17025:2017 scope of accreditation

4-4. Package Contents

Check the package contents first; if any missing parts or any damage is noticed, please contact EKO immediately.

Table 4-1. Package Contents

Item	MS-60	MS-60S
Pyranometer	○	
Output cable	○ ⁽¹⁾	
Sun screen	○	
Instruction Manual	Not included in the package [Please download from EKO Website]	
Setting Report	-	○
Calibration certificate	○	
Quick Start Guide	○	
Fixing Bolts	[M5] × 2 [Bolt Length: 75mm]	
Washers	[M5] × 4	
Nuts	[M5] × 2	

(1) The standard length of the Output cable for the MS-60 / MS-60S is 10 m. If you need a cable longer than 10 m, please contact EKO or your local distributor.

5. Getting Started

5-1. Parts Name and Descriptions

Each part name and its main function is described below.

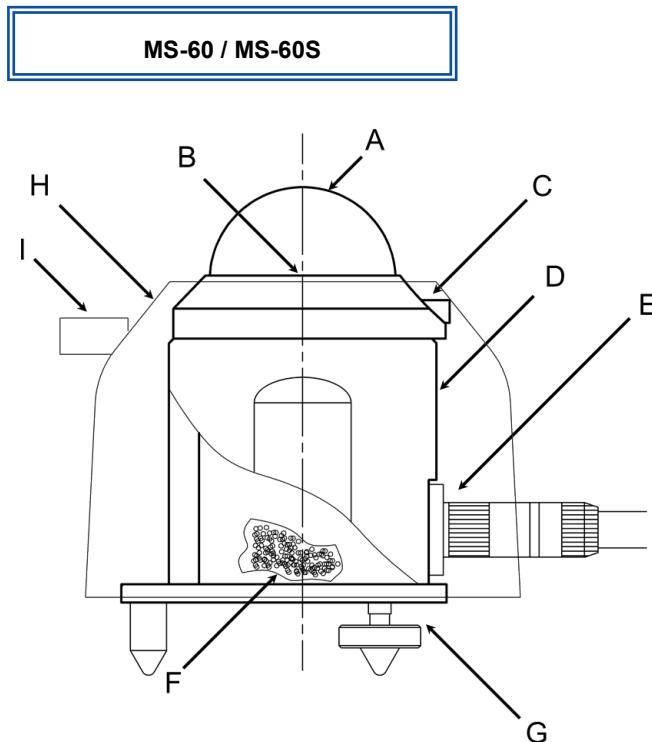


Table 5-1. Part Names
[MS-60 / MS-60S]

Names of parts	
A.	Glass dome (Inner/Outer)
B.	Detector
C.	Spirit level
D.	Body
E.	Cable/Connector
F.	Drying agent
G.	Leveling Screw
H.	Sun screen
I.	Knurled screw

*Signal converter is built-in for MS-60S.

Figure 5-1. Pyranometer Parts Name [MS-60/MS-60S]

1. Inner glass dome/outer glass dome

Glass domes serve to protect the detector from raindrops, snow, and dust, and have an important role in cutting unwanted wavelengths so that only the wavelengths required for the measurement of global pyranometers reach the detector.

By making the glass dome-shaped, light from all directions of the hemisphere can be transmitted with little reflection.

(View angle: 180 degrees) and double structure make it less susceptible to changes in output due to wind, etc.

2. Detector

Thermopile, which generates a voltage proportional to temperature difference [Seebeck Effect], is used for the detector. When light is irradiated on the sensor, temperature of the detector increases; creating the temperature difference at cold junction [body part] will generate an electromotive force on the thermopile. The pyranometer will output this electromotive force as voltage and measuring this voltage will determine the solar irradiance. The thermopile detector, which is the heart of the sensor, determines the majority of the measurement properties [e.g., response time, zero offset B, non-linearity, sensitivity, etc.]. EKO thermopile detectors are very stable in time due to the black absorber material, which has high absorption, and no wavelength dependency is used on the detector surface.

3. Sun screen/Body

MS-60 and MS-60S have a sun screen to prevent any excessive body temperature increase generated by direct sun light. Weather resistant metals are used to reduce the effects and degradation caused by heat radiation, rain, and windblown dusts.

4. Spirit level

The integrated spirit level is used to setup and maintain the sensor in a horizontally leveled position.

* Depending on the operating environment, bubbles may come out of the level gauge, liquid may be missing, the reference circles may fade out, or cracks may occur.

5. Drying agent

Enclosed drying agents inside the sensor body keep the sensor inside dry, prevents condensation of humidity inside of the glass dome.

6. Cable/connector

All pyranometers are shipped with a 10-meter-long output cable as standard length*.

Durable materials are used for the cable and connector, and pin terminals are attached at the end of the cable for easy connection with data logger terminal block.

*If longer cables, round terminals or fork terminals are required, please contact EKO Instruments or your distributor. [Also see [7. Specification, 7-4. Accessories List] for optional items.]

The connector should be protected by the self-fusing tape when the pyranometers are used in the areas with the risk of the salt damage.

5-2. Setup

In order to obtain representative measurements from pyranometers, several criteria with respect to setup and mounting of the instruments have to be considered.

The ideal mounting position for pyranometers is a location which has a full hemispheric field-of-view without any obstructions [such as buildings, trees, and mountain]; however, it might be difficult to find such locations. Therefore, in practice, it is ideal to install in a position which is free from obstructions at 5° above horizon. The setup location should be easily accessible for periodic maintenance [glass dome cleaning, etc.], and avoid surrounding towers, poles, walls or billboards with bright colors that can reflect solar radiation onto the pyranometer. A strong physical impact to the pyranometer can lead to product damage and/or may cause changes to the sensitivity.

1. Installing at Horizontal or Tilted Position

- 1) Check the installation base where the pyranometer must be mounted and make sure it has two fixing holes with the appropriate pitch. The pitch sizes of the fixing holes are as follows [in mm]:

Table 5-2. Fixing Hole Pitch and Bolt Size for Pyranometers

	MS-60 / MS-60S
Fixing Hole Pitch	65 mm
Fixing Bolt Size	M5 x 75 mm

- 2) Remove the sun screen.

The sun screen can be removed by loosening the knurled screw and sliding it towards the spirit level direction.

*When carrying the MS-60 with sun screen attached, always hold the instrument from the bottom. Holding only the sun screen part may lead to dropping the sensor as it comes off from the sun screen.

Setup the pyranometer with the signal cable connector facing the nearest Earth's pole.

In the Northern hemisphere, the connector should be orientated North, in the Southern hemisphere, the connector should be orientated South. If the signal cable connector is facing towards the sun, the temperature of the connector increases and may cause measurement error due unwanted thermoelectric power invited by the connector temperature increase.

- 3) There are two ways to setup the pyranometer (Horizontal or Tilted Position).

Installing at horizontal Position

Adjust the pyranometer in a horizontal position by using the 2 levelling screws observing the air bubble in the spirit level while manipulating the levelling screws. The instrument is levelled horizontally if the air bubble is in the centre ring. The sensitivity of the bubble vial is (0.1° / mm). If the pyranometer is not levelled properly, the pyranometer readings are affected by cosine and azimuth errors. Periodically check the spirit level and adjust the pyranometer's position if necessary.

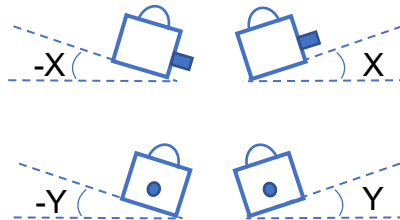
Installing at Tilted Position

After the MS-60, MS-60S is adjusted to horizontal position on a levelled surface, install it on tilted a tilted mount.



When installing the pyranometer, do not remove the levelling feet or fixed feet. If the levelling feet are removed, it may induce offsets to output values due to the thermal effects from the mounting plate.

In the case of MS-60S, it is possible to acquire tilt information obtained from the built-in tilt position sensor through Modbus RTU. The sensor position can be measured in two different planes (X,Y).



- <Tilt (X axis)> (180° to 0) and (0 to -180°)
- <Roll (Y axis)> (180° to 0) and (0 to -180°)

Figure 5.2A Tilt angle (-180 to 0°) and (0 to 180°)
Roll angle (-180 to 0°) and (0 to 180°)

The tilt and roll angles are relative to the calibrated X and Y axis of the sensor and surface mounting plane X' and Y'. When the sensor is positioned in the same plane X = X' and Y = Y', the measured tilt and roll angles (X and Y) correspond to plane of installation X' and Y'.

The pyranometer connector is an important reference for setup and corresponds to the X-axis reference plane.



For setup at horizontal plane: Setup the pyranometer with the signal cable connector facing the nearest Earth's pole. In the Northern hemisphere, the connector should be orientated North, in the Southern hemisphere, the connector should be orientated South. Even if the cable is not oriented to the nearest pole, it does not affect the angle measurement. The angle measurement reflects the tilt and roll of the corresponding sensor position.

For setup at tilted position: Setup the pyranometer with signal cable aligned with the installation platform (X' , Y'), see figure 5-2B. When the sensor is not aligned, the tilt (X) and roll (Y) measurement does not reflect the angle X' and Y' , see figure 5-2C.

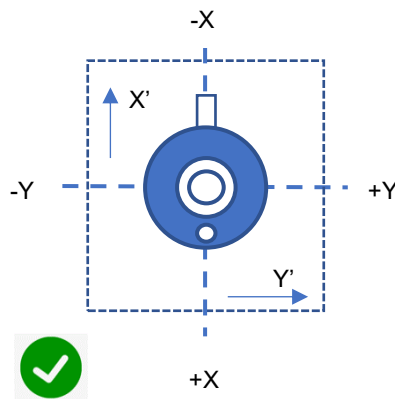


Figure 5-2B Tilt and roll angle corresponding to reference plane

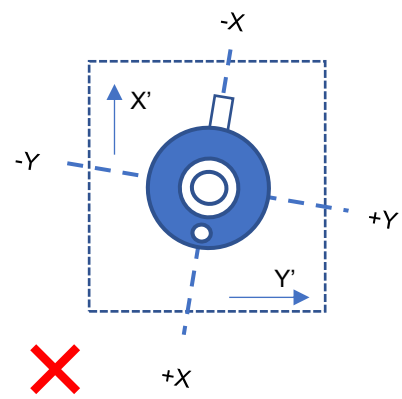


Figure 5-2C Tilt and roll angle not corresponding to reference plane

- 4) Fasten the pyranometer to the base with the 2 bolts [included] and put the sun screen back on the pyranometer.

5-3. Wiring

To extend the cable lifetime, make sure that the cables are not exposed to direct sun light or rain/wind by lining the cable through a cable conduit. Cable vibrations will potentially cause noise in the output signal. Fasten the cable so that the cable does not swing or move by wind blowing. Exposure of the signal cable to excessive electromagnetic emissions can cause noise in the output signal as well. Therefore, the cable should be lined at a safe distance from a potential source generating EMC noise, such as an AC power supply, high voltage lines or telecom antenna.

1. Shield wire connection



<MS-60>

Please be sure to connect the shield wire of the cable to the SG of the measuring instrument side. If it is not connected, it may be affected by noise.

<MS-60S>

The pyranometer housing is connected to the shield wire of the cable, so connect the shield wire to the ground on the measuring instrument side.

Do not connect the pyranometer housing to ground. It will be a two-point ground and it cause a noise.

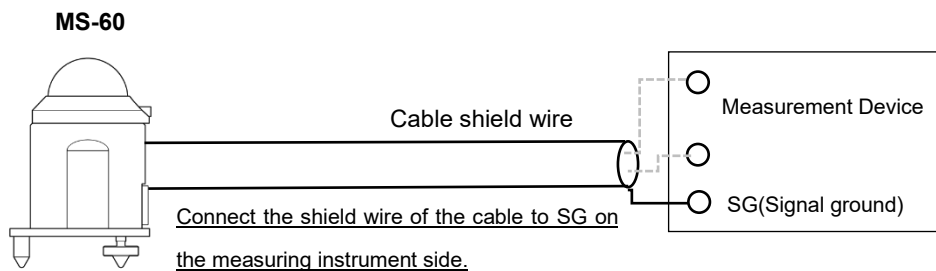


Figure 5-3A. MS-60 shield wire connection method

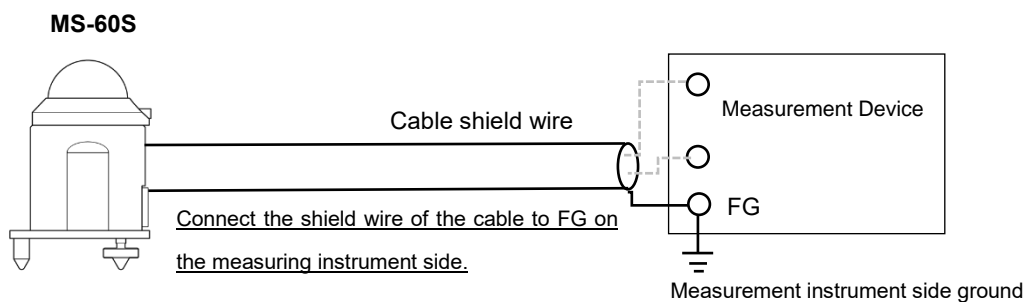


Figure 5-3B. MS-60S shield wire connection method

2. Wiring procedure

- 1) Connect the output cable to the MS-60 and MS-60S by inserting the cable connector to the connector on the body then turn the screw cap. Make sure to check the pin layout of the connector before connecting the cable. If the connector cannot be easily inserted, DO NOT use any force as it will damage the connector. Visually check the pin layout again before retrying to insert the connector. Make sure to fasten the screw cap by turning it all the way.

5-4. Connections

The MS-60S is based on a digital Smart processing interface providing advanced measurement functions with 4 different industrial signal outputs (**Modbus 485 RTU**, configurable **SDI-12**, **4-20mA**, configurable **0-10mA** and **0-1V** with external precision shunt resistor 100Ω).

Table 5-3. Pyranometer outputs

Output	MS-60	MS-60S
Analog (mV)	○	-
Modbus 485 RTU (Default)	-	○
SDI-12	-	○
4 - 20 mA (Default)	-	○
0 - 1V	-	○(*)

(*) MS-60S 0-1V output with external precision shunt resistor 100Ω

Table 5-4. Pyranometer output parameters

Output parameters	MS-60	MS-60S
Irradiance	○	○
Temperature	-	○(*)
Tilt position	-	○(*)
Relative humidity	-	○(*)
Sensor information	-	○(*)

(*) MS-60S digital output (Modbus 485 RTU / SDI-12)

1. Analog output

MS-60S has two analog outputs (4-20mA and 0-1V). The 4-20mA output is default, the 0-1V(0-10mA) output can be enabled through the “Hibi” software which can be downloaded from the EKO website (MS-60S product page). See appendix 3 to change the current output settings. The current output can be converted into a voltage output when a shunt resistor is used in series. In combination of 0-10mA with an external 100Ω precision shunt resistor (0.1%, 15 ppm) a 0-1V output can be made.

Current output (4-20mA)

Connect the 3 wires with corresponding color to the input terminals of the current meter or data logger (figure 5-4). Connect the power terminals to a DC power supply [8 to 30 V]. We recommend to use a fuse [0.5A] to the DC power supply line [+] for over current protection.



Interconnect the power supply (-) and 4-20mA (-) line. The MS-60S current output requires a 3 wire connection.

- **To protect your equipment from noise and surges, the shield wire of the cable must be connected to ground at a single point. If it is not connected, the electronic equipment may be damaged.**
- **The shield wire of the cable is connected to the surge protection circuit inside the pyranometer itself and to the enclosure.**
- **Be sure to connect a fuse, as this may lead to a fire.**

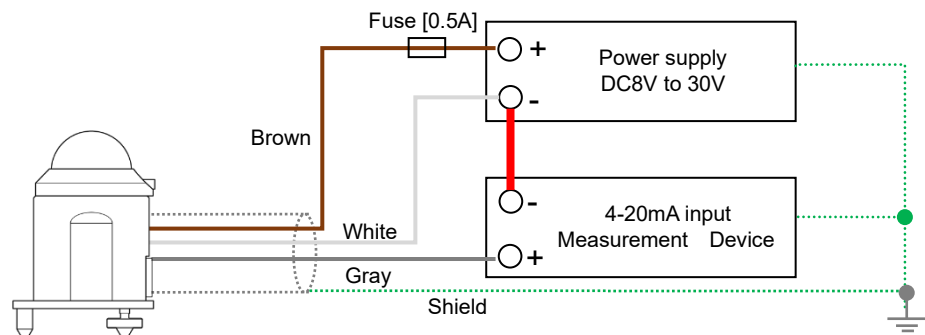


Figure 5-4. How to connect MS-60S (4-20mA output)

Voltage output (0-1V)

The current output can be converted into a voltage output when a shunt resistor is used in parallel. The default output is 4-20mA. The settings can be changed when the MS-60S is connected to a PC through the Hibi software, see appendix 3 for instruction.

Connect the 3 wires with corresponding color to the input terminals of the Voltmeter or data logger (figure 5-5). Connect the power terminals to a DC power supply [8 to 30 V]. We recommend to use a fuse [0.5A] to the DC power supply line [+] for over current protection. A precision shunt resistor (0.1%, 15 ppm) need to be placed across the voltage input terminals of the measurement device.



Interconnect the power supply (-) and 0-1V (-) line. The MS-60S voltage output requires a 3 wire connection.

- **To protect your equipment from noise and surges, the shield wire of the cable must be connected to ground at a single point. If it is not connected, the electronic equipment may be damaged.**
- **The shield wire of the cable is connected to the surge protection circuit inside the pyranometer itself and to the enclosure.**
- **Be sure to connect a fuse, as this may lead to a fire.**

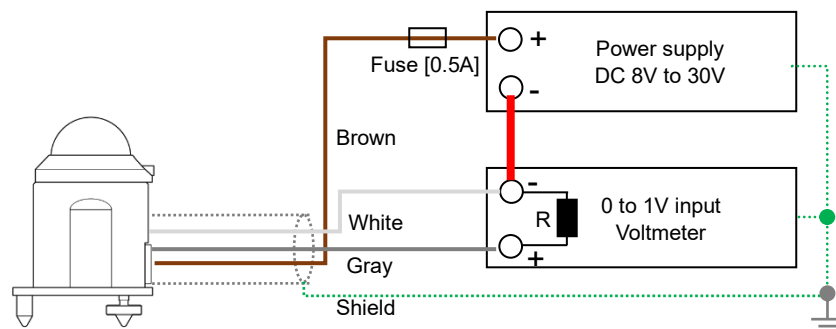


Figure 5-5. How to connect MS-60S (0-1V output)



When a precision shunt resistor (0.1%, 15ppm) is used in combination with the 4-20mA output it is required to match the precision shunt resistor value with supply Voltage to compensate for the voltage drop across the shunt resistor.(See the Table 5-5.)

Table 5-5. Shunt resistor value at supply voltage

Supply voltage	Shunt resistor value
8VDC to 15VDC	100Ω to 250Ω
15VDC to 24VDC	250Ω to 500Ω
24VDC to 30VDC	500Ω

2. Digital output (Modbus / SDI-12)

The MS-60S can work in two digital output modes, respectively Modbus 485 RTU and SDI-12. Modbus 485 output is set to default, the SDI-12 output can be selected through the Hibi software.

PC connection (Modbus)



EKO can provide an optional and approved USB converter for connection with a PC. The converter cable is needed for setup, sensor diagnostics and data logging through the Hibi software. Depending on your region, the optional converter can be different.

- **To protect your equipment from noise and surges, the shield wire of the cable must be connected to ground at a single point. If it is not connected, the electronic equipment may be damaged.**
- **The shield wire of the cable is connected to the surge protection circuit inside the pyranometer itself and to the enclosure.**
- **Be sure to connect a fuse, as this may lead to a fire.**

For any converter with screw terminals or open wires, connect the 4 wires of the sensor cable with the corresponding wire color to the RS-485 to USB converter (figure 5-6). Some converter cables provide a 5V supply voltage from the USB port, in such case no additional power supply is required. In any other case use an additional power supply. Connect the power terminals to a DC power supply [8 to 30 V]. We recommend to use a fuse [0.5A] to the DC power supply line [+] for over current protection.

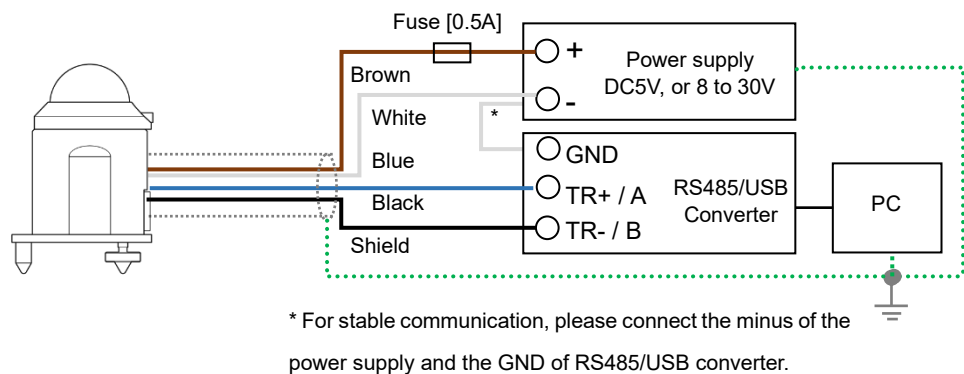


Figure 5-6. How to connect MS-60S (Modbus RS485)



Depending on the converter type and design properties, some commercial RS-485 to USB converters may not work properly. A termination resistor is required to prevent reflections from the end of the transmission line. Pull-up and pull-down resistors are necessary to keep the voltage level constant when the transmission line is in a high impedance state.

Data logger connection (Modbus)

Connect the 4 wires of the sensor cable with the corresponding wire color to the RS-485 communication port of the data logger master and power supply unit (figure 5-7). Connect the power terminals to a DC power supply [8 to 30 V]. We recommend to use a fuse [0.5A] to the DC power supply line [+] for over current protection.

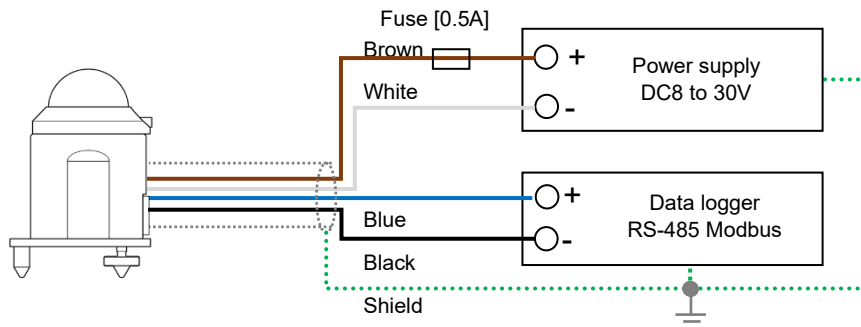


Figure 5-7. How to connect MS-60S (Modbus RS-485)

MS-60S can be configured within a multi sensor RS-485 Modbus communication network. Up to 31 units of S-series sensors per one Master can be connected and be assigned with a unique address. For a multiple sensor network the sensors need to be configured according to the recommended RS-485 configuration standards as shown in figure 5-8.

The master represents the data-logging device and slaves represent devices such as MS-60S or other serial devices in the same network. Connect the communication wires of the slave to the modbus communication input of the master. Connect a 120Ω termination resistor at the end of the communication line. The master device may have an integrated termination resistor and pull-up and pull-down resistors. If any communication issues occur, apply those separately.

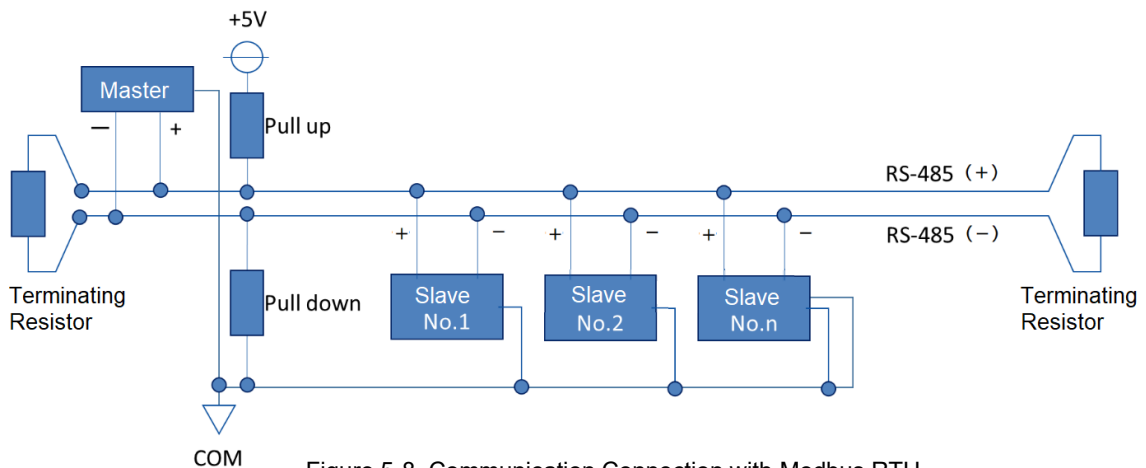


Figure 5-8. Communication Connection with Modbus RTU



Apply a Termination resistor (typically 120 to 150 Ω) : Typically reflections occur on long lines, resulting in a receiver misreading logic levels. Proper termination prevents reflections, improving data integrity.

Apply Pull-up and pull-down resistors (typically 680 to 850 Ω): Necessary to keep the voltage level constant when the transmission line is in a high impedance state.



Communication errors may occur depending on the connection distance and the number of connections. In that case, please prepare and apply a RS485 booster or a repeater.

Communication problems may occur if Modbus and SDI-12 are used at the same network.



- Although a surge protection board is embedded inside the pyranometer, if the cable length exceeds 10 m, add an appropriate SPD or the like to protect the measurement system from lightning surges (see A-8).

Data logger connection (SDI-12)

Connect the 3 wires of the sensor cable with the corresponding wire color to the SDI-12 communication port of the data logger master and power supply unit (figure 5-9). Connect the power terminals to a DC power supply [12 V]. We recommend to use a fuse [0.5A] to the DC power supply line [+] for over current protection.



Interconnect the power supply (-) and SDI-12 (-) line.

- **Communication problems may occur if Modbus and SDI-12 are used at the same network.**



- **Although a surge protection board is embedded inside the pyranometer, if the cable length exceeds 10 m, add an appropriate SPD or the like to protect the measurement system from lightning surges (see A-8).**

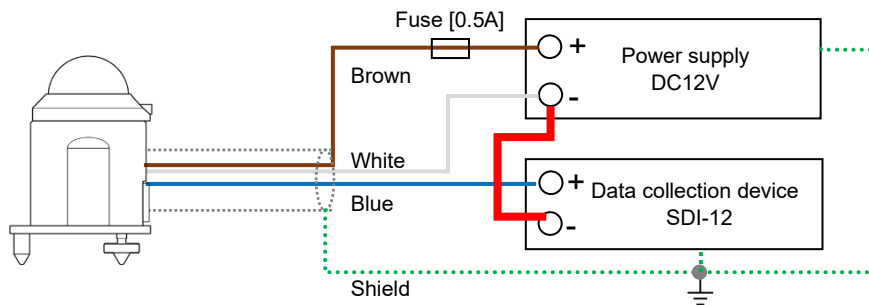


Figure 5-9. How to connect MS-60S (SDI-12)

MS-60S can be configured within a multi sensor SDI-12 communication network. Up to 20 units of S-series sensors can be connected and be assigned with a unique address(*). For a multiple sensor network the sensors need to be configured according to the recommended SDI-12 configuration standards as shown in figure 5-10. Make sure the cable length between the connecting slave and master be less than 60m. The shield cable must be connected to the ground, otherwise noises may occur.

(*) When connecting other SDI-12 communication devices, the upper limit may change.

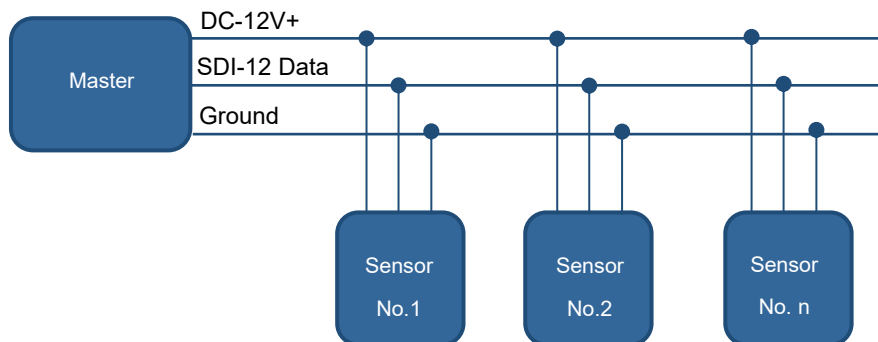


Figure 5-10. Communication Connection with SDI-12

3. Overview wire assignments

Table 5-6. Wire Color Codes of MS-60 (Also see [7-3. Output Cables])

No.	Cable Color	MS-60
1.	White	mV [+]
2.	Black	mV [-]
Shield	Shield	SG

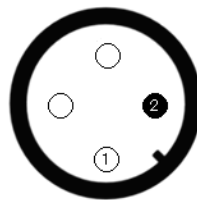


Figure 5-11. Connector pin number of MS-60

Each number corresponds to the number in Table 5-6.

Table 5-7. Color Codes of cable of MS-60S

No.	Wire Color	4-20mA	Modbus	SDI-12	0-1V [*]
1.	Brown (+)	8 to 30VDC (+)	5 to 30VDC (+)	12VDC (+)	8 to 30VDC (+)
2.	White (-)	4~20mA (-) / GND	Vcc GND / RS485 GND	Vcc GND	0~10mA (-) / 0-1V (-) / GND
3.	Blue (+)	---	RS485 (+)	SDI-12 Data (+)	---
4.	Black (+)	---	RS485 (-)	---	---
5.	Gray (+)	4~20mA (+)	---	---	0~10mA (+) / 0-1V (+)
Shield	Shield	FG	FG	FG	FG

[*] When selecting 0-1V output, a precision shunt resistor is required separately.

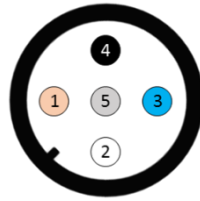


Figure 5-12. Connector pin number of MS-60S

Each number corresponds to the number in Table 5-7.

5-5. Measurements

1. Data logger settings

The output voltage is measured by a measuring device such as a voltmeter or a data logger. If solar irradiance is measured continuously, it is recommended to use a data logger, which has sufficient memory to record data over a longer period and functions to process the measurement parameters of the pyranometer. Depending on the sensor output which will be used, the data logger should be capable to measure the assigned output type.

For MS-60 with analog output, the data logger should have a voltage input range (0-20mV), and resolution ($\sim 1\mu\text{V}$). For the MS-60S with current output, Modbus 485 RTU and SDI-12, the data logger should have one of those inputs. For MS-60S the input range, resolution and impedance are not critical, and considered as standard for any meteorological or industrial type data logger. For current measurement the measurement range should be selected according to the range settings of the MS-60S.

When configuring the data logger parameters, the sampling rate and data reduction methods can be defined right at the beginning of the data acquisition process. The response time that is given in the specifications of the EKO pyranometers states the amount of time, which is necessary to reach 95% of the final measurement value. It is also possible to define a 63.2% response [which is equal to $1-1/e$]. This time constant, represented by the symbol τ , is 3 times smaller than the values specified by EKO. The recommended^[1] sampling rate for pyranometers is smaller than τ . So, for EKO pyranometers, the sampling rates that have to be programmed in the data logger systems should not exceed the values as given in Table 7-1.

Recommendations for irradiance measurements are explained in ^[1]“Guide to Meteorological Instruments and Methods of Observation”, WMO reference document No. 8.

2. Pyranometer default settings

The MS-60S is based on a digital Smart processing interface providing advanced measurement functions with 4 different industrial signal outputs (**Modbus 485 RTU**, configurable **SDI-12**, **4-20mA**, configurable **0-10mA** and **0-1V** with external precision shunt resistor 100Ω).

Where to find information regarding the MS-60 defaults settings and important parameters:

Table 5-8. MS-60 where to find the settings

MS-60	Defaults setting and parameters
Sensitivity figure	<ul style="list-style-type: none"> - Calibration certificate - Serial number label
Impedance	<ul style="list-style-type: none"> - Serial number label

Table 5-9. MS-60S where to find the settings

MS-60S	Defaults setting and parameters
Sensitivity figure	<ul style="list-style-type: none"> - Calibration certificate - Modbus register - SDI-12 register
Modbus 485 RTU (Default)	<ul style="list-style-type: none"> - Setting report (see appendix A-7 MS-60S setting report) - Modbus register <ul style="list-style-type: none"> ○ Address (last two digits of serial number, 100 if “00”) ○ Baud rate 19200 ○ Parity Even
SDI-12	<ul style="list-style-type: none"> - Setting report - SDI-12 register <ul style="list-style-type: none"> ○ Address 0 ○ Baud rate 1200 ○ Parity Even
4 - 20 mA (Default)	<ul style="list-style-type: none"> - Setting report <ul style="list-style-type: none"> ○ 4-20mA = 0 – 1600W/m²
0 – 1V	<ul style="list-style-type: none"> - Setting report <ul style="list-style-type: none"> ○ 0-1V = 0 – 1600W/m²

3. Irradiance conversion

For MS-60 with analog mV output the global solar Irradiance [W/m²] can be determined by measuring the output voltage [mV] divided by the individual sensor sensitivity [$\mu\text{V}/\text{W} \cdot \text{m}^{-2}$]. The maximum output voltage can be calculated by multiplying the maximum solar irradiance with the calibration factor [e.g., when the sensitivity of the MS-60 pyranometer is about $10\mu\text{V}/\text{W} \cdot \text{m}^{-2}$ or $0.010\text{mV}/\text{W} \cdot \text{m}^{-2}$, the maximum output voltage is about $1,400\text{W}/\text{m}^2$ times $0.010\text{mV}/\text{W} \cdot \text{m}^{-2} = 14\text{mV}$].

Analog output

The solar irradiance in Watts per meter squared [W/m²] is obtained when the output voltage **E** [μV] is divided by the sensitivity of the pyranometer **S** [$\mu\text{V}/\text{W} \cdot \text{m}^{-2}$]. This calculation is expressed by the following formula:

$$I [\text{W}/\text{m}^2] = \frac{E [\mu\text{V}]}{S [\mu\text{V}/\text{W} \cdot \text{m}^{-2}]}$$

*The sensitivity **S** for the pyranometer is stated on the calibration certificate and the product label.

4-20mA output

If the measurement range can be selected on the data logger, select the measurement range, which can accurately measure the signal within a range of 4 to 20mA. The output for the MS-60S is set to be $1,600\text{W}/\text{m}^2$ at 20mA.

When the solar irradiance current value is **A** [mA], the solar irradiance **I** [W/m²] can be determined by the following formula:

$$I [\text{W}/\text{m}^2] = (\mathbf{A} [\text{mA}] - 4) \times (1600 / 16)$$

Note: When the range setting is changed for example 4-20 mA = 0-2000 [W/m²]

$$I [\text{W}/\text{m}^2] = (\mathbf{A} [\text{mA}] - 4) \times (2000 / 16)$$

0-1V output

If the measurement range can be selected on the data logger, select the measurement range, which can accurately measure the signal within a range of 0 to 1V. The output for the MS-60S is set to be $1,600\text{W}/\text{m}^2$ at 1V.

When the solar irradiance voltage value is **V** [V], the solar irradiance **I** [W/m²] can be determined by the following formula:

$$I [\text{W}/\text{m}^2] = \mathbf{V} [\text{V}] \times 1600$$

MS-60S [Modbus RTU Output, SDI-12 Output]

When using the digital output (Modbus or SDI-12) by default the irradiance conversion is performed on-board and is one of the measurement parameters within the data string.

4. Daily radiant energy

The total daily radiant energy in Joule per meter squared [J/m^2] is obtained by integrating the solar irradiance over time. To calculate the total daily radiant energy in Joule per meter square [J/m^2], multiply the averaged solar irradiance I [W/m^2] by the averaging interval period [s]. Then sum-up the total data number [n] of averaged data points in one day.

Its physical unit is expressed with [J/m^2] and can be calculated with $J = W \cdot S$

$$\text{DTI} = \sum_{k=1}^n I_k \times t^k$$

6. Maintenance & Troubleshooting

6-1. Maintenance

By using the MS-60 pyranometers accurate results can be obtained if the glass dome and the condition of the instrument are maintained properly. Furthermore, regular maintenance and scheduled re-calibrations can extend the lifetime of the pyranometers. However, environmental conditions, such as for instruments mounted near highly frequented traffic lanes or airports, may have a deteriorating effect on the materials. Therefore, proper maintenance is needed and has to be adapted to the local environmental conditions.

The following table describes the common maintenance tasks that should be performed on a regular basis:

Table 6-1. Maintenance Items1

Maintenance Item	Frequency	How To	Effect
Clean Glass Dome	Several times per week	Keep the glass dome clean by using demineralized water and wiping with a soft cloth dry and clean.	The irradiance measurement will be affected due to a change in transmittance.
Check Appearance Condition	Weekly	Check for cracks and scratches on the glass dome and body.	May lead to shade on the detector and enhanced soiling.
Check Spirit level	Weekly	Verify if the pyranometer is levelled by checking the bubble is in the center ring of spirit level. [When the pyranometer is setup in horizontal position].	An additional cosine/azimuth error will be introduced.
Check Cable Condition	Weekly	Verify if the cable connector is properly connected, tightened to the instrument, and how cable is lined; make sure the cable is not shaking from the wind.	A disconnected cable will cause sporadic reading errors or failure of operation. If the cable is damaged, it may lead to noise or electric shock.
Check Setup Base Condition	Weekly	Check if the instrument is tightened properly to the mounting base plate and the base plate and/or table is securely fastened in a proper condition.	Loose instruments and/or mounting plates can lead to damages of the instruments and/or injury.
Check the Sun screen	Weekly, Before/After Bad Weather	Verify if the sun screen is securely fixed on the body, and knurling screw is securely tightened.	May lead to damaging the instrument and/or lead to increasing measurement error due to temperature increase by sun screen coming off.
Recalibration	Every 2 Years	To maintain the best possible measurement accuracy, recalibration of the pyranometer is recommended. Contact EKO for more details and requests for a recalibration and maintenance service.	Due to natural aging of materials the detector sensitivity of the pyranometer can gradually change over time.

Table 6-2. Maintenance Items2(Advanced remote check can be done on MS-60S)

Maintenance Item	Frequency	How To	Effect
Data validity	Weekly	Check the daytime irradiance data and compare to previous days or adjacent pyranometers.	When large difference occurs operating problems or installation issues can be detected.
Presence of noise	Weekly	Check night-time irradiance values	Night-time offsets and sensor stability issues can be revealed.
Abnormal temperature detection	Weekly	[MS-60S] Check the body temperature via Modbus or SDI-12 output.	If the inside temperature becomes abnormally high, the life of the product will be shortened.
Confirm the effect of desiccant	Weekly	[MS-60S] Check the relative humidity via Modbus or SDI-12 output.	The condition of the drying agent can slightly change over time. If the relative humidity become high, the glass dome might be fogging up.
Checking the tilt angle	Weekly	[MS-60S] Check the tilt angle and roll angle via Modbus or SDI-12 output.	Any change in tilt position after the installation can affect the measurements due to the cosine response of the sensor.

6-2. Calibration and Measurement Uncertainty

It is recommended to recalibrate MS-60 pyranometer once every 2 years to verify the good quality of the solar radiation measurements. In the following paragraph the calibration method of EKO pyranometers and their calibration uncertainty is explained. For further information about recalibration and maintenance procedures, please contact EKO or find on the EKO website [<http://eko-eu.com>].

EKO can offer calibration service for pyranometers and pyrhemometers in-house. Based on the applied calibration methods EKO provides the best quality solar sensor calibrations compliant to the international standards defined by ISO9847 [Indoor method] and ISO9059 [Outdoor method] [Certification: L13-94-R2 / www.pjllabs.com]

1. Calibration method

MS-60 is calibrated indoors according to the ISO9847 international standard against a 1000W/m² AAA class solar simulator radiation source and designated calibration facility.

Indoor Calibration Procedure

Both reference and field pyranometers are placed in horizontal position in the center of the light beam at equal distance to the solar simulator light source. The pyranometers are alternatively exposed to the solar simulator beam hence the output is measured from each pyranometer for a specified time. From the reference pyranometer output [mV] and known sensitivity [$\mu\text{V}/\text{W}/\text{m}^2$] the sensitivity figure [$\mu\text{V}/\text{W}/\text{m}^2$] of the field pyranometer based on 10 data samples can be calculated.

Measurement Uncertainty of Indoor Calibration

The calibration uncertainty of MS-60 can be kept below (0.8%) as stated in the scope of accreditation and stated on each calibration certificate. Calibration in the lab is performed at a constant ambient temperature and ultra stable light conditions. Hence the repeatability of the method and pyranometers under test can be well maintained. The pyranometer calibration uncertainty is determined with consideration of uncertainty of the reference pyranometer and maximum variation of incident light during the measurement of field pyranometer and reference pyranometer. The expanded calibration uncertainty of each calibrated MS-60 model, and its results are stated on the calibration certificate.

2. Calibration Traceability

The MS-60 reference pyranometer is traceable to the absolute cavity radiometer maintained at EKO. The absolute cavity radiometer is directly traceable to the WRR [World Radiometric Reference] which is the Primary Standard Group of Absolute Cavity radiometer maintained at PMOD (Davos, Switzerland). The logger system used for the calibration measurement is traceable to JEMIC [Japan Electric Meters Inspection Cooperation].

Every year the MS-60 reference pyranometers are calibrated against the absolute cavity pyrhemometer, together with the other unit part of the internal reference of MS-60 pyranometers according the Shade / unshade Method [Method for Calibrating Reference and Field Pyranometers (1995)] Bruce W Forgan]. During the IPC the EKO absolute cavity radiometer is calibrated against the WRR every 5 years. Every year except IPC year, the EKO absolute cavity scale is examined during the NPC at NREL (Boulder, USA).

6-3. Trouble shooting

Read the following in case of any sensor trouble. If any questions should remain, please contact EKO for further technical support.

Table 6-3. Troubleshooting in field

Failure		Action
There is no output.	MS-60	Make sure that the sensor cable is connected properly to the instrument. To verify the connection, measure the impedance of Output cable [between the “+” and the “-” wires] and check if the measured impedance is within the proper range as shown in the specification table.
	MS-60S	Make sure that the sensor is properly connected, and type of power supply and voltage values are appropriate. Also check the communication settings [i.e. port, baud rate, converter ID] are appropriate.
Output value is too low		The glass dome maybe soiled with rain or dust. Clean the glass dome with demineralized water and soft cloth. The output may decrease over time. Recalibrate periodically.
Negative output signal during night-time.		Pyranometers generate an output signal, which is proportional to the temperature differences between the sensor’s so-called hot and cold junctions. Night-time offset can occur when the dome temperature will cool down below the temperature of the detector. A negative offset within the specification can be expected.
Unusual noise		Check the shield connection and make sure it is connected securely. Make sure if the Output cable is not shaking from the wind; take necessary measure by fixing or lining the cables through metal pipe. Check for any objects, which emit electromagnetic wave around the instrument and or cable. For MS-60, please implement the following methods in a combined manner. <ol style="list-style-type: none"> 1. Set up the integration time and stability time as long as possible. 2. Use moving average processing on the data 3. Loop two or more ferrite cores around the end of the cable. 4. Avoid ground loops. Isolate the pyranometer electrically from the installation base. The sensor enclosure and the adjustment foot are electrically isolated by anodizing, but the isolation can be further strengthened by inserting an insulation sheet between the pyranometer and the installation base, and by inserting a resin washer in the enclosure fixing screw. 5. Connect the shield cable of the cable to an appropriate ground. 6. Use a data logger with differential voltage input.
4-20mA and 0-1V output outside range Example) 2mA output when using 4-20mA. The fluctuation of measured current is large.		If it is confirmed that the wiring is correct, connect the ground wire of this product to the negative side of the data logger voltage (current) measurement terminal. Note that the appropriate ground wire connection method for this product may differ depending on the type of data logger and measurement environment. Select an appropriate ground wire connection method for this product according to the type of data logger and measurement environment.

Table 6-4. Troubleshooting Hibi (MS-60S)

Failure	Action
No connection with PC	Make sure that the sensor is properly connected, and power supply and voltage levels are appropriate. Also check the communication settings [i.e. port, baud rate, converter ID] are correct.
No communication with USB cable	<p>If no COM port shows up when Hibi software is started.</p> <ul style="list-style-type: none"> - Reconnect the USB converter and refresh to search new COM devices - Check for COM port settings in Windows settings - Install an appropriate driver
Settings changes not saved to pyranometer	<p>Make sure that the sensor is properly connected, and power supply and voltage levels are appropriate. Also check the communication settings [i.e. port, baud rate, converter ID] are correct.</p> <p>Power off/on the pyranometer, some of the setting are effective after power off/on.</p>
<p>4-20mA and 0-1V output outside range Example) 2mA output when using 4-20mA. The fluctuation of measured current is large.</p>	<p>If it is confirmed that the wiring is correct, connect the ground wire of this product to the negative side of the data logger voltage (current) measurement terminal.</p> <p>Note that the appropriate ground wire connection method for this product may differ depending on the type of data logger and measurement environment. Select an appropriate ground wire connection method for this product according to the type of data logger and measurement environment.</p>

7. Specifications

7-1. Specifications

1. Pyranometer Specifications

The comparison table below, Table 7-1, shows typical values for the characteristic parameters of the EKO Pyranometers and the corresponding values of the ISO 9060: 2018 standard. The content of the characteristic item is partly changed from ISO 9060: 1990. Please also refer to "A-2. Pyranometer Characteristics List".

Table 7-1. Pyranometer specifications

Characteristics		MS-60	MS-60S
	ISO9060: 2018	Class B	Class B
	ISO9060: 1990	First Class	First Class
	Spectrally flat	Compliant	Compliant
	Fast response	-	-
Response time (95% output)	<20 Sec	<18 Sec	<18 Sec
Zero offset a -200W/m ²	±15 W/m ²	±5 W/m ²	±5 W/m ²
Zero offset b 5K/hr	±4 W/m ²	±2 W/m ²	±2 W/m ²
Total zero off-set (c)	±21 W/m ²	±7 W/m ²	±7 W/m ²
Non-stability	±1.5 %/1yr	±1.5 %/1yr	±1.5 %/1yr
Non-linearity	±1 %	±1 %	±1 %
Directional response	±20 W/m ²	±18 W/m ²	±18 W/m ²
Spectral error	±1 %	±0.2%	±0.2%
Spectral selectivity	±3 %	±3 %	±3 %
Temperature response (-10~40°C)	±2 %	±2 %	±2 %
Temperature response (-20~50°C)	---	±4 %	±4 %
Tilt response	±2 %	±1 %	±1 %
Additional signal processing error	±5 W/m ²	---	±1 W/m ²

Table 7-2. Other Specifications

Characteristic item	MS-60	MS-60S
Field of View	2π (sr)	
Wavelength range	285 to 3000nm	
^[1] Operating temperature	-40 to +80°C Accuracy guaranteed temperature range: -20 to +50°C	
^[2] Maximum Operational Irradiance	2000W/m ²	
Spirit level accuracy	0.1°	
Tilt sensor accuracy	---	<±1°
Humidity sensor accuracy	---	Nominal: ±2%RH
Temperature sensor of PCB (tolerance)	---	±0.5°C (maximum tolerance)
Environmental Protection [IP Code]	IP67 Equivalent [IEC60529]	
Weight	0.37kg	0.43kg
Body	Anodized	
Sensitivity	Approx. 7 to 14μV/W·m ⁻²	Approx. 7 to 14μV/W·m ⁻²
		0-1V/4-20mA: 0-1600W/m ² ⁽³⁾
Impedance	Approx. 60 to 100 Ω	---
Output Cable [Outer diameter]	AWG22 0.3mm ² x 2 core (φ4.8mm)	AWG22 0.3mm ² x 5 core (φ5.3mm)
Output cable terminal	Pin terminal (1.25-11S)	Pin terminal (0.3-9.5)
Output [or Signal]	Voltage (mV)	Modbus 485 RTU (default), configurable SDI-12, 4-20mA(default) ⁽³⁾ ⁽⁴⁾ , configurable 0-10mA / 0-1V ⁽³⁾ ⁽⁴⁾ with external 100Ω precision shunt resistor
Resolution	---	<0.01 (W/m ²)
Input Power Supply	---	Modbus: DC5V ±5% or DC8V-DC30V±10% 0-1V/4-20mA: DC8V-DC30V±10% SDI-12: DC9.6V-DC16V
Power consumption	---	Digital output: <200mW Analog output: <700mW

(1) When the instrument is used in the ambient temperature exceeding the accuracy assurance temperature range, the measurement error may increase.

(2) The operational maximum irradiance is defined as the maximum irradiance exposure level. Beyond this point damage may occur to the sensor.

(3) When 4-20mA is 0 to 1,600W·m⁻², 0-10mA/0-1V: 0 to 1,600W·m⁻².(default)

(4) Sensor setting can be changed by connecting the sensor to a PC (Use the USB cable for MS-60S (option) and download the free configuration software from the EKO website.

Table 7-3. Power consumption supply Voltage specific

	5V DC	12V DC	24V DC	Remarks
During stand-by	75mW (Approx. 15mA)	90mW (Approx. 7.5mA)	110mW (Approx. 4.5mA)	-
Modbus RS-485	170mW (Approx. 34mA)	180mW (Approx. 15mA)	190mW (Approx. 8mA)	Peak value during communication
4-20mA output	-	300mW (Approx. 30mA)	640mW (Approx. 27mA)	Apply the shunt resistor 250 Ω and 20mA output
0-1V output	-	300mW (Approx. 30mA)	640mW (Approx. 27mA)	Apply the shunt resistor 100 Ω and 10mA output

7-2. Dimensions

1. MS-60 / 60S

Table 7-4. Dimension List [MS-60/60S]

	MS-60 / 60S
A. Fixing hole width	65 mm
B. Body height	72 mm
C. Fixing screw height	16 mm
D. Full width (including sun screen)	Φ96 mm
E. Overall height	107.5mm

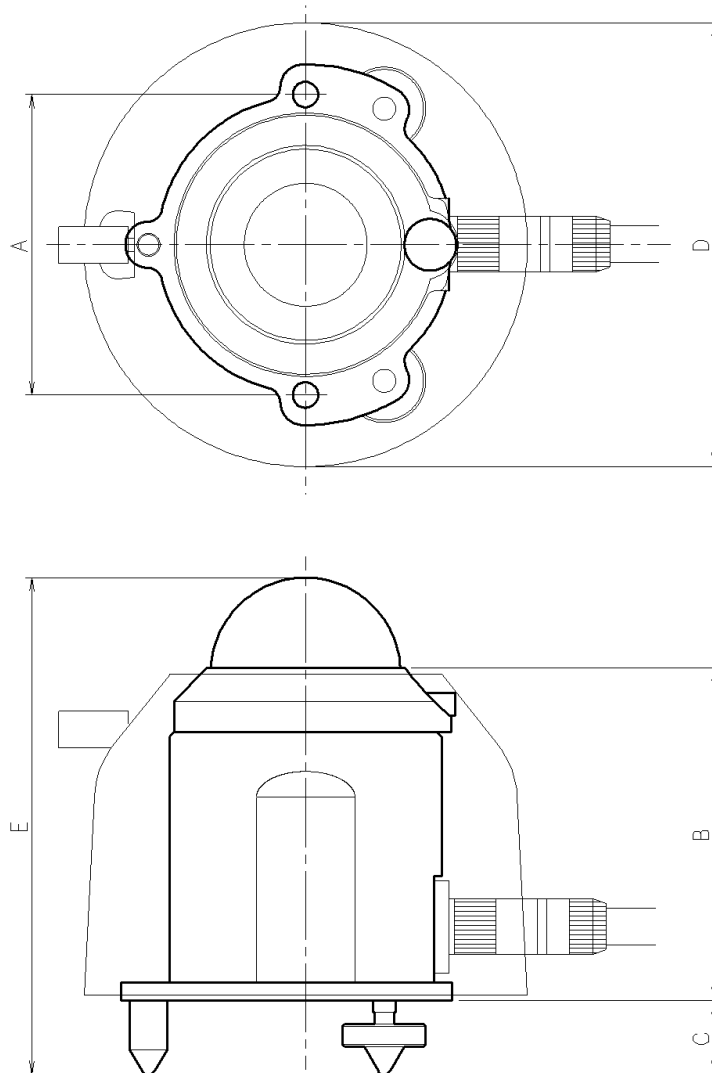


Figure 7-1. External Dimensions [MS-60/60S]

7-3. Output cables

See [5-2. Setup, 2. Wiring] for instruction

1. MS-60

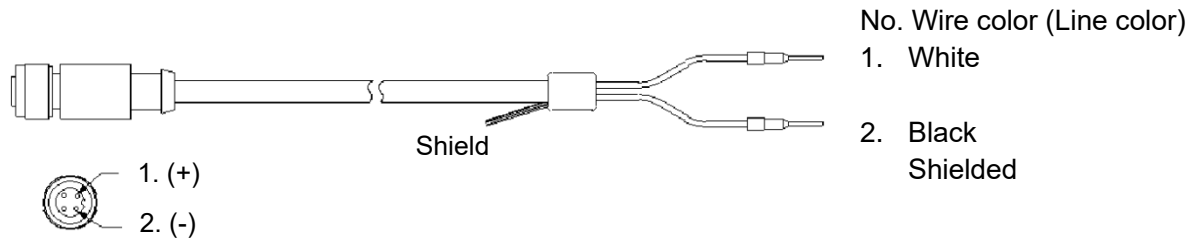


Figure 7-2. Output-Cable [MS-60]

2. MS-60S

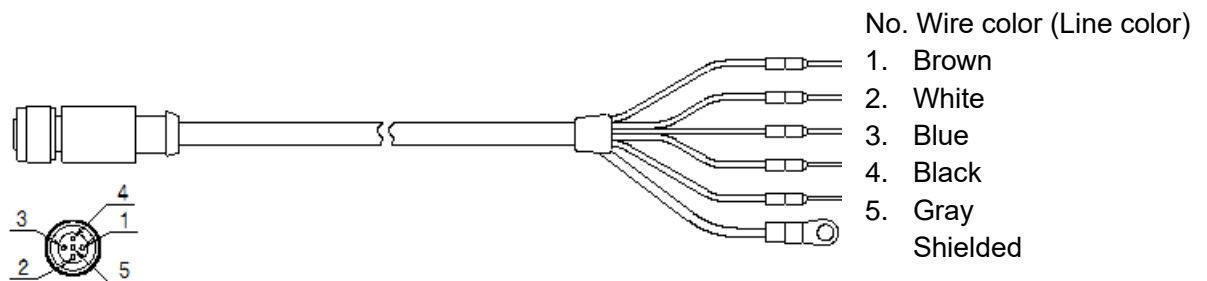


Figure 7-3. Output-Cable [MS-60S]

Different length (10m standard, 20m / 30m / 40m / 50m optional).

3. EKO Converter Cable (Option)

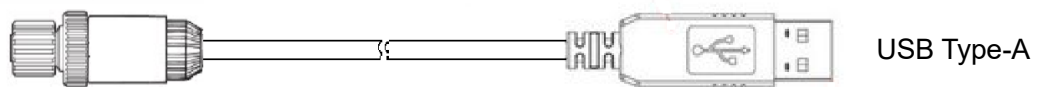


Figure 7-4. EKO Converter cable [MS-60S]

7-4. Accessories List

Table 7-5. Accessories List

Option Items	Description	Pyranometers
Output cable	Cable Length: 10m, 20m, 30m, 50m Terminals: Fork Terminals, Round Terminals, Pin Terminals	MS-60 / 60S
Ventilation Unit with Heater	MV-01 ventilator and heater	MS-60 / 60S
EKO Converter Cable	Converts from RS485 → USB for the communication with MS-60S and allows to connect to PC via USB terminal. Cable Length:1.8m	MS-60S

A-1. Radiometric Terms

Table A1-1: Definitions of Terms

Hemispheric Solar Irradiance	Cosine-weighted solar irradiance received over a solid angle of 2π sr on a plane surface, expressed in units of W/m^2 or kW/m^2 .
Global Solar Irradiance, Global Horizontal Irradiance [GHI]	Hemispherical solar irradiance received on a horizontal plane surface, expressed in units of W/m^2 or kW/m^2 .
Direct Solar Irradiance, Direct Normal Irradiance [DNI]	Normal-incidence solar irradiance received over a small solid angle which includes the circumsolar irradiance, expressed in units of W/m^2 or kW/m^2 .
Diffuse Solar Irradiance, Diffuse Horizontal Irradiance [DHI]	Hemispherical solar irradiance without the direct solar irradiance, i.e. indirect irradiance of the scattered solar radiation [by air molecules, aerosol particles, clouds, etc.], expressed in units of W/m^2 or kW/m^2 .
Pyranometer	A radiometer designed to measure the hemispheric solar irradiance over the wavelength range of about 300 to 3,000nm.
Pyrheliometer	A radiometer designed to measure the direct solar irradiance over a certain solid angle including the circumsolar irradiance.
World Meteorological Organization (WMO)	It is a specialized organization of the International Union that carries out international standardization and coordination of meteorological work. WMO: Abbreviation for World Meteorological Organization
World Radiation Reference [WRR]	Radiometric reference instrument system which has an uncertainty of less than $\pm 0.3\%$, expressed in SI units. This reference is maintained by the World Meteorological Organization [WMO], and it has been issued since January 1, 1980
ISO9060	An ISO norm [International Standard]. The first edition was published in 1990, then the second edition was revised in 2018. Based on the performance of each characteristic, Pyranometer is classified into three classes A, B, and C, and specifications of "Spectrally flat radiometer" and "Fast response radiometer" are set as sub-categories. Pyrheliometer is classified into 4 classes of AA, A, B and C based on the performance of each characteristic, and specifications of "Spectrally flat radiometer" and "Fast response radiometer" are set as sub-categories.

A-2. Pyranometer Characteristics

Table A2-1. Pyranometer Characteristics [see also ISO9060:2018, CIMO Guide, WMO No. 8, 2008]

Response Time	The time [seconds] of a pyranometer sensor to reach 95% of its final output signal. [ISO 9060: 2018 added] If the response time reach to 95% is less than 0.5 seconds, "fast response" is attached to the applicable class as a subcategory.
Zero Off-Set a	Response [dark-signal] to 200W/m ² net thermal radiation [ventilated]
Zero Off-Set b	Response [dark-signal] to 5K per hour change in ambient temperature
Total Off-set c	[ISO 9060: 2018 added] Total zero off-set including the effects a), b) and other sources
Non-Stability	Rate of change [%] of the pyranometer sensitivity per year.
Nonlinearity	Percentage deviation from the responsivity at 500W/m ² due to any change of irradiance within the range 100W/m ² to 1000W/m ² .
Directional Response	Also referred to as cosine error [W/m ²]; the range of errors caused by assuming that the normal incidence responsivity is valid for all directions when measuring, from any direction, a beam radiation whose normal incidence irradiance is 1000W/m ² [ISO 9060: 2018 modified] Include the zenith angle of zenith angle 90 ° or more.
Spectral error	[ISO 9060: 2018 added] Maximum spectral mismatch error of Pyranometer [%] with respect to spectral irradiance at AM 1.5 and AM 5 under multiple atmospheric conditions on fine weather against the reference standard spectral irradiance defined by IEC60904-3: 2016 Photovoltaic devices - "Measurement principles for terrestrial photovoltaic [PV] solar devices with reference spectral irradiance data."
Spectral selectivity	Percentage deviation of the product of spectral absorptance and spectral transmittance from the corresponding mean within the range 0.35µm to 1.5µm.
Spectrally flat Pyranometer	[ISO 9060: 2018 added] If the spectral selectivity is less than 3 %, "spectrally flat" is attached to the applicable class as a subcategory.
Temperature Response	[ISO 9060: 2018 modified] Percentage maximum output error due to any change of ambient temperature between -10 to 40°C against the output at 20°C.
Tilt Response	[ISO 9060: 2018 modified] Percentage deviation from the responsivity at 0 ° tilt [horizontal] due to change in tilt from 0 ° to 180 ° at 1000W/m ² .
Additional processing errors	[ISO 9060: 2018 added] Error generated when converting the analog output of Pyranometer or Pyrhemliometer into a digital signal with a signal converter etc.

A-3. Software (Hibi)

'Hibi' means 'day by day' in Japanese, and with this program, users will be able to visualize detection signals, set communication parameters, and rapidly troubleshoot any issues from day one. You can change the settings of the MS-60S using the Windows software downloadable from the EKO website (MS-60S product page) and the optional USB cable.

1. Software Installation

Follow the steps below to install "Hibi" configurator software.

- 1) Download the latest version of the "hibi.zip" file [Compressed file: Zip format] from MS-60S product page on the EKO website.
- 2) Unzip "hibi.zip" file and check that the "setup.exe" file exists.
- 3) Run the "setup.exe" file to install "Hibi" configurator software.

2. Hardware Preparation

After the software is installed, connect the MS-60S with a PC to change the setting.

- 1) After installing the software, connect the USB connector of "RS485/USB Converter cable" to the PC.
- 2) Connect the ends of the signal cable of MS-60S to the communication terminal of "RS485/USB converter".
- 3) Connect the power lines of the signal cable to the power supply (DC5V or 8 to 30V) and turn on the power supply.(Refer to Figure A3-1.)

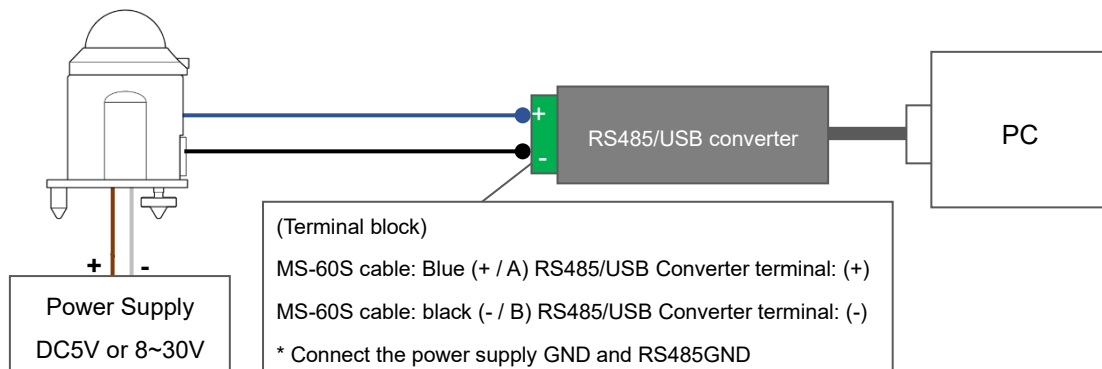


Figure A3-1. Hardware preparation

If you use the optional "EKO Converter cable", you can install it simply by inserting the cable connector into MS-60S. Power for the MS-60S can be supplied via USB. (See Figure A3-2).

* This conversion cable is for installation, so please avoid using it outdoors for a long time. Because the ground wire is not connected, surges can damage your PC during a lightning strike.

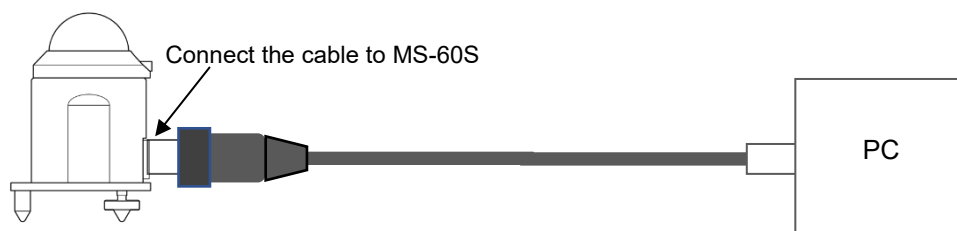


Figure A3-2. Using "EKO Converter cable"

3. Software

Start the “Hibi” software and make the required settings.

- 1) Start “Hibi” software. (Launch the software from “EKOApp1.exe” located in the shortcuts or installation folder.)
- 2) After the software starts, the "Welcome" window appears.

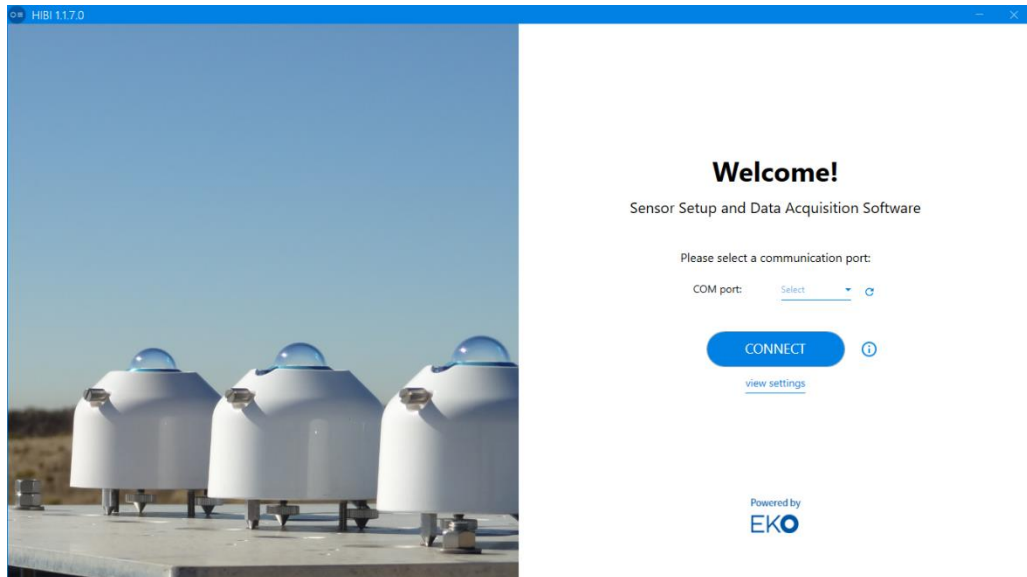


Figure A3-3. Welcome window

- 3) Automatic connection

When using the “Auto-connect” function to connect MS-60S with the “Hibi” software, select the COM port that the RS485/USB converter cable is connected to.

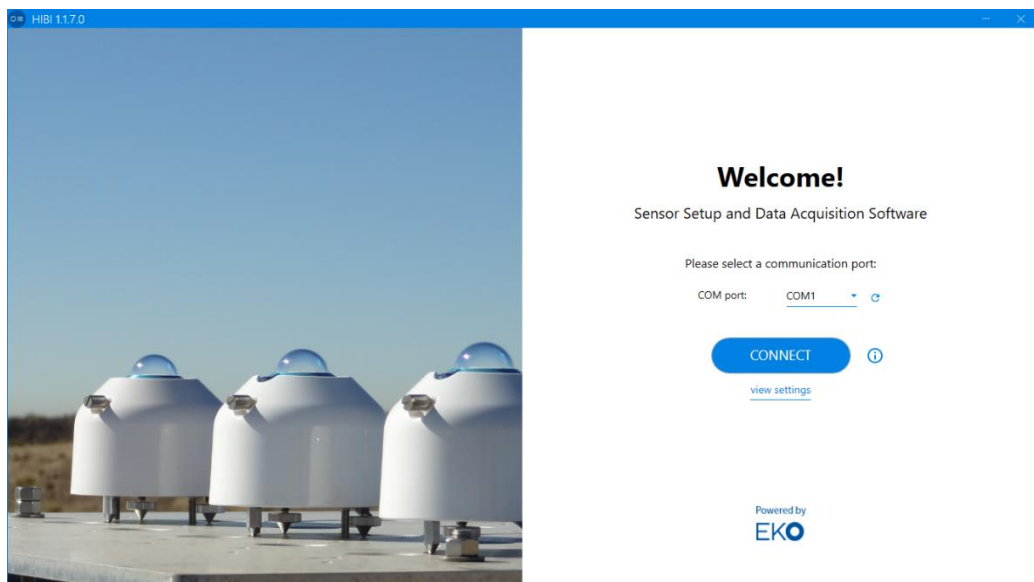


Figure A3-4. Com port select

Click “Select” of “COM port:” on the startup screen and select the COM port number assigned to the RS485 / USB conversion cable from the displayed COM port numbers.

If you cannot find a selectable COM port, click the Refresh button and click Select again to try again.

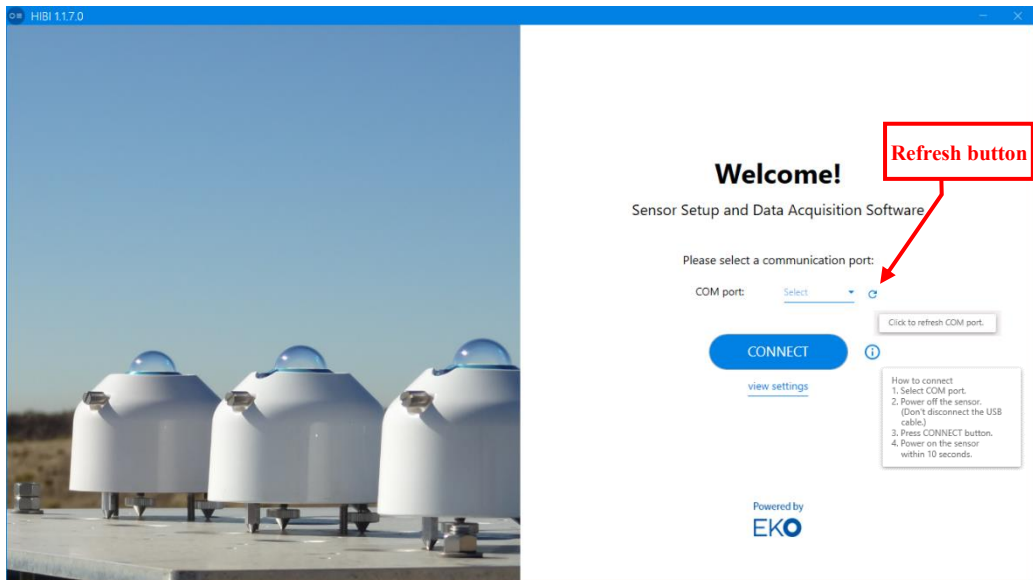


Figure A3-5. Com port select

Check that the power supply of MS-60S is "OFF". Then, click "CONNECT" button.

If the COM port is not recognized, press the refresh button and try again.

Power "ON" the MS-60S within 10 seconds once the "Connecting your sensor" message appears.

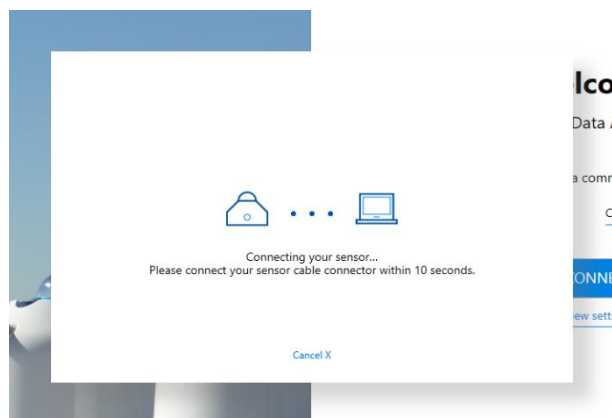


Figure A3-6. Connecting screen

When the connection is completed, the window automatically switches to the "Dashboard" window. In the upper-right corner of the display changes to "Pyranometer Connected".



Figure A3-7. Dashboard

If the connection fails, the screen returns to the "Welcome" screen and "CONNECTION FAILED" is displayed.

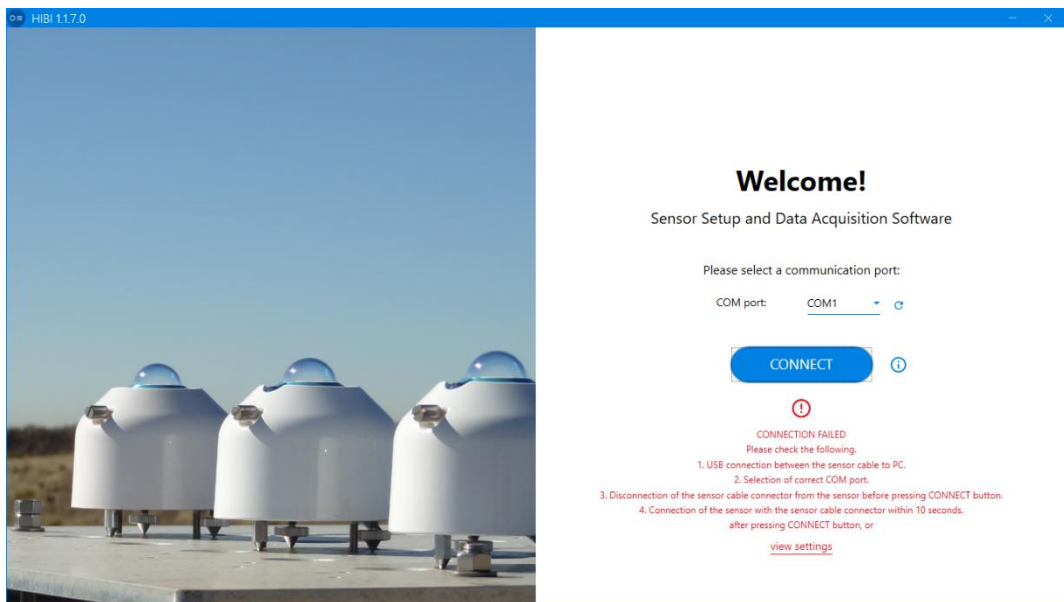


Figure A3-8. CONNECTION FAILED

Make sure the connection settings are correct. To perform the "Auto-connection" again, turn off the power of the MS-60S, select "COM port", and then click "CONNECT". For manual connections, click "View settings" at the bottom of "CONNECTION FAILED" to go to "Settings screen". (As for how to set and connect by "Manual connection", refer to the procedures (4) Manual connection) from the next section.

4) Manual connection

After turning on the power of the MS-60S, click "CONNECT" without selecting "COM port".

Clicking "view settings" at the bottom of the "CONNECTION FAILED" screen moves to the "Settings" screen. (The same screen appears even when the "Auto-connection" fails. To perform manual connection, set and connect using this procedure.)

After that, click the "CONNECT" button in Connection status.

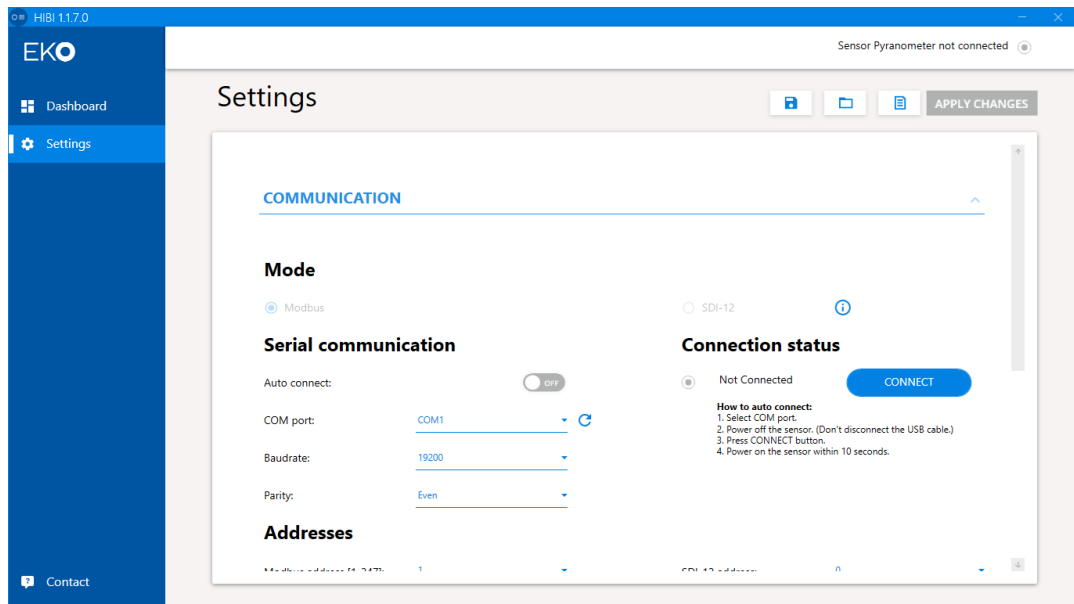


Figure A3-9. Manual connection

When the connection is completed, "Connected" is displayed.

"XXXX Pyranometer Connected" is also shown in the upper-right corner of the display.

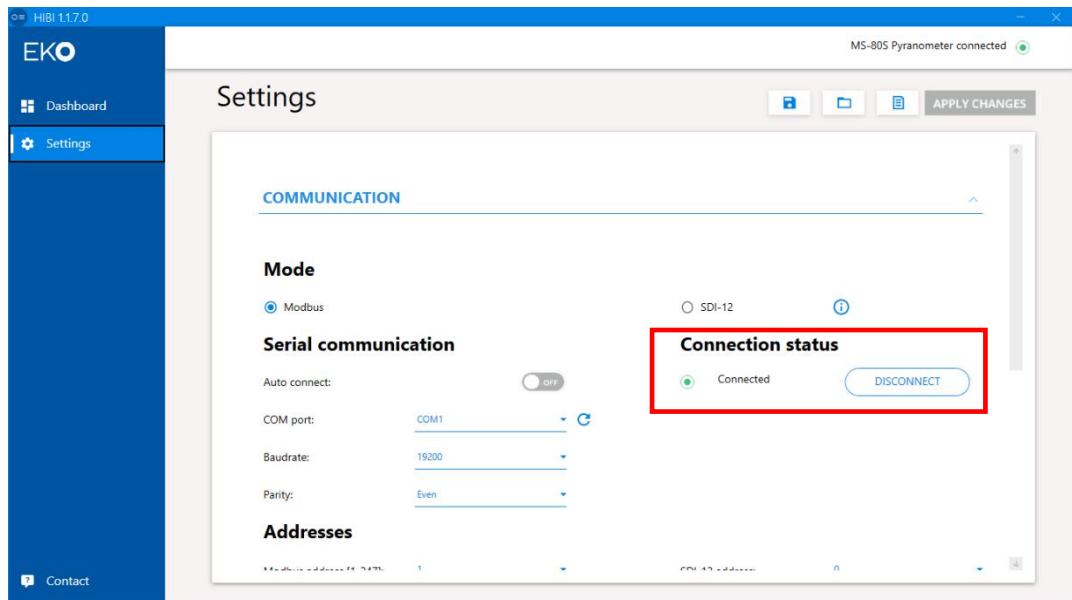


Figure A3-10. Connected appear

When the connection fails, the "Oops..." screen is displayed with the cause of the connection failure.

When connection fail appears

Check that the cable connection, COM port and the communication requirements are correct.

When changing the connection condition after successful connection, set "COM port", "Baud rate" and "Parity" in the "Serial communication" setting of the "COMMUNICATION" items and set "Modbus address [1-247]" and "Register Type" in the "Addresses" setting.

After entering the settings, click "APPLY CHANGES"

A confirmation window will be displayed.

Click "YES, SAVE" to make the settings for the MS-60S.

The settings in "Settings" can be saved / read / exported to CSV files.

Click the button with icons in the upper-right corner of "Settings" window.

- "Save" button: Save the settings.
- "Read" button: Read out the settings.
- "Output" button: Output the settings to CSV file

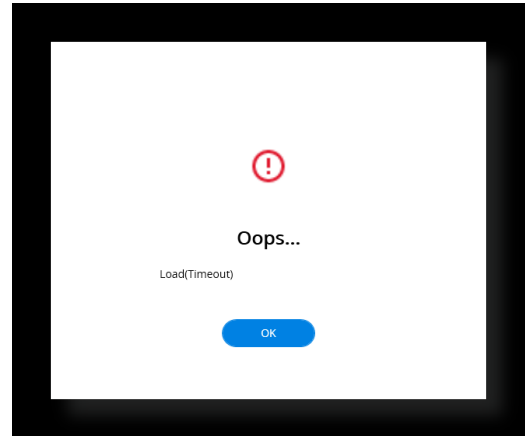


Figure A3-11. Oops screen

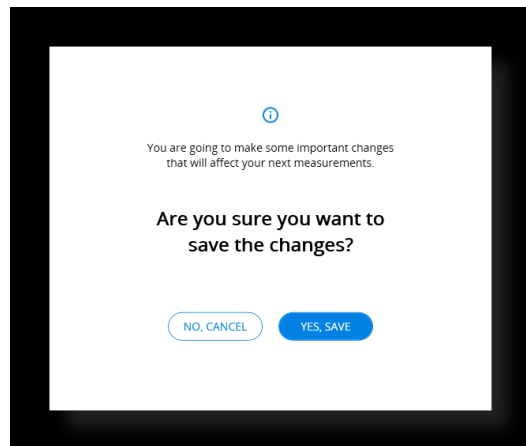


Figure A3-12. Apply changes screen

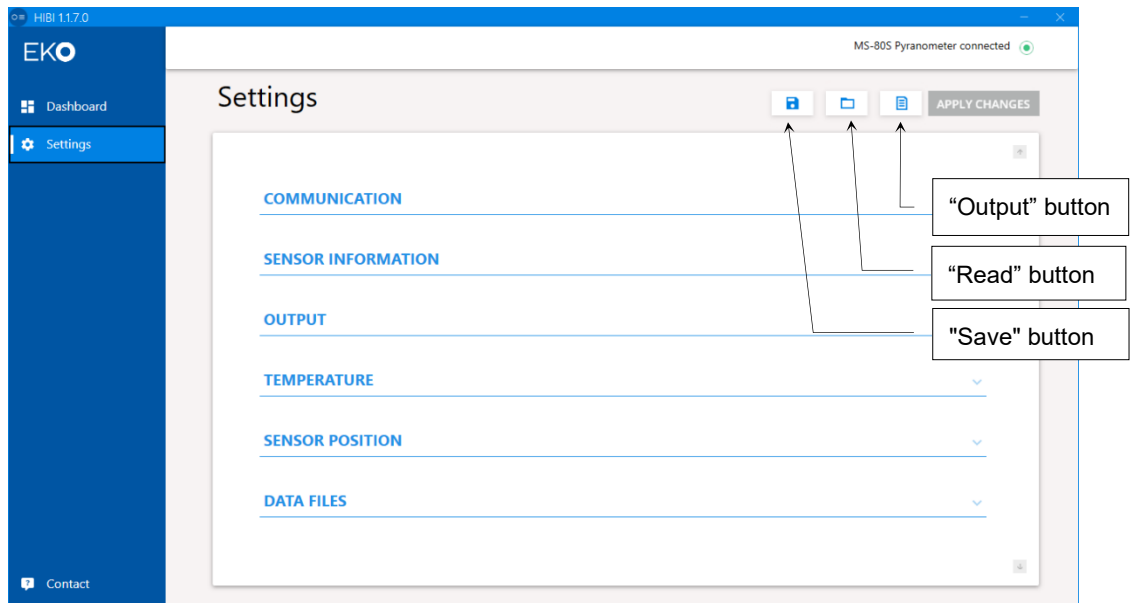


Figure A3-13. Settings screen

5) Setting items

1. COMMUNICATION setting items

Item Name	Setting contents	Setting range
Mode	Modbus	Switch to Modbus 485 RTU interface (Default)
	SDI-12	Switch to SDI-12 interface.
Serial communication	Auto search	OFF/ON: Manual/Auto-connect
	COM Port	COM1 to COM256
	Baud rate	2400 / 4800 / 9600 / 19200 / 38400 / 115200bps
	Parity	Even / Odd / None
Addresses	Modbus address [1-247]	1 to 247 (last 2 digits of serial number is the default address, 100 when "00")
	Register Type	S-series / M-series/ SMP-series/ SRD-series
	SDI-12 address	0 to 9 / A to Z / a to z
Connection status	---	Connected / Disconnect

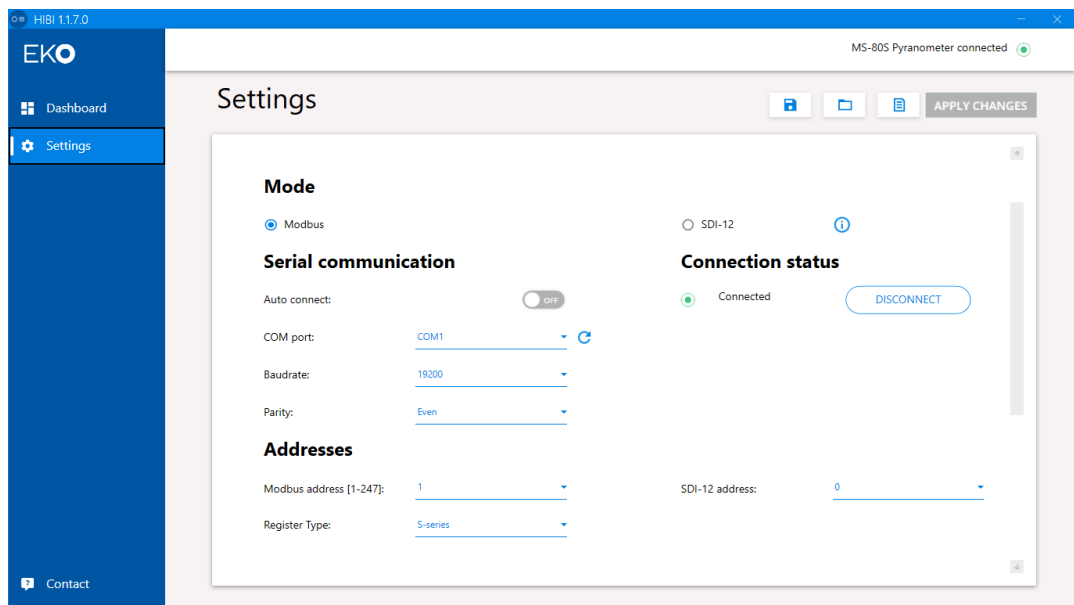


Figure A3-14. Communication setting screen

2. "SENSOR INFORMATION" setting items

Item Name	Setting contents	Setting range
Model information	Model	Model name registered in the MS-60S (cannot be changed)
	Serial number	Serial number registered to the MS-60S (cannot be changed)
	MFG. date	Date of manufacturing (cannot be changed)
	Firmware version	Firmware version of MS-60S (cannot be changed)
	Hardware version	Hardware version of MS-60S (cannot be changed)
Calibration	Calibration date	Calibration date and time: Registered at the time of calibration by the manufacturer but can also be registered by the user.
	Sensitivity [$\mu\text{V}/\text{W}\cdot\text{m}^{-2}$]	Sensitivity constant: Registered at the time of manufacturer calibration, but can also be registered at the user side.

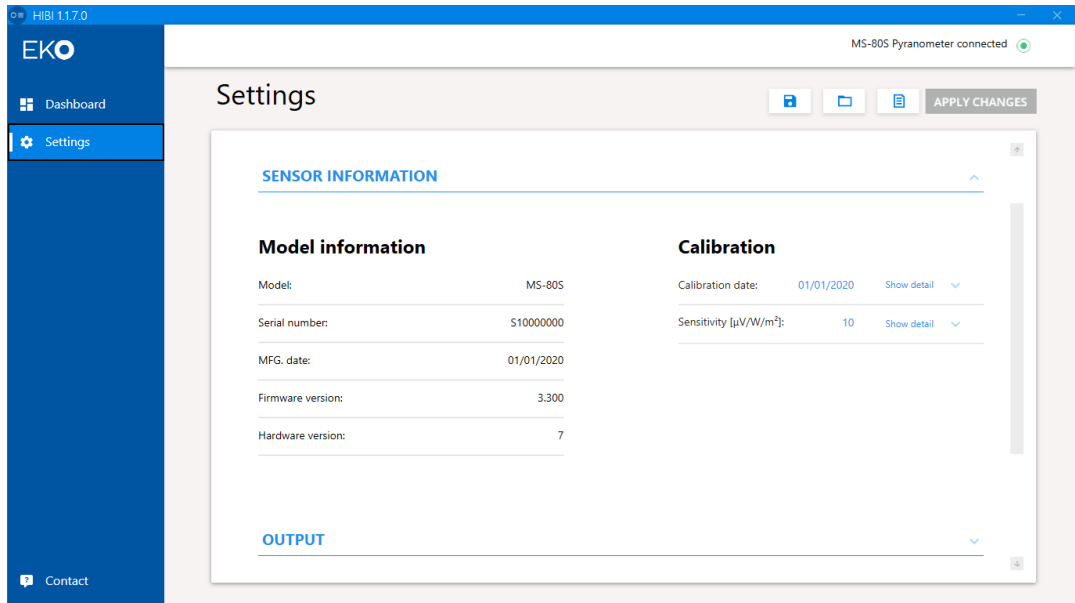


Figure A3-15. Sensor information settings

3. "OUTPUT" setting items

Item Name	Setting contents	Setting range
Analog output	Enable analog output	Analog output OFF/ON (selected with the radio button) Either 4-20mA or 0-1V power can be selected. * Default is 4-20mA.
	4-20mA	Current(mA)/Irradiance(W/m^2): Setting of minimum and maximum irradiance (W/m^2) corresponding to the output.
	0-1V	Voltage(V)/Irradiance(W/m^2): Setting of minimum and maximum irradiance (W/m^2) corresponding to the output.
	Resistance (ohm)	Load resistor value for calculating output current at 0-1V output

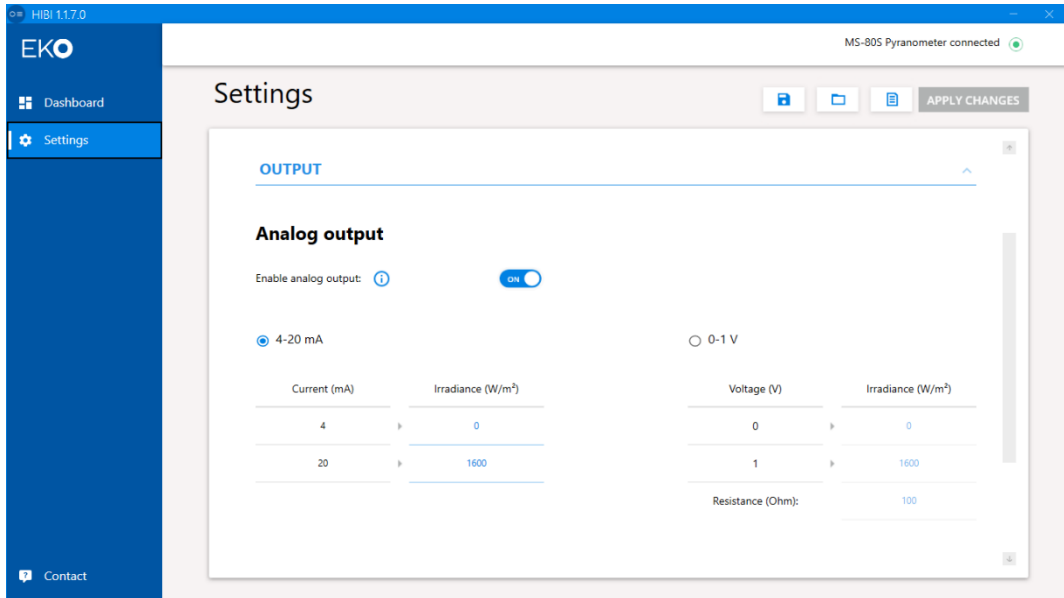


Figure A3-16. Analog settings screen

4. "TEMPERATURE" setting items

Item Name	Setting contents	Setting range
UNIT	Preferred unit (temperature unit setting)	°C-Celsius / °F-Fahrenheit / K-Kelvin

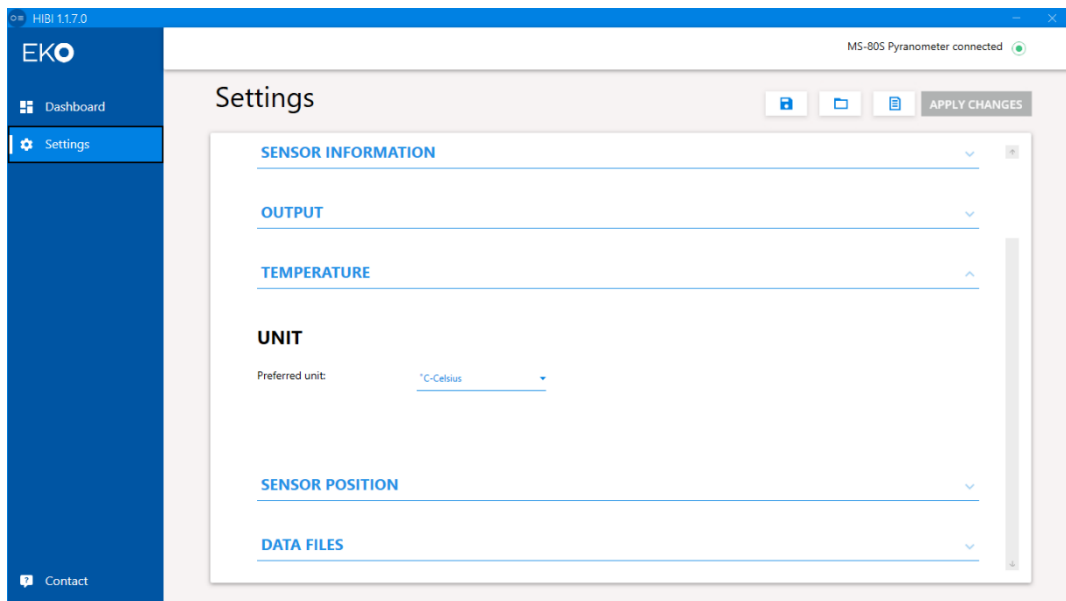


Figure A3-17. Sensor settings screen

5. "SENSOR POSITION" setting items

The sensor position can be measured in two different planes (X, Y).

<Tilt (X axis)> (180° to 0) and (0 to -180°)

<Roll (Y axis)> (180° to 0) and (0 to -180°)

The tilt and roll angles are relative to the calibrated X and Y axis of the sensor and surface mounting plane X' and Y'. When the sensor is positioned in the same plane $X = X'$ and $Y = Y'$, the measured angles X and Y represent the corresponding plane of installation X' and Y'.



Clicking "ZERO ADJUSTMENT" allows you to adjust Tilt (X axis) and Roll (Y axis) of Tilting items using the present tilt angle as 0°. The spirit vial can be used as a reference to readjust the tilt and roll position. The MS-60S X and Y position is factory calibrated.

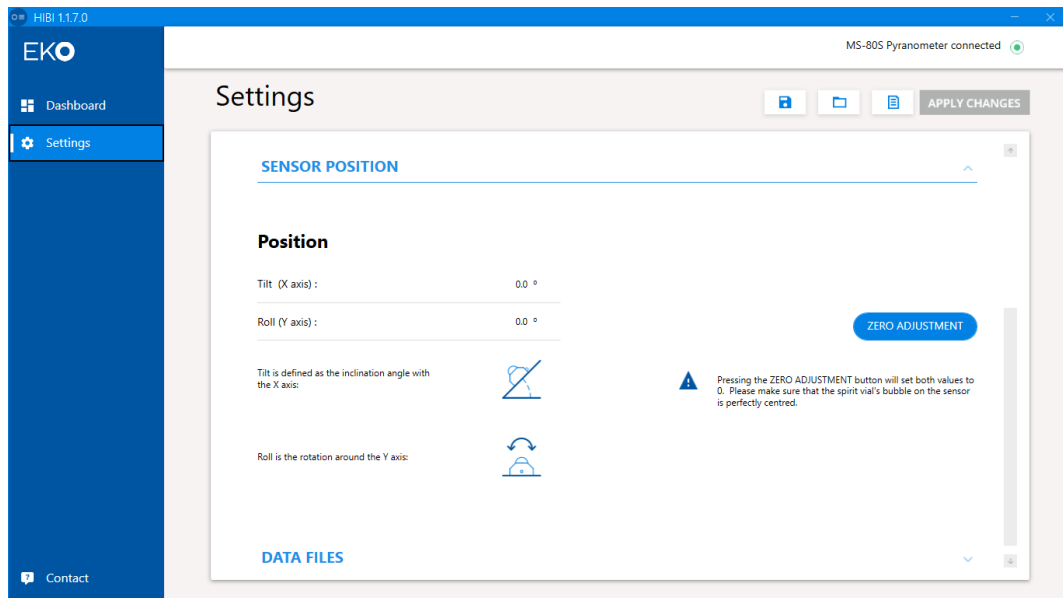


Figure A3-18. Sensor Position setting

6. DATA FILES setting items

[Measurements]

<Save file to> Enter the name of the measurement data storage folder.

[Sensor settings]

<Save file to> Enter the name of the setting file storage folder.

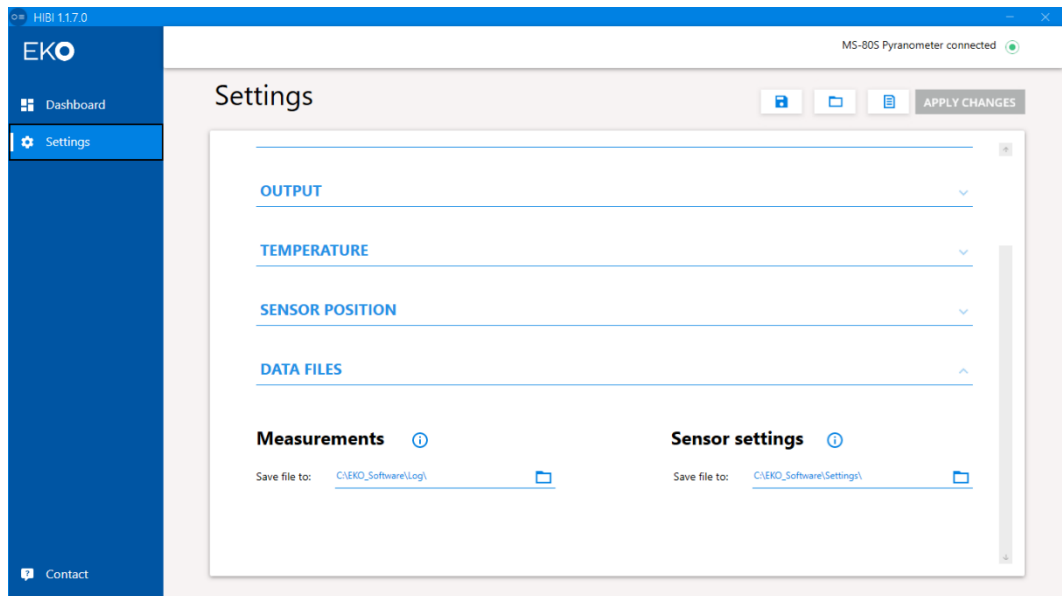


Figure A3-19. Data Files setting

6) Measurement (Dashboard)

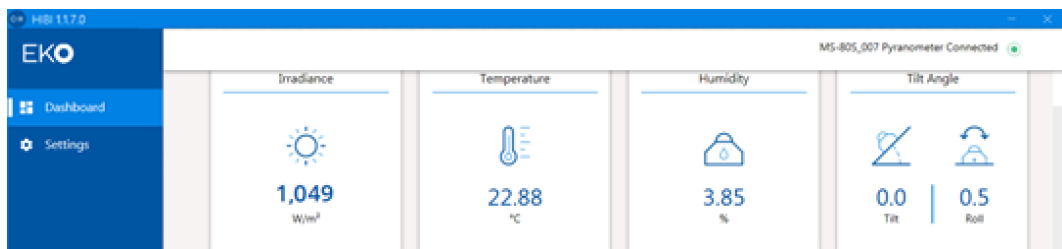


Figure A3-20. Dashboard screen

[Overview]

- Measurement data of irradiance, temperature, humidity, and tilt angle are read from MS-60S every 1 second and displayed.

<Irradiance> Irradiance measurement data (Unit: W/m²)

<Temperature> Internal temperature measurement data.

Unit: selected from °C (Celsius), °F (Fahrenheit) or °K (Kelvin). (°C: default)

<Humidity> Humidity measurement data (Unit: "%RH")

<Tilt Angle> Tilt (X axis angle) and Roll (Y axis angle) data

[Real-time measurement view]



Figure A3-21. Real-time measurement view

<Real time measurement-Irradiance>

- Display measured irradiance data in a graph (1-second update).
- Drag the graph to change the horizontal axis position and use the mouse wheel to zoom in or out on the desired area.
- The time range of the graph is 00:00:00 to 23:59:59.
- Clicking "Back to default" resets the change of the setting of the graph.

<Data Logging>

Logging function of measurement data

- "Sample time:" Set the logging interval for measurement data.
Setting range: 00:01~01:00 (1 sec to 1 min)
- "Average interval:" Set the logging interval for averaged measurement data.
Setting range: 00:01~01:00 (1 sec to 1 min)
- "Measure intervals:" Set the time interval for data logging.
By checking "Continue next days", it is also possible to perform data logging everyday automatically.
- "Start at:" Set the start time for data logging.
- "Ends at:" Set the end time for data logging.
- * Setting across the day is not possible. The start time must be earlier than the end time. (Start time < End time)
- "LOG DATA buttons:" Click to start logging measurement data.
When "STOP" is clicked while measurement data is being logged, logging stops.

7) Contact (Contact)

When you click the "Contact" button, the contact page on [EKO Instruments] website appears in the Browser.

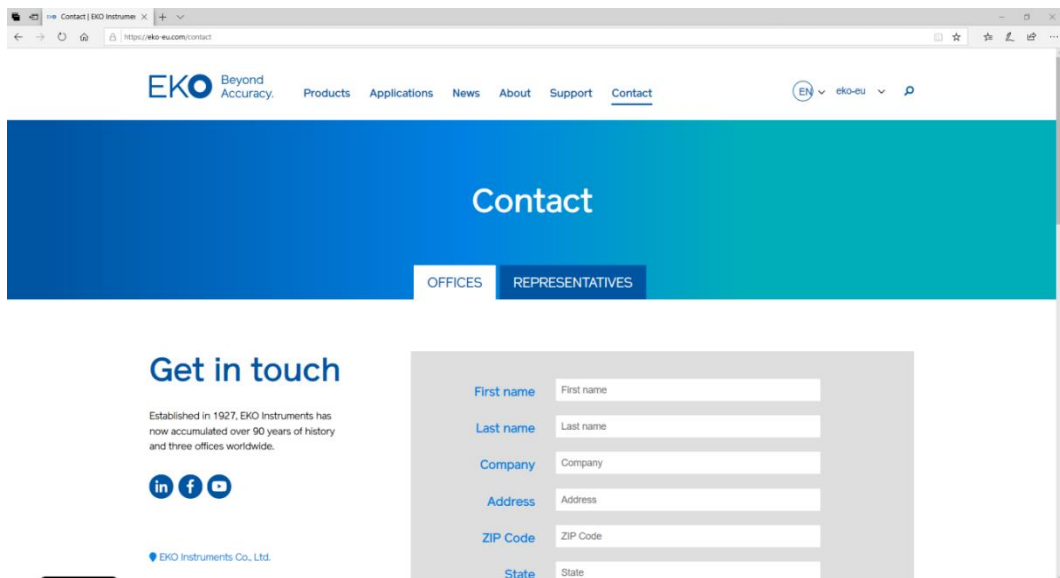


Figure A3-22. Contact page @EKO website

8) Sensor internal humidity abnormality alert

Hibi has a sensor internal humidity indication function, which displays an alert when the sensor internal humidity rises, and an abnormality is detected. If you see an alert, please contact us.

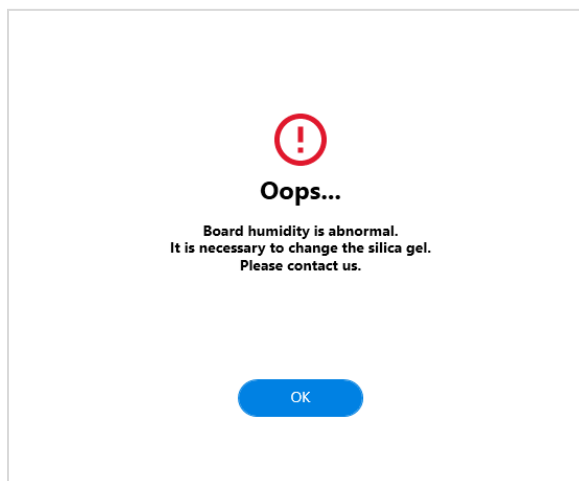


Figure A3-23. Sensor internal humidity abnormality alert

9) Exiting the software (Hibi)

To exit Hibi, click the "X" in the upper-right corner of the window.

A-4. Communication Specifications (Modbus RTU)

A4-1. Outlines

- This device is compatible with Modbus RTU*. ASCII modes are not supported.
(* This is an open protocol for serial communication developed by Modicon.)
- The initial setting of the communication interface is Modbus mode. To use the SDI-12 mode, change the settings from “Hibi” software. After changing the setting, turn the power off and then on again to operate with SDI-12. To return to Modbus mode again, change the setting from “Hibi” software.
- It corresponds to RS485, half-duplex and double-wire multi-drop networks.

The communication specifications are as follows.

Table A4-1. Modbus communication protocol

Optional item	Remarks
Electrical specifications	EIA-485
Connection form	Multi-drop method (1 for Master, 31 for Slave, 32 for total)
Communications protocols	Modbus RTU *1 (Slave)
Communication speed baud rate	2400, 4800, 9600, 19200 , 38400, 115200 bps
Data length	8 Bit
Stop bit	1 bit/2 bit *2
Parity bit	None/Odd/ Even
Communication distance	Max.1000m (ideal value)
Error detecting system	CRC-16

*1: An open protocol developed by Modicon for serial communication.

*2: The value of the stop bit is determined automatically by the parity bit setting.

A4-2. Function code

- There is no distinction between Coil and Discrete Input addresses.
- There is no distinction between Holding Register and Input Register addresses.
- Coil, Discrete Input, Holding Register, Input Register addresses start from “0”.

Table A4-2. Supported Function Codes

Function code (hexadecimal)	Function
0x01	Read Coils
0x02	Read Discrete Inputs
0x03	Read Holding Registers
0x04	Read Input Register
0x05	Write Single Coil
0x06	Write Single Register
0x10	Write Multiple Registers

A4-3. Communication specification

- The address range can be used from 1 to 247.
- The maximum frame size that can be communicated at a time is 256 bytes (maximum read registers: 125, maximum write registers: 123).
- The baud rate (bit/sec) can be selected from 2400, 4800, 9600, 19200, 38400 and 115200.
- Parity can be selected from "Even", "Odd" or "None".
- The bit width is 8 bits, the stop bit is 1 bit when parity is present, and 2 bits when parity is absent.
- If the address and communication settings are changed, the equipment must be restarted.

Table A4-3. Communication setting

Setting No.	Bit rate	Parity
0	2400	None
1	2400	Even
2	2400	Odd
3	4800	None
4	4800	Even
5	4800	Odd
6	9600	None
7	9600	Even
8	9600	Odd
9	19200	None
10 (default)	19200	Even
11	19200	Odd
12	38400	None
13	38400	Even
14	38400	Odd
15	115200	None
16	115200	Even
17	115200	Odd

A4-4. Cable connection

- RS485 communication ground and the power ground are the same.
Be sure to connect the ground of RS485 communication interface to the power ground.

A4-5. Data format

Table A4-4. Data format to use.

Format	Abstract
U16	Unsigned 16bit Integer
S16	Signed 16bit Integer
U32	Unsigned 32bit Integer
S32	Signed 32bit Integer
F32	IEEE754 32bit floating point format
Str	ASCII characters string

- The byte order for communication is big endian.
 2byte values are sent in the order of H byte → L byte
 4byte values are sent in the order of H word → L word
 Character strings are sent in the order of 1 byte from the beginning.
 Allocation of each format is shown in the table below.

Table A4-5. Assignment of 8/16/32 bit value

8bit	0x12	0x34	0x56	0x78
16bit	0x1234(MSW)		0x5678(LSW)	
32bit	0x12345678			

Table A4-6. Assignment of 8/16 bits and F32

8bit	0x41	0x45	0x85	0x1E
16bit	0x4145(MSW)		0x851E(LSW)	
F32	12.345			

Table A4-7. Assignment of 8/16bit and Str

8bit	0x41	0x42	0x43	0x44
16bit	0x4142(MSW)		0x4344(LSW)	
Str	'ABCD'			

- The 32-bit register is in the order of high word (MSW) followed by low word (LSW).
 The following table shows the cases where 0x12345678 is assigned to address n of Modbus register.

Table A4-8. Relationship between 32-bit values and Modbus registers

32-bit value	0x12345678
Modbus register (address n)	0x1234(MSW)
Modbus register (n+1)	0x5678(LSW)

A4-6. Outline of 1 Holding/Input register map

- The register map starts from address 0.
- The contents of registers No. 0 to 49 are switched according to the register type setting (No.103).
- Registers No. 0 to 99 are read-only.
- Registers after No.100 can be read or written to.

A4-7. No. 0-49 Register details

- The register map changes depending on the register type setting. The following table shows 4 register maps.
- See in parentheses for the unit.
- Fixed value if the content is numeric.
- The blank space is not used. It is filled with zero in U16 format.
- The abbreviations are as follows.

Addr: Modbus slave address (1-247)

Comp Irr: Irradiance value after compensation of temperature and linearity.

Raw.Irr: Irradiance before correction

AD: Input voltage

Sensitivity: Calibration factor

Cal. Date: Calibration date

Supply: Supply Voltage

Sensor Name: Sensor name (MS-60S)

Firm Ver: Firmware version number

Hard Ver: Hardware version number

L. Coeff: Linearity compensation factor, set by No.182-189

Table A4-9. No. 0-49 Register S-series type (default)

0	Model	U16	Model number of the transmitter.
1	0	U16	Fixed value
2	Comp.Irr	F32	Adjusted solar radiation intensity Unit: W/m ²
3			
4 to 13 are Reserve			
14	X-axis tilt angle (degree)	F32	X-axis component of the tilt angle Unit: °
15			
16	Y-axis tilt angle (degree)	F32	Y-axis component of the tilt angle Unit: °
17			
18	Raw.Irr	F32	Intensity of solar radiation before correction Unit: W/m ²
19			
20	ADmV	F32	Sensor output voltage Unit: mV
21			
22	Internal temperature	F32	Temperature measured by the internal temperature sensor Unit: (°C / °F / K)
23			
24	Internal humidity	F32	Relative humidity measured by the internal humidity sensor Unit: RH %
25			
26 to 49 are Reserve			

Table A4-10. No.0-49 register M-series type

0	Serial number	U16	Serial No. 1st /2nd ASCII
1			Serial No. 3rd/4th ASCII
2			Serial No. 5th/6th ASCII
3			Serial No. 7th/8th ASCII
4			Serial No. 9th/10th ASCII
5			Serial No. 11st/12nd ASCII
6			Serial No. 13rd/14th ASCII
7			Serial No. 15th/16th ASCII
8	"0000000000"	U16	"00" (fixed)
9			"00" (fixed)
10			"00" (fixed)
11			"00" (fixed)
12			"00" (fixed)
13	0	U16	Minimum solar radiation intensity 0 (fixed)
14	1600	U16	Maximum solar radiation intensity 1600 (default)
15	2	U16	Measurement Mode (default)
16	Sensitivity (μV/W·m ⁻²)	F32	Sensitivity (LSW)
17			Sensitivity (MSW)
18	1	U16	Temperature unit, unit: °C (default)
19	AD(mV)	F32	Input Voltage (LSW)
20			Input voltage (MSW)
21	Comp.Irr(W/m ²)	F32	Corrected insolation intensity (LSW)

22			Corrected insolation intensity (MSW)
23 to 24 are Reserve			
25	8355	U16	Password (fixed)
26 to 33 are Reserve			
34	L.Coeff. k1	F32	Linearity correction factor 1-k1 (LSW)
35			Linearity correction factor 1-k1 (MSW)
36	L.Coeff. k2	F32	Linearity correction factor 2-k2 (LSW)
37			Linearity correction factor 2-k2 (MSW)
38	L.Coeff. k3	F32	Linearity correction factor 3-k3 (LSW)
39			Linearity correction factor 3-k3 (MSW)
40	L.Coeff. k4	F32	Linearity correction factor 4-k4 (LSW)
41			Linearity correction factor 4-k4 (MSW)
42	Addr	U16	Node number
43	BPS	U32	Communication speed (LSW)
44			Communication speed (MSW)
45	Parity	U16	Parity bit
46 to 49 are Reserve			

Table A4-11. No. 0-49 register SMP-series type

0	65535	U16	Fixed value
1	100	U16	Fixed value
2	1	U16	Fixed value
3	0	U16	Fixed value
4	1	S16	Fixed value
5	Comp.Irr (W/m ²)	S16	
6	Raw.Irr (W/m ²)	S16	
7	0	S16	Fixed value
8			
9	Supply (0.1V)	S16	
10	0	S16	Fixed value
11	0	S16	Fixed value
12	0	S16	Fixed value
13	0	S16	Fixed value
14	0	S16	Fixed value
15	0	S16	Fixed value
16	0	U16	Fixed value
17	0	U16	Fixed value
18	AD(0.01uV)	S32	
19			
20	0	S32	Fixed value
21			Fixed value
22	0	S32	Fixed value
23			Fixed value
24	0	S32	Fixed value
25			Fixed value
26	0	U16	Fixed value
27	0	U16	Fixed value
28	0	U16	Fixed value
29	0	U16	Fixed value
30	0	U16	Fixed value
31	0	U16	Fixed value
32	0	U16	Fixed value
33	0	U16	Fixed value
34	0	S16	Fixed value
35 to 40 are Reserve			
41	2020	U16	Fixed value
42	0	U16	Fixed value
43	Firm Ver	U16	
44	Hard ver.	U16	
45	Address	U16	
46 to 49 are Reserve			

Table A4-12. No. 0-49 Registers SRD-series type

0	Address	U16	
1	Com.Set	U16	
2	Comp.Irr(0.01W/m ²)	S32	
3			
4	Raw.Irr(0.01W/m ²)	S32	
5			
6			
7	0	U16	Fixed value
8	100	U16	Fixed value
9	100	U16	Fixed value
10	AD(nV)	S32	
11			
12 to 31 are Reserve			
32	Sensor Name	Str	
33			
34			
35			
36			
37			
38			
39			
40	0	U16	Fixed value
41	Sensitivity ($\mu\text{V}/\text{W}\cdot\text{m}^{-2}$)	F32	
42			
43	0	U16	Fixed value
44	0	U16	Fixed value
45	0	U16	Fixed value
46	Cal.date (YYYYMMDD)	U32	
47			
48 to 49 are Reserve			

A4-8. Measurement value register update cycle

- The sensor output and the tilt angle measurement value in the register are automatically updated.
The update cycle is about 110 msec. If the data read cycle is less than 110msec, the same data will be read multiple times. The data read cycle should be 110msec or more.

A4-9. Register details from No.50 to 99

- A fixed value of zero (U16) has been written to an address that is not used.
- The "EKO" character is written as the company name registration in register No. 96 and 97.

Table A4-13. Register No.50-95

50 to 95 are Reserve			
----------------------	--	--	--

Table A4-14. Register No.96-99

96	Company name (0,1)	Str	The company name in ASCII format "EKO" is read. Four "EKO" characters, three "EKO" characters and one space (0x20).
97	Company name (2,3)		
98	Firmware version	U16	Firmware version number.
99	Hardware version	U16	Various parts of hardware

A4-10. No. 100 or later registers

- Registers after No.100 are readable and writable, and values written are immediately reflected.
- To save the written data, use Discrete Coil shown below to save the data.
- The 2 registers, Modbus address (No.101) and serial communication setting (No.102) related to communication are not reflected in the operation after saving and rebooting.

Table A4-15. Register No.100-199

100	Model	U16	Model number of the transmitter. (0x0110)
101	Modbus Address	U16	Modbus slave address
102	Serial communication setting	U16	Set bit rate and parity, see Table A4-3. "Communication setting"
103	Register Type	U16	No. Refer to the register type setting Table A4-9 - Table A4-12 of No.0-49 register.
104 to 105 are Reserve			
106	Setting the analog outputs	U16	Analog current output setting, Table A4-18. "Analog output setting details"
107 to 130 are Reserve			
131	0-1V loading resistor	F32	Accurate load resistance value, default 100 Ω
132			Used to calculate the output current in 0-1V mode.
133	Irradiance (0-1Vmode 0V)	F32	Sets the radiance in 0-1V or 0V.
134			
135	Irradiance (0-1Vmode 1V)	F32	Sets the radiance in 0-1V or 1V.
136			
137	Irradiance (4-20mode 4mA)	F32	Radiation intensity value at 4-20 mA mode and output current of 4mA defaults to 0W/m ²
138			
139	Irradiance (4-20mode 20mA)	F32	Radiation intensity value at 4-20mA mode and an output current of 20mA defaults use 1600W/m ²
140			
141 to 161 are Reserve			
162	Date of manufacture	U32	Date of manufacture in YYYYMMDD format
163			
164	Serial number	U32	Serial number with 32-bit integer value (maximum value 4294967295)
165			

			Enter the number part excluding the alphabet S.
166	Sensor name (0,1)	Str	Sensor name according to ASCII format, up to 16 characters Null-terminated unless all 16 characters are used
167	Sensor name (2,3)		
168	Sensor name (4,5)		
169	Sensor name (6,7)		
170	Sensor name (8,9)		
171	Sensor name (10,11)		
172	Sensor name (12,13)		
173	Sensor name (14,15)		
174 to 181 are Reserve			
182	L.Coeff.k1	F32	Linear correction factor k1
183			
184	L.Coeff.k2	F32	Linear correction factor k2
185			
186	L.Coeff.k3	F32	Linear correction factor k3
187			
188	L.Coeff.k4	F32	Linear correction factor k4
189			
190	Cal.Date	U32	Calibration date in YYYYMMDD format
191			
192	Cal.Value	F32	Calibration value, $\mu\text{V}/\text{W}\cdot\text{m}^{-2}$
193			
194 to 199 are Reserve			

Table A4-16. Register No.200-219

200	Cal.Date history0	U32	Calibration History, Date 0
201			
202	Cal.Value history0	F32	Calibration history, sensitivity constant 0
203			
204	Cal.Date history1	U32	Calibration History, Date 1
205			
206	Cal.Value history1	F32	Calibration History, Sensitivity Constant 1
207			
208	Cal.Date history2	U32	Calibration History, Date 2
209			
210	Cal.Value history2	F32	Calibration History, Sensitivity Constant 2
211			
212	Cal.Date history3	U32	Calibration History, Date 3
213			
214	Cal.Value history3	F32	Calibration History, Sensitivity Constant 3
215			
216	Cal.Date history4	U32	Calibration History, Date 4
217			
218	Cal.Value history4	F32	Calibration History, Sensitivity Constant 4
219			

Table A4-17. Analog output setting details

Analog output setting value	Operation modes
0	Output OFF
1	0-1V Mode
2	4-20 mA Mode

A4-11. Linear correction factor

- Calculate the pyranometer output after linear correction using the following equation using the coefficient k1/k2/k3/k4 for the solar radiation meter output V(raw) after temperature correction.
- Linear post-correction sun photometer output $V(L) = k1 + (k2 \cdot V(\text{raw})) + (k3 \cdot V(\text{raw})^2) + (k4 \cdot V(\text{raw})^3)$
- The default value is k2=1, k1=k3=k4=0, so V(L)=V(raw), and the raw value is used for the corrected pyranometer output.

A4-12. Solar irradiance after correction

- After the linear correction and temperature correction written above, using the sensitivity value $S(\mu V/W \cdot m^2)$ for the output voltage, according to the following equation, calculate the irradiance value.

$$\text{Corrected solar irradiance: } I(C) = V(L) \times 1000/S$$

*Since the unit of $V(L)$ is millivolts, multiply it by 1000 to obtain the irradiance value.

A4-13. Outline of Coil / Discrete Input Registers

- Reboot the device and save the settings by writing a specified bit.
- Do not write to any Coil other than Reboot/Save.
- The readout is always zero.

A4-14. Register details

Table A4-18. Coil register

Addr	Parameter	R/W	Type
0	-	-	-
1	Reboot	W	Bit
2	-	-	-
3	Save	W	Bit
4	-	-	-
5	-	-	-
6	-	-	-
7	-	-	-

A-5. Communication specification (SDI-12)

A5-1. Abstract

- SDI-12 (Version:1.4) is supported.
- The initial setting of the communication interface is Modbus. To use the SDI-12 interface, change the settings from "Hibi" software. After changing the setting, turn the power off and then on again to operate with SDI-12 mode. To return to Modbus mode again, change the setting from "Hibi" software.
- When SDI-12 is enabled, the unit operates in "low power standby mode" with power consumption of approx. 2.5mA (at 12V) during non-communication.

A5-2. Communication specification

- The communication specifications of SDI-12 are as follows.

Table A5-1. SDI-12 Communication Specifications

Item	Description
Communications protocols	SDI-12 Version 1.4
Baud rate	1,200 bps
Data length	7bit
Stop bit	1
Parity bit	Even
Communication distance	Within 60 m

A5-3. Command list

- SDI-12 commands are listed below.
- The lowercase letter 'a' in the command list indicates SDI-12 address number.
- SDI-12 address number that can be set is 0-9, A-Z, a-z.

Table A5-2. SDI12 Commands

Command	Response	Description
?!	a<CR><LF>	Check the address number of the connected device. NOTE: If more than one device is connected, it will not function properly. Be sure to use the device alone.
a!	a<CR><LF>	Verify that the device with address number "a" is active.
aAb!	b<CR><LF>	Change the address number of the device with address number "a" to "b".
al!	Refer to the right section	Returns information. <Response example> "a14EKOINST_MS-60SV3220000001<CR><LF>" a: SDI-12 address 14: SDI-12 version (represents version 1.4) EKOInst: Company name (8 characters) MS-60S: Sensor model name (6 characters) V32: Sensor version (3 characters) 20000001: Serial number (8 characters)

aM!	a0001<CR><LF>	Request the device with address number "a" to execute measurement. 0001: indicates the 3-digit measurement execution time (000 indicates instantaneous), and the 4th digit indicates the number of data to be returned (1 piece).
aD0! aD1! aD2! aD3!	a+1000.0<CR>><LF>	Request to send data to the device with address number "a". The output value is always appended with a sign (+ or -). If there is more than one output, the sign is also the delimiter. D0: Irradiance (W/m ²) 1 digit after decimal point D1: Sensor output voltage (mV) 4 digits after decimal point and Sensor temperature (Celsius) 2 digits after decimal point D2: X-axis tilt angle (degree) 1 digit after decimal point, forward/backward with connector facing back, positive value when back is up, Y-axis tilt angle (degree) 1 digit after decimal point, left/right with connector facing back, negative value when left is down D3: Temperature inside enclosure (°C) 1 digit after the decimal point, Humidity inside the enclosure (RH %) 1 digit after the decimal point. If the pre-measurement command is "MC", then three CRC characters are followed, please refer to SDI-12 standard for the content of CRC characters.
aMC!	a0011<CR><LF>	Request the device with address number "a" to start measurement and request the CRC to confirm that the command is correctly accepted. The response format is the same as "aM!"
aC!	a00101<CR><LF>	This device is the same as the "aM!" command except for the difference in the number of response characters. The character following a indicates the number of seconds (3 digits) and the number of data (2 digits).
aCC!	a00101<CR><LF>	This transmitter is the same as the "aMC!" command except for the difference in the number of response characters.
aR0!	a+0.0<CR><LF>	Request a measurement from the device with address number "a". Measurement is executed and a response is returned immediately. The answer is similar to "aD0!" to "aD2!" command.
aRC0!	a+0.0EmT<CR><LF>	Request measurement from the device with address number "a" and request error detection to verify that the command was accepted correctly. Measurement is executed and the measured value with three CRC characters added at the end is returned instantly.
aXSE!	a+XX.XX<CR>><LF>	Read the sensitivity constant of this device. Two digits after the decimal point.
aXCD!	aYYYYMMDD<CR><LF>	Read the calibration date of this device. YYYY: AD, MM: month, DD: day.
METADATA	Variable depending on request data	Identify Measurement Commands and Identify Measurement Parameter Commands are supported.

A-6. About recalibration

When recalibrating at a recalibration agency other than EKO, the sensitivity constant ($\mu\text{V}/\text{W}\cdot\text{m}^2$) provided by the agency may differ slightly from the sensitivity constants by EKO. The differences may be caused by differences in the calibration method, differences in the reference standard, measurement uncertainty, and measurement conditions.

If a new sensitivity constant was found and needs to be applied to the pyranometer, it can be applied in two ways:

- 1) (Post data correction) Multiply the relative difference of the irradiance value measured with the pyranometer.

In this case, the original factory sensitivity value given by EKO remains unchanged. When the new sensitivity figure was found apply the ratio of the new and original calibration figure according to the formula below:

$$I_{new} [\text{W}/\text{m}^2] = \frac{E [\mu\text{V}]}{S_{original} [\mu\text{V}/\text{W}\cdot\text{m}^2]} \times \frac{S_{original} [\mu\text{V}/\text{W}\cdot\text{m}^2]}{S_{new} [\mu\text{V}/\text{W}\cdot\text{m}^2]}$$

Example:

It was proven that there was a relative difference in irradiance measured by MS-60S and the reference pyranometer. In this example the irradiance measured by MS-60S was lower than the irradiance measured by the reference pyranometer, a new sensitivity value can be calculated and applied by the following equation.

$$S_{new} = I_{MS60S} / I_{ref} \times S_{original}$$

S_{new}	New MS-60S Sensitivity ($\mu\text{V}/\text{W}\cdot\text{m}^2$)
S_{origin}	MS-60S Original Sensitivity ($\mu\text{V}/\text{W}\cdot\text{m}^2$)
I_{MS60S}	Irradiance measured by MS-60S (W/m^2)
I_{ref}	Irradiance measured by reference pyranometer (W/m^2)

- 2) (Change the sensitivity figure of the MS-60S) Set a new sensitivity figure to the MS-60S.

This can be done via through Hibi software. Connect the MS-60S to a PC with a RS485/USB converter cable. In settings, the new sensitivity figure can be applied. The original sensitivity figure remains, but will be replaced by the "last" sensitivity figure ($\mu\text{V}/\text{W}\cdot\text{m}^2$). Multiple calibration figures can be stored inside the pyranometer, the "last" sensitivity figure is the actual one to calculate the irradiance.

A-7. MS-60S Setting Report



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S-series Setting Report(Example)

Issue Date: 10-Apr-21

Factory setting data	
Sensor type	Pyranometer
Model name	MS-60S
Serial number (S*****)	12345678
Manufacturing date	April 7, 2021
Calibration date	April 5, 2021
Analog sensitivity [μV/W/m ²]	11.36
Hardware version	7
Firmware version (*.***)	3713

Current output mode of 4-20 [mA]	Setting
Enable/Disable	Enable (Default)
Output range corresponding to 4-20 [mA].	0 - 1600 [W/m ²]

Current output mode of 0-10 [mA]	Setting
Enable/Disable	Disable (Default)
Output range corresponding to 0-10 [mA].	0 - 1600 [W/m ²]

Modbus RTU	Setting
Enable/Disable	Enable (Default)
Address	1
Baudrate	19200
Parity	EVEN
Reg. type	S-series

SDI-12	Setting
Enable/Disable	Disable (Default)
Address	0
Baudrate	1200

A-8. Surge protection

Since a surge protection board is embedded inside the pyranometer, this alone provides strong protection against lightning surges.

However, if the pyranometer cable is longer than 10m, or if multiple pyranometer are connected and the total cable length exceeds 10m, the connected loggers, power supply, and other devices may be damaged by lightning surges.

Please refer to the figure below and add an appropriate SPD to protect the measurement system.

A. Modbus connection (when the cable length exceeds 10m)

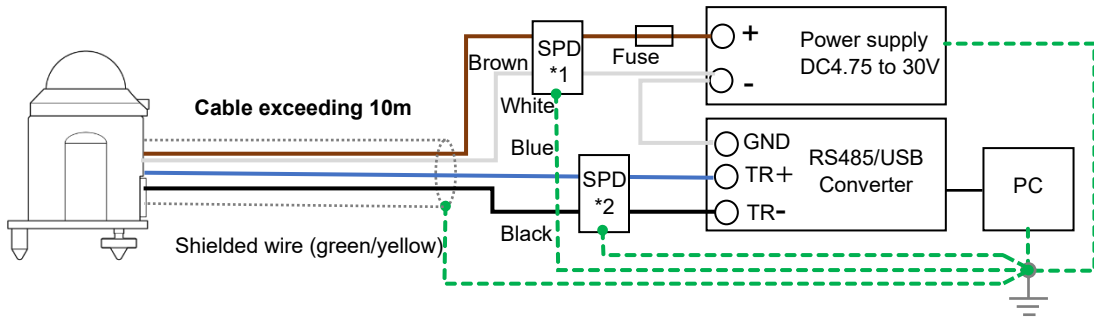


Figure A8-1. Modbus connection (when the cable length exceeds 10m, etc.)

*1 *2

If the cable length exceeds 10m, it is recommended to set up an SPD for the communication line and an SPD for the DC power supply because surges may enter from the communication line and the power supply line.

B. SDI-12 connection (when the cable length exceeds 10m)

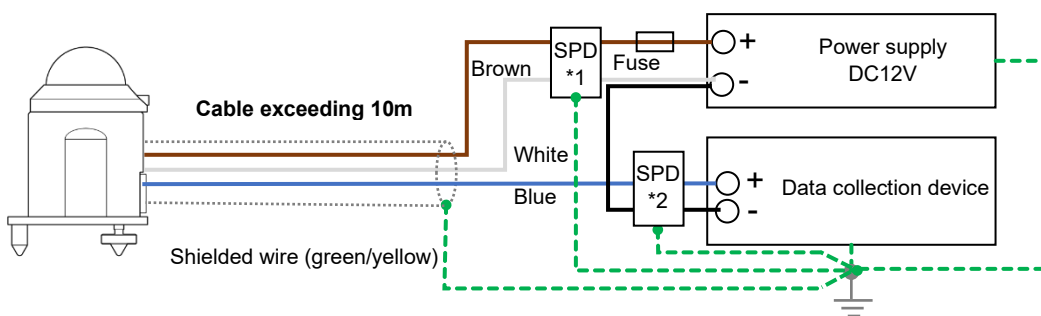


Figure A8-2. SDI-12 connection (when the cable length exceeds 10m, etc.)

*1 *2

If the cable length exceeds 10m, it is recommended to set up an SPD for the communication line and an SPD for the DC power supply because surges may enter from the communication line and the power supply line.

In the case of lightning surges, the more countermeasure components are used, the lower the probability of failure. However, the type, rating, and connection method of the SPD to be used vary depending on the manufacturer, so please read the instruction manual of each manufacturer carefully.



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