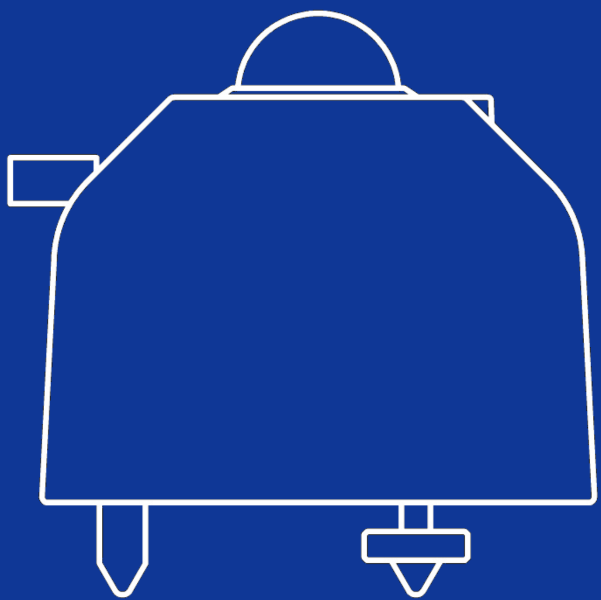
INSTRUCTION MANUAL

MS-80

Pyranometer
ISO9060: 2018 Class A
ISO9060: 1990 Secondary Standard



EKO

1. Index

2. Important User Information

Thank you for using EKO Products

Make sure to read this instruction manual thoroughly and to understand the contents before starting to operate the instrument. Keep this manual at safe and handy place for whenever it is needed.
For any questions, please contact us at one of the EKO offices given below:

2-1. Contact Information

EKO INSTRUMENTS CO., LTD.			
Asia, Oceania Region			
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2-2. Warranty and Liability

For warranty terms and conditions, contact EKO or your distributor for further details.
EKO guarantees that the product delivered to customer has been verified, checked and tested to ensure that the product meets the appropriate specifications. The product warranty is valid only if the product has been installed and used according to the directives provided in this instruction manual.

In case of any manufacturing defect, the product will be repaired or replaced under warranty. However, the warranty does not apply if:

- Any modification or repair was done by any person or organization other than EKO service personnel.
- The damage or defect is caused by not respecting the instructions of use as given on the product brochure or the instruction manual.

2-3. About Instruction Manual

This manual was issued: 2019/05/20

Version Number: 3

2-4. Environment

1. WEEE Directive 2002/96/EC (Waste Electrical and Electronic Equipment)

This product is not subjected to WEEE Directive 2002/96/EC however it should not be mixed with general household waste. For proper treatment, recovery and recycling, please take this product(s) to the designated collection points.

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 pyrheliometer calibrations in accordance with the requirements of ISO/IEC17025, which are relevant to calibration and testing.

EKO is a unique manufacturer who can offer calibration service for pyranometers and pyrheliometers in-house. Based on the applied calibration methods EKO provides the best quality solar sensor calibrations compliant to the international standards defined by ISO/IEC17025 / 9847 (Indoor method) and ISO9059 (Outdoor method) (Certification: L13-94-R2 / www.pjlabs.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 pyrheliometer
  - ISO9847 Calibration of field pyranometer by comparison to a reference pyranometer
  - ISO9059 Calibration of field pyrheliometers by comparison to a reference pyrheliometer
- Obtain repeatable and reliable calibration test results through consistent operations

Our clients will obtain a 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

EKO

IMPORTANT USER INFORMATION

CE

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-80, MS-80A, MS-80M, MS-80U

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: Dec. 1, 2015

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

Name of Authorized Signatory: Shuji Yoshida

Signature of Authorized Signatory: Shuji Yoshida

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. WARNING/CAUTION

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 gale or earthquake, which may lead to unexpected accidents.
- Make sure the instrument and the cables are installed in a location where they will not get soaked.
- When using this instrument by connecting to a measuring instrument, make sure to connect the shield cable to either the signal ground terminal on the measuring instrument side or GND (the reference potential on the single end input side). Noise 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 environment where corrosive gas, such as ammonia and sulfurous acid gas, are generated. It may cause malfunction.
- Do not install in area that cause salt damages. It may cause malfunction by paint peeling off or corrosion. When installing in 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 resin pipe or metal pipe treated with salt-resistant paint such as molten zinc plating, 4. Periodically clean.
- Do not use this instrument in vacuum environment.
- If the cable and main unit are in risk for getting damaged by birds and small animals, protect the cable and the main unit by using: 1. Reflective tape, 2. Repellent, 3. Cable duct, 4. Installing bird-spike

2. Handling

- Be careful with glass dome when handling instruments. Strong impact to this part may damage the glass and may cause injuries by broken glass parts.
- When carrying any MS-80 model with the sunscreen attached, always hold the instrument from the bottom. Holding only the sunscreen part may lead to dropping the sensor as it comes off from the sunscreen.

3. Power Supply (MS-80A/MS-80M)

- Make sure to ground the grounding cable on the power supply cable. When grounding is insufficient, it may cause not only measurement error due to noise, but also cause electric shock and leakage accidents.
- Check the voltage and types (AC or DC) 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 on the electronics will occurs.

4. Introduction

EKO's new generation sensor, called MS-80 broke with the rules of traditional pyranometer architecture. The innovative design was inspired by the combination of latest technologies and state-of-the-art thermopile sensor, enabling a breakthrough in unprecedented low zero-offset behaviour and fast sensor response.
The compact sensor with single dome is immune to offsets and integrates all value added functions such as a ventilator, heater and different industrial interfaces.

MS-80 unique properties:

Long term stability Compared to our conventional pyranometer, the long term stability is further enhanced with improved airtightness and the sensor architecture with low sensitivity degradation.

Fast detector response The MS-80 is based on the latest thermopile technology, and realized with a response time of <0.5sec @95% or <1sec @99%. Such response time is suitable for measuring solar irradiance which changes momentarily.

Excellent temperature coefficient MS-80 has excellent temperature response in wide temperature range compared to our conventional pyranometer, and it provides linear output against solar irradiance.

Lowest zero off-set Compared to the conventional pyranometers using double-dome, MS-80 has the lowest zero off-set effects. The combination of the isolated thermopile detector architecture and optics keep the sensor in thermal balance within variable atmospheric conditions.

Warranty and re-calibration The MS-80 has 5 years warranty and 5 years recommended re-calibration period.

ISO 9060, an international industry standard, was revised to the 2nd edition in 2018. Along with this revision, the Pyranometers are classified in order of the highest grade "Class A" "Class B" "Class C" and for Pyranometers that meet the response time and spectral selectivity criteria, "fast response pyranometer" and "spectrally flat radiometer" are classified as a sub-category.

4-1. About the Pyranometer Series

EKO offers four different MS-80 pyranometer models each with different features. With this wide range of sensors, EKO pyranometers can meet all possible application requirements, ranging from PV module efficiency measurements to climatology research and material durability testing.

The MS-80 sensor gives excellent durability. It 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 case of the MS-80 the detector it 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.

During production and inspection, the directional response and temperature dependency are measured and validated through a measurement report that comes with each sensor. Besides, EKO provides a unique calibration service for pyranometers compliant to the international standards defined by ISO/IEC17025 / 9847 (indoor method). When an ISO/ IEC17025 calibrated sensor is purchased, EKO offers sensor at nearly constant calibration uncertainty. The Accredited lab is regularly re-examined to ensure that they maintain their standards of technical expertise.

In case of MS-80, MS-80A and MS-80M, 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 the air.

In the following paragraphs, the four instrument types are described individually.

1. MS-80

The analogue MS-80 pyranometer can be used as a reference sensor to measure the global broad-band solar radiation with a high accuracy. With excellent temperature response and non-linearity characteristics, it provides optimal performance throughout the year and day.

Category of ISO9060: 2018

"Fast response and spectrally flat pyranometer of class A"

Key features:

- Fast Response time (<0.5s@95%, <1s@99%)
- Excellent temperature response over a wide temperature range (-20 to +50℃)
- Low offset characteristics

2. MS-80A

The MS-80A is a MS-80 with built in 4-20mA converter which can transfer data in long distance. Due to the ultralow temperature dependency and non-linearity characteristics, the converter guarantees an optimal sensor performance throughout year and day. For easy conversion, the MS-80 output by the integrated converter is set to 4-20mA | 0 - 1600 W/m^2.

With the optional USB controller and EKO Sense software (Multiple languages), the converter settings can be freely changed.

Category of ISO9060: 2018

"Spectrally flat pyranometer of class A"

Key features:

- Fast Response time (<1.5s@95%, <2s@99%)
- Excellent temperature response over a wide temperature range (-20 to +50℃)
- Measurements at long distances (Recommended maximum transmission range 1.2km when using DC24V, AWG28 cable)

3. MS-80M

The MS-80M is a MS-80 with built in MODBUS RTU 485 converter which can be connected in series with devices using the same communication protocol. It is also compatible to the industrial photovoltaic system power conditioner input. Due to the excellent temperature dependency and non-linearity characteristics, the converter guarantees an optimal sensor performance, throughout year. MS-80M can be used with instruments connected with EKO Modbus Signal Converter MC-20 and MS-80M up to 100 units through BUS connection. The digital signal from MS-80M can be converted to irradiance 0 - 1600 W/m^2 (default setting). With the optional USB controller and EKO Sense software (Multiple languages) the converter settings can be freely changed.

Category of ISO9060: 2018

"Spectrally flat pyranometer of class A"

Key features:

- Fast Response time (<1s@95%, <1s@99%)
- Excellent temperature response over a wide temperature range (-20 to +50℃)
- Measurements at long distances (transmission distance 1.2km, theoretical value stated on EIA-485.

4. MS-80U

MS-80U is the most compact and light weight Class A pyranometer on the market. With a total weight of 0.2 kg and low body height the sensor can be easily used for drone and UAV applications.

Category of ISO9060: 2018

“Fast response and spectrally flat pyranometer of class A”

Key features:

- Compact and light weight
- Fast Response time (<0.5s@95%, <1s@99%)
- Excellent temperature response over a wide temperature range (-20 to +50℃)
- Low offset characteristics

4-2. 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

Contents	MS-80 / MS-80A / MS-80M	MS-80U
Pyranometer	○	○
Output Cable*	○	○
Sunscreen	○	-
Instruction Manual	Not included in the package (Please download from EKO Website)	
Inspection Report	○	
Quick Start Guide	○	-
Fixing Bolts	(M5) x2 (Bolt Length: 75mm)	
Washers	(M5) x4	
Nuts	(M5) x2	

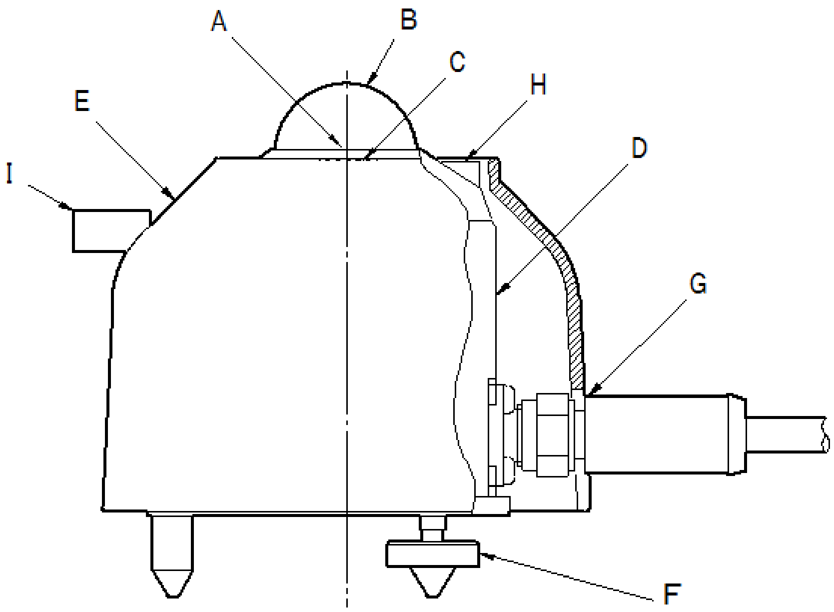
*In case of MS-80/80A/80M, standard length is 10m for both signal/power cable. For different length of cables (e.g. to meet your application needs) please contact EKO or your local distributor. MS-80U cable length is 3m, no other optional lengths are available.

5. Getting Started

5-1. Parts Name and Descriptions

Each part name and its main function is described below.

MS-80 / 80A/ 80M

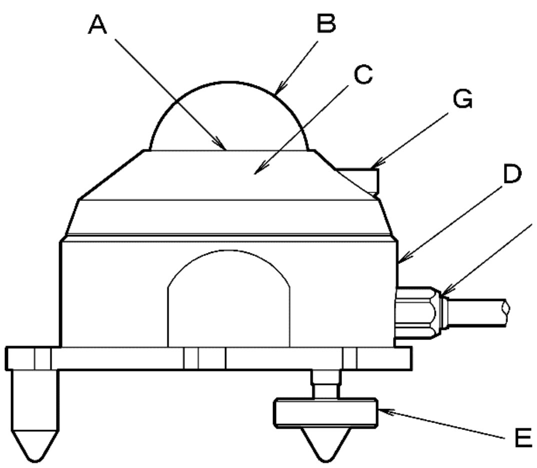


*Signal converter is built-in for MS-80A and MS-80M.
Figure 5-1. Pyranometer Parts Name (MS-80 / 80A / 80M)

Table 5-1. Parts Name (MS-80 / 80A / 80M)

Parts Name
A. Diffuser
B. Glass Dome
C. Sensor
D. Body
E. Sunscreen
F. Levelling Screw
G. Cable, Connector
H. Bubble Level
I. Knurling Screw

MS-80U



*The cable can't be removed from the pyranometer
Figure 5-2. Pyranometer Parts Name (MS-80U)

Table 5-2. Parts Name (MS-80U)

Parts Name
A. Diffuser
B. Glass Dome
C. Sensor
D. Body
E. Levelling Screw
F. Cable
G. Bubble Level

1. Glass Dome, Diffuser

A glass dome creates a sealed environment for the detector and protects it against dirt and rain. The dome of the EKO pyranometers is only transparent for radiation emitted by the sun. Hence they block the undesired infrared radiation emitted by the Earth's atmosphere.　By the combination of the glass dome and the diffuser, it improves the cosine response generated by the incident light from the entire hemisphere.

2. Sensor

The sensor (thermopile detector), which is the heart of the pyranometer generates a voltage signal that is proportional to the solar irradiance. The sensor determines the majority of the measurement properties (e.g. response time, zero offset B, non-linearity, sensitivity, etc.). MS-80 sensor varies less by aging due to special construction.

3. Sunscreen, Sensor Body, and Level

MS-80, MS-80A and MS-80M have a sunscreen to prevent body temperature increase generated by direct sun light. Weather resistant metal is used for the body, which has resistant against decrease of nocturnal radiation and heat radiation, and rain and dusts. The integrated sprit level is used for setup and maintaining the sensor in a horizontally levelled position.

4. Drying agent

Enclosed drying agents inside the sensor body keep the sensor inside dry, prevents condensation of humidity inside of the glass dome. There is no need to replace the drying agents as they are replaced when sensor is recalibrated at EKO.

5. Cable and Cable Connector

MS-80/ 80A/ 80M 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.)

MS-80U has a 3 meter long output cable already attached, and the leads of the cable are soldered.

5-2. Setup

In order to obtain high quality measurements from pyranometers, several criteria with respect to set-up and mounting of the instruments have to be considered. Also see the Quick Start Guide for comprehensive setup instruction details (included in the package of MS-80, MS-80A and MS-80M).

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, desiccant replacement, 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 Positions

1) Check the installation base where the pyranometer has to 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 5-3. Fixing Hole Pitch and Bolt Size for Pyranometers

	MS-80 / 80A / 80M / 80U
Fixing Hole Pitch	65 mm
Fixing Bolt Size	M5 x 75 mm

2) 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) Remove a sunscreen (except for MS-80U)
The sunscreen can be removed by loosening the knurling screw and sliding it towards the bubble level direction.
*When carrying the MS-80 with sunscreen attached, always hold the instrument from the bottom. Holding only the sunscreen part may lead to dropping the sensor as it comes off from the sunscreen.

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

[Installing at Tilted Position]

After the MS-80 is adjusted to horizontal position in levelled surface, install it on tilted mounting position. *When installing the instrument, do not remove the levelling feet or fixed feet; if the levelling feet are removed, it may cause abnormal output values due to the thermal effects from the mounting part.

5) Fasten the pyranometer to the base with the 2 bolts (included) and put the sunscreen back on the pyranometer.

2. 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 EM noise, such as an AC power supply, high voltage lines or telecom antenna.

■ Wiring Procedure

1) Connect the output cable to the pyranometer 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.

   *except for MS-80U

2) Connect the output cable:

   2-1. <u>How to Connect MS-80</u> (See Table 5-3. Wire Color Codes also)

   Connect the wires with colors that corresponds to each terminal to voltmeter or data logger.

   <u>*Use measuring device with input impedance more than 100MΩ. Noise or offset may be generated if data logger with low input impedance is used.</u>

   <u>*Always connect the shield cable. Failing to do so, it will lead to causing noise.</u>

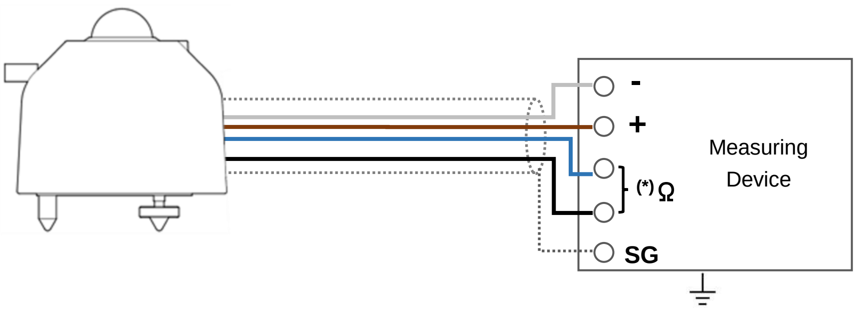


Figure 5-3. How to Connect MS-80

(*) Please select the ohmmeter or data logger which can measure the resistance value (Ω), in case of measuring the detector temperature (10kΩ@25℃). Please also see the Appendix A-6.

2-2. How to Connect MS-80A (See Table 5-3. Wire Color Codes also)

Connect the output cable ends to DC power supply (12-24V), ammeter, voltmeter or data logger (voltage can be measured by connecting precision resistance in series). For overcurrent protection, install fuse (0.5A) in series between the DC power supply and MS-80A connecting wire.

Connection for measuring by Current

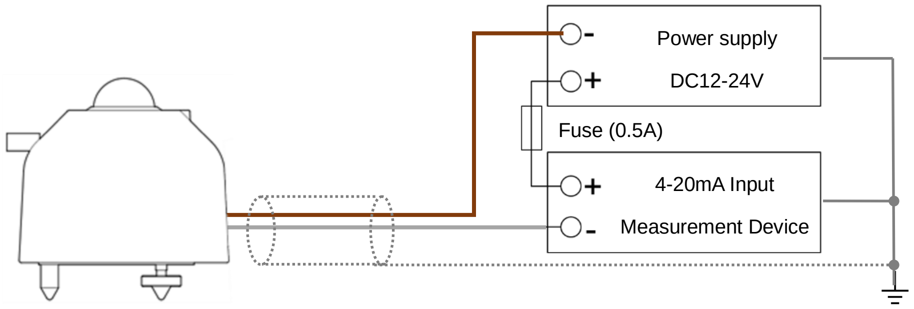


Figure 5-3A. How to Connect MS-80A

Connection for measuring by Voltage
(Connecting precision resistance in series)

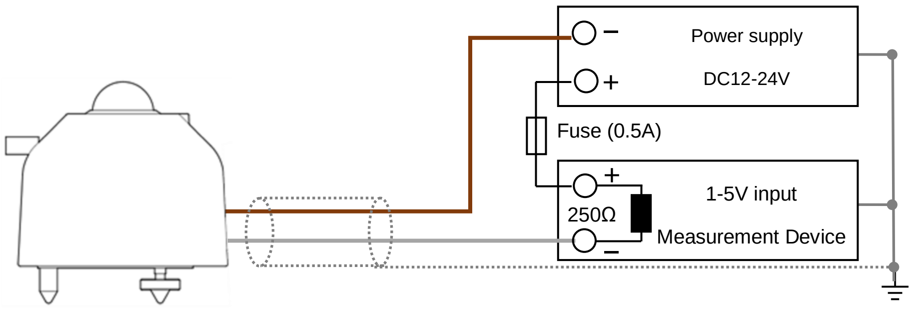


Figure 5-3B. How to Connect MS-80A

*A voltage drop will occur when a precision resistance is connected in series. To compensate the voltage drop, it is recommended to use 24V for power supply voltage.

*Please choose the precision resistance value and cable length those can keep the power supply to MS-80 over DC 9.6V

2-3. How to Connect MS-80M (See Table 5-3. Wire Color Codes also)

Connect the output cable end to DC power supply (12-24V), PC or data logging device. For overcurrent protection, install a fuse (0.5A) in series between DC power supply and MS-80M connecting wire.

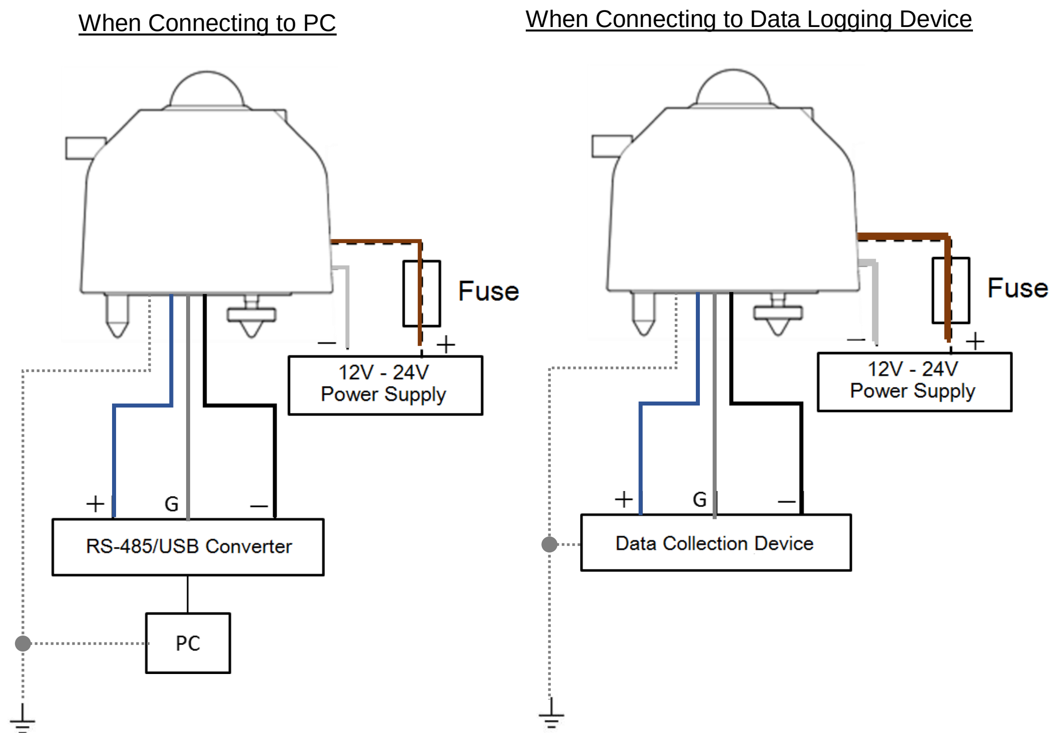


Figure 5-3C. How to Connect MS-80M

2-4. How to Connect Communication with Modbus RTU

MS-80M can connect to a system that communicates with MODBUS RTU by using RS-485. Maximum of 100 units can be connected, and individual address can be assigned.

Connection of MS-80M to the RS-485 communication network is shown below.

Master represents the data logging device (such a PC), and slaves represent devices such as MS-80M.

Connect the + and – for the master to (A/Tx) and (B/Rx) for each MS-80M. Also at the end of network, connect 120Ω terminating resistance.

*Modbus ID setting is required separately. (See [A-5. Change MS-80M Settings]).

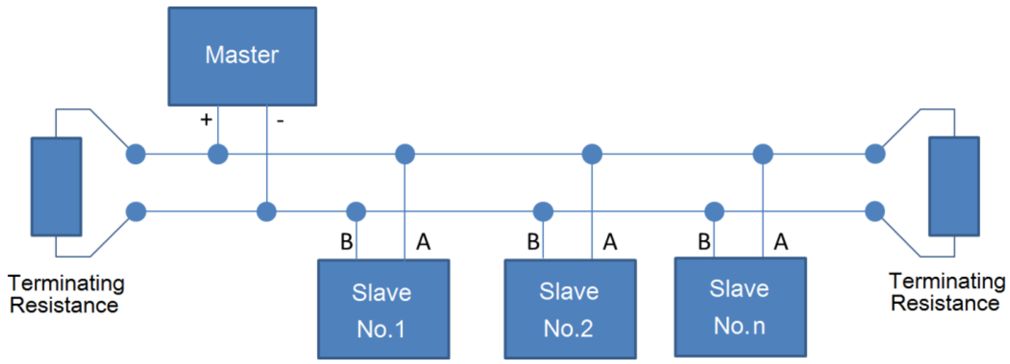


Figure 5-4. Communication Connection with Modbus RTU

2-5. How to Connect MS-80U (See Table 5-4. Wire Color Codes also)

Connect the wires with colors that corresponds to each terminal to voltmeter or data logger

*Use measuring device with input impedance more than 100MΩ. Noise or offset may be generated if data logger with low input impedance is used.

*Always connect the shield cable. Failing to do so, it will lead to causing noise.

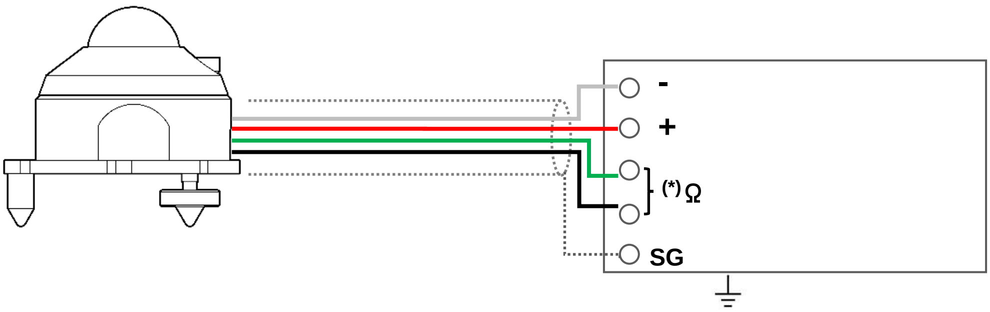


Figure 5-5. How to Connect MS-80U

2-6. Wire Assignments

Also see [7-3. Output Cables].

Table 5-4. Wire Color Codes (MS-80 / 80A / 80M)

No.	Cable Color	MS-80	MS-80A	MS-80M
1.	Brown	mV (+)	4-20mA (+)	Power Supply DC12V(+)
2.	White	mV (-)	4-20mA (-)	Power Supply DC12V(-)
3.	Blue	NTC (10kΩ)	---	RS485/USB TD/ (+)
4.	Black	NTC (10kΩ)	---	RS485/USB RD/ (-)
5.	Gray	---	---	RS485 G
Shield	Shield	FG	FG	FG

Table 5-5. Wire Color Codes (MS-80U)

No.	Cable Color	MS-80U
1.	Red	mV (+)
2.	White	mV (-)
3.	Green	NTC (10kΩ)
4.	Black	NTC (10kΩ)
Shield	Shield	FG

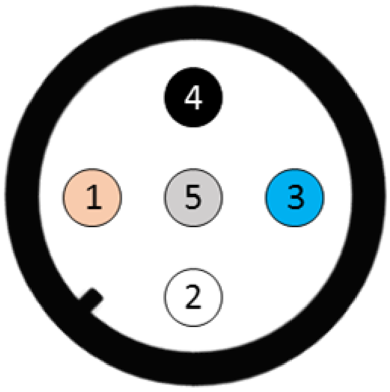


Figure 5-6. Connector pin number of MS-80/80A/80M

Each number corresponds to the number in Table 5-4. There is no corresponding figure for MS-80U because the cable can't be removed from MS-80U body.

5-3. Measuring Solar Irradiance

1. Solar Irradiance Measurement

1) In case of MS-80, MS-80U (mV output):

   Global solar Irradiance [W/m^2] can be determined by measuring the output voltage [mV] divided by the individual sensor sensitivity [μV/W･m^{-2}]. The output voltage is measured by a measuring device such as voltmeter or data logger. If solar irradiance is measured continuously, it is recommended to use data logger which has sufficient recording capacity and calculation function.

   Procedure for solar irradiance measurement is described below:

   a. Configuration with a Data logger

      If the measurement range can be selected on the data acquisition system, select the measurement range which can accurately measure the signal over a range of 0 to 20mV. The solar irradiance assumed that it does not exceed 1,400W/m^2 in both horizontal and tilted measurement positions. 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-80 pyranometer is about 10μV/W･m^{-2} or 0.010mV/W･m^{-2}, the maximum output voltage is about 1,400W/m^2 times 0.010mV/W･m^{-2} = 14mV).

   b. Calculate the Solar Irradiance [W/m^2].

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

$$\boldsymbol{I}\ (\mathrm{W/m^2}) = \frac{\boldsymbol{E}\ (\mu\mathrm{V})}{\boldsymbol{S}\ (\mu\mathrm{V/W{\cdot}m^{-2}})}$$

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

2) In Case of MS-80A (4-20mA Output)

   a. Configure the Measurement Range

      If the measurement range can be selected on the data acquisition system, select the measurement range which can accurately measure the signal within a range of 4 to 20mA. The global broad-band solar irradiance assumed that it does not exceed 1,400W/m^2 in both horizontal and tilted measurement positions. When this is converted into MS-80A output, the result will be 18mA (default).

   b. Calculate the Solar Irradiance [W/m^2]

      When the solar irradiance current value is ***A*** [mA], the solar irradiance ***I*** [W/m^2] can be determined by the following formula:

$$\boldsymbol{I}\ [\mathrm{W/m^2}] = (A\ [\mathrm{mA}] - 4) \times 100$$

      *MS-80A output is setup as 1mA = 100W/m^2 (default setting).

3) In Case of MS-80M(Modbus RTU Output)

By the built-in signal converter, the converted solar irradiance can be obtained as output; thus measurement range setting and conversion to solar irradiance are not necessary.

2. Integration of Measurement Value:

In continuous operation mode the pyranometer is usually connected to a programmable data logger system. Hence, sampling rates 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.
Performing averaging and/or integration of measurement data can be meaningful to, e.g., reduce the data volume or to meet application-specific requirement. Note that shorter sampling rates allow to use shorter averaging/integration times (example for MS-80: <1 second sampling rate, 1 minute averaging period). It could also be meaningful to store not only average values, but to keep track of all statistical values during the averaging period, namely: average, integral, minimum and maximum values, and standard deviation.
As a general recommendation, the averaging/integration period should be as short as possible, but long enough to reduce the data volume to store the processed data safely.

[(1)]"Guide to Meteorological Instruments and Methods of Observation", WMO reference document Nr. 8.

Examples:

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・S

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

6. Maintenance & Troubleshooting

6-1. Maintenance

Using the EKO 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 EKO pyranometers over 10th of years. 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 Items

Maintenance Item	Frequency	How To	Effect
Clean Glass Dome	Several times per week	Keep the glass dome clean by wiping with a soft cloth and alcohol	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 water leakage due to rain/dew which causes damage of the detector inside the pyranometer.
Check Bubble Level	Weekly	Verify if the pyranometer is levelled by checking the bubble is in the center ring of bubble 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 swinging by 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 Sunscreen[*]	Weekly, Before/After Bad Weather	Verify if the sunscreen 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 sunscreen coming off.
Recalibration	Every 5 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 properties of the pyranometer can change in time which affects the sensor sensitivity.

※except for MS-80U

6-2. Calibration and Measurement Uncertainty

It is recommended to recalibrate MS-80 pyranometer once every 5 years in order to verify the good quality of the solar radiation measurements. Below explains about the calibration methods of EKO pyranometers and their calibration uncertainty. For further information about recalibration and maintenance procedures, please contact EKO or find on the EKO website (http://eko-eu.com).

1. Calibration Method

MS-80 is calibrated indoors against a 1000W/m^2 AAA class solar simulator radiation source and designated calibration facility.

Indoor Calibration Procedure:

As the calibration procedure, 1) place both reference and production pyranometers in the center of the light in horizontal position at the same distance from the solar simulator; 2) alternatively irradiate the reference and production pyranometers with 1000W/m^2 continuously and measure the output (mV) from each pyranometer for a specified time; 3) From the reference output (mV) and sensitivity (μV//W/m^2), calculate the irradiance (W/m^2); 4) finally the sensitivity (μV/W/m^2) value is calculated by division of the pyranometer output (mV) and reference irradiance (W/m^2).

Measurement Uncertainty of Indoor Calibration

The calibration uncertainty becomes smaller as the calibration is performed in a constant ambient temperature and using a solar simulator with stable light source; hence the repeatability of indoor calibration method is better than 99%.

The expanded calibration uncertainty depends on the pyranometer model, and its result is stated on the calibration certificate.

The operation environment (such as ambient temperature) and solar simulator output are relatively stable, the pyranometer calibration uncertainty is determined with consideration of uncertainty of the reference pyranometer and maximum variation of incident light during the measurement of production pyranometer and reference pyranometer.

2. Calibration Traceability

The Internal reference pyranometer maintained at EKO is traceable to the absolute cavity pyrheliometer which is directly compared against the WRR (World Radiometric Reference) Primary Standard (Absolute Cavity) maintained at PMOD (Davos, Switzerland). The logger system used for the calibration measurement is traceable to JEMIC (Japan Electric Meters Inspection Cooperation).

Internal reference pyranometer is calibrated directly compared against the pyrheliometer, which is measured against the EKO absolute cavity, and 2 units of internal reference pyranometers by Shading Method ([A New Method for Calibrating Reference and Field Pyranometers (1995)] Bruce W Forgan) every one year.

EKO absolute cavity is directly traceable to WRR by comparing against WRR every 5 years.

6-3. Troubleshooting

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

Table 6-2. Troubleshooting

<table>
<tr><th colspan="2">Failure</th><th>Action</th></tr>
<tr><td rowspan="3">There is no output.</td><td>MS-80
MS-80U</td><td>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.</td></tr>
<tr><td>MS-80A</td><td>Make sure that the sensor is properly connected, and type of power supply and voltage value are appropriate</td></tr>
<tr><td>MS-80M</td><td>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.</td></tr>
<tr><td colspan="2">Output value is too low</td><td>The glass dome maybe soiled with rain or dust. Clean the glass dome with a soft cloth.
The output may be decreased due to regular change. Recalibrate periodically.</td></tr>
<tr><td colspan="2">There are some output signals during night time.</td><td>Pyranometers generate an output signal, which is proportional to the temperature differences between the sensor's so-called hot and cold junctions; hence, small differences in temperatures between, for example, the housing and the sensor generate in some cases a small voltages. This is an instrument-intrinsic phenomenon, which has no significance related to the quality of the instrument.</td></tr>
<tr><td colspan="2">There are unusual noise.</td><td>Check the shield connection and make sure it is connected securely.
Check to make sure the output cable is not swinging by 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.
When using data logger or measuring device with <100MΩ input impedance, the datalogger potentially won't measure the sensor output correctly; thus take following measures in composition:
1. Use measuring device with input impedance more than 100MΩ
2. Setup the integration time and stability time as long as possible.
3. Use moving average processing on the data
4. Attach 2 or more ferrite cores at the end of the cable.</td></tr>
</table>

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 norm. 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-80, MS-80U	MS-80A	MS-80M
	ISO9060: 2018	Class A		
	(ISO9060: 1990)	(Secondary Standard)		
	Spectrally flat	Compliant	Compliant	Compliant
	Fast response	Compliant	---	---
Response time 95% output	＜10 Sec	＜0.5 Sec	＜1.5 Sec	＜1 Sec
Response time 99% output	---	＜1 Sec	＜2 Sec	＜1 Sec
Zero off-set a) -200W/m^2	±7 W/m^2	±1 W/m^2	±1 W/m^2	±1 W/m^2
Zero off-set b) 5K/hr	±2 W/m^2	±1 W/m^2	±1 W/m^2	±1 W/m^2
Total zero off-set c)	±10 W/m^2	±2 W/m^2	±2 W/m^2	±2 W/m^2
Non-stability	±0.8 %/1yr	±0.5 %/5yrs	±0.5%/5yrs	±0.5 %/5yrs
Nonlinearity	±0.5 %	±0.2 %	±0.2 %	±0.2 %
Directional response	±10 W/m^2	±10 W/m^2	±10 W/m^2	±10 W/m^2
Spectral error	±0.5%	±0.2%	±0.2%	±0.2%
Spectral selectivity	±3 %	±3 %	±3 %	±3 %
Temperature response -10 to +40℃	±1 %	±1 %	±0.5 %	±0.5 %
Temperature response -20 to +50℃	---	±1 %	±0.5 %	±0.5 %
Tilt response	±0.5 %	±0.2 %	±0.2 %	±0.2 %
Additional signal processing error	±2 W/m^2	---	±1.7 W/m^2	±1.5 W/m^2

The content of the characteristic item is partly changed from ISO 9060: 1990. Please also refer to "A-2. Pyranometer Characteristics"

Table 7-2. Other Specification

Characteristics	MS-80	MS-80A	MS-80M	MS-80U
Field of View	2π (sr)			
Wavelength range	285 to 3000nm			
* Operating Temperature(Accuracy Assurance Temp. Range)	-40 to +80℃(-20 to +50℃)			
*** Maximum Operational Irradiance	4000W/m^2			
Bubble level accuracy	0.1 °			
Detector Temperature sensor	10kΩ NTC	---	**10kΩ NTC	10kΩ NTC
Environmental Protection (IP Code)	IP67 Equivalent (IEC60529)			
Weight	0.35kg	0.39kg		0.21 kg
Body	Anodized			
Sensitivity	Approx.10μV/W·m^{-2}	Approx.10μV/W·m^{-2} (4-20mA:0-1600W/m^2)	Approx.10μV/W·m^{-2}	Approx.10μV/W·m^{-2}
Impedance	Approx. 45kΩ	---	---	Approx. 45kΩ
Output Cable (outer diameter)	AWG22 0.5mm^2 x 5 pins (φ6.7mm)			AWG28 0.1mm^2 x 4 pins (φ3.3mm)
Output Cable Terminal	Pin-Terminal (0.3-9.5)			Solder
Output (or Signal)	Voltage (mV)	Current (mA)	Digital (Modbus RTU)	Voltage (mV)
Resolution	---	<0.5 (W/m^2)	<0.5 (W/m^2)	---
Input Power Supply	---	DC12 – 24V ±10%	DC12 – 24V ±10%	---
Power Consumption	---	0.08 to 0.75W	< 0.3W (Average power consumption)	---

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

** Temperature sensor is internally connected to MODBUS electronics

***The operational maximum irradiance is defined as the irradiance level beyond which damage may occur to the sensor.

7-2. Dimensions

. MS-80 / 80A / 80M

Table 7-3. Dimensions (MS-80 / 80A / 80M)

	MS-80 / MS-80A / MS-80M
A. Fixing Hole Pitch	65 mm
B. Body Height	72 mm
C. Levelling Screw Height	16 mm
D. Width (including Sunscreen/Cover)	Φ96 mm
E. Overall Height (approx.)	101mm

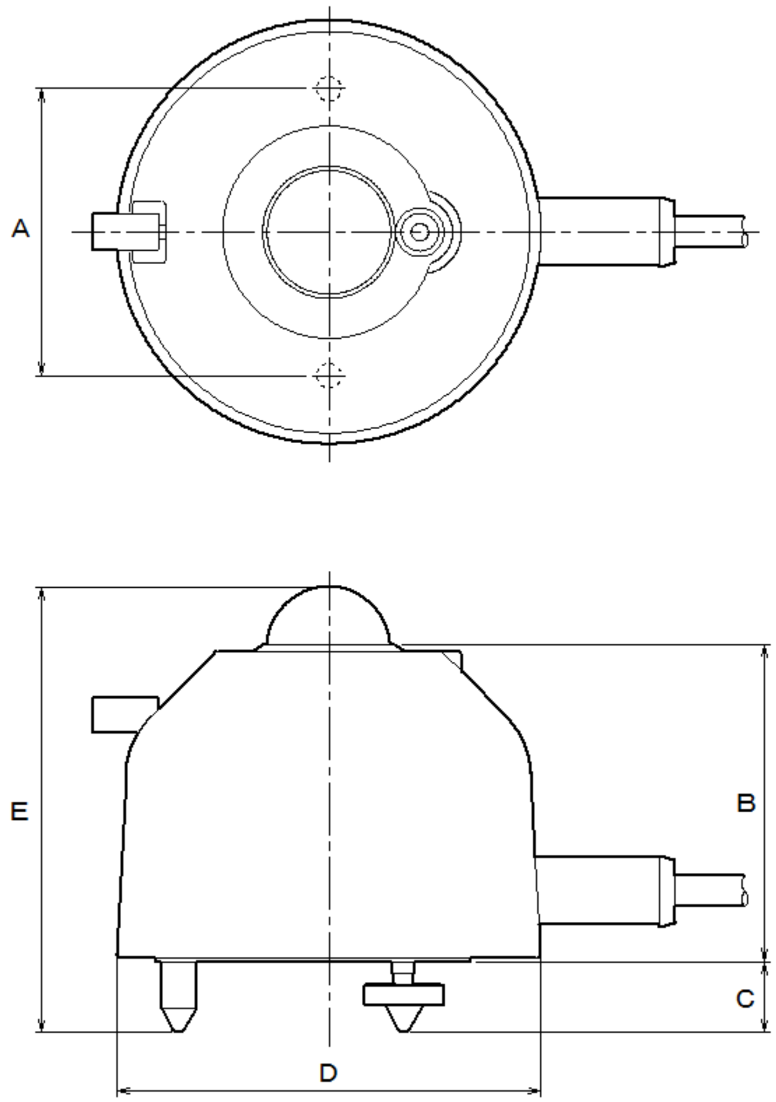


Figure 7-1. Outer Dimensions (MS-80 / 80A / 80M)

2. MS-80U

Table 7-4. Dimensions (MS-80U)

	MS-80U
A. Fixing Hole Pitch	65 mm
B. Body Height	50 mm
C. Levelling Screw Height	16 mm
D. Width	Φ78 mm

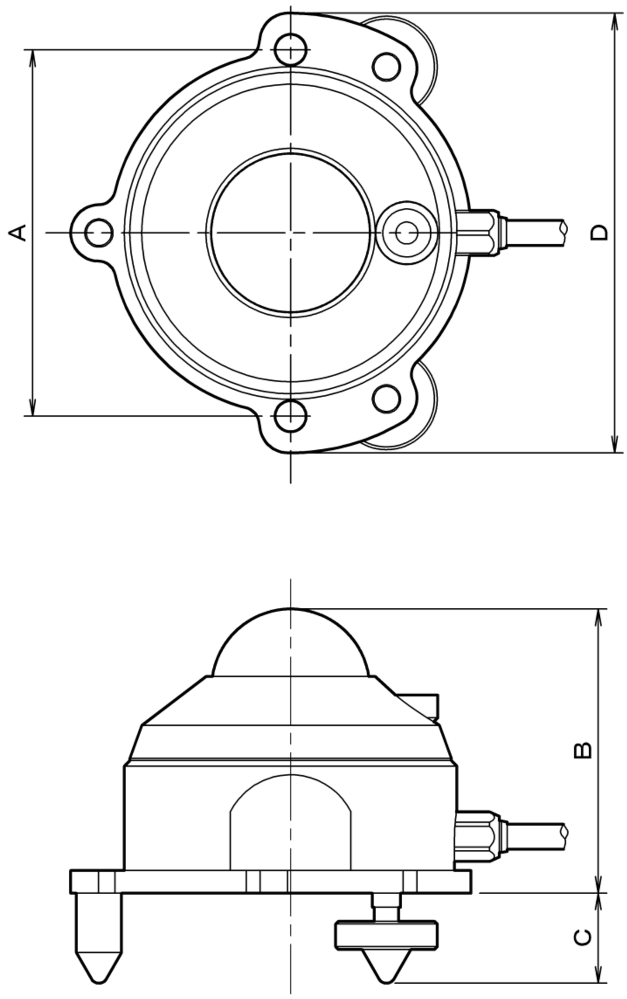


Figure 7-2. Outer Dimensions (MS-80U)

7-3. Output Cables

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

1. MS-80 / MS-80A / MS-80M

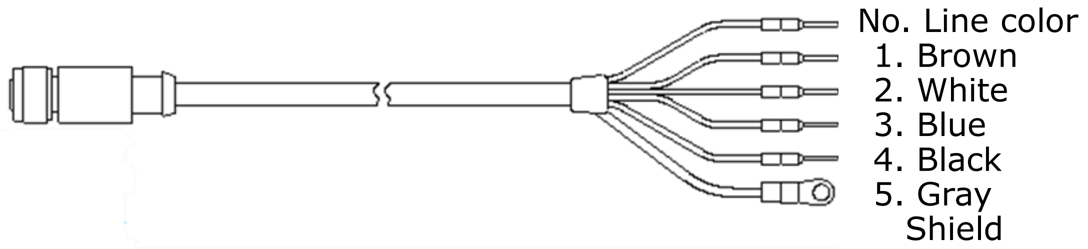


Figure 7-3. Output Cables (MS-80 / 80A / 80M)

2. MS-80U

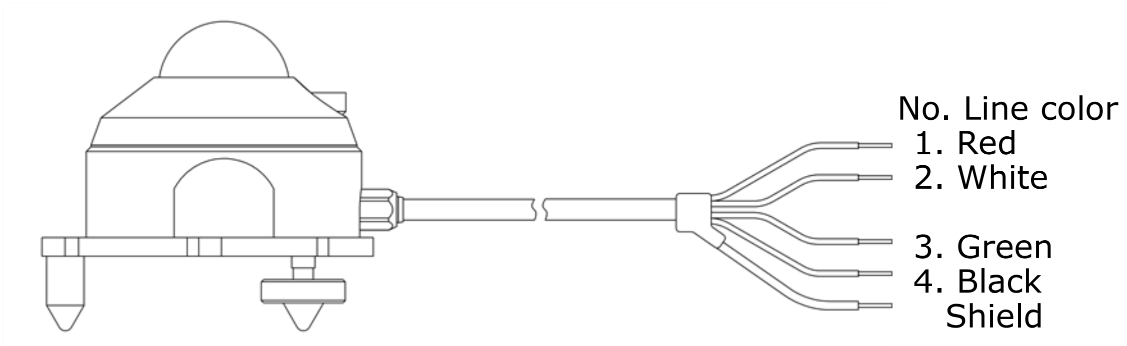


Figure 7-4. Output Cables (MS-80U)

7-4. Accessories List

MS-80U does not have an accessory.

Table 7-5. Accessories List (MS-80 / 80A / 80M)

Option Items	Remarks
Output Cable	Cable Length: 20m, 30m, 50m Terminals: Fork Terminals, Round Terminals, Pin Terminals
EKO Sensor USB Controller	For MS-80A Configuration Cable
RS485 / USB Converter Cable	Converts from RS485 → USB for the communication with MS-80M and allows to connect to PC with USB terminal

APPENDIX

A-1. Radiometric Terms

Table A-1. Definitions of Terms

Hemispheric Solar Irradiance	Cosine-weighted solar irradiance received over a solid angle of 2πsr 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 circum solar 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 Radiation Reference (WRR)	Radiometric reference instrument system which has an uncertainty of less than +/-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 A-2. Pyranometer Characteristics (see also 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 to1.5μm.
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℃ against the output at 20℃.
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 Pyrheliometer into a digital signal with a signal converter etc.

A-3. Configurator Software (MS-80A, MS-80M)

With the EKO Sense Configurator software which can be downloaded from the EKO website and optional controller, MS-80A and MS-80M configurations, such as output range and sensitivity, can be changed.

For MS-80A: EKO Sense USB Controller (optional)

For MS-80M: RS485/USB Conversion Cable (optional)

1. Software Installation

Install the special configurator software according to the following procedure

1) Download the recent version software "EKO Sense Configurator (Installer File, Compressed file: Zip Format)" from the EKO website: http://eko-eu.com/

2) Open the installer file and click the execute file; the following window appears. Click [Next] button. (Depending on the operating system, a dialog window for installation authorization may appear)

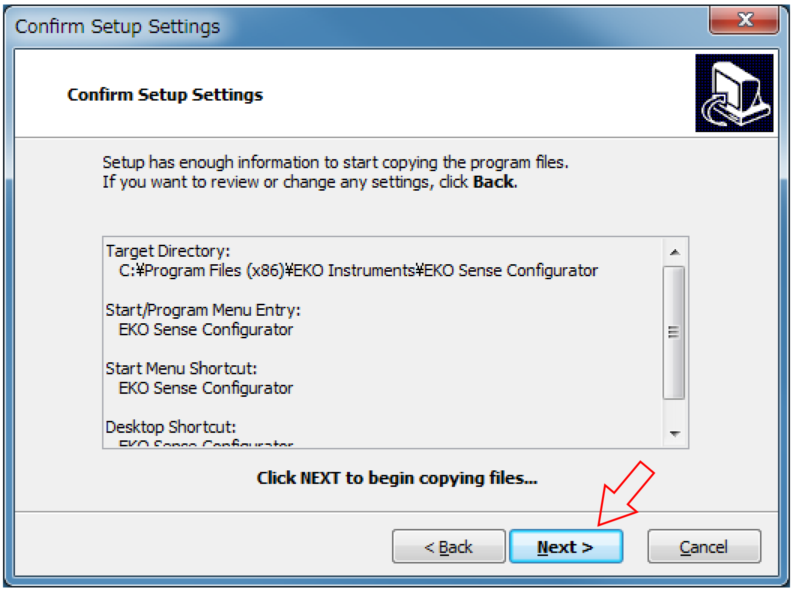


Figure A-1. Confirm Setup Settings Window

3) Select the location of installation from the [Browse] button then click [Next].

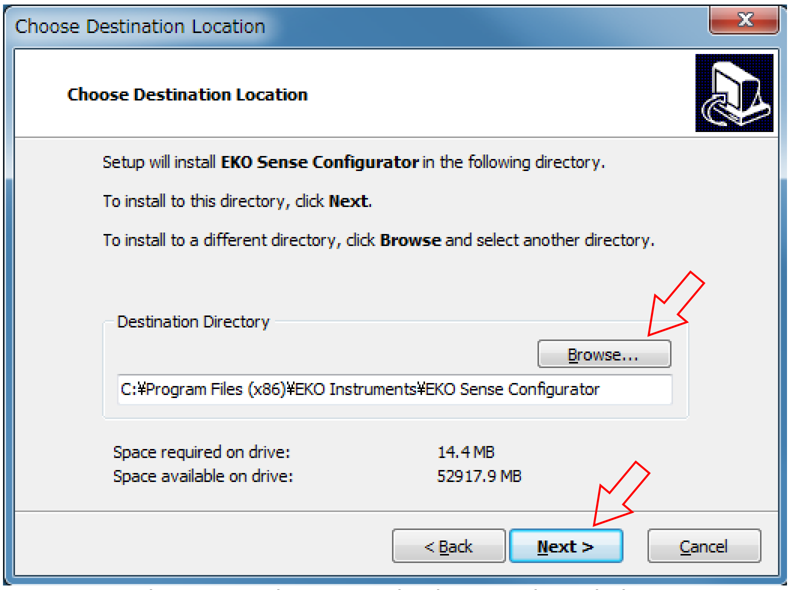


Figure A-2. Choose Destination Location Window

4) In the following window, select the location of software shortcut. As default, the shortcut s are created in Start Menu and on desktop. Uncheck the checkbox as necessary, then click [Next].

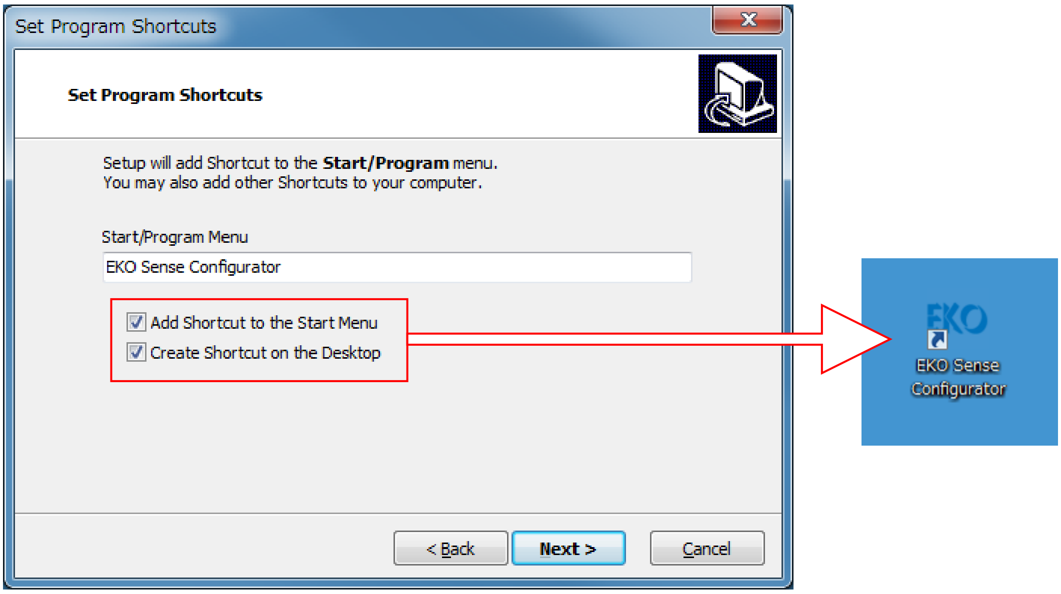


Figure A-3. Set Program Shortcuts Window

5) It starts to copy the necessary files for the software; once the copying is completed, following window appears. The software installation finishes when [Finish] button is clicked and software starts up. If you don’t wish to start the software immediately, check the checkbox before clicking the [Finish] button.

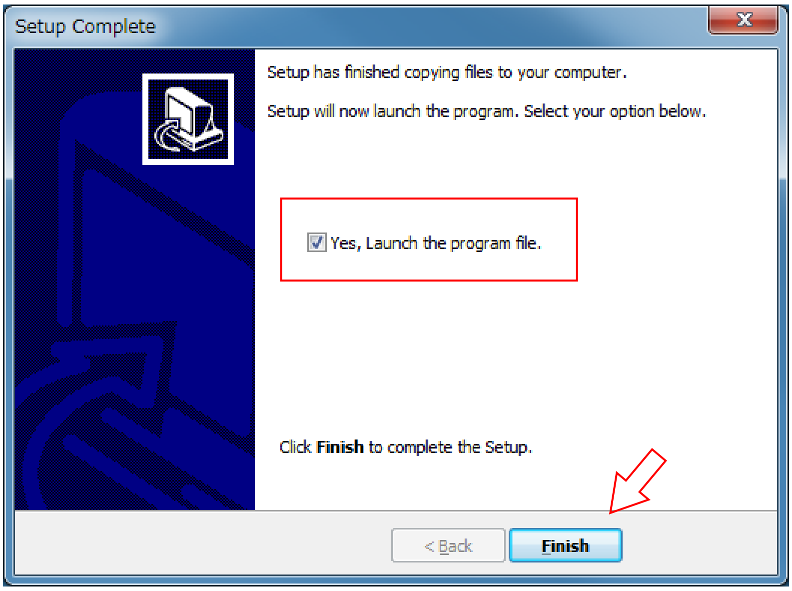


Figure A-4. Setup Complete Window

2. Hardware Preparation

Once the software is installed, connect the devices necessary for configuring.

1) <u>Connections for MS-80A</u>

After software installation, connect the USB connector of "EKO Sensor USB Controller" to PC, and clamp the MS-80A output cable terminal with the crocodile clip on the other end of the cable.

The power is supplied from the PC through the USB connector, so there is <u>NO NEED to supply power</u>.

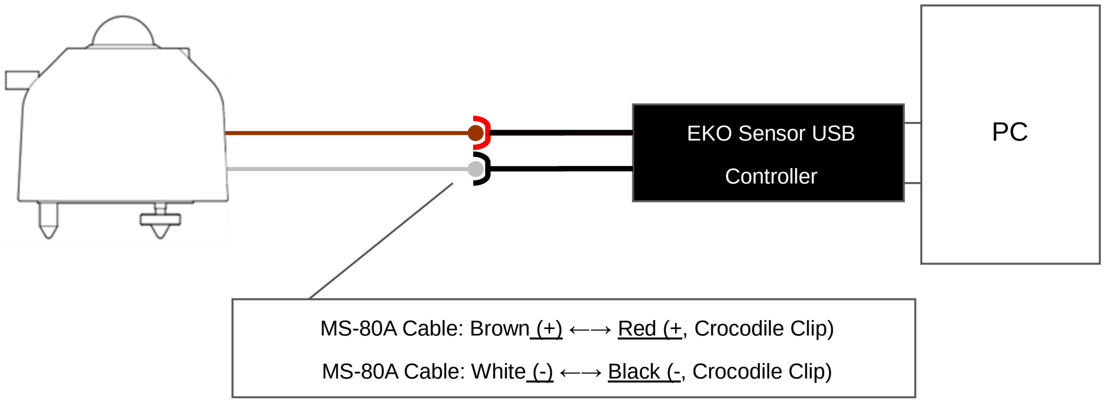


Figure A-5. Connection by EKO Sensor USB Controller

2) <u>Connections for MS-80M</u>

After software installation, connect the "RS485/USB Converter Cable" to the USB connector on PC and clamp the crocodile clip at the other end to the MS-80M output cable end.

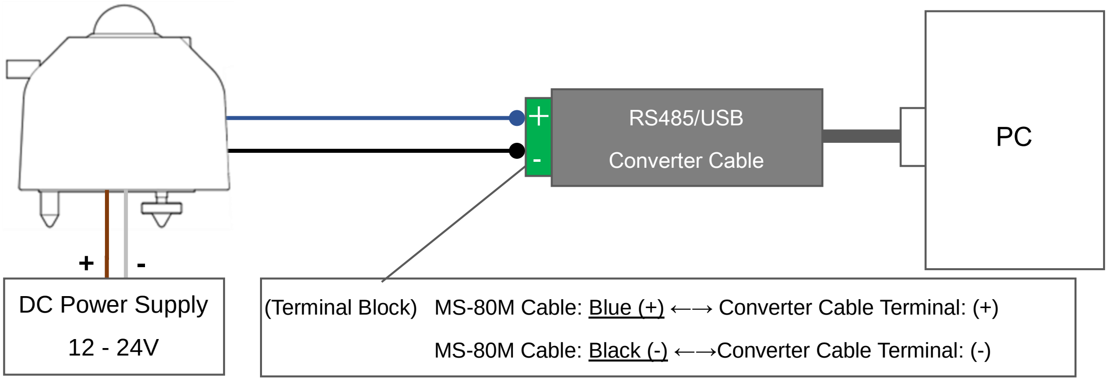


Figure A-6. Connection by RS485 / USB Converter Cable

3. Changing the Configuration (MS-80A)

In this section provides how to change the MS-80A configurations, such as output range and sensitivity value. Make sure the software installation is completed and devices are connected through the 4-20mA Control Cable to a PC.

1) Start up the software. Software is in English when it is first started up. Change the language setting from the tool bar at the window top (Tools/Language) to change the language to be used: English, Portuguese, Spanish, or Japanese.

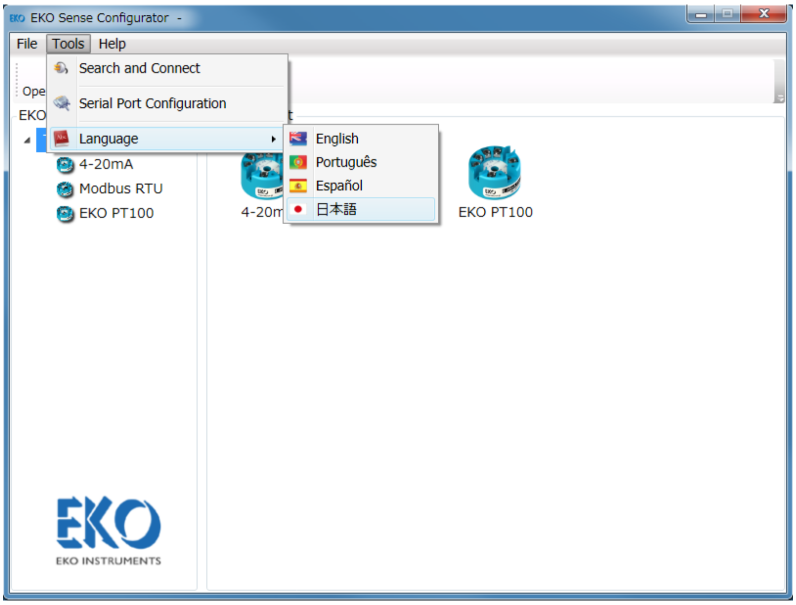


Figure A-7. Language Setting

2) Next, select the device to be configured. Click [4-20mA] icon for MS-80A.

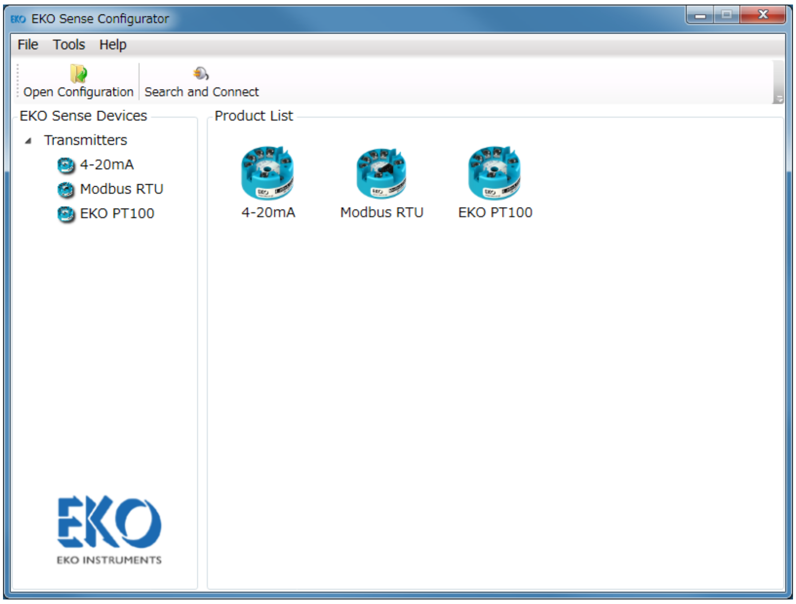


Figure A-8. Selecting Configuring Device

3) After clicking [4-20mA], the USB controller automatically identifies the converter within 5 seconds then "Read OK" is indicated as shown below.

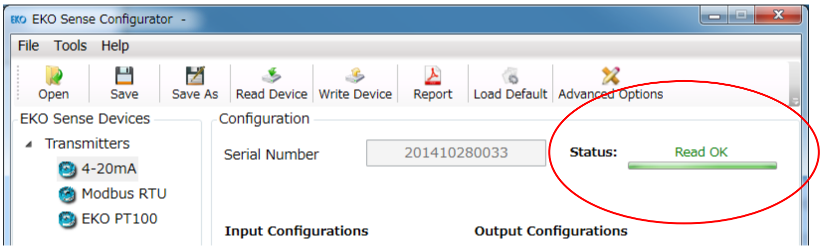


Figure A-9. Converter "Read OK" Status

<u>In case the converter is not identified, check the setup of serial port to be connected; change as necessary.</u>

1. Go to [Tools] → [Serial Port Configuration]: Below window appears. Check if the connected serial port is the correct one. Serial port can be selected from the "Serial Port" section and click [Save] to change.
2. Next, go to [Tools] → [Search and connect] to reconnect the converter.
   Just in case, disconnect / connect the power (Red crocodile clip) to establish the connection.

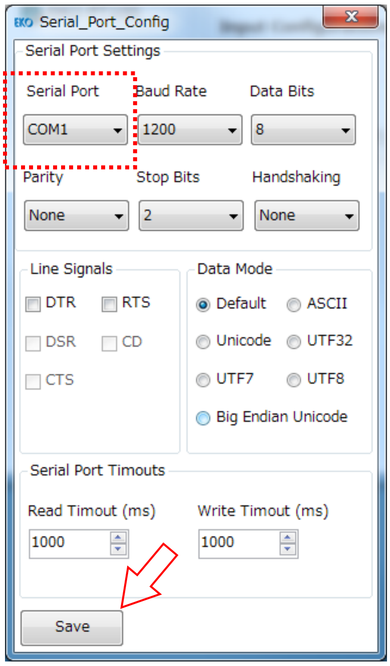


Figure A-10. Serial Port Setting

<u>Software Functions</u>

Some of the software functions are introduced below. There are several basic functions, such as Open/Save, create a report of configuration that was used.

1. Change and Write Configuration
   Pyranometer model name, sensitivity, minimum irradiance, maximum irradiance, and offset can be changed. After making the changes, the changed configuration can be written in the MS-80A by clicking [Write Device].
   The written configuration is maintained even in the condition without power being supplied.
   *Unless [Write Device] is clicked, the changes will not be reflected on the configuration.

2. Read Configuration

   Current device configuration can be displayed by clicking the [Read Device] button.

3. Checking the Outputs

   Current outputs (pyranometer output: mV, irradiance: W/m^2, internal temperature) can be retrieved by clicking the [Read] button.

   *This is for the purpose of test, thus these output data cannot be recorded to PC.

4. Save Configuration

   Configuration can be saved in selected location by clicking [Save] button. (File format: XML)

5. Save and Print Configuration

   Configuration can be printed out by clicking [Report] button.

6. Restore the Factory Setting

   Invoke the factory setting by clicking [Load Default]. To restore the factory setting to the MS-80A, click [Write Device].

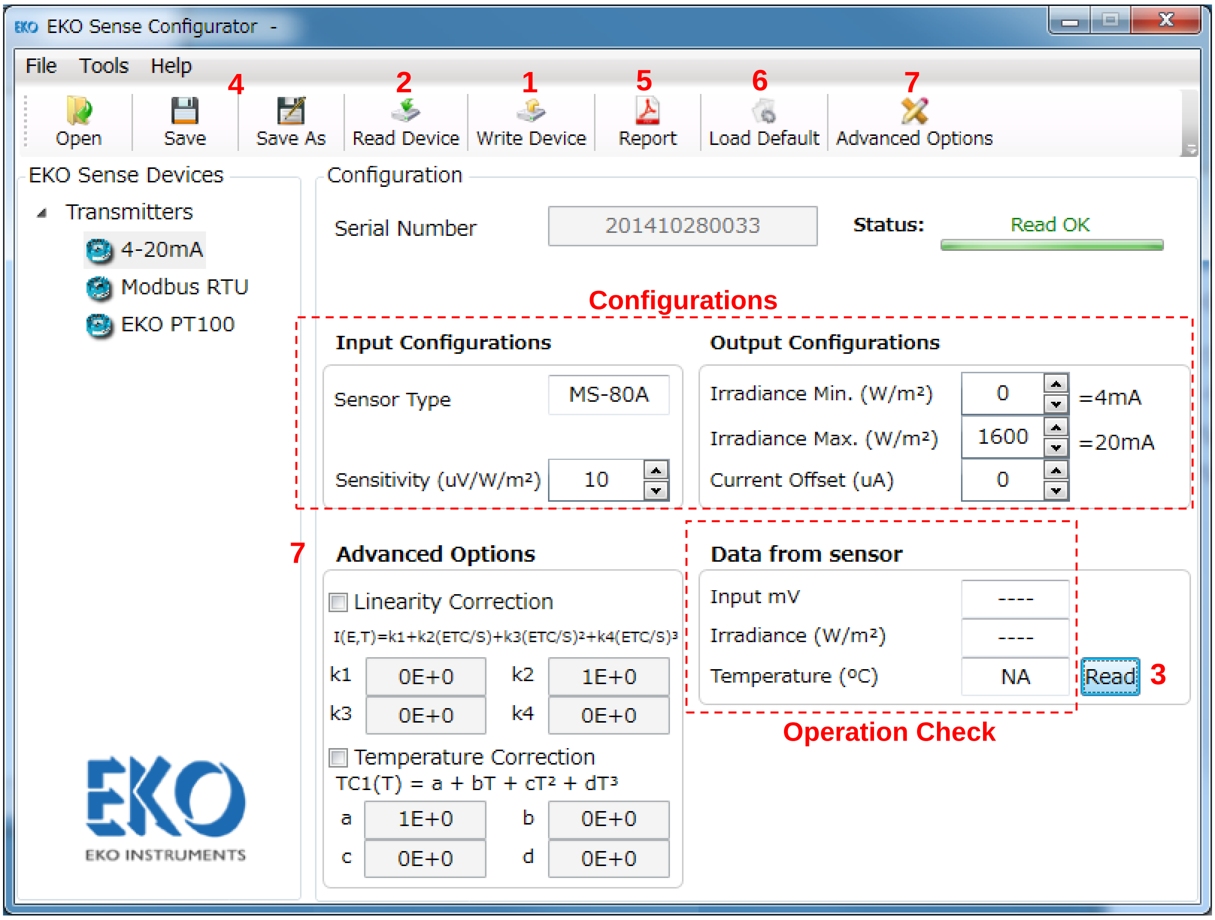


Figure A-11. EKO Sense Configurator Configuration Window

7. To Configure Advanced Options (Linearity Correction, Temperature Correction)

   By clicking [Advanced Options], a dialog window for entering password appears. After the password [eko2014] is entered, configuration items for [Advanced Options] appear on the window. The linearity correction and temperature correction can be configured in this section.

*The advanced options are not setup in default setting; the sensor is designed to meet the performance stated on the specification without setting the advanced options. Make sure to fully understand the contents before make any changes to these settings.

Place a check in the checkbox then enter the parameter determined by the following formula in the 4 boxes provided to apply the configuration.

Linearity Correction

Parameters (x4) for correcting the linearity of output against solar irradiance

*Linearity correction is not configured in default setting. It is recommended not to change the configuration in general use.

To calculate the correction, enter each item for the approximation formula (cubic expression)

$$I = (k1 + (k2 \times ETC\ (E,\ T) + (k3 \times ETC\ (E,\ T)^2) + (k4 \times ETC\ (E,\ T)^3)) / S$$

Where:

I : Irradiance after Linearity Correction

ETC(E,T) : Measurement Voltage after Temperature Correction mentioned above

S : Pyranometer Sensitivity

k1, k2, k3, k4 : Correction Coefficient

Ex.) If K1 is changed, offset output (μV) can be changed.

Default Value {*k1*: 0, *k2*: 1, *k3*: 0, *k4*: 0}: Configuration for when not using linearity correction

Temperature Correction

Parameters (x4) for correcting the temperature response which occur by the change in ambient temperature.

*Temperature correction is not configured in default setting. It is recommended not to change the configuration in general use.

To calculate the correction, enter each item for the approximation formula (cubic expression)

$$ETC\ (E,\ T) = E\ /\ TC1\ (T), TC1\ (T) = a + b \times T + c \times T^2 + d \times T^3$$

Where:

ETC (E,T) : Measurement Voltage after Temperature Correction

E : Measurement Voltage

TC1(T) : Correction Efficient

T : Measurement Temperature (Internal Temperature)

a, b, c, d : Correction Efficient

Default Value {*a*: 1, *b*: 0, *c*: 0, *d*: 0} (= Configuration for when not using temperature correction)

4. Changing the Configuration (MS-80M)

This section provides how to change the MS-80M configurations, such as output range and sensitivity value. Make sure the software installation is completed and devices are connected through (MODBUS 485 to USB) cable to a PC.

1) Start up the software. Software is in English when it is first started up. Change the language setting from the tool bar at the window top (Tools/Language) to change the language to be used: English, Portuguese, Spanish, or Japanese.

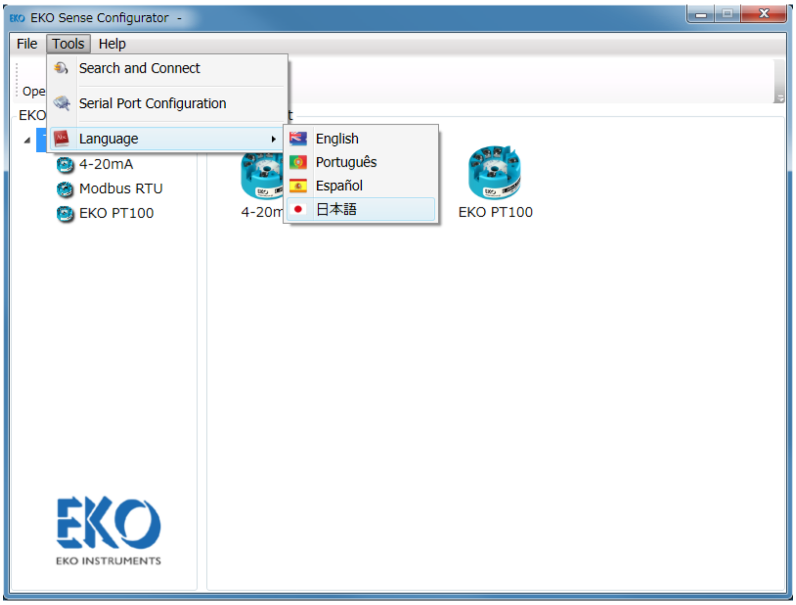


Figure A-12. Language Setting

2) Next, select the device to be configured. Click [MODBUS RTU] icon for MS-80M.

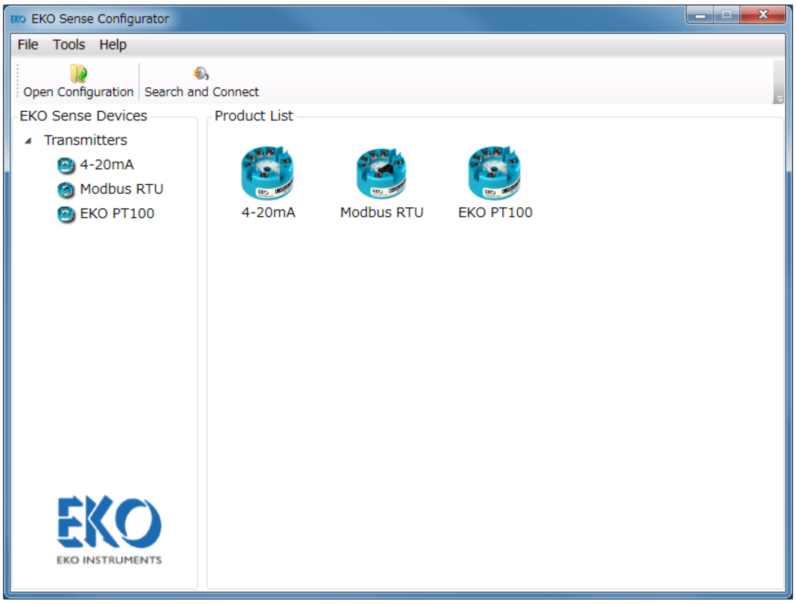


Figure A-13. Selecting Configuring Device

3) In order to make changes to the MODBUS sensor, connect the sensor with the USB/RS485 cable to a PC. The upper field of the EKO Sense Configurator is used to change the USB/RS485 sensor communication settings.

By clicking [MODBUS RTU], following section appears on the window.

1. Set Communication port name (Refresh Serial Ports when no COM port was detected)

   When it successfully communicates and completes the connection, “Reading Success” message appears on the window.

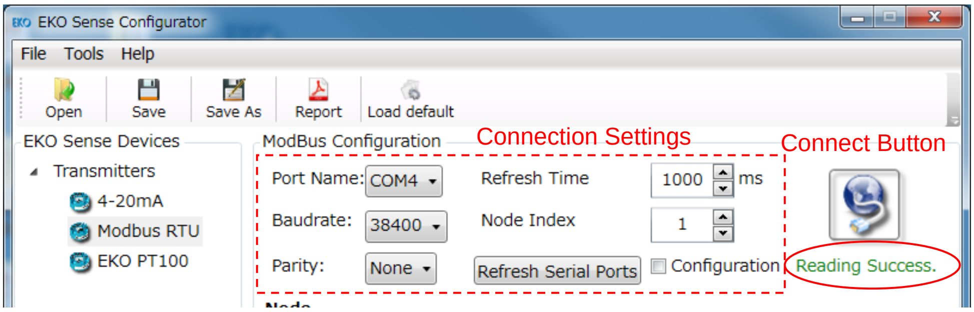


Figure A-14. MS-80M Connection Setting

Table A-3. Items for Communication Settings

Items	Contents	Default Values
Port Name	Port that is connected	No setting
Baudrate	Communication Speed [bps]	9600
Parity	Parity	None
Refresh Time	Data refresh time [msec]	1000
Node Index	Node number	1

Change sensor parameters

2. The lower field of the EKO Sense Configurator is used to change the sensor parameters. The sensor parameters can be changed in order to connect to a large Node network where each sensor has it private address (ID). Some of the parameters are password (“8355”) protected (Sensor Temperature Compensation, Sensor non-linearity, Node ID (address), baud rate, Parity). All other parameters field, except the measurement result filed can be modified without any password. Once the connection is established, check the [Configuration] checkbox; [Node Index] becomes 101.
3. Turn OFF the power supply to MS-80M and after confirming the voltage becomes 0V (zero volt), turn the Power ON again.
   (NOTE: When using stabilized power supply, due to the power supply internal capacitors, power may remain OFF for a minute).

4. After power ON and within 5 seconds, click the [Connect] button; the window becomes available for configuring and following items can be changed (Do not change the product serial number).

   The following sensor parameters can be changed without password. Settings need to be changed one by one, followed by “Send Config”. Note the settings are reflected to Sensors Modbus 485 RTU only when “Send Config” button is clicked.

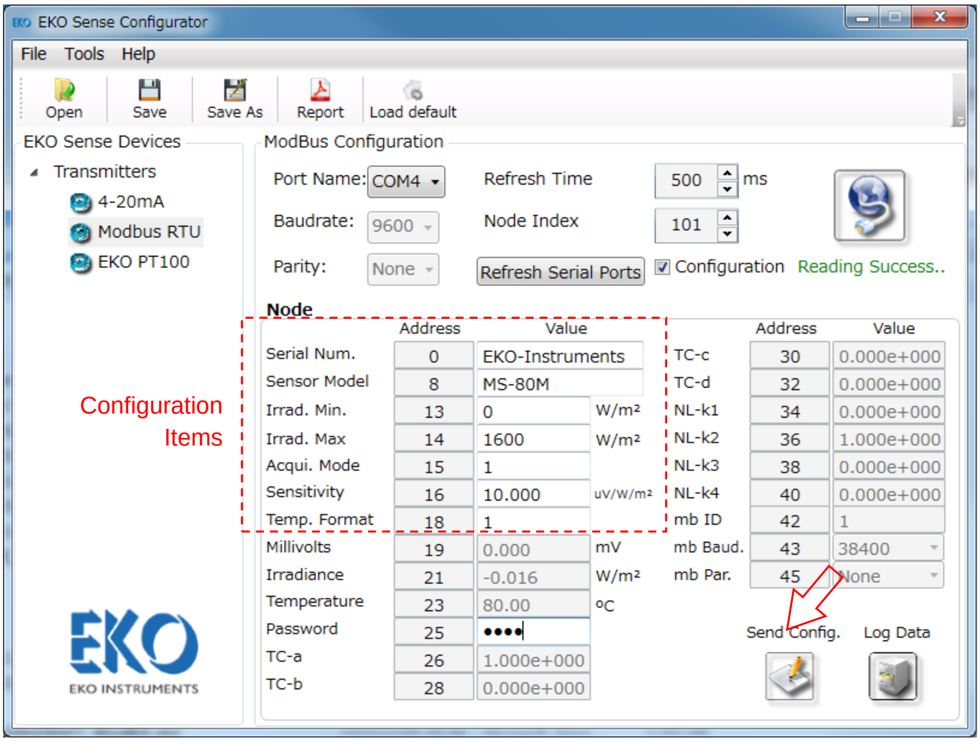


Figure A-15. MS-80M Configuration Changeable Items

Table A-4. Configuration Items

Items	Contents	Default Values
Serial Num.	Product Serial Number (DO NOT CHANGE)	Already setup by each product
Sensor Model	Model Name	MS-80M
Irrad. Min.	Minimum Irradiance [W/m^2]	0
Irrad. Max.	Maximum Irradiance [W/m^2]	1600
Acqui. Mode	Measurement Mode (DO NOT CHANGE)	1
Sensitivity	Product Sensitivity	Already setup by each product
Temp. Format	Internal Temperature Units {℃, F, K}	℃
Password	Enter when changing the advanced configuration	8355

5. Change the configuration and click [Send Config] to write the changed configuration to MS-80M
6. Repeat the No. 2 step and confirm that the changes are reflected in the configuration.

<u>Refresh Serial Ports</u>

In case the connected COM port that is not recognized, click the [Refresh Serial Ports] button.

<u>Other Functions</u>: Following functions are available on Software

Load default: Reset the configuration to the factory settings ([Send Config] button must be clicked or the configuration will not be reflected.)

Report: Outputs current configuration on PDF file.

Save, Save As: Save the configuration on a file (XML file format)

Open: Reads the saved configuration (XML file format)

Log Data: Measurement data can be logged easily.

Click [Log Data] button → Starts to save the measurement data by assigning the destination folder for the log file to be saved.

The data measurement interval is the time setup for the data refresh time on software.

Recorded data items are as follow (CSV Format File, separated by semi-column)

・Date ・Time	Time-stamp
・Minimum Irradiance (W/m^2) ・Maximum Irradiance (W/m^2) ・Pyranometer Sensitivity (μV/W/m^2)	Configured Values
・Measurement Voltage (mV) ・Solar Irradiance (W/m^2) ・Temperature (℃)	Measured Values

Changing the Configurations Protected by Password (Linearity Correction, Temperature Correction, Communication Setting)

With the condition that configurations can be changed (as described in above section), click [Send Config]; the window display changes to as shown below, linearity correction, temperature correction and communication settings (Modbus ID, baud rate, parity) becomes available for making changes.

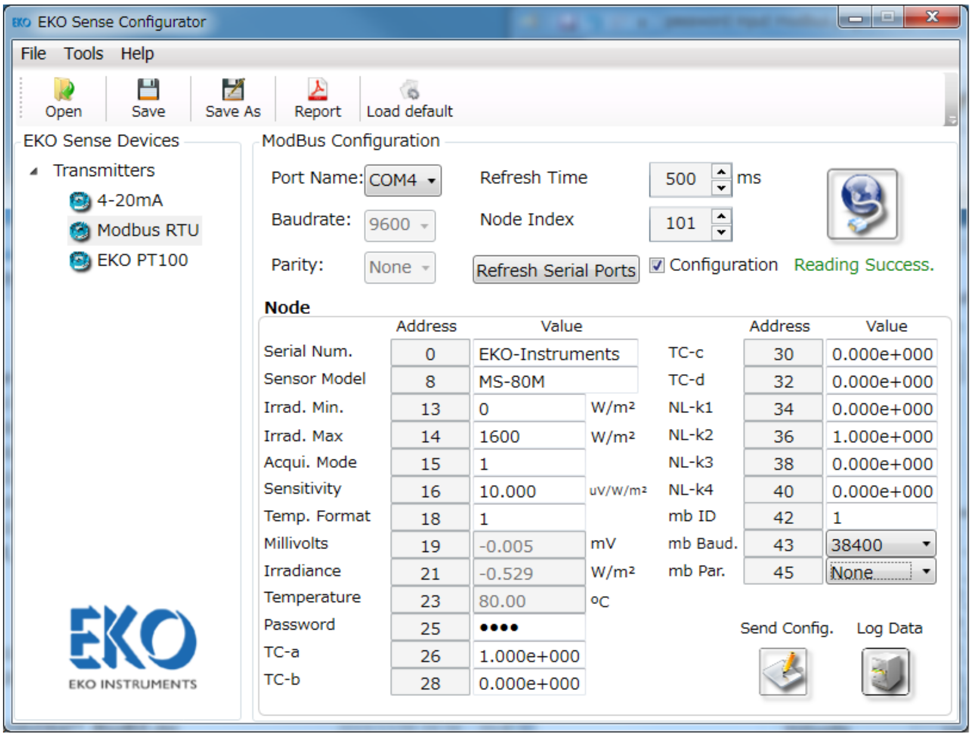


Figure A-16. Changing Configuration of Items Protected by Password

Linearity Correction

Parameters (x4) for correcting the linearity of output against solar irradiance.

*Linearity correction is not setup in default setting. For general use, it is recommended not to change the linearity correction setting.

Use following equation for correction by setting each item in the approximation formula (cubic equation):

$$I = (k1 + (k2 \text{ x } ETC\ (E, T) + (k3 \text{ x } ETC\ (E, T)^2\ ) + (k4 \text{ x } ETC\ (E, T)^3\ )) / S$$

Where:

I : Irradiance after Linearity Correction (W/m^2)

$ETC\ (E, T)$: Measurement Voltage after Temperature Correction above (mV)

S : Pyranometer Sensitivity (µV/W/m^2)

k1, *k2*, *k3*, *k4*: Correction Coefficient (Ex.) When *k1* is changed, Offset Output (µV) can be changed.

Default Values {*k1*: 0, *k2*: 1, *k3*: 0, *k4*: 0} Setting that does not use Linearity Correction

Temperature Correction

Parameters (x4) for correcting the temperature response which occur by the change in ambient temperature

*Temperature correction is not setup in default setting. For general use, it is recommended not to change the temperature correction setting.

Use following equation for correction by setting each item in the approximation formula (cubic equation):

$$ETC\ (E, T) = E\ /\ TC1\ (T)\ , \quad TC1\ (T) = a + b \times T + c \times T^2 + d \times T^3$$

Where:

$ETC\ (E, T)$: Temperature Corrected Measurement Voltage (mV)

E : Measurement Voltage (mV)

$TC1\ (T)$: Correction Efficient

T : Measurement Temperature (℃, Internal Temperature)

a, b, c, d : Correction Efficient

Default Values {*a*: 1, *b*: 0, *c*: 0, *d*: 0}: Setting that does not use Temperature Correction

Communication Settings

- mb ID (Modbus ID, Default: 1)

When connecting more than 2 units of MS-80M or connecting the EKO's MC-20 and Bus, individually setup a unique mb ID before connecting with Bus.

mb Baud. (Modbus Baudrate, Default: 9600)

Configurable Baud Rate [bps] {4800, 9600, 19200, 38400, 56000, 57600, 115200}

mb Par. (mb Parity bit, Default: None)

Configurable Parity {None, 1, 2 (for programming application by client)}

After changing the configurations, click [Send Config] button to write the changes to MS-80M, as well as check the changes are reflected.

NOTE: When setting node with something different (i.e. Baud Rate 38400), the communication baud rate must correspond to (38400).

A-4. Communication Specifications (MS-80M)

Communication data format is determined by the Modbus protocol.

Table A-5. Communications Specifications

Specification	Details
Telecommunication Standard	EIA RS-485
Topology	Multidrop (Master: 1, Slave: 100, Total: 100)
Communication protocol	MODBUS slave RTU※1 (Slave)
Communication speed (baud rate）	4800, 9600, 19200, 38400, 56000, 57600, 115200 bps
Data Length	8bits
Stop Bit	1bit/2bits※2
Parity Bit	none/odd/even
Communication Distance	Maximum 1.2km (theoretical value)
Error Detection	CRC-16

※1: The open protocol for the serial communication which is developed by Modicon.

※2: when there is no parity bit, stop bit will be 2 bits; for other cases, stop bit will be 1 bit.

Table A-6. Data Format

Start	Address	Function	Data	CRC	End
T1-T2-T3-T4 A silent interval (≧3.5 char)	8bit	8bit	n * 8bit	16bit	T1-T2-T3-T4 A silent interval (≧3.5 char)

Modbus Data (RTU)

Table A-7. Function Code

Code: decimal	Function
03	Read Holding Registers

Table A-8. Data Contents

Address	Data Type	Descriptions	Notes
0	UINT16※1	Serial Number 1º /2º ASCII Code	
1	UINT16	Serial Number 3º/4º ASCII Code	
2	UINT16	Serial Number 5º/6º ASCII Code	
3	UINT16	Serial Number 7º/8º ASCII Code	
4	UINT16	Serial Number 9º/10º ASCII Code	
5	UINT16	Serial Number 11º/12º ASCII Code	
6	UINT16	Serial Number 13º/14º ASCII Code	
7	UINT16	Serial Number 15º/16 ASCII Code	
8	UINT16	Measuring Instrument Model1º/2º ASCII Code	
9	UINT16	Measuring Instrument Model3º/4º ASCII Code	
10	UINT16	Measuring Instrument Model5º/6º ASCII Code	
11	UINT16	Measuring Instrument Model7º/8º ASCII Code	
12	UINT16	Measuring Instrument Model9º/10º ASCII Code	
13	UINT16	Irradiance Minimum Output	
14	UINT16	Irradiance Maximum Output	
15	UINT16	Measurement Mode	A
16,17	FLOAT※2	Pyranometer Sensitivity	B
18	UINT16	Unit for Temperature	C
19,20	FLOAT	Measuring Voltage	D
21,22	FLOAT	Irradiance	E
23,24	FLOAT	Internal Temperature	F
25	UINT16	Password	G
26,27	FLOAT	Temperature Response Correction Factor1 – a	H
28,29	FLOAT	Temperature Response Correction Factor2 – b	
30,31	FLOAT	Temperature Response Correction Factor3 – c	
32,33	FLOAT	Temperature Response Correction Factor4 – d	
34,35	FLOAT	Linearity Correction Factor 1 - k1	I
36,37	FLOAT	Linearity Correction Factor 2 - k2	
38,39	FLOAT	Linearity Correction Factor 3 - k3	
40,41	FLOAT	Linearity Correction Factor 4 - k4	

※1: UINT16: Integer without 16 bits symbol.

※2: FLOAT: Single precision floating point number, Send and receive the low order word first then high order word second

Details of each data contents are as follows:

A. Measurement Mode (Address No:15) , Value: 1 (Default) *Do not change this value*

B. Pyranometer Sensitivity (Address No: 16)

Sensitivity (μV/W/m^2) maintained in the internal memory; also stated on calibration certificate.

C. Unit of Temperature (Address No: 18), Value: 1 (Default)

There are three types of temperature units: {1: ℃ (Centigrade), 2: K (Kelvin), 3: F (Fahrenheit)}, with 2 decimals (ex: 20.12ºC)

D. Measurement Voltage (Address No: 19)

This register shows the acquired voltage value (mV), with 3 decimals (ex: 1.254mV)

E. Irradiance (Address No: 21)

The irradiance (W/m^2) which measurement voltage is converted, with 2 decimals (ex: 1010.25 W/m^2)

F. Internal Temperature (Address No: 23)

Measured internal temperature (ºC), with 3 decimals (ex: 12.34 (ºC)

G. Password (Address No: 25)

Password required for setting the temperature correction and linearity correction

H. Temperature Correction Coefficient (Address No: 26, 28, 30, 32)

Parameters (x4) for correcting the temperature response occur by the change in ambient temperature.

Temperature correction is not setup in default setting.

If temperature correction is required, refer to following correction formula:

$$ETC\ (E,\ T) = E\ /\ TC1\ (T), \quad TC1\ (T) = a + b \times T + c \times T^2 + d \times T^3$$

Where:

ETC (E,T) : Measurement Voltage Treated with Temperature Correction (mV)

E : Measurement Voltage (mV)

TC1(T) : Correction Coefficient

T : Measurement Temperature (℃, Internal Temperature)

a, b, c, d : Correction Coefficient

Default Values {*a*: 1, *b*: 0, *c*: 0, *d*: 0}: Setting for not using temperature correction

I. Linearity Correction Coefficient (Address No: 34, 36, 38, 40)

Parameters (x4) for correcting the linearity error of the output against solar irradiance.

Linearity correction is not setup in default setting. Do not change this value.

If linearity correction is required, refer to following correction formula:

$$I = (k1 + (k2 \times ETC\ (E,\ T) + (k3 \times ETC\ (E,\ T)^2\ ) + (k4 \times ETC\ (E,\ T)^3))\ /\ S$$

Where:

I : Irradiance after Linearity Correction (W/m2)

ETC (E,T): Measurement Voltage after Temperature Correction mentioned above (mV)

S : Pyranometer Sensitivity (μV/W/m^2)

k1, k2, k3, k4: Correction Coefficient; When *k1* is changed, offset output (μV) can be changed

Default Values {*k1*: 0, *k2*: 1, *k3*: 0, *k4*: 0}: Setting for not using linearity correction

Data Samples

1. Data frame from Master to the Slave No. 0x01 for inquiring the solar irradiance

Node No.	Function No.: Read out holding register	Starting register No.		Read out register value			
		(High)	(Low)	(High)	(Low)		
0x01	0x03	0x00	0x15	0x00	0x02	CRC	CRC

*0xXX is hexadecimal

2. Response data frame from Node No. 0x01 to Master

Node No.	Function No.: Holding register readout	Data length	Register No.21 (0x15)		Register No.22 (0x16)			
			(High)	(Low)	(High)	(Low)		
0x01	0x03	0x04	0x??	0x??	0x??	0x??	CRC	CRC

*0x?? is response value (hexadecimal)

Data Conversion

1. To Convert Data for Address Numbers 0 to 12

- Output Data Format: UINT16 (hexadecimal)
- Data Format after Conversion: ASCII * Convert according to the ASCII Code Table

Example:

Converting data for Pyranometer Model Number (Addresses 8 to 12)

Conversion result: MS-60 _ _ _ _ _

Address No.	8		9		10		11		12	
Output Data	4d	53	2d	38	30	20	20	20	20	20
Conversion result	M	S	-	8	0	_	_	_	_	_

2. To Convert Data for Address Numbers 13 to 15, 18, 25, 42 and 45

- Output Data Format: UINT16 (hexadecimal)
- Data Format after Conversion: Decimal * Convert the hexadecimal to decimal

Example:

Converting data for Minimum Irradiance and Maximum Irradiance (Addresses No. 13 to 14)

Conversion result: Minimum Irradiance: 0 [W/m^2], Maximum Irradiance: 1600 [W/m^2]

Address No.	13		14	
Output Data	00	00	06	40
Conversion result	0		1600	

3. To Convert Data for Address Numbers: 16 to 17, 19 to 24, 26 to 41 and 43 to 44

- Output Data Format: FLOAT (hexadecimal)
- Data Format after Conversion: Decimal * Convert the hexadecimal to decimal

Example:

Converting data for Minimum Irradiance and Maximum Irradiance (Addresses No. 23 to 24)

* For FLOAT format data, data for No.23 is LOW, and data for No.24 is HIGH. With No.24 at the top. Connect the No.23 data to make one data for before conversion. Next, calculate the data before conversion according to the IEEE754 standard.

Conversion result: 820.52 [W/m^2]

Address No.	23		24	
Output Data	21	47	44	4d
Data Before Conversion	444D2147			
Conversion result	820.52			

A-5. Recalibration (MS-80A, MS-80M)

Since the sensor has no analog mV output, a recalibration can only be done when the MS-80A or MS-80M can be connected to a measurement device with a corresponding input (4-20mA or MODBUS).

When MS-80 is calibrated at an external calibration laboratory, in practice slight differences can be expected relative to the MS-80 manufacturer calibration scale and lab-scale. A difference in the calibration measurement results can be explained by the differences with respect to the method of calibration, reference sensors, sensor characteristics and measurement conditions.

In case the sensor needs to be adapted to the new calibration scale, there are two ways to adopt the sensor sensitivity.

1) The scale difference can be applied as a relative factor. A conversion multiplication factor can be applied to calculate the irradiance. In this case, the original manufacturer calibration remains unchanged. The multiplication factor can be applied in the data logger or processing software.

2) The scale difference can be applied to the sensitivity figure default to the sensor. This can be done through the EKO Sense Configurator Software. Since the internal sensor sensitivity figure is specified in $\mu V/W/m^2$, the sensitivity figure can be changed relative to the irradiance scale change.

   Example for MS-80A or MS-80M:
   The sensor recalibration revealed a difference with respect to the irradiance measured by the MS-80 relative to the lab-scale. The MS-80 irradiance readings are underestimated and can be adapted by lowering the MS-80 sensitivity factor, which can be calculated with following:

   $S_{new} = I_{MS80} / I_{ref} \times S_{origin}$

   Where:

S_{new} :	New Sensitivity of MS-80A or 80M ($\mu V/W/m^2$)
S_{origin} :	Original sensitivity of MS-80A or 80M ($\mu V/W/m^2$)
I_{MS80} :	Irradiance measured by MS-80A or 80M (W/m^2)
I_{ref} :	Reference Irradiance (W/m^2)

A-6. Temperature Sensor (10kΩNTC MS-80)

When a thermistor temperature sensor (44031 10kΩ NTC) is used, the detector temperature T(℃) can be converted from the resistance value R(Ω) by using the following formula. Please also see the temperature conversion table shown in Appendix A-7.

$T = (\alpha + \beta\,(\mathrm{LN}(R)) \quad + \gamma\,(\mathrm{LN}(R))^3\,)^{-1} - 273.15$

Where:

T :	Detector temperature (℃)
R :	Resistance value (Ω)
α :	1.0295・ 10-3
β :	2.3910・ 10-4
γ :	1.5680・ 10-7

A-7. Temperature Conversion Table (44031, 10kΩNTC)

Table A-9. Temperature Conversion table for the Thermistor (44031, 10kΩ@25℃)

T (°C)	R (Ω)	T (°C)	R (Ω)	T (°C)	R (Ω)
-30	135200	0	29490	30	8194
-29	127900	1	28150	31	7880
-28	121100	2	26890	32	7579
-27	114600	3	25690	33	7291
-26	108600	4	24550	34	7016
-25	102900	5	23460	35	6752
-24	97490	6	22430	36	6500
-23	92430	7	21450	37	6258
-22	87660	8	20520	38	6026
-21	83160	9	19630	39	5805
-20	78910	10	18790	40	5592
-19	74910	11	17980	41	5389
-18	71130	12	17220	42	5193
-17	67570	13	16490	43	5006
-16	64200	14	15790	44	4827
-15	61020	15	15130	45	4655
-14	58010	16	14500	46	4489
-13	55170	17	13900	47	4331
-12	52480	18	13330	48	4179
-11	49940	19	12790	49	4033
-10	47540	20	12260	50	3893
-9	45270	21	11770	51	3758
-8	43110	22	11290	52	3629
-7	41070	23	10840	53	3504
-6	39140	24	10410	54	3385
-5	37310	25	10000	55	3270
-4	35570	26	9605	56	3160
-3	33930	27	9227	57	3054
-2	32370	28	8867	58	2952
-1	30890	29	8523	59	2854

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