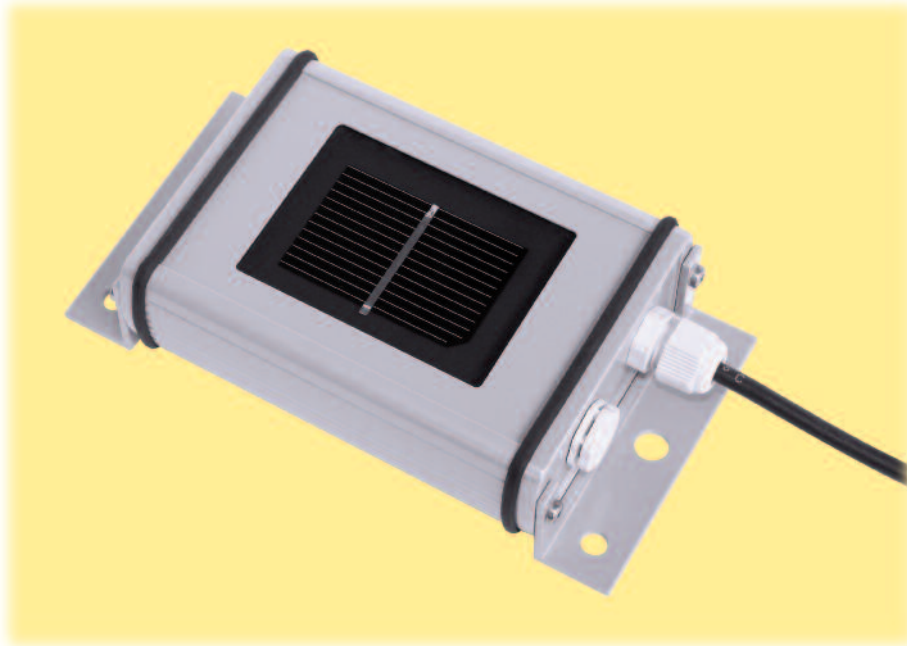


# SILICON IRRADIANCE SENSOR

## Measurement of Solar Irradiance

Silicon irradiance sensors (Si sensor) show a cost-effective, but rugged and reliable solution for the measurement of solar irradiance, especially for the monitoring of Photovoltaic (PV) systems. Based on the construction of the sensor element corresponding to a PV module they are ideal as reference for the monitoring of PV systems. Especially the spectral response comparable to PV modules as well as the similar inclination error (incident angle modifier) allow an exact analysis of PV energy yields using Si sensor data.



## General Information

### Mode of Operation

A silicon solar cell can be used as an irradiance sensor, because the short-circuit current is proportional to the irradiance. Our sensors are built out of a monocrystalline Si solar cell connected to a shunt. Due to the low resistance of the shunt the cell operates next to short-circuit.

To minimize influences of temperature to the measuring signal all of our sensors with the extension „TC“ have an active temperature compensation via a temperature sensor laminated to the back surface of the solar cell.

**All sensors are calibrated in artificial sunlight against a reference cell calibrated at the Physikalisch-Technische Bundesanstalt (PTB, National Metrology Institute of Germany).**

### Mechanical Construction

The solar cell is embedded in Ethylen-Vinyl-Acetat (EVA) between glass and Tedlar. The laminated cell is integrated into a case of powder-coated aluminium. Therefore the sensor construction is comparable to that of a standard PV module. The electrical connection is realized by a 3 m cable or a waterproof (IP67) connector.

### Optional Temperature Measurement

Additionally to the irradiance measurement our silicon sensors with the extension “-T” are able to measure the temperature of the solar cell using a temperature sensor laminated to the back of the cell. This solar cell temperature can approximately be used as module temperature.



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# SILICON IRRADIANCE SENSOR

## Technical Data

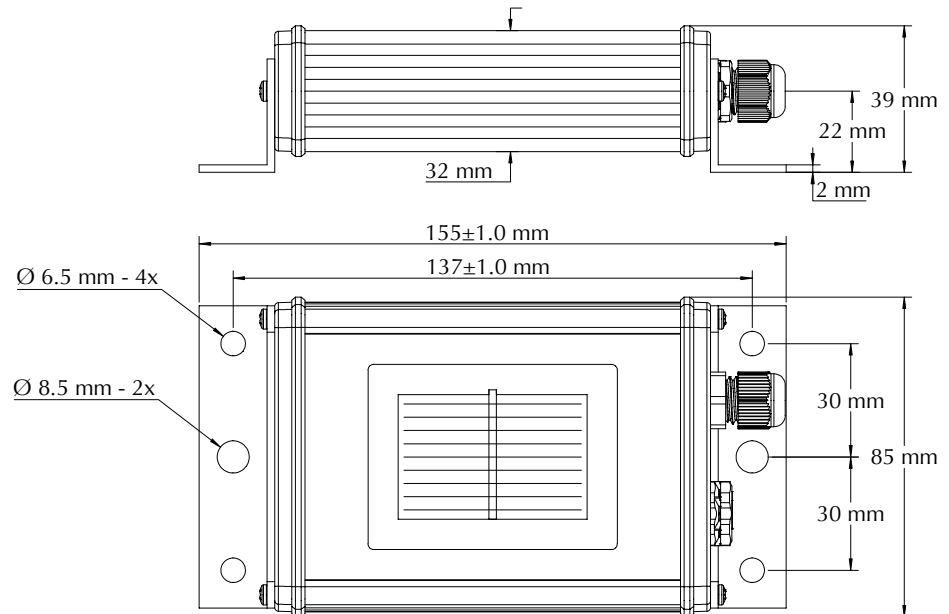
### SI-SENSOR General Information

- Solar cell: Monocrystalline silicon (50 mm x 33 mm)
- Operating temperature: -35°C to 80°C
- Electrical connection: 3 m shielded cable
- Load impedance for Si-V-1.5TC-batt: minimal 1 M $\Omega$
- Load impedance for Si-V-1.5TC and -TC-T, Si-V-10TC and -TC-T: min. 10 k $\Omega$
- Load impedance for Si-I-420TC and -TC-T: minimal 20  $\Omega$  and maximal 400  $\Omega$
- Case, protection mode: Powder-coated aluminium, IP 65
- Dimension, weight: 155 mm x 85 mm x 39 mm, approx. 350 to 470 g
- Customs number for all sensors: 85 41 40 90

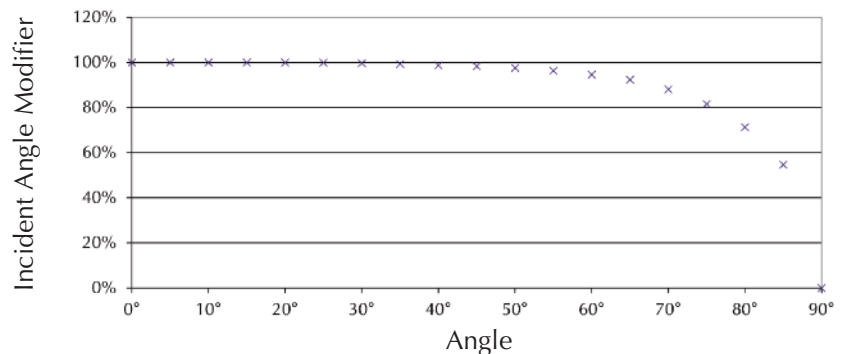
### Digital

- Protocol: M&T (type -MT), MODBUS RTU (type -MB), CANopen CiA 487
- Interface: RS485 up to 38.4 kBaud, CAN up to 250 kBaud
- Galvanic isolation: 1.000 V between power supply and bus

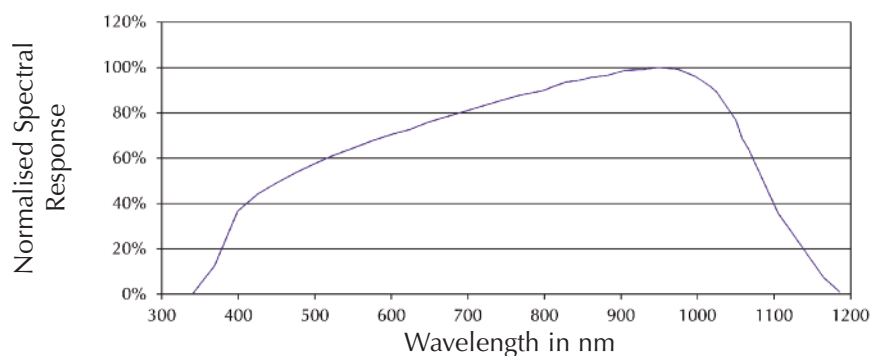
## DIMENSIONS



## INCIDENT ANGLE MODIFIER



## SPECTRAL RESPONSE



# SILICON IRRADIANCE SENSOR

## Technical Data

### Sensor Types:

Type Measured Variable	Irradiance			Cell Temperature
	Power Supply Current Consumption	Temperature compensation	Output Signal	Output Signal
<b>Si-V-1.5TC-batt</b> Irradiance	Internal Lithium Battery typic 15 µA	Yes	0 to 1.5 V for 0 to 1,500 W/m <sup>2</sup>	./.
<b>Si-V-1.5TC</b> Irradiance	24 V <sub>DC</sub> (4 to 28 V <sub>DC</sub> ) typic < 1 mA	Yes	0 to 1.5 V for 0 to 1,500 W/m <sup>2</sup>	./.
<b>Si-V-1.5TC-T</b> Irradiance, Cell Temperature	24 V <sub>DC</sub> (5.5 to 28 V <sub>DC</sub> ) typic < 1 mA	Yes	0 to 1.5 V for 0 to 1,500 W/m <sup>2</sup>	0 to 2 V for -40 to +90°C
<b>Si-mV-85</b> Irradiance	./. ./.	No	approx. 85 mV for 1,500 W/m <sup>2</sup>	./.
<b>Si-mV-85-Pt100(-4L)</b> Irradiance, Cell Temperature	./. ./.	No	approx. 85 mV for 1,500 W/m <sup>2</sup>	Pt100
<b>Si-mV-85-Pt1000(-4L)</b> Irradiance, Cell Temperature	./. ./.	No	ca. 85 mV for 1,500 W/m <sup>2</sup>	Pt1000
<b>Si-V-10TC</b> Irradiance	24 V <sub>DC</sub> (12 to 28 V <sub>DC</sub> ) typic < 1 mA	Yes	0 to 10 V for 0 to 1,500 W/m <sup>2</sup>	./.
<b>Si-V-10TC-T</b> Irradiance, Cell Temperature	24 V <sub>DC</sub> (12 to 28 V <sub>DC</sub> ) typic 2 mA	Yes	0 to 10 V for 0 to 1,500 W/m <sup>2</sup>	0 to 10 V for -40 to +90°C
<b>Si-I-420TC</b> Irradiance	24 V <sub>DC</sub> (12 to 28 V <sub>DC</sub> ) typic 5 to 23 mA	Yes	4 to 20 mA for 0 to 1,500 W/m <sup>2</sup>	./.
<b>Si-I-420TC-T</b> Irradiance, Cell Temperature	24 V <sub>DC</sub> (12 to 28 V <sub>DC</sub> ) typic 10 to 46 mA	Yes	4 to 20 mA for 0 to 1,500 W/m <sup>2</sup>	4 to 20 mA for -40 to +90°C
<b>Si-CANopenTC-T</b> Irradiance, Cell Temperature	24 V <sub>DC</sub> (12 to 28 V <sub>DC</sub> ) typic 35 mA	Yes	CANopen CiA 487 0 to 1,400 W/m <sup>2</sup>	CANopen CiA 487 -25 to +75°C
<b>Si-RS485TC-T</b> Irradiance, Cell Temperature	24 V <sub>DC</sub> (12 to 28 V <sub>DC</sub> ) typic 25 mA	Yes	M&T, MODBUS 0 to 1,500 W/m <sup>2</sup>	M&T, MODBUS -40 to +90°C
<b>Si-RS485TC-2T</b> Irradiance, Cell Temperature, Ambient Temperature (sensor firmly connected with 3 m cable)	24 V <sub>DC</sub> (12 to 28 V <sub>DC</sub> ) typic 25 mA	Yes	M&T, MODBUS 0 to 1,500 W/m <sup>2</sup>	M&T, MODBUS -40 to +90°C
<b>Si-RS485TC-T-Tm</b> Irradiance, Cell Temperature, Module Temperature (sensor firmly connected with 3 m cable)	24 V <sub>DC</sub> (12 to 28 V <sub>DC</sub> ) typic 25 mA	Yes	M&T, MODBUS 0 to 1,500 W/m <sup>2</sup>	M&T, MODBUS -40 to +90°C
<b>Si-RS485TC-2T-v</b> Irradiance, Cell Temperature Accessories: External Temperature, Wind Speed	24 V <sub>DC</sub> (12 bis 28 V <sub>DC</sub> ) typic 25 mA	Yes	M&T, MODBUS 0 to 1,500 W/m <sup>2</sup>	M&T, MODBUS -40 to +90°C

## ACCESSORIES FOR Si-RS485TC-2T-v

- **Tamb-Si**, Ambient temperature sensor in stainless steel sleeve with 3 m cable and connector (IP67), measuring range: -40 to +90°C
- **Tmodul-Si**, Module temperature sensor in aluminium block with 3 m cable and connector (IP67), measuring range: -40 to +90°C
- **Vwind-Si**, Wind speed sensor with 5 m cable and connector (IP67), measuring range: 0.9 to 40 m/s

# SILICON IRRADIANCE SENSOR

## Measurement Uncertainty of Irradiance (does not apply for sensors with filter glass or polycrystalline cells)

Parameter	Sensor Type	Typical Measurement Uncertainty
<b>Response time (99 %)</b> for $G > 50 \text{ W/m}^2$	Si-mV-85(-Pt100/-Pt1000)	0.001 s
	Si-mV-85TC(-T), Si-V-10TC(-T), Si-I-420TC(-T)	0.15 s
	Si-RS485TC(-2T-v), Si-CANopenTC-T	1 s
<b>Offset</b>	Si-mV-85(-Pt100/-Pt1000)	0 $\text{W/m}^2$
	Si-V-1.5TC(-T), Si-V-10TC(-T)	2 $\text{W/m}^2$
	Si-I-420TC(-T)	2.2 $\text{W/m}^2$
	Si-RS485TC(-2T-v), Si-CANopenTC-T	1 $\text{W/m}^2$
<b>Stability per anno</b> <sup>1)</sup>	all	0.50 %
<b>Non-Linearity</b> <sup>2)</sup>	all	0.10 %
<b>Temperature Dependency</b> <sup>2)</sup> for $-35$ to $+80^\circ\text{C}$	Si-mV-85(-Pt100/-Pt1000) (with external temperature comp.) <sup>3)</sup>	0.20 %
	Si-mV-85(-Pt100/-Pt1000) (without external temperature comp.)	3.00 %
	Si-V-1.5TC(-T), Si-V-10TC(-T), Si-I-420TC(-T)	0.40 %
	Si-RS485TC(-2T-v), Si-CANopenTC-T	0.40 %
<b>Factory-Calibration</b>	all (repeatability against reference)	0.75 %
	all (measurement uncertainty of reference at STC and vertical light beam)	0.50 %
<b>Measurement Uncertainty over all</b> <sup>4)</sup>	<b><math>\pm 5 \text{ W/m}^2 \pm 2.5 \%</math> of reading</b> valid for temperature compensation, spectrum AM 1.5 and vertical light beam	

Sensor Type	Measurement Uncertainty of the internal Temperature Measurement Condition	Measurement Uncertainty
<b>Si-mV-85(-Pt100/-Pt1000)</b>	$-35$ to $+80^\circ\text{C}$	IEC 60751, class A for version (-4L)
<b>Si-V-1.5TC-T</b>	$-35$ to $+70^\circ\text{C}$ / $-35$ to $+80^\circ\text{C}$	1.0 K / 1.1 K
<b>Si-V-10TC-T</b>	$-35$ to $+70^\circ\text{C}$ / $-35$ to $+80^\circ\text{C}$	1.0 K / 1.1 K
<b>Si-I-420TC-T</b>	$-35$ to $+60^\circ\text{C}$ / $-35$ to $+80^\circ\text{C}$	1.0 K / 1.3 K
<b>Si-RS485TC-XX</b>	$-35$ to $+80^\circ\text{C}$	1.0 K

<sup>1)</sup> Percentage rate referred to the measurement range

<sup>2)</sup> Percentage rate referred to the measurement value

<sup>3)</sup> External temperature compensation must be calculated on data acquisition side (temperature coefficient at AM 1.5: 0.0005 1/K)

<sup>4)</sup> Based on GUM (Guide to the Expression of Uncertainty in Measurement) with  $k=2$ , not valid for Si-mV-85 or Si-mV-85(-Pt100/-Pt1000) without external temperature compensation

## EXTEND OF Supply Options

- Silicon sensor with shielded cable,  $0.14 \text{ mm}^2$ , UV- and temperature resistant, 3m length and ferrules (except Si-V-1.5TC-batt)
- Calibration protocol and quick reference guide
- DaKKS calibration certificate
- Customized cable lengths
- Version with waterproof connector (Si-V-1.5TC-batt always with connector)
- Adaptation of spectral response to different PV materials
- Customised scaling or measuring range

# SILICON IRRADIANCE SENSOR

## Option Connector

### ELECTRICAL CONNECTION

#### Optional Version with Connectors

The electrical connection of the Si sensor is realized with the inbuilt connector and the suitable plug.

#### Technical Data of the Plug

- Cable dimensions (best / max.): 0.14 mm<sup>2</sup> / 0.25 mm<sup>2</sup> (AWG26 / AWG24)
- Diameter of cable: 3.5 ... 5 mm
- Protection mode: IP67 in conjunction with the suitable connector

The connection of the different Silicon irradiance sensors are listed in the following table. The pin numbers are printed at the inside of the plug. Please take care of the mounting of the plugs as shown at the end of this page. Only if these mounting steps are realised the plug meets IP67 when connected.

Type	Pin Numbers of the Plug			
	Pin 1	Pin 2	Pin 3	Pin 4
Si-V-1.5TC-batt	Plus Signal Irradiance	Minus Signal Irradiance	not available	not available
Si-V-1.5TC	Plus Signal Irradiance	Minus Signal* Irradiance	Plus Signal Power Supply	not available
Si-V-1.5TC-T	Plus Signal Temperature	Plus Signal Irradiance	Plus Signal Power Supply	Minus Signal* Irradiance
Si-mV-85	Plus Signal Irradiance	Minus Signal Irradiance	not available	not available
Si-mV-85-Pt100 Si-mV-85-Pt1000	Plus Signal Irradiance	Minus Signal Irradiance	Pt100 Pt1000	Pt100 Pt1000
Si-I-420TC	Plus Signal Irradiance	Minus Signal* Irradiance	Plus Signal Power Supply	not available
Si-I-420TC-T	Plus Signal Temperature	Plus Signal Irradiance	Plus Signal Power Supply	Minus Signal* Irradiance
Si-V-10TC	Plus Signal Irradiance	Minus Signal* Irradiance	Plus Signal Power Supply	
Si-V-10TC-T	Plus Signal Temperature	Plus Signal Irradiance	Plus Signal Power Supply	Minus Signal* Irradiance

\* Minus signals of all sensors are identical to supply ground.

### MOUNTING OF PLUG

