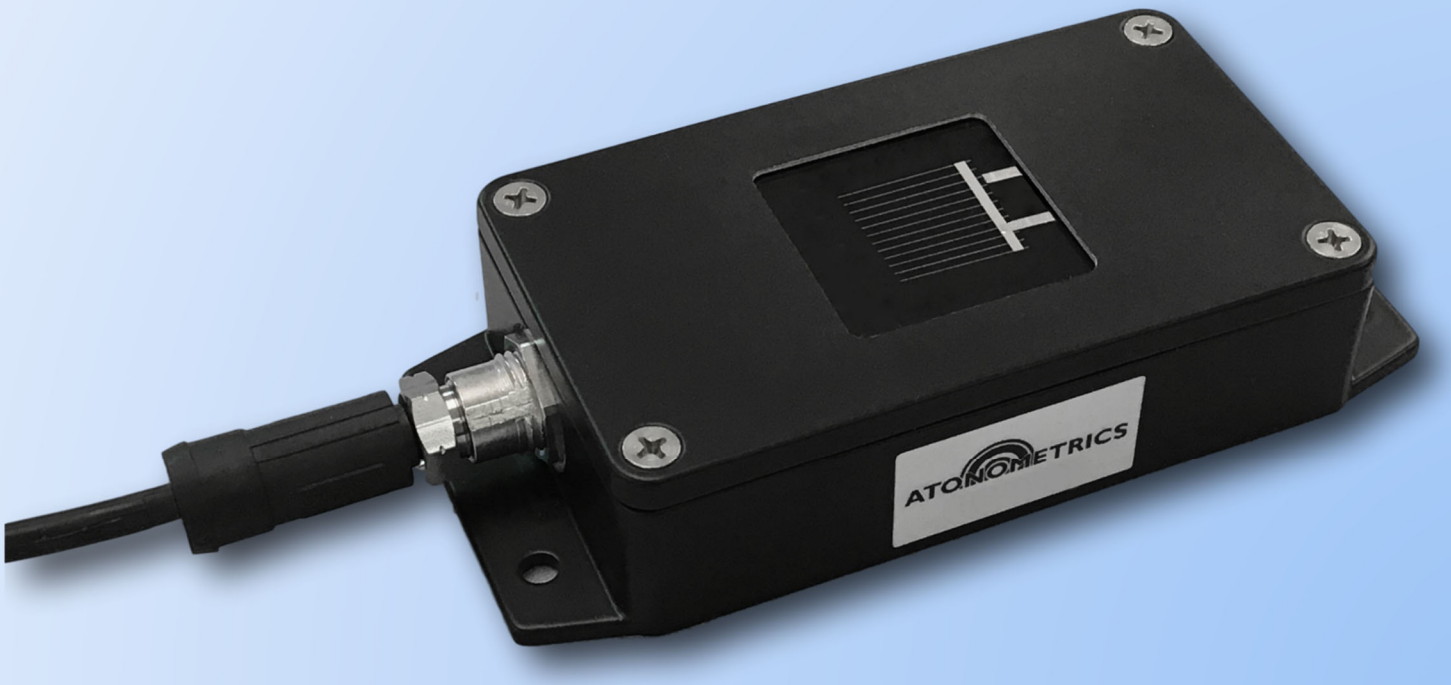
User's Guide

RC18 Series PV Reference Cell

Digital and Analog Irradiance Sensor



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1 Product Overview

The Atonometrics RC18 Series PV Reference Cell, shown in **Figure 1-1**, is specifically designed for low-cost, high-accuracy solar irradiance measurements for outdoor monitoring of PV systems.

The RC18 includes both user-configurable analog outputs and digital communication via Modbus (RS-485) in a single flexible product. Since all calibration data are stored internally in the unit's microprocessor, you never have to track calibration data or reprogram data loggers or SCADA systems when you install a new unit.

The RC18 measures irradiance using a crystalline silicon PV cell. The PV cell short-circuit current is measured with a precision shunt resistor and PV cell temperature is measured with a back-of-cell RTD. An optional spectral matching window is available for use with thin-film modules.

The IP67-rated cast aluminum enclosure provides for solid mounting and protection from the elements. The M12 circular connector allows easy installation and change-out for recalibration when desired.

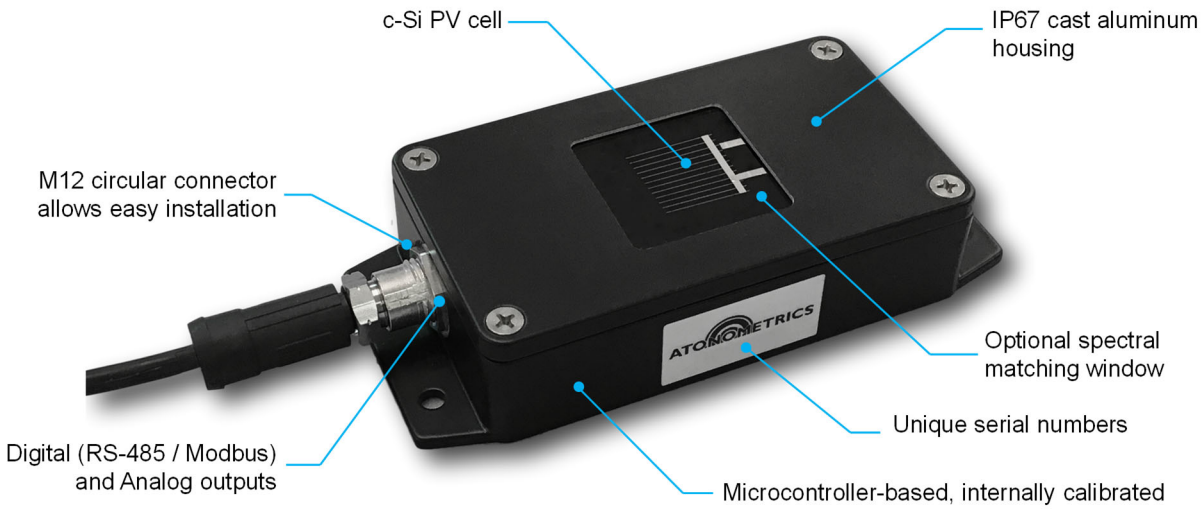

Figure 1-1: RC18 Series PV reference cell

2 Wiring

2.1 Cable Options

You will need a compatible cable assembly to use with the RC18's M12 circular connector.

Compatible cable assemblies are available from Atonometrics, sold separately. See Section 2.3.

Alternatively, you may use an Atonometrics-supplied connector, sold separately, with user-supplied cables. See Section 2.4.

Note: **Use only Atonometrics-supplied cable assemblies or connectors.** Although other M12 connectors may appear to fit, use of non-approved connectors may result in water penetration.

2.2 Power

Power requirements for different configurations are shown in **Table 2-1**.

Table 2-1: Power requirements

Configuration	Power
Digital	8-28 VDC, 8-15 mA
Analog, 0-1.5 V	8-28 VDC, 8-15 mA
Analog, 0-10 V	12-28 VDC, 8-15 mA
Analog, 4-20 mA	8-28 VDC, 15-55 mA

2.3 Atonometrics-Supplied Cables

Details for optional Atonometrics-supplied cable assemblies (PN 830256-XX) are shown in **Figure 2-1**.

Select the wires necessary for your application. For example, for digital-only operation, use wires 1, 2, 7, 8.

Note: **Protect any unused wires** from accidental contact. See Section 2.5.

Note: For any Atonometrics cable assemblies with **part numbers not shown below**, contact Atonometrics for the wiring information.

WARNING: **Check all wiring before turning on power. Incorrect wiring may damage the unit and/or your other equipment.**

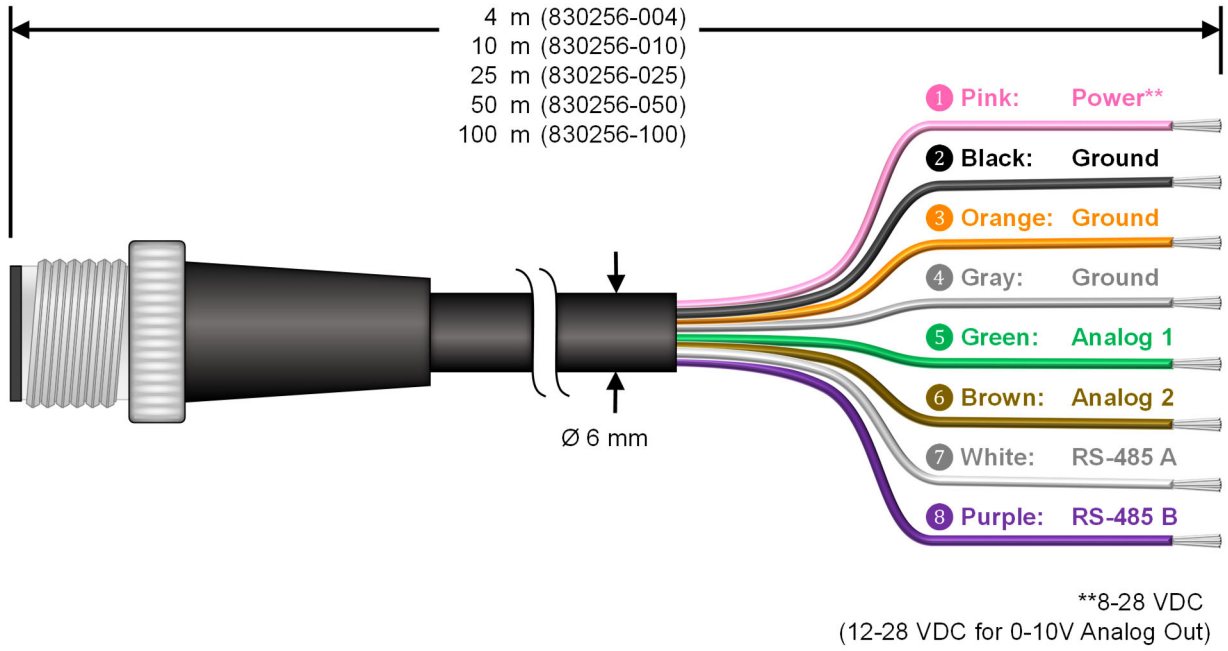

Figure 2-1: Atonometrics cable assemblies 830256-XX (sold separately)

2.4 User-Supplied Cables

User-supplied cables may be user-terminated with an Atonometrics-supplied RC18-compatible connector (PN 160375-XX), shown in **Figure 2-2**, sold separately.

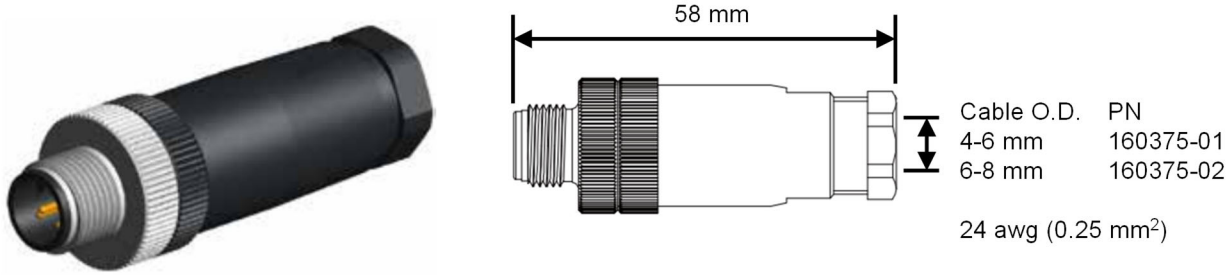

Figure 2-2: Compatible connectors (sold separately)

When wiring the user-supplied cable, note the pinout of the RC18 connector, shown in **Figure 2-3**. Note that the view is facing the connector from the outside. Select the contacts necessary for your application. For example, for digital-only operation, use contacts 1, 2, 7, 8.

Note: **Protect any unused wires** from accidental contact. See Section 2.5.

Note: **Use only Atonometrics-supplied connectors.** Although other M12 connectors may appear to fit, use of non-approved connectors may result in water penetration.

WARNING: **Check all wiring before turning on power. Incorrect wiring may damage the unit and/or your other equipment.**

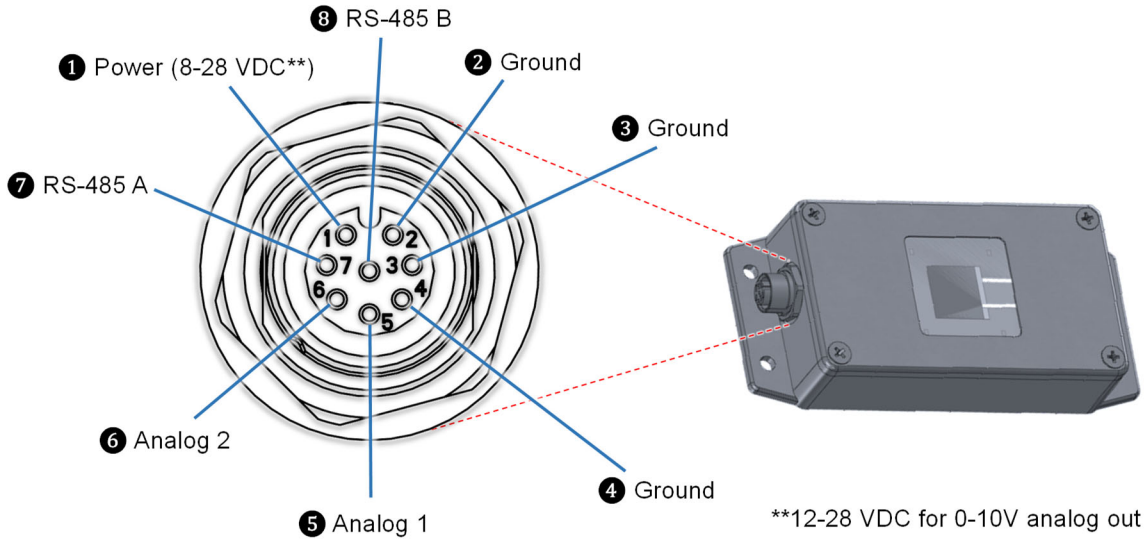

Figure 2-3: Pinout of RC18 connector

2.5 Protecting Unused Wires

Protect any unused wires from accidental contact by cutting to unequal lengths, folding back, and insulating, as shown in **Figure 2-4**.

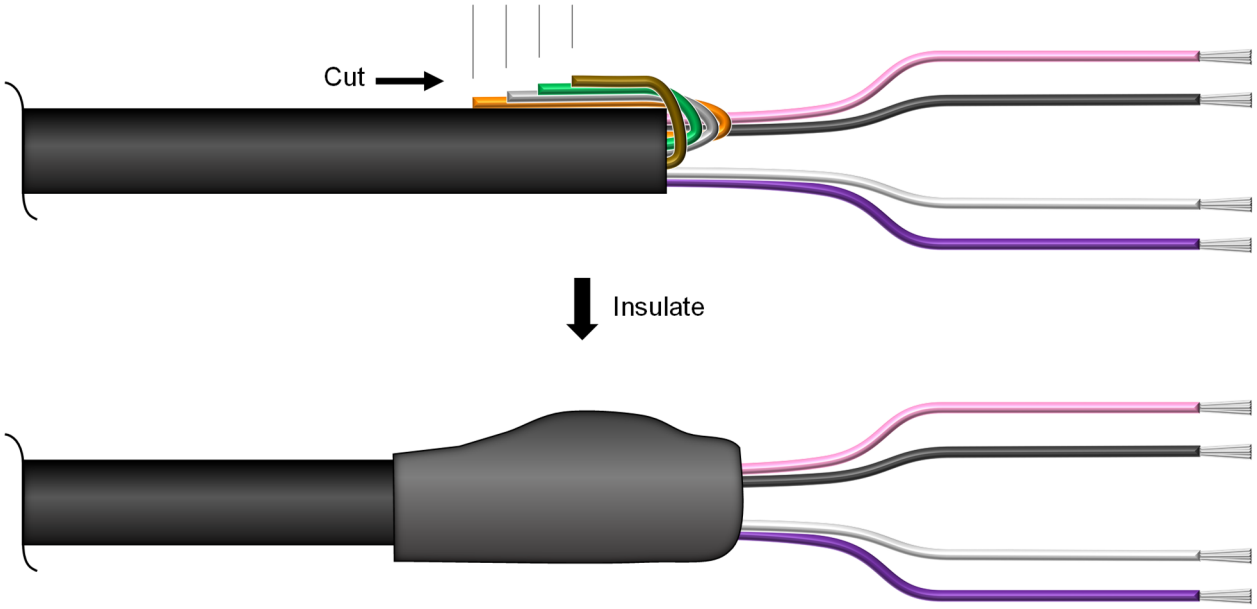

Figure 2-4: Protecting unused wires from accidental contact

3 Mounting

3.1 Mounting Directions

To mount the RC18, use the four mounting holes on the flange of the unit shown in **Figure 3-1.**

To minimize the potential for water entry to the sealed housing, mount the RC18 with the cable facing down or to the side, as shown in **Figure 3-2**, never with the cable facing up.

See **Figure 3-3** for dimensions.

Contact Atonometrics to order optional mounting plates.

Note: Do not remove the screws on the top cover of the unit, as this may compromise the weather-proof seal.

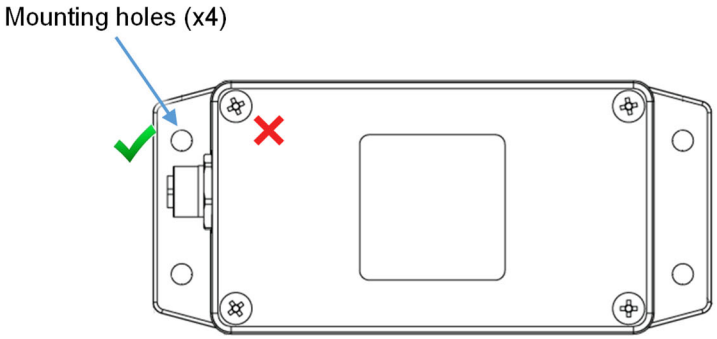

Figure 3-1: Mounting holes

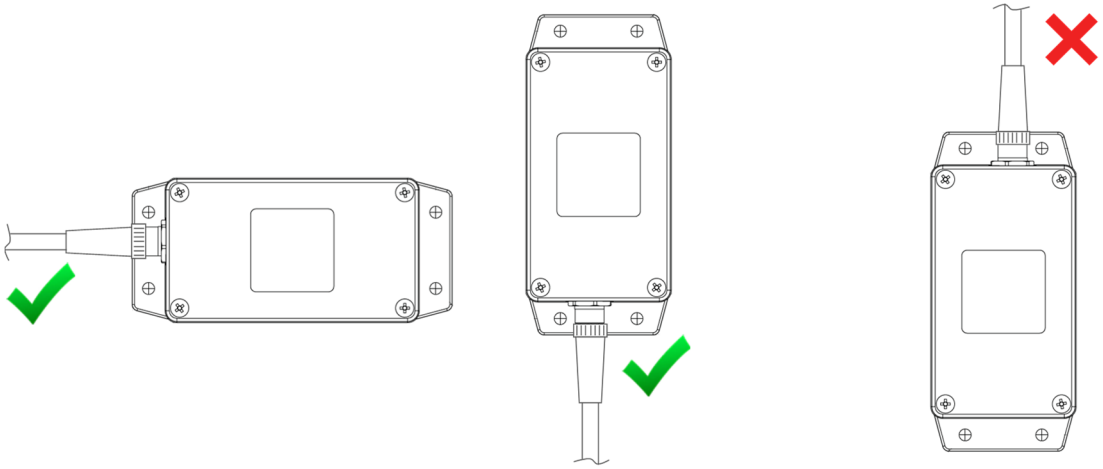

Figure 3-2: Recommended mounting orientations

3.2 Dimensions

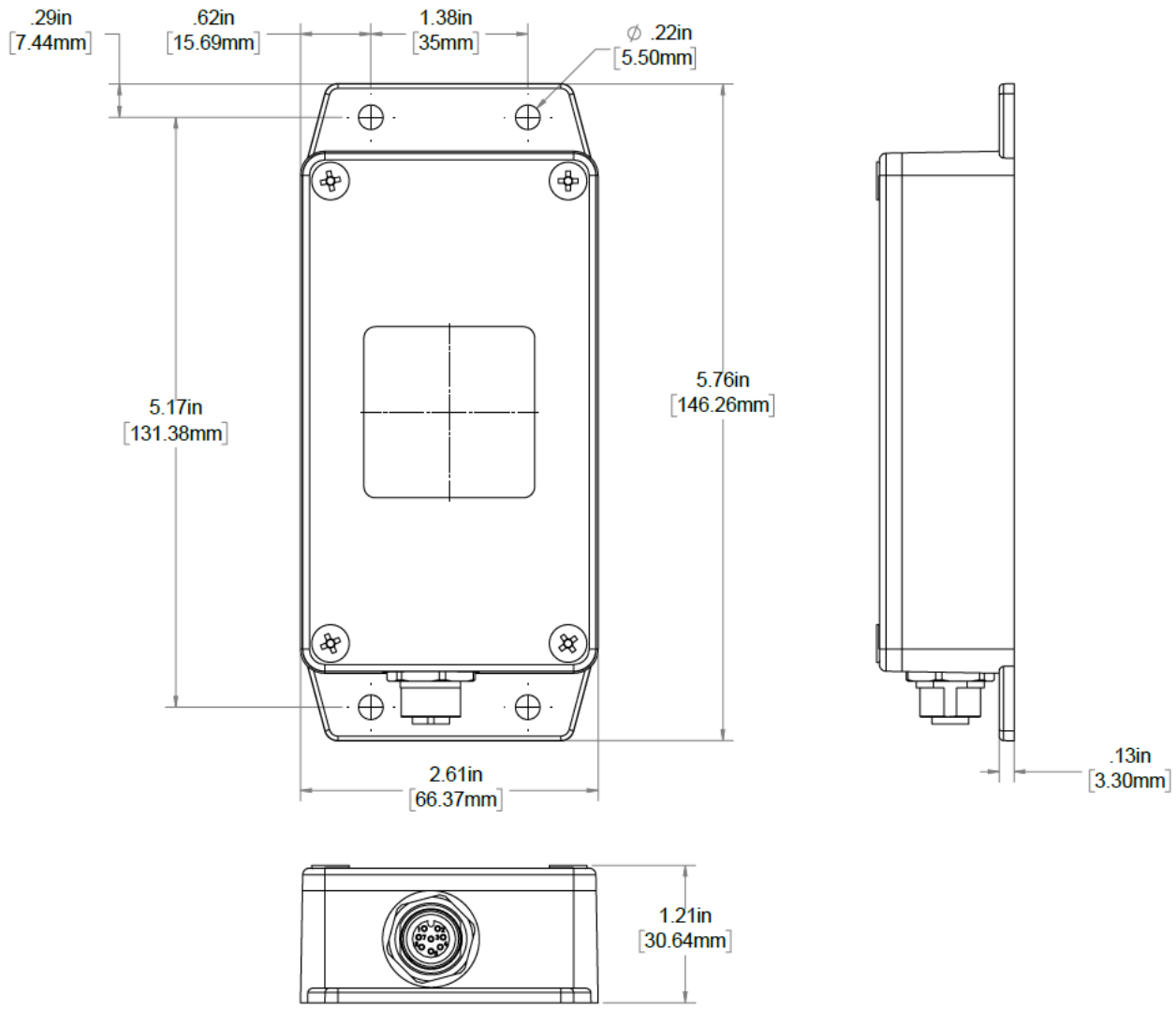

Figure 3-3: RC18 dimensions

3.3 Mounting Plates

Figure 3-4 shows optional flat or right-angle mounting plates, sold separately.

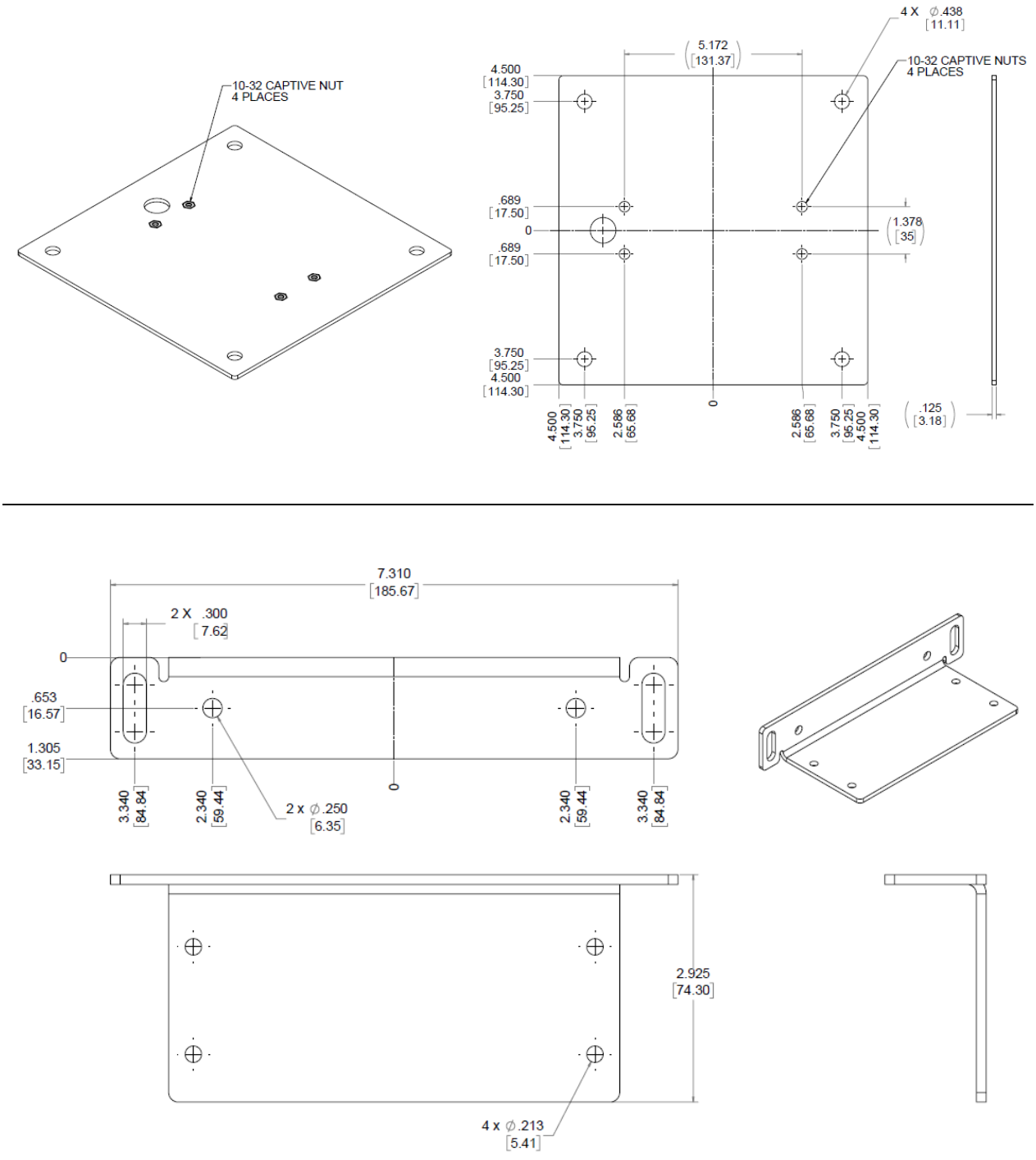

Figure 3-4: Flat (610440) and right-angle (610452) mounting plates (sold separately)

4 Modbus

4.1 Communication Parameters

By default the RC18 is configured for Modbus Node Address of 18, Baud Rate of 57600, and Data Format of 8-N-1 (8 data bits, no parity bit, and 1 stop bit).

4.2 Modbus Map

Table 4-1 lists the registers available for your client software to read data from the RC18.

Each numbered register in the table is a 16-bit (2-byte) register. Parameters requiring more than two bytes must be read from sequential registers as indicated by the Register Start and Register End columns. For a 4-byte value with bytes in the order *ABCD*, from most to least significant, the first register reads out bytes *AB* and the second reads out bytes *CD*.

For detailed information on Modbus protocols, please reference the specifications published by Modbus.org.

Note: On some user data acquisition devices, it is necessary to add 1 to all the register values shown in **Table 4-1** to determine the Modbus address.

Table 4-1: Modbus map

Register Start	Register End	Parameter Name	Units	Data Format	Bytes	Description
1	2	**Irradiance**	W/m^2	Float32 [1]	4	Measured irradiance, calculated with Eq. 1 on page 18
3	4	**Short-Circuit Current**	A	Float32 [1]	4	Measured short-circuit current (I_{SC}) of the PV cell, without temperature correction
5	6	**PV Temperature**	°C	Float32 [1]	4	Measured temperature (T) of the PV cell
104	107	**Serial Number**	n/a	Char x 2	8	Serial number of the unit, up to 8 characters, two characters per register
120	124	**Part Number**	n/a	Char x 2	10	Part number of the unit, up to 10 characters, 2 characters per register

[1] Float32 denotes single-precision 32-bit floating point per IEEE 754

5 Analog Outputs

Each of the two analog outputs may be configured in one of three output formats and to encode one of three signals. Signal scaling for each analog configuration is shown in **Table 5-1**.

Table 5-1: Signal scaling for each analog configuration

			Signal		
			Irradiance	**Temperature**	**Short-Circuit Current**
Analog Configuration	**0 to 1.5 V**	0 V	0 W/m^2	-45.5 °C	0.0000 A
		1.5 V	1500 W/m^2	100.0 °C	0.2233 A
	0 to 10 V	0 V	0 W/m^2	-45.5 °C	0.0000 A
		10 V	1500 W/m^2	100.0 °C	0.2233 A
	4 to 20 mA	4 mA	0 W/m^2	-45.5 °C	0.0000 A
		20 mA	1500 W/m^2	100.0 °C	0.2233 A

6 Configuring

6.1 Overview

To change the configuration of your unit, you may use the RC18 Configuration Kit (PN 810235-01, sold separately) with the RC18 Configuration Manager software (PN 500078).

6.2 RC18 Configuration Kit

The RC18 Configuration Kit (PN 810235-01) allows you to connect your RC18 unit to your Windows-based PC for configuration. The kit, shown in **Figure 6-1**, contains a power adapter (AC to 15 VDC) with slide-on worldwide receptacle adapters, an RS-485 to USB adapter, and a cable for connecting power and communication to your RC18 unit.

To assemble and install the kit:

- Select and install the receptacle adapter appropriate for your country
- Insert the 15 VDC plug into the RC18 cable assembly
- Connect the RC18 cable assembly to the RC18 unit
- Insert the RS-485 to USB adapter into your PC's USB port
- Connect the power adapter to AC power
- Allow Windows Update to detect the RS-485 to USB adapter and automatically install its driver, or install the driver from the CD included in the kit

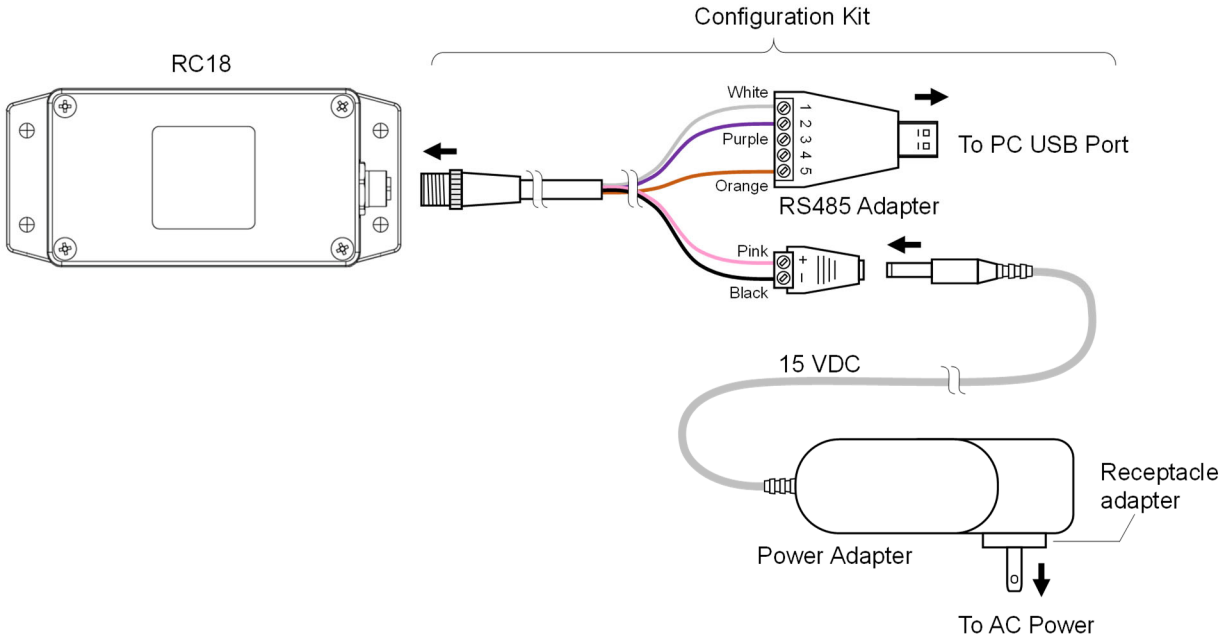

Figure 6-1: RC18 Configuration Kit, PN 810235-01 (sold separately)

6.3 RC18 Configuration Manager

6.3.1 Installing the Software

The RC18 Configuration Manager software (PN 500078) runs on a Windows PC and requires Windows 7 or higher.

You may obtain the software as well as the RC18 User Guide (PN 880058, this document) from the Atonometrics web site.

6.3.2 Connecting To Your RC18

Ensure that the RC18 Configuration Kit (see Section 6.1) is assembled, connected to your RC18 unit, and powered.

Launch the software by double-clicking the file “RC18 Configuration Manager.exe”.

From the Measurements tab, shown in **Figure 6-2**, select the COM port of the RS-485 to USB adapter, press “Find” to detect your RC18 unit and its communication settings, then press “Connect”. If connection is successful, a “Connected” message will appear in the Status area.

Note: To determine the COM port corresponding to your RS-485 to USB adapter, check Device Manager in Windows and look for the adapter under “Ports”. Alternatively, use the “Refresh” button to list COM ports in the RC18 Configuration Manager. Be aware that Windows may change the COM port number each time the adapter is plugged in.

Note: Use the “Find” feature with the RC18 Configuration Kit, and with only a single RC18 unit connected. (For units shipped prior to January 2019, the “Find” feature works differently; contact Atonometrics for details.)

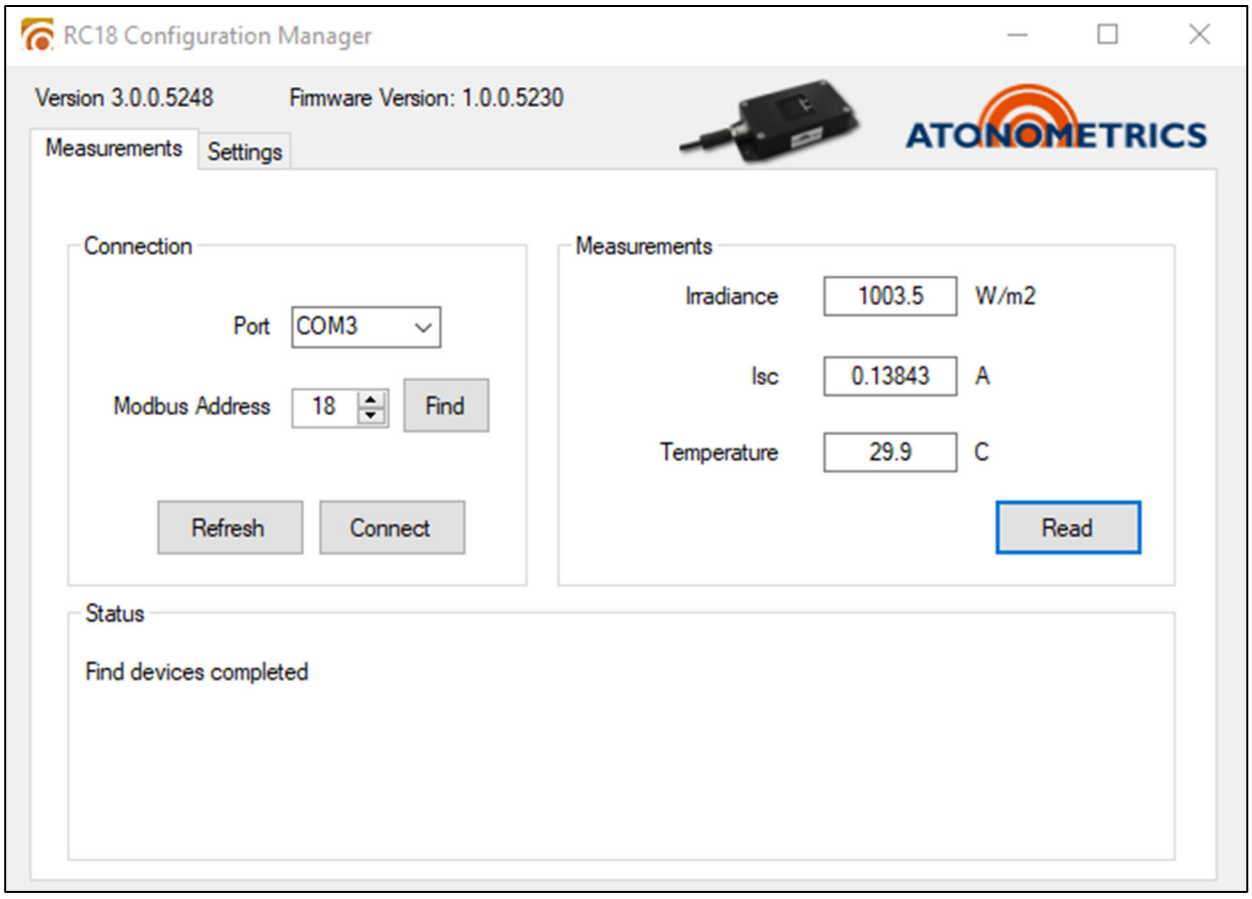

Figure 6-2: RC18 Configuration Manager

6.3.3 Setting Modbus Node Address, Baud Rate, and Data Format

From the Settings tab, shown in **Figure 6-3**, select your new desired Modbus Node Address (1-247), Baud Rate, and/or Data Format. Press Update in the Communication Settings box.

Note: To confirm the new settings, cycle power to the RC18 and restart the RC18 Configuration Manager. Use the “Find” button in the Connection area to detect the device at its new settings and press “Connect”.

6.3.4 Configuring Analog Outputs

From the Settings tab, shown in **Figure 6-3**, select your desired configuration for Analog 1 and Analog 2, including both signal and analog output format, and press Update in the Analog Output Settings box.

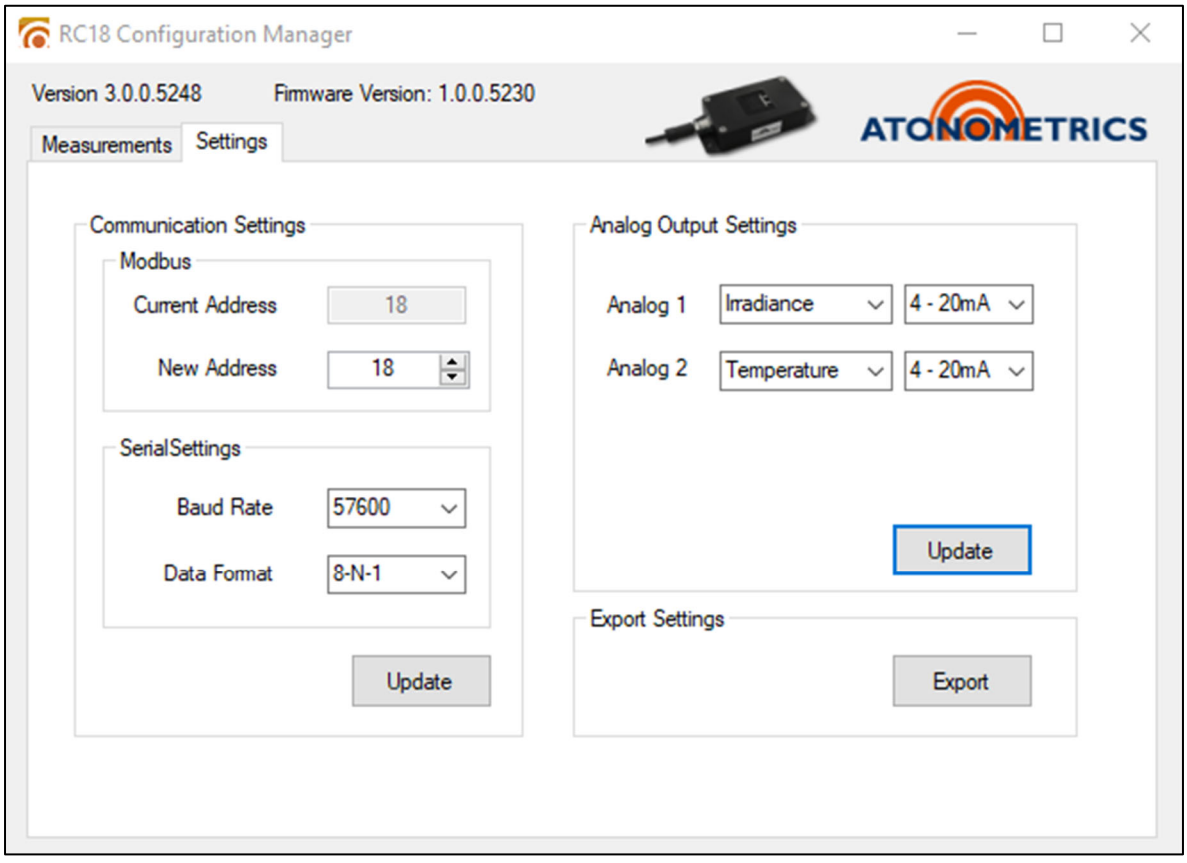

Figure 6-3: RC18 Configuration Manager, Settings tab

7 Using Multiple RC18 Units

When using digital communication, multiple RC18 units can be combined onto a single RS485 bus for querying via Modbus. Atonometrics provides a Bus Box and associated cables (sold separately) that make this combination simple. See **Figure 7-1**.

Combining multiple RC18's is especially beneficial for bifacial PV monitoring applications. See our Applications Note 880089.

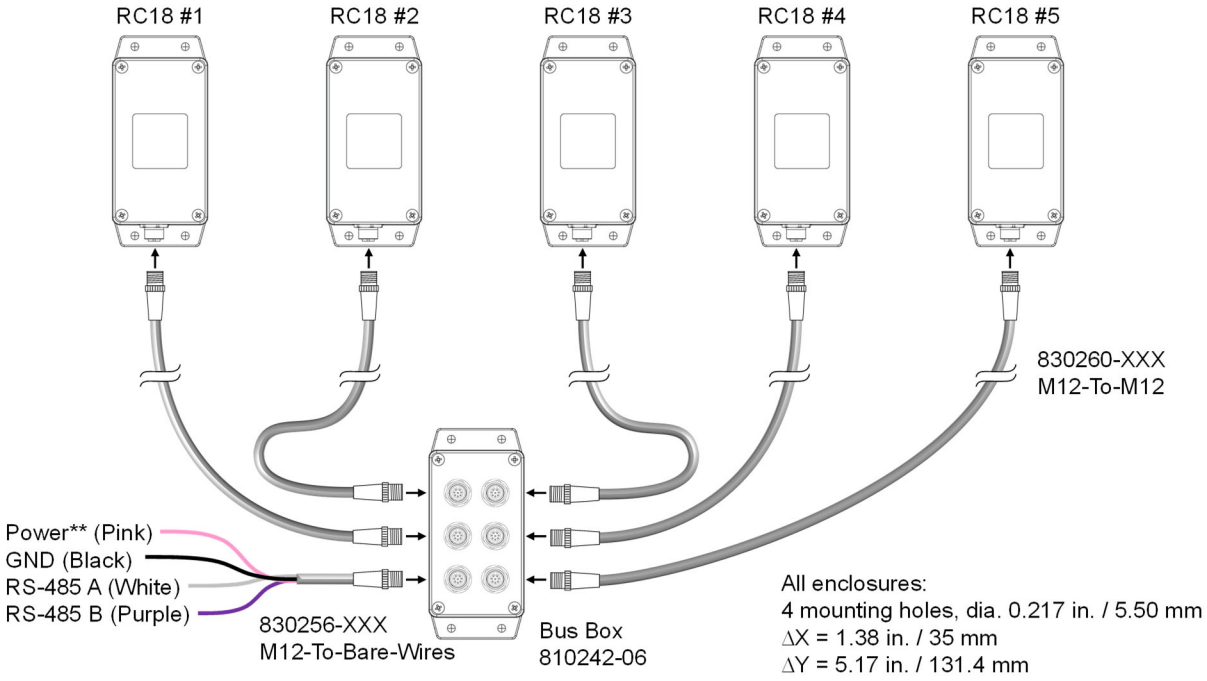

Figure 7-1: Combining multiple RC18 units using Bus Box and associated cables

When using multiple RC18 units, each unit must have a unique Modbus Node Address. To configure addresses, you must connect to each unit individually.

Note: To use the "Find" feature of the Configuration Manager software, you must have one and only one RC18 unit connected to your computer running the software. The software will not identify multiple units on your RS485 bus. Connect to each unit individually for configuration, then connect the units together onto your combined bus.

8 Theory of Operation

The RC18 measures irradiance using the temperature-corrected short-circuit current of the c-Si PV cell. Irradiance is calculated using the following equation:

$$Irradiance = \frac{I_{sc}}{I_{sc,0} \cdot \left(1 + \alpha \cdot (T - 25\ ^{\circ}\mathrm{C})\right)} \cdot 1000\ \mathrm{W/m^2} \qquad (1)$$

Here I_{sc} is the measured short-circuit current and T is the measured PV cell temperature. The other variables are constants for the device: $I_{sc,0}$ is the known short-circuit current at the reference condition (STC) and α is the temperature coefficient of short-circuit current. These constants are programmed into the RC18 non-volatile memory.

Figure 8-1 shows the block diagram of the RC18. Precision circuitry measures the I_{sc} and T of the PV cell, and from these values the microcontroller calculates irradiance. Modbus over RS-485 is used for digital communication to the microcontroller for both device configuration and polling of sensor data. Two configurable analog outputs can be used to provide irradiance, temperature, or short-circuit current signals to analog data loggers if desired.

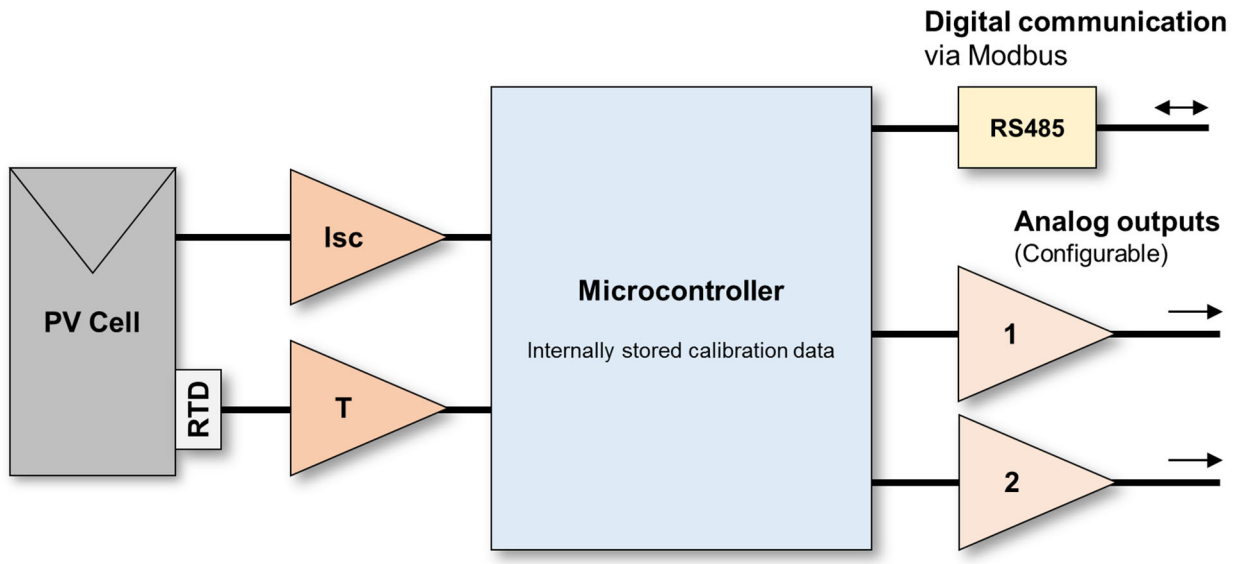

Figure 8-1: Block diagram

9 Specifications

Table 9-1: Specifications

Main Data	Model name	RC18 Series
	Measurement range	0 to 1500 W/m^2
	Resolution	0.1 W/m^2
	Operating temperature	-35 to 80 °C
	Input power	8-28 VDC (12-28 VDC for 0-10V analog output)
	PV cell	Crystalline Si, 20 mm x 20 mm
	Window	Low-iron solar glass
	Cell temperature measurement	-40 to 100 °C, RTD
	Calibration data	Internally calibrated; no calibration data to manage
	Setup	Optional configuration kit allows PC-based setup
Digital	Communication protocol	Modbus over RS485, user-settable Modbus address
	Baud rate	Up to 57.6k
	Current consumption	typ. 8-15 mA
Analog	Analog output options	0-1.5V, 0-10V, or 4-20mA
	Analog output signals	Irradiance, Cell Temperature, Short-Circuit Current
	Current consumption	0-1.5V or 0-10V mode: typ. 8-15 mA 4-20mA mode: 15-55 mA
	Output impedance	0-1.5V or 0-10V mode: 2 kohm
	Internal voltage drop	4-20mA mode: Allow 3.5 V minimum
Enclosure	Material	Powder-coated cast aluminum housing
	Outdoor rating	IP67
Dimensions	Dimensions	4.53 x 2.56 x 1.18 in. / 115.1 x 65.0 x 30.0 mm
	Weight	0.6 lb / 0.3 kg
	Mounting	4 mounting holes, dia. 0.217 in. / 5.50 mm

Cable	Type	Shielded, weather resistant, UV-rated, 24 awg / 0.2 mm^2
	Cable length options	4 m, 10 m, 25 m, 50 m, 100 m, custom
	Connector	M12 circular connector, IP67
	Pinout	Power, Ground (3x), Analog 1 & 2, RS485 A & B, Shield
Measurement Specifications	Response time	0.15 s
	Electronics non-linearity	± 0.03% of range
	Repeatability	± 0.02% of range
	Temperature drift, -35 °C to 80 °C	± 0.4% at 1000 W/m^2
	Cell temperature measurement	± 1 °C
	Irradiance calibration	± 1.2%, calibrated to NREL-traceable reference standard
	Overall measurement uncertainty	± 2.0% @ 1500 W/m^2, ± 2.9% @ 100 W/m^2
	Stability	0.5% / year
Standards Compliance		IEC 61724-1 Class A, IEC 60904-2, IEC 60904-3, IEC 60904-10 CE