PRODUCT MANUAL

Sensor

SN500SS

Net Radiometer

Revision: 10/2024

RELIABLE MONITORING SINCE 1974

Campbell SCIENTIFIC®

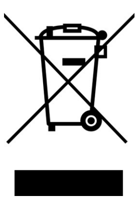
Please read first

About this manual

Please note that this manual was produced by Campbell Scientific Inc. primarily for the North American market. Some spellings, weights and measures may reflect this. In addition, while most of the information in the manual is correct for all countries, certain information is specific to the North American market and so may not be applicable to European users. Differences include the U.S. standard external power supply details where some information (for example the AC transformer input voltage) will not be applicable for British/European use. Please note, however, *that when a power supply adapter is ordered from Campbell Scientific it will be suitable for use in your country*.

Reference to some radio transmitters, digital cell phones and aerials (antennas) may also not be applicable according to your locality. Some brackets, shields and enclosure options, including wiring, are not sold as standard items in the European market; in some cases alternatives are offered.

Recycling information for countries subject to WEEE regulations 2012/19/EU



At the end of this product's life it should not be put in commercial or domestic refuse but sent for recycling. Any batteries contained within the product or used during the products life should be removed from the product and also be sent to an appropriate recycling facility, per The Waste Electrical and Electronic Equipment (WEEE) Regulations 2012/19/EU. Campbell Scientific can advise on the recycling of the equipment and in some cases arrange collection and the correct disposal of it, although charges may apply for some items or territories. For further support, please contact Campbell Scientific, or your local agent.

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1. Introduction

This four-component net radiometer, manufactured by Apogee Instruments, provides individual measurement of net radiation components. This sensor features an SDI-12 output, eliminating the need for multiple analog terminals to measure the individual components of net radiation. The SN500SS offers a complete package that includes a net radiometer, mounting rod, pigtail lead cable for data logger interface, and a carrying case.

> NOTE:
> This manual provides information only for CRBasic data loggers. For retired Edlog data logger support, contact Campbell Scientific.

2. Precautions

- READ AND UNDERSTAND the Safety section at the back of this manual.
- Care should be taken when opening the shipping package to not damage or cut the cable jacket. If damage to the cable is suspected, consult with Campbell Scientific.
- The SN500SS is a precision instrument. Please handle it with care.
- When cleaning the sensor, never use an abrasive material or cleaner on the diffuser.

3. Initial inspection

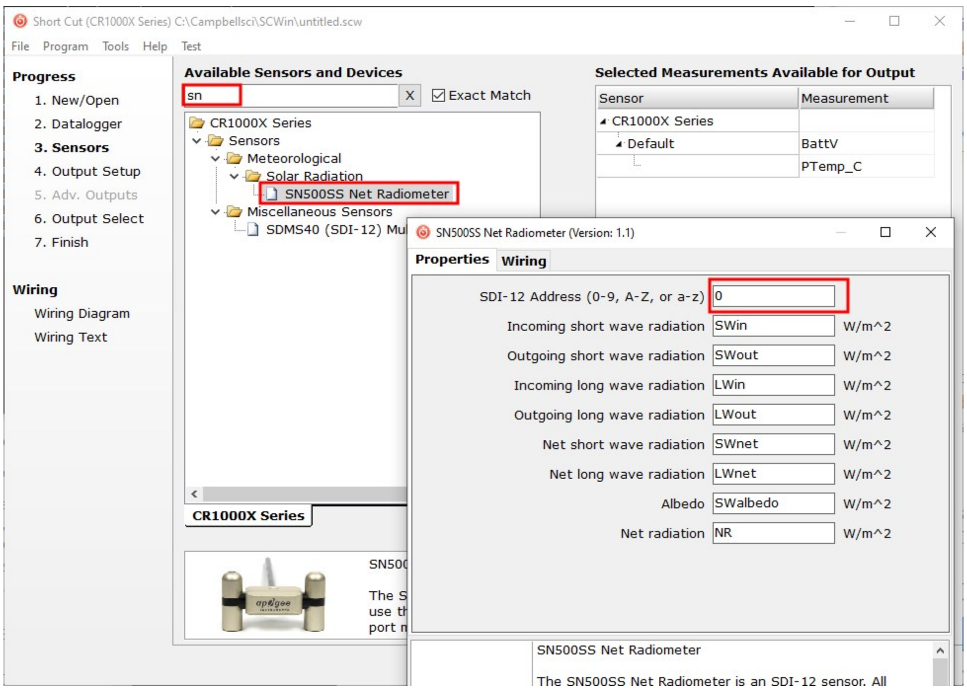
Upon receipt of the SN500SS, inspect the packaging and contents for damage. File damage claims with the shipping company.

4. QuickStart

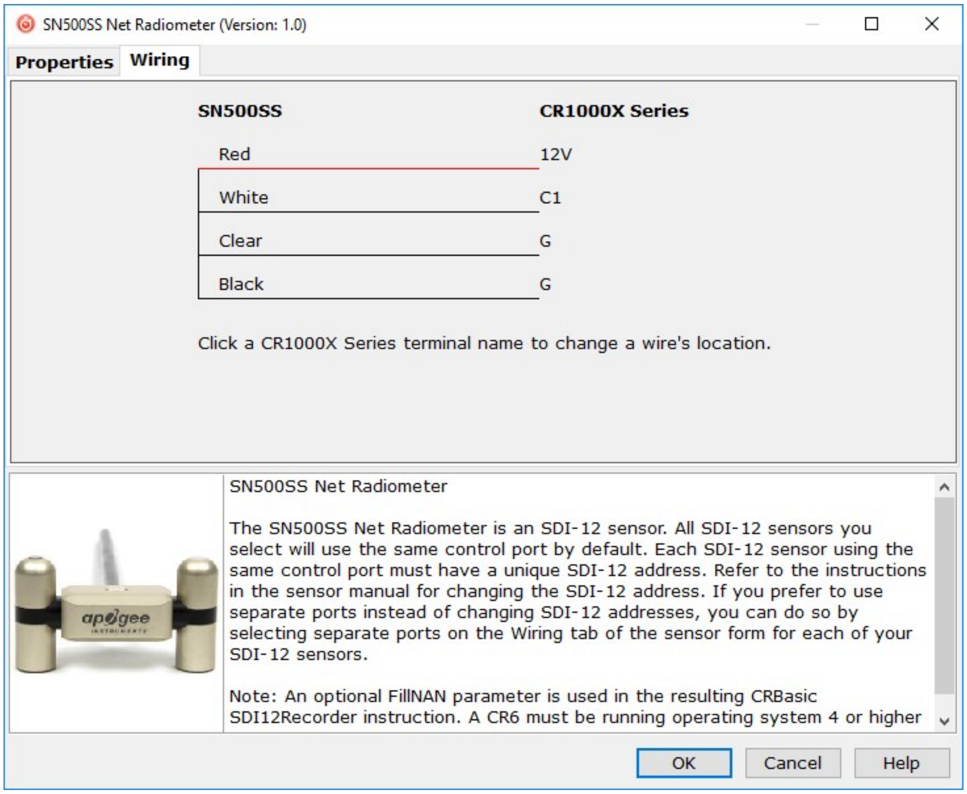
A video that describes data logger programming using ***Short Cut*** is available at: www.campbellsci.com/videos/cr1000x-data logger-getting-started-program-part-3. ***Short Cut*** is an easy way to program your data logger to measure the sensor and assign data logger wiring terminals. ***Short Cut*** is available as a download on www.campbellsci.com. It is included in installations of ***LoggerNet***, ***RTDAQ***, and ***PC400***.

The following procedure also shows using ***Short Cut*** to program the SN500SS.

1. Open ***Short Cut*** and click **Create New Program**.
2. Double-click the data logger model.
3. In the **Available Sensors and Devices** box, type SN500SS or locate the sensor in the **Sensors > Meteorological > Solar Radiation** folder. Double-click **SN500SS**. Type the correct **SDI-12 Address**.

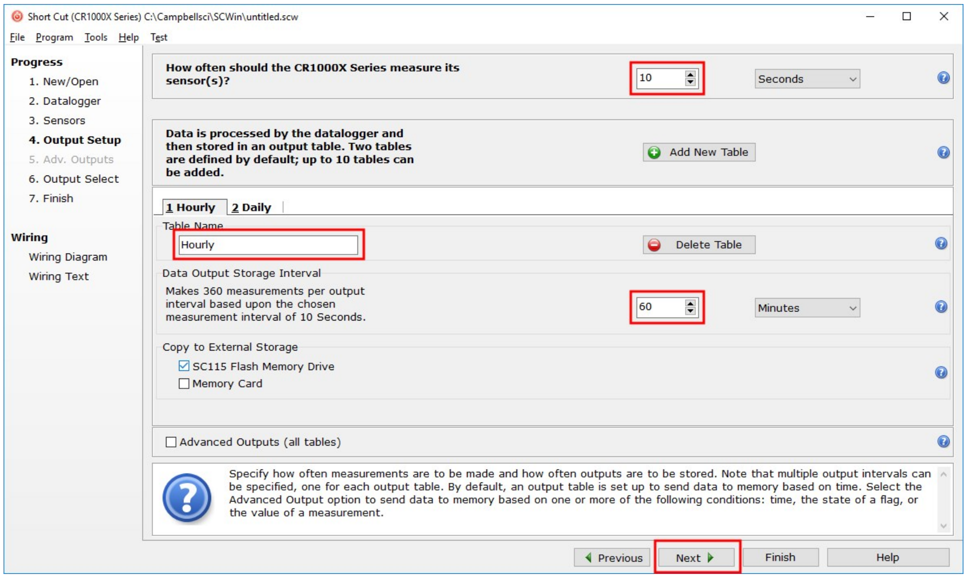


4. Click the **Wiring** tab to see how the sensor is to be wired to the data logger. Click **OK** after wiring the sensor.

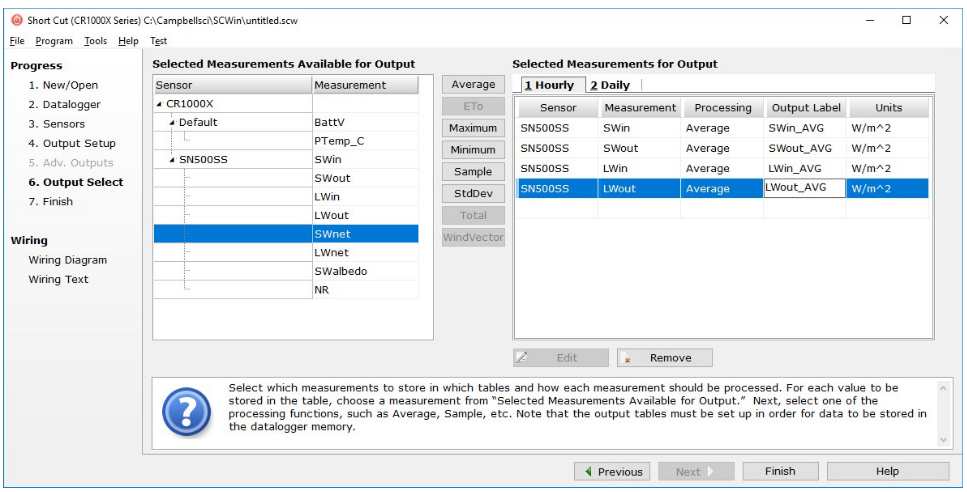


5. Repeat steps three and four for other sensors.
6. In **Output Setup**, type the scan rate, meaningful table names, and **Data Output Storage Interval**.

> **NOTE:**
> Because of the delays using SDI-12, Campbell Scientific recommends measurement scans of 10 seconds or more.



7. Select the measurement and its associated output option.



8. Click **Finish** and save the program. Send the program to the data logger if the data logger is connected to the computer.
9. If the sensor is connected to the data logger, check the output of the sensor in the data display in *LoggerNet*, *RTDAQ*, or *PC400* to make sure it is making reasonable measurements.

5. Overview

The SN500SS is a four-component instrument with individual upward- and downward-looking pyranometers and pyrgeometers. Each radiometer consists of a thermopile detector and filter mounted in an anodized aluminum housing. Each radiometer is heated to minimize the effects of dew, frost, snow, and ice on the filter and sensor head. Analog signals from each radiometer are measured with an onboard voltmeter and converted to SDI-12 outputs, eliminating the need for multiple analog data logger terminals to make the four-component measurement of net radiation. The SN500SS is small and lightweight to facilitate mounting.

Net radiation at Earth surface is the source of available energy that drives key processes, including surface and atmospheric heating, evaporation, sublimation, and transpiration. Shortwave radiation (approximately 280 to 4000 nm) is emitted by the sun, and a fraction incident at Earth's surface is reflected. Longwave radiation (approximately 4000 to 100,000 nm) is emitted by molecules in the atmosphere and land surfaces. Net radiation is the difference between incoming (downwelling) and outgoing (upwelling) shortwave and longwave radiation. Net radiation at Earth surface is spatially and temporally variable due to changes in position of the sun with respect to Earth's surface, changes in atmospheric conditions, and differences in land surface conditions. Shortwave radiation accounts for a larger proportion of net radiation during the day when the sun is shining. Longwave radiation contributes to net radiation during the day and at night.

Net shortwave radiation is the difference between incoming shortwave (from sun, SW_i) and outgoing shortwave (reflected by surface, SW_o). Net longwave radiation is the difference between incoming longwave (emitted by molecules in the atmosphere, LW_i) and outgoing longwave (emitted by elements at the surface, LW_o). Net radiation is the sum of net shortwave and net longwave radiation. Net radiation changes with solar zenith angle, atmospheric conditions (for example, degree of cloudiness), and surface conditions (for example, bare soil, plant cover, snow).

Typical applications of net radiometers include measurement of net radiation on surface flux towers and weather stations. Net radiation is a key variable in the surface energy balance and influences turbulent fluxes, including evapotranspiration.

Features:

- Individual measurement of four net radiation components
- SDI-12 output, eliminating the need for multiple analog terminals to measure the individual components of net radiation
- Complete package that includes net radiometer, mounting rod, cable for data logger interface, and carrying case
- Compatible with Campbell Scientific CRBasic data loggers: GRANITE-series, CR6, CR3000, CR1000Xe, CR1000X, CR800-series, CR300-series, CR1000

6. Specifications

Pyranometer spectral response:	385 to 2105 nm (upward-looking) 295 to 2685 nm (downward-looking)
Pyranometer sensitivity range:	0.057 mV per W/m^2 (upward-looking) 0.15 mV per W/m^2 (downward-looking)
Pyranometer expected output range:	0 to 114 mV (upward-looking) 0 to 300 mV (downward-looking)
Pyrgeometer spectral response:	5,000 to 30,000 nm
Pyrgeometer sensitivity range:	0.12 mV per W/m^2
Pyrgeometer expected output range:	–24 to 24 mV
Operating temperature range:	–50 to 80 °C
Relative humidity:	0 to 100%
Response time:	1 s (SDI-12 data transfer rate; detector response times are 0.5 s)
Heater current drain (at 12 VDC):	63 mA (heaters on; communication enabled) 1.5 mA (heaters off; communication enabled) 0.6 mA (heaters off; communication disabled)
Dimensions:	11.6 x 4.5 x 6.6 cm (4.6 x 1.8 x 2.6 in)
Weight:	320 g (11.29 oz) with mounting rod and 5 m (16.4 ft) cable
Compliance:	View compliance documents at: www.campbellsci.com/sn500ss

7. Installation

If you are programming your data logger with ***Short Cut***, skip Wiring to the data logger (p. 7) and Programming (p. 7). ***Short Cut*** does this work for you. See QuickStart (p. 1) for a tutorial.

7.1 Wiring to the data logger

Connect the SN500SS to the data logger in the order shown in Table 7-1 (p. 7).

Table 7-1: Wire color, function, and data logger connection

Wire color	Wire function	Data logger connection
White	SDI-12 signal	**C**, **SDI-12**, or **U** configured for SDI-12[1]
Clear	Shield	**G**
Red	Power	**12V**
Black	Power ground	**G**

[1] **U** and **C** terminals are automatically configured by the measurement instruction.

For the CR6 and CR1000X data loggers, triggering conflicts may occur when a companion terminal is used for a triggering instruction such as `TimerInput()`, `PulseCount()`, or `WaitDigTrig()`. For example, if the SN500SS is connected to C3 on a CR1000X, C4 cannot be used in the `TimerInput()`, `PulseCount()`, or `WaitDigTrig()` instructions.

7.2 Programming

Short Cut is the best source for up-to-date programming code for Campbell Scientific data loggers. If your data acquisition requirements are simple, you can probably create and maintain a data logger program exclusively with ***Short Cut***. If your data acquisition needs are more complex, the files that ***Short Cut*** creates are a great source for programming code to start a new program or add to an existing custom program.

> NOTE:
> ***Short Cut*** cannot edit programs after they are imported and edited in ***CRBasic Editor***.

A ***Short Cut*** tutorial is available in QuickStart (p. 1). If you wish to import ***Short Cut*** code into ***CRBasic Editor*** to create or add to a customized program, follow the procedure in Importing Short Cut code into CRBasic Editor (p. 15). Programming basics for CRBasic data loggers are provided in the following section. Downloadable example program is available at www.campbellsci.com/downloads/sn500ss-example-program.

7.2.1 CRBasic programming

The `SDI12Recorder()` instruction is used to measure an SN500SS. This instruction sends a request to the sensor to make a measurement and then retrieves the measurement from the sensor. See Sensor measurements (p. 11) for more information.

For most data loggers, the `SDI12Recorder()` instruction has the following syntax:

```
SDI12Recorder(Destination, SDIPort, SDIAddress, “SDICommand”, Multiplier, Offset,
FillNAN, WaitonTimeout)
```

For the `SDIAddress`, alphabetical characters need to be enclosed in quotation marks (for example, `“A”`). Also enclose the `SDICommand` in quotation marks as shown. The `Destination` parameter must be an array. The required number of values in the array depends on the command (see Table 8-1 [p. 12]).

`FillNAN` and `WaitonTimeout` are optional parameters (refer to the ***CRBasic Editor*** help for more information).

7.3 Siting

Mount the sensor so no shadows or reflections will be cast on it at any time of day from obstructions such as trees, buildings, or the mast or structure on which it is mounted. For the lower sensors, 99% of the input comes from a circular area with a radius of ten times the mounting height. For example, if the instrument is mounted 6 m above the surface, 99% of the input of the lower sensors comes from a circular area with a 60 m radius.

To avoid shading or reflection effects and to promote spatial averaging, the SN500SS should be mounted at least 1.5 m (5 ft) above the ground or crop surface. Campbell Scientific recommends that the SN500SS be mounted to a separate vertical pipe at least 7.6 m (25 ft) from any other mounting structures.

The sensor should be mounted with the cable pointing towards the nearest magnetic pole. For example, in the Northern Hemisphere, point the cable toward the North Pole.

7.4 Mounting

The SN500SS mounting kit secures the sensor directly to a vertical pipe, or to a CM202, CM203, CM204, or CM206 crossarm. Mount the sensor as follows:

1. Attach the mounting rod to the SN500SS (Figure 7-1 [p. 9] and Figure 7-2 [p. 9]).

Figure 7-1. Back of SN500SS shows the mounting rod port (left) and cable connector

Figure 7-2. Back of SN500SS with the mounting rod and cable connected

2. Attach the mounting bracket to the vertical mounting pipe, or CM200-series crossarm using the provided U-bolt (Figure 7-3 [p. 10]). If mounted to a vertical pipe, ensure that the pipe does not cast a reflection on the sensor. This includes both the incoming and outgoing sections of the sensor.

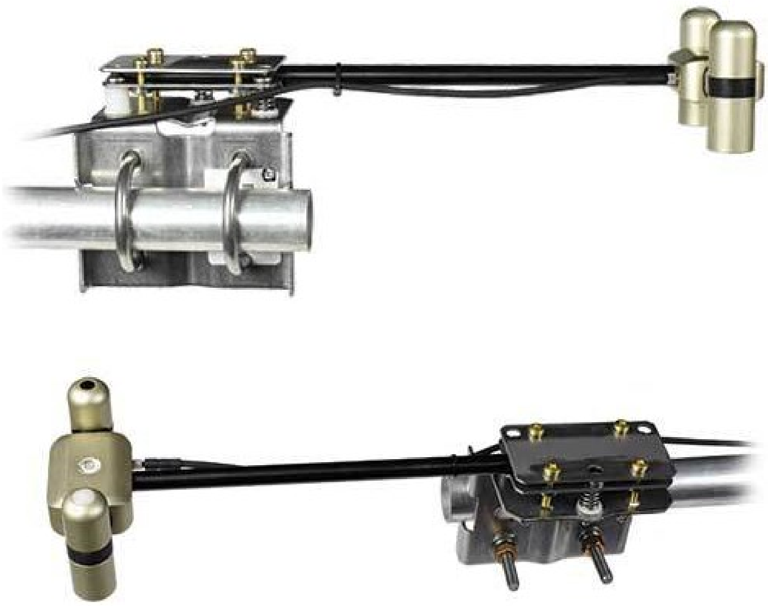


Figure 7-3. Two views of the SN500SS mounted to a horizontal crossarm

3. Insert the sensor support arm into the mounting block of the mounting bracket kit (Figure 7-3 [p. 10]). Make sure the sensor points in the direction of the arrows that appear after the word SENSOR on top of the bracket.

   > **CAUTION:**
   > Do not attempt to rotate the instrument using the sensor heads, or you may damage the sensors; use the mounting rod only.

4. Perform a coarse leveling of the sensor using the sensor bubble level.
5. Tighten the four screws on top of the mounting bracket to properly secure the support arm so that it does not rotate (Figure 7-3 [p. 10]).

   > **CAUTION:**
   > The four screws need to be tightened evenly to ensure that the screwhead is in full contact with the V-plate.

6. Perform the fine leveling using the three spring-loaded leveling screws.
7. Plug the sensor cable into the connector and route the cable to the instrument enclosure.
8. Use the UV-resistant cable ties included with the tripod or tower to secure the cable to the vertical pipe or crossarm and tripod/tower.

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8.1 Sensor measurements

The SN500SS responds to the SDI-12 commands shown in Table 8-1 (p. 12). When using an `M!`, `M1!`, `M2!`, `M3!`, or `M4!` command, the data logger waits for the time specified by the sensor, sends the `D!` command, pauses its operation, and waits until either it receives the data from the sensor or the sensor timeout expires. If the data logger receives no response, it will send the command a total of three times, with three retries for each attempt, or until a response is received. Because of the delays this command requires, it is only recommended in measurement scans of 10 seconds or more.

A `C!`, `C1!`, `C2!`, `C3!`, or `C4!` command follows the same pattern as an `M!`, `M1!`, `M2!`, `M3!`, or `M4!` command with the exception that it does not require the data logger to pause its operation until the values are ready. Rather, the data logger picks up the data with the `D!` command on the next pass through the program. Another measurement request is then sent so that data is ready on the next scan.

NOTE:
This section briefly describes using the SDI-12 commands. Additional SDI-12 information is available in SDI-12 sensor support (p. 16), or at www.sdi-12.org.

The `MC!` and `CC!` commands are the same as the previous commands, but where the C at the end of the command forces a validation for the data received from the sensor using a checksum. If the checksum is invalid, the data logger will re-request the data up to three times. The checksum validation increases the measurement time by about 40 milliseconds if there are no errors. Retries will increase the measurement time in proportion to the number of retries. The checksum option is necessary only for long cable lengths or when electronic noise may impact measurement transmission to the data logger.

Table 8-1: SN500SS SDI-12 commands		
SI-12 command (*a* is the sensor address)	Values returned or function	Units
*a*M!, *a*C!, *a*MC!, or *a*CC!	1. Incoming short-wave (SW) radiation 2. Outgoing SW radiation 3. Incoming long-wave (LW) radiation 4. Outgoing LW radiation	W m^{-2} W m^{-2} W m^{-2} W m^{-2}
*a*M1!, *a*C1!, *a*MC1!, or *a*CC1!	1. Net SW 2. Net LW 3. Total Net Radiation	W m^{-2} W m^{-2} W m^{-2}
*a*M2!, *a*C2!, *a*MC2!, or *a*CC2!	1. Voltage signal for incoming SW 2. Voltage signal for outgoing SW	mV mV
*a*M3!, *a*C3!, *a*MC3!, or *a*CC3!	1. Voltage signal for incoming LW 2. Sensor body temperature for incoming LW 3. Voltage signal for outgoing LW 4. Sensor body temperature for outgoing LW	mV °C mV °C
*a*M4!, *a*C4!, *a*MC4!, or *a*CC4!	Albedo	W m^{-2}
*a*XHON!	Turn heater on	
*a*XHOFF!	Turn heater off	
?!	Returns the SDI-12 Address	

See SDI-12 sensor support (p. 16) for additional commands and details of the SDI-12 protocol.

8.2 Long cables

The SDI-12 standard specifies the maximum total cable length to be 61 m (200 ft). Digital data transfer eliminates offset errors due to cable lengths. However, digital communications can break down when cables are too long, resulting in either no response from the sensor or corrupted readings.

9. Maintenance, calibration, and troubleshooting

> **NOTE:**
> All factory repairs and recalibrations require a returned material authorization (RMA) and completion of the "Statement of Product Cleanliness and Decontamination" form. Refer to the Assistance page for more information.

9.1 Maintenance

Moisture or debris on the filters (diffuser for upward-looking pyranometer, glass window for downward-looking pyranometer, silicon windows for pyrgeometers) is a common cause of errors. Remove dust or organic deposits by using water or window cleaner and a soft cloth or cotton swab. Remove salt deposits by using vinegar and a soft cloth or cotton swab.

> **CAUTION:**
> Never use an abrasive material or cleaner on the diffuser.

9.2 Calibration

The Clear Sky Calculator (www.clearskycalculator.com) can be used to determine the need for pyranometer recalibration. It determines total shortwave radiation incident on a horizontal surface at any time of day at any location in the world. It is most accurate when used near solar noon in spring and summer months, where accuracy over multiple clear and unpolluted days is estimated to be ±4% in all climates and locations around the world. For best accuracy, the sky must be completely clear, as reflected radiation from clouds causes incoming radiation to increase above the value predicted by the clear sky calculator. Measured values of total shortwave radiation can exceed values predicted by the Clear Sky Calculator due to reflection from thin, high clouds and edges of clouds, which enhances incoming shortwave radiation. The influence of high clouds typically shows up as spikes above clear sky values, not a constant offset greater than clear sky values.

To determine recalibration need, input site conditions into the calculator and compare total shortwave radiation measurements to calculated values for a clear sky. If sensor shortwave radiation measurements over multiple days near solar noon are consistently different than calculated values (by more than 6 %), the sensor should be cleaned and re-leveled. If measurements are still different after a second test, return to Campbell Scientific for recalibration (see Assistance page).

9.3 Troubleshooting

Symptom: –9999 or NAN readings

1. Check that the sensor is wired to the control or U terminal specified by the `SDI12Recorder()` instruction.
2. Check the voltage to the sensor with a digital voltage meter. If a switched 12V terminal is used, temporarily connect the red wire to a 12V terminal (non-switched) for test purposes.
3. Verify the probe SDI-12 address matches the address entered for the `SDI12Recorder()` instruction. The address can be verified or changed with the commands described in SDI-12 sensor support (p. 16).

Appendix A. Importing *Short Cut* code into *CRBasic Editor*

Short Cut creates a .DEF file that contains wiring information and a program file that can be imported into ***CRBasic Editor***. By default, these files reside in the C:\campbellsci\SCWin folder.

Import ***Short Cut*** program file and wiring information into ***CRBasic Editor***:

1. Create the ***Short Cut*** program, then save it. Click the **Advanced** tab then the **CRBasic Editor** button. Your program file will open in CRBasic with a generic name. Provide a meaningful name and save the CRBasic program. This program can now be edited for additional refinement.

   > **NOTE:**
   > Once the file is edited with ***CRBasic Editor***, ***Short Cut*** can no longer be used to edit the program.

2. To add the ***Short Cut*** wiring information into the new CRBasic program, open the .DEF file located in the C:\campbellsci\SCWin folder. Copy the wiring information found at the beginning of the .DEF file.
3. Go into the CRBasic program and paste the wiring information at the beginning of the program.
4. In the CRBasic program, highlight the wiring information, right-click, and select **Comment Block**. This adds an apostrophe (') to the beginning of each of the highlighted lines, which instructs the data logger compiler to ignore those lines when compiling. The **Comment Block** feature is demonstrated at about 5:10 in the CRBasic | Features video ▶.

Appendix B. SDI-12 sensor support

Serial Data Interface at 1200 baud (SDI-12) is a protocol developed to simplify sensor and data logger compatibility. Only three wires are necessary—serial data, ground, and 12 V. With unique addresses, multiple SDI-12 sensors can connect to a single SDI-12 terminal on a Campbell Scientific data logger.

This appendix discusses the structure of SDI-12 commands and the process of querying SDI-12 sensors. For more detailed information, refer to version 1.4 of the SDI-12 protocol, available at www.sdi-12.org.

For additional information, refer to the SDI-12 Sensors | Transparent Mode and SDI-12 Sensors | Watch or Sniffer Mode videos and the SDI-12 Sensors Troubleshooting Tips application note.

B.1 SDI-12 command basics

SDI-12 commands have three components:

- **Sensor address (a)** – a single character and the first character of the command. Use the default address of zero (0) unless multiple sensors are connected to the same port.
- **Command body** – an uppercase letter (the "command"), optionally followed by one or more alphanumeric qualifiers.
- **Command termination (!)** – an exclamation mark.

An active sensor responds to each command. Responses have several standard forms and always terminate with <CR><LF> (carriage return and line feed). Standard SDI-12 commands are listed in Table B-1 (p. 16).

Table B-1: Campbell Scientific sensor SDI-12 command and response set

Name	Command[1]	Response
Acknowledge active	`a!`	a<CR><LF>
Send identification	`aI!`	allccccccccmmmmmmvvvxxx...xx <CR><LF>

Table B-1: Campbell Scientific sensor SDI-12 command and response set

Name	Command[1]	Response
Start verification	`aV!`	atttn<CR><LF>
Address query	`?!`	a<CR><LF>
Change address	`aAb!`	b<CR><LF>
Start measurement	`aM!` `aM1!...aM9!`	atttn<CR><LF>
Start measurement and request CRC	`aMC!` `aMC1!...aMC9!`	atttn<CR><LF>
Start concurrent measurement	`aC!` `aC1!...aC9!`	atttnn<CR><LF>
Start doncurrent measurement and request CRC	`aCC!` `aCC1!...aCC9!`	atttnn<CR><LF>
Send data	`aD0!...aD9!`	a<values><CR><LF> or a<values><CRC><CR><LF>
Continuous measurement	`aR0!...aR9!`	a<values><CR><LF>
Continuous measurement and request CRC	`aRC0!...aRC9!`	a<values><CRC><CR><LF>
Extended commands	`aXNNN!`	a<values><CR><LF>

[1] Information on each of these commands is given in the following sections.

B.1.1 Acknowledge active command (a!)

The acknowledge active command (`a!`) is used to test a sensor on the SDI-12 bus. An active sensor responds with its address.

B.1.2 Send identification command (aI!)

Sensor identifiers are requested by issuing command `aI!`. The reply is defined by the sensor manufacturer but usually includes the sensor address, SDI-12 version, manufacturer name, and sensor model information. Serial number or other sensor-specific information may also be included. Source: SDI-12: A Serial-Digital Interface Standard for Microprocessor-Based Sensors (see References [p. 25]).

Command: `aI!`

Response: *allccccccccmmmmmmvvvxxx...xx*<CR><LF>

Where

a = sensor address

ll = SDI-12 version number (indicates compatibility)

cccccccc = eight-character vendor identification

mmmmmm = six characters specifying the sensor model

vvv = three characters specifying the sensor version (operating system)

xxx...xx = up to 13 optional characters used for a serial number or other specific sensor information that is not relevant for operation of the data logger

<CR><LF> = terminates the response

B.1.3 Start verification command (aV!)

The response to a start verification command can include hardware diagnostics, but like the `aI!` command, the response is not standardized.

Command: `aV!`

Response: *atttfffhhhhn<CR><LF>*

Where

a = sensor address

ttt = time, in seconds, until verification information is available

fff = firmware (OS) version

hhh = hardware version

n = number of values to be returned when one or more subsequent `D!` commands are issued

B.1.4 Address query command (?!)

Command `?!` requests the address of the connected sensor. The sensor replies to the query with the address(*a*). This command should only be used with one sensor on the SDI-12 bus at a time.

B.1.5 Change address command (aAb!)

Multiple SDI-12 sensors can connect to a single SDI-12 terminal on a data logger. Each device on a single terminal must have a unique address.

A sensor address is changed with command **aAb!**, where *a* is the current address and *b* is the new address. For example, to change an address from *0* to *2*, the command is **0A2!**. The sensor responds with the new address *b*, which in this case is 2.

> NOTE:
> Only one sensor should be connected to a particular terminal at a time when changing addresses.

B.1.6 Start measurement commands (aM!)

A measurement is initiated with the M! command. The response to each command has the form *atttn<CR><LF>*, where

a = sensor address

ttt = time, in seconds, until measurement data is available; when the data is ready, the sensor notifies the data logger, and the data logger begins issuing D commands

n = number of values returned when one or more subsequent D commands are issued; for the aM! command, *n* is an integer from 0 to 9

When aM! is issued, the data logger pauses its operation and waits until either it receives the data from the sensor or the time (*ttt*) expires. Depending on the scan interval of the data logger program and the response time of the sensor, this may cause skipped scans to occur. To avoid this, make sure your scan interval is longer than the longest measurement time (*ttt*).

Table B-2: Example aM! sequence

0M!	The data logger makes a request to sensor 0 to start a measurement.
00352<CR><LF>	Sensor 0 immediately indicates that it will return two values within the next 35 seconds.
0<CR><LF>	Within 35 seconds, sensor 0 indicates that it has completed the measurement by sending a service request to the data logger.
0D0!	The data logger immediately issues the first D command to collect data from the sensor.
0+.859+3.54<CR><LF>	The sensor immediately responds with the sensor address and the two values.

B.1.7 Start concurrent measurement commands (aC!)

A concurrent measurement (aC!) command follows the same pattern as the aM! command, with the exception that it does not require the data logger to pause its operation, and other SDI-12 sensors may take measurements at the same time. The sensor will not issue a service request to notify the data logger that the measurement is complete. The data logger will issue the **aD0!** command during the next scan after the measurement time reported by the sensor has expired. To use this command, the scan interval should be 10 seconds or less. The response to each command has the form *atttn<CR><LF>*, where

a = sensor address

ttt = time, in seconds, until measurement data is available

nn = number of values to be returned when one or more subsequent **D** commands are issued

See the example in Table B-3 (p. 20). A data logger has three sensors wired into terminal **C1**. The sensors are addresses X, Y, and Z. The data logger will issue the following commands and receive the following responses:

Table B-3: Example aC! sequence

XC!	The data logger makes a request to sensor X to start a concurrent measurement.
X03005<CR><LF>	Sensor X immediately indicates that it will have five (05) values ready for collection within the next 30 (030) seconds.
YC!	The data logger makes a request to sensor Y to start a concurrent measurement.
Y04006<CR><LF>	Sensor Y immediately indicates that it will have six (06) values ready for collection within the next 40 (040) seconds.
ZC!	The data logger makes a request to sensor Z to start a concurrent measurement.
Z02010<CR><LF>	Sensor Z immediately indicates that it will have ten (10) values ready for collection within the next 20 (020) seconds.
ZD0!	After 20 seconds have passed, the data logger starts the process of collecting the data by issuing the first **D** command to sensor Z.
Z+1+2+3+4+5+6+7+8+9+10<CR><LF>	Sensor Z immediately responds with the sensor address and the ten values.

Table B-3: Example aC! sequence	
XD0!	10 seconds later, after a total of 30 seconds has passed, the data logger starts the process of collecting data from sensor X by issuing the first **D** command.
X+1+2+3+4+5<CR><LF>	The sensor immediately responds with the sensor address and the five values.
YD0!	10 seconds later, after a total of 40 seconds has passed, the data logger starts the process of collecting data from sensor Y by issuing the first **D** command.
Y+1+2+3+4+5+6<CR><LF>	The sensor immediately responds with the sensor address and the six values.

B.1.8 Start measurement commands with cyclic redundancy check (aMC! and aCC!)

Error checking is done by using measurement commands with cyclic redundancy checks (**aMC!** or **aCC!**). This is most commonly implemented when long cable lengths or electronic noise may impact measurement transmission to the data logger. When these commands are used, the data returned in response to **D** or **R** commands must have a cyclic redundancy check (CRC) code appended to it. The CRC code is a 16-bit value encoded within three characters appended before the <CR><LF>. This code is not returned in the data table but checked by the data logger as it comes. The code returned is based on the SDI-12 protocol. See the SDI-12 communication specification for version 1.4, available at www.sdi-12.org, to learn more about how the CRC code is developed.

B.1.9 Stopping a measurement command

A measurement command (**M!**) is stopped if it detects a break signal before the measurement is complete. A break signal is sent by the data logger before most commands.

A concurrent measurement command (**C!**) is aborted when another valid command is sent to the sensor before the measurement time has elapsed.

B.1.10 Send data command (aD0! ... aD9!)

The send data command requests data from the sensor. It is issued automatically with every type of measurement command (`aM!`, `aMC!`, `aC!`, `aCC!`). When the measurement command is `aM!` or `aMC!`, the data logger issues the `aD0!` command once a service request has been received from the sensor or the reported time has expired. When the data logger is issuing concurrent commands (`aC!` or `aCC!`), the send data command is issued after the required time has elapsed (no service request will be sent by the sensor). In transparent mode (see SDI-12 transparent mode [p. 23]), the user asserts this command to obtain data.

Depending on the type of data returned and the number of values a sensor returns, the data logger may need to issue `aD0!` up to `aD9!` to retrieve all data. A sensor may return up to 35 characters of data in response to a `D` command that follows an `M!` or `MC!` command. A sensor may return up to 75 characters of data in response to a `D` command that follows a `C!` or `CC!` command. Data values are separated by plus or minus signs.

Command: `aD0!` (`aD1!` ... `aD9!`)

Response: *a<values><CR><LF>* or *a<values><CRC><CR><LF>*

where

a = sensor address

<values> = values returned with a polarity sign (+ or –)

<CR><LF> = terminates the response

<CRC> = 16-bit CRC code appended if data was requested with `aMC!` or `aCC!`

B.1.11 Continuous measurement command (aR0! ... aR9!)

Sensors that are able to continuously monitor the phenomena to be measured can be read directly with the `R` commands (`R0!` ... `R9!`). The response to `R` commands mirrors the send data command (`aD0!`). A maximum of 75 characters can be returned in the *<values>* part of the response to the `R` command.

B.1.12 Extended commands

Many sensors support extended SDI-12 commands. An extended command is specific to a make of sensor and tells the sensor to perform a specific task. They have the following structure. Responses vary from unit to unit. See the sensor manual for specifics.

Command: `aXNNNN!`

The command will start with the sensor address (*a*), followed by an **X** then a set of optional letters, and terminate with an exclamation point.

Response: *a<optional values><CR><LF>*

The response will start with the sensor address and end with a carriage return/line feed.

B.2 SDI-12 transparent mode

System operators can manually interrogate and enter settings in probes using transparent mode. Transparent mode is useful in troubleshooting SDI-12 systems because it allows direct communication with probes. Data logger security may need to be unlocked before activating the transparent mode.

Transparent mode is entered while the computer is communicating with the data logger through a terminal emulator program. It is accessed through Campbell Scientific data logger support software or other terminal emulator programs. Data logger keyboards and displays cannot be used.

The terminal emulator is accessed through Campbell Scientific ***Device Configuration Utility*** software.

Watch videos/sdi12-sensors-transparent-mode from the Campbell Scientific website.

Data loggers from other manufacturers will also have a transparent mode. Refer to those manuals for information on how to use their transparent mode.

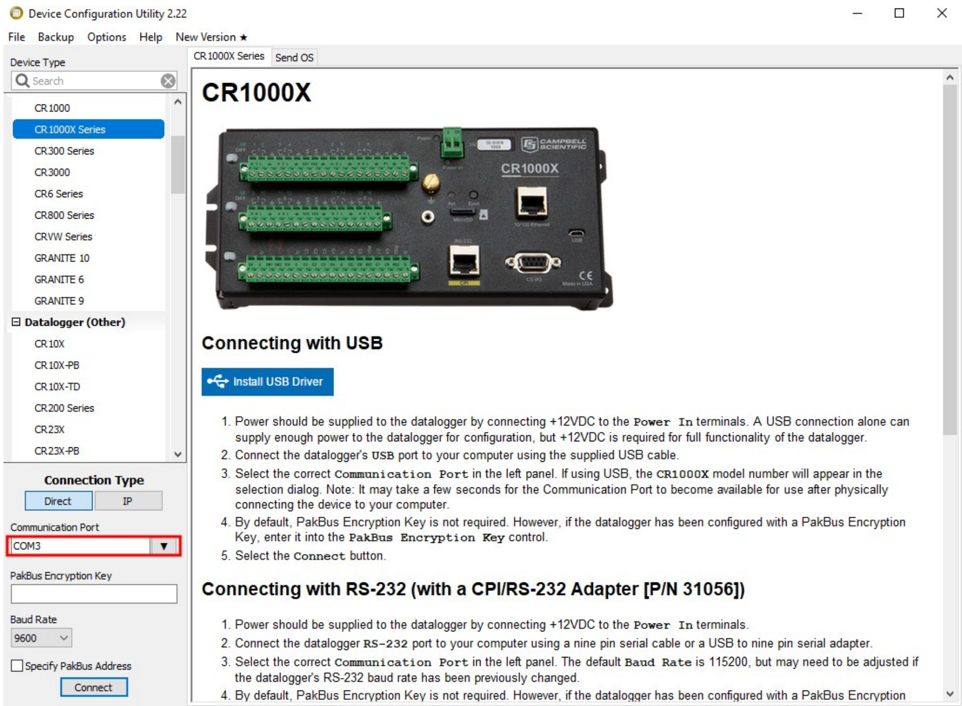
The following examples show how to enter transparent mode and change the SDI-12 address of an SDI-12 sensor. The steps shown in Changing an SDI-12 address (p. 23) are used with most Campbell Scientific data loggers.

B.2.1 Changing an SDI-12 address

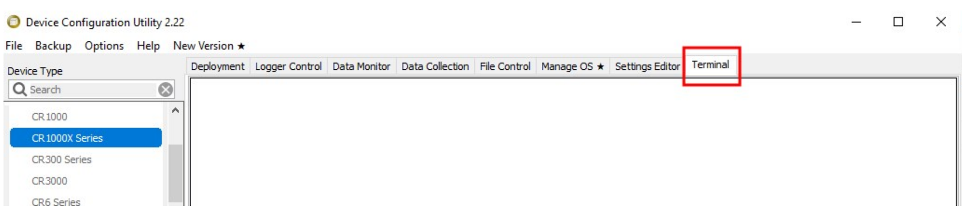
This example was done with a CR1000X, but the steps are only slightly different for Granite-series, CR6, CR800-series, CR300-series data loggers.

1. Connect an SDI-12 sensor to the CR1000X.
2. Open ***Device Configuration Utility***.
3. Under **Device Type**, type the data logger model and double-click on the model type. This example uses a CR1000X directly connected to the computer USB port.

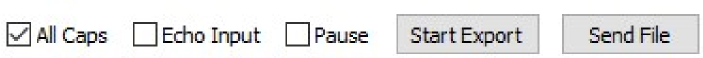
4. Select the correct **Communication Port** and click **Connect**.



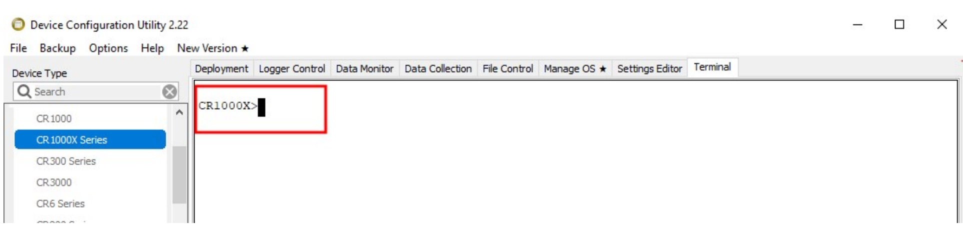
5. Click the **Terminal** tab.



6. Select **All Caps Mode**.



7. Press **Enter** until the data logger responds with the data logger (**CR1000X>**) prompt.



8. Type **SDI12** and press Enter.
9. At the **Select SDI12 Port** prompt, type the number corresponding to the control port where the sensor is connected and press **Enter**. In this example the sensor is connected to C3. The

response **Entering SDI12 Terminal** indicates that the sensor is ready to accept SDI-12 commands.

```
CR1000X>
CR1000X>SDI12
1: C1
2: C3
3: C5
4: C7
Select SDI12 Port: 2
```

10. To query the sensor for its current SDI-12 address, type **?!** and press **Enter**. The sensor responds with its SDI-12 address. If no characters are typed within 60 seconds, the mode is exited. In that case, simply type **SDI12** again, press **Enter**, and type the correct control port number when prompted.

```
?!
0
```

11. To change the SDI-12 address, type **aAb!**, where **a** is the current address from the previous step and **b** is the new address. Press **Enter**. The sensor changes its address and responds with the new address. In the following example, the sensor address is changed from 0 to B.

```
SDI12
SDI12>0AB!B
```

12. To exit SDI-12 transparent mode, click **Close Terminal**.

> NOTE:
> The transparent mode for the Granite-series, CR6, CR3000, CR800-series, CR300-series data loggers is similar to that shown for the CR1000X.

B.3 References

SDI-12 Support Group. 2017. *SDI-12: A Serial-Digital Interface Standard for Microprocessor-Based Sensors – Version 1.4*. River Heights, UT: SDI-12 Support Group. http://www.sdi-12.org/current_specification/SDI-12_version-1_4-Dec-1-2017.pdf.

Limited warranty

Covered equipment is warranted/guaranteed against defects in materials and workmanship under normal use and service for the period listed on your sales invoice or the product order information web page. The covered period begins on the date of shipment unless otherwise specified. For a repair to be covered under warranty, the following criteria must be met:

1. There must be a defect in materials or workmanship that affects form, fit, or function of the device.

2. The defect cannot be the result of misuse.

3. The defect must have occurred within a specified period of time; and

4. The determination must be made by a qualified technician at a Campbell Scientific Service Center/ repair facility.

The following is not covered:

1. Equipment which has been modified or altered in any way without the written permission of Campbell Scientific.

2. Batteries; and

3. Any equipment which has been subjected to misuse, neglect, acts of God or damage in transit.

Campbell Scientific regional offices handle repairs for customers within their territories. Please see the back page of the manual for a list of regional offices or visit www.campbellsci.com/contact to determine which Campbell Scientific office serves your country. For directions on how to return equipment, see Assistance.

Other manufacturer's products, that are resold by Campbell Scientific, are warranted only to the limits extended by the original manufacturer.

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In the event of any conflict or inconsistency between the provisions of this Warranty and the provisions of Campbell Scientific's Terms, the provisions of Campbell Scientific's Terms shall prevail. Furthermore, Campbell Scientific's Terms are hereby incorporated by reference into this Warranty. To view Terms and conditions that apply to Campbell Scientific, Logan, UT, USA, see Terms and Conditions. To view terms and conditions that apply to Campbell Scientific offices outside of the United States, contact the regional office that serves your country.

Assistance

Products may not be returned without prior authorization. Please inform us before returning equipment and obtain a **return material authorization (RMA) number** whether the repair is under warranty/guarantee or not. See Limited warranty for information on covered equipment.

Campbell Scientific regional offices handle repairs for customers within their territories. Please see the back page of the manual for a list of regional offices or visit www.campbellsci.com/contact to determine which Campbell Scientific office serves your country.

When returning equipment, a RMA number must be clearly marked on the outside of the package. Please state the faults as clearly as possible. Quotations for repairs can be given on request.

It is the policy of Campbell Scientific to protect the health of its employees and provide a safe working environment. In support of this policy, when equipment is returned to Campbell Scientific, Logan, UT, USA, it is mandatory that a "Declaration of Hazardous Material and Decontamination" form be received before the return can be processed. If the form is not received within 5 working days of product receipt or is incomplete, the product will be returned to the customer at the customer's expense. For details on decontamination standards specific to your country, please reach out to your regional Campbell Scientific office.

> **NOTE:**
> All goods that cross trade boundaries may be subject to some form of fee (customs clearance, duties or import tax). Also, some regional offices require a purchase order upfront if a product is out of the warranty period. Please contact your regional Campbell Scientific office for details.

Safety

DANGER — MANY HAZARDS ARE ASSOCIATED WITH INSTALLING, USING, MAINTAINING, AND WORKING ON OR AROUND TRIPODS, TOWERS, AND ANY ATTACHMENTS TO TRIPODS AND TOWERS SUCH AS SENSORS, CROSSARMS, ENCLOSURES, ANTENNAS, ETC. FAILURE TO PROPERLY AND COMPLETELY ASSEMBLE, INSTALL, OPERATE, USE, AND MAINTAIN TRIPODS, TOWERS, AND ATTACHMENTS, AND FAILURE TO HEED WARNINGS, INCREASES THE RISK OF DEATH, ACCIDENT, SERIOUS INJURY, PROPERTY DAMAGE, AND PRODUCT FAILURE. TAKE ALL REASONABLE PRECAUTIONS TO AVOID THESE HAZARDS. CHECK WITH YOUR ORGANIZATION'S SAFETY COORDINATOR (OR POLICY) FOR PROCEDURES AND REQUIRED PROTECTIVE EQUIPMENT PRIOR TO PERFORMING ANY WORK.

Use tripods, towers, and attachments to tripods and towers only for purposes for which they are designed. Do not exceed design limits. Be familiar and comply with all instructions provided in product manuals. Manuals are available at www.campbellsci.com You are responsible for conformance with governing codes and regulations, including safety regulations, and the integrity and location of structures or land to which towers, tripods, and any attachments are attached. Installation sites should be evaluated and approved by a qualified engineer. If questions or concerns arise regarding installation, use, or maintenance of tripods, towers, attachments, or electrical connections, consult with a licensed and qualified engineer or electrician.

General

- Protect from over-voltage.
- Protect electrical equipment from water.
- Protect from electrostatic discharge (ESD).
- Protect from lightning.
- Prior to performing site or installation work, obtain required approvals and permits. Comply with all governing structure-height regulations, such as those of the FAA in the USA.
- Use only qualified personnel for installation, use, and maintenance of tripods and towers, and any attachments to tripods and towers. The use of licensed and qualified contractors is highly recommended.
- Read all applicable instructions carefully and understand procedures thoroughly before beginning work.
- Wear a hardhat and eye protection, and take other appropriate safety precautions while working on or around tripods and towers.
- Do not climb tripods or towers at any time, and prohibit climbing by other persons. Take reasonable precautions to secure tripod and tower sites from trespassers.
- Use only manufacturer recommended parts, materials, and tools.

Utility and Electrical

- You can be killed or sustain serious bodily injury if the tripod, tower, or attachments you are installing, constructing, using, or maintaining, or a tool, stake, or anchor, come in contact with overhead or underground utility lines.
- Maintain a distance of at least one-and-one-half times structure height, 6 meters (20 feet), or the distance required by applicable law, whichever is greater, between overhead utility lines and the structure (tripod, tower, attachments, or tools).
- Prior to performing site or installation work, inform all utility companies and have all underground utilities marked.
- Comply with all electrical codes. Electrical equipment and related grounding devices should be installed by a licensed and qualified electrician.
- Only use power sources approved for use in the country of installation to power Campbell Scientific devices.

Elevated Work and Weather

- Exercise extreme caution when performing elevated work.
- Use appropriate equipment and safety practices.
- During installation and maintenance, keep tower and tripod sites clear of un-trained or non-essential personnel. Take precautions to prevent elevated tools and objects from dropping.
- Do not perform any work in inclement weather, including wind, rain, snow, lightning, etc.

Internal Battery

- Be aware of fire, explosion, and severe-burn hazards.
- Misuse or improper installation of the internal lithium battery can cause severe injury.

- Do not recharge, disassemble, heat above 100 °C (212 °F), solder directly to the cell, incinerate, or expose contents to water. Dispose of spent batteries properly.

Use and disposal of batteries

- Where batteries need to be transported to the installation site, ensure they are packed to prevent the battery terminals shorting which could cause a fire or explosion. Especially in the case of lithium batteries, ensure they are packed and transported in a way that complies with local shipping regulations and the safety requirements of the carriers involved.
- When installing the batteries follow the installation instructions very carefully. This is to avoid risk of damage to the equipment caused by installing the wrong type of battery or reverse connections.
- When disposing of used batteries, it is still important to avoid the risk of shorting. Do not dispose of the batteries in a fire as there is risk of explosion and leakage of harmful chemicals into the environment. Batteries should be disposed of at registered recycling facilities.

Avoiding unnecessary exposure to radio transmitter radiation

- Where the equipment includes a radio transmitter, precautions should be taken to avoid unnecessary exposure to radiation from the antenna. The degree of caution required varies with the power of the transmitter, but as a rule it is best to avoid getting closer to the antenna than 20 cm (8 inches) when the antenna is active. In particular keep your head away from the antenna. For higher power radios (in excess of 1 W ERP) turn the radio off when servicing the system, unless the antenna is installed away from the station, e.g. it is mounted above the system on an arm or pole.

Maintenance

- Periodically (at least yearly) check for wear and damage, including corrosion, stress cracks, frayed cables, loose cable clamps, cable tightness, etc. and take necessary corrective actions.
- Periodically (at least yearly) check electrical ground connections.

WHILE EVERY ATTEMPT IS MADE TO EMBODY THE HIGHEST DEGREE OF SAFETY IN ALL CAMPBELL SCIENTIFIC PRODUCTS, THE CUSTOMER ASSUMES ALL RISK FROM ANY INJURY RESULTING FROM IMPROPER INSTALLATION, USE, OR MAINTENANCE OF TRIPODS, TOWERS, OR ATTACHMENTS TO TRIPODS AND TOWERS SUCH AS SENSORS, CROSSARMS, ENCLOSURES, ANTENNAS, ETC.

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