

# SN500SS

## Net Radiometer



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# 1. Introduction

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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

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- 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


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

## 4. QuickStart

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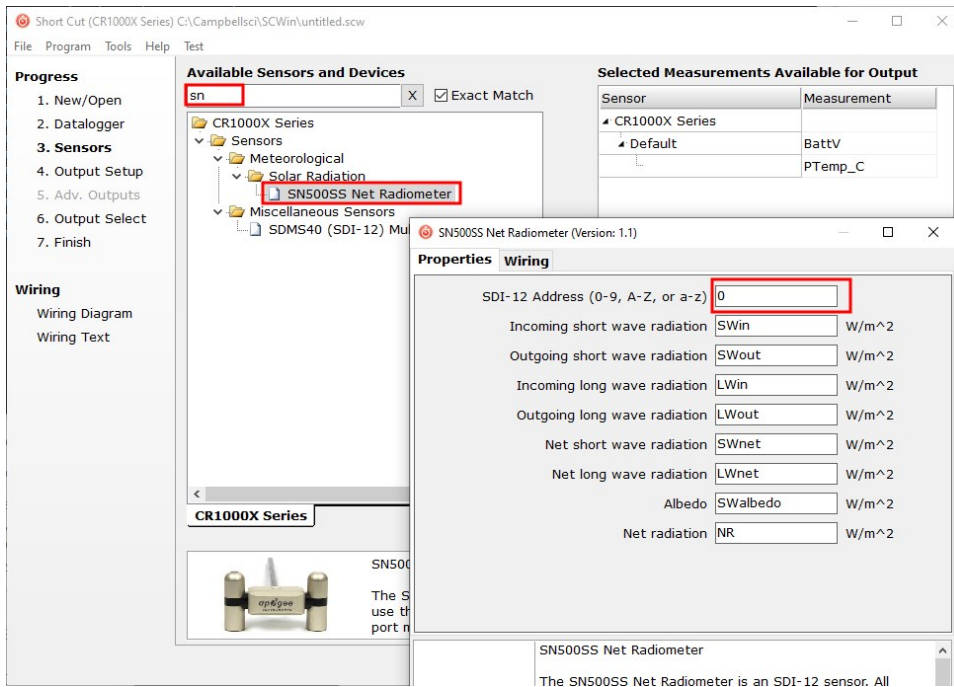
A video that describes data logger programming using *Short Cut* is available at:

[www.campbellsci.com/videos/cr1000x-data-logger-getting-started-program-part-3](http://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

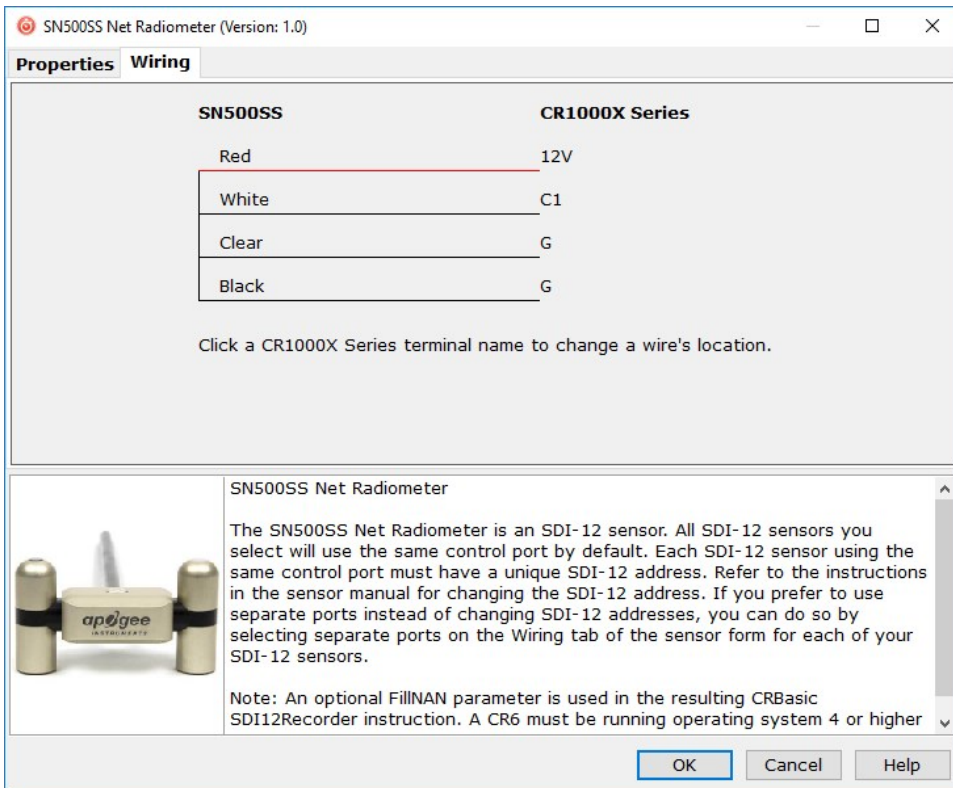
wiring terminals. *Short Cut* is available as a download on [www.campbellsci.com](http://www.campbellsci.com). It is included in installations of *LoggerNet*, *RTDAQ*, and *PC400*.

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**.



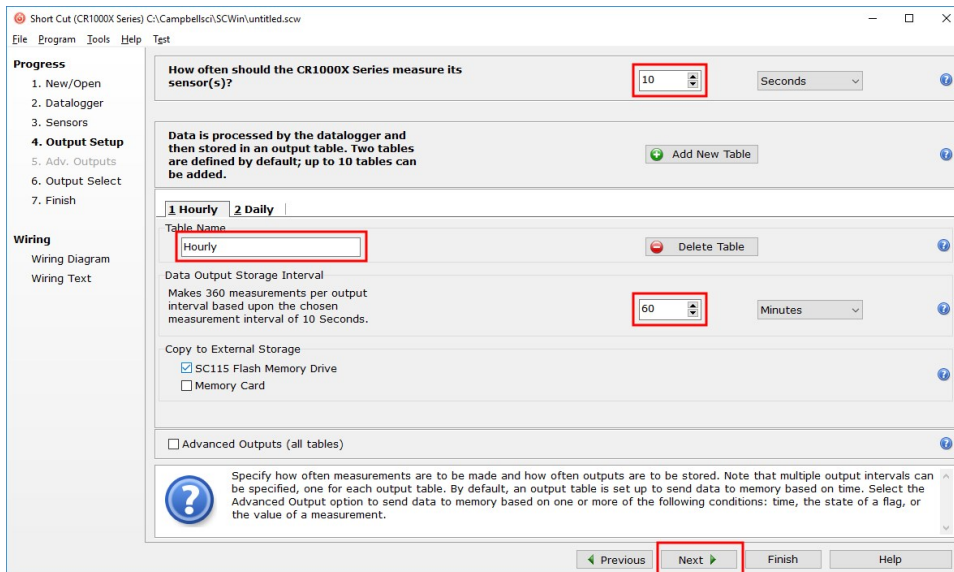
- Click the **Wiring** tab to see how the sensor is to be wired to the data logger. Click **OK** after wiring the sensor.



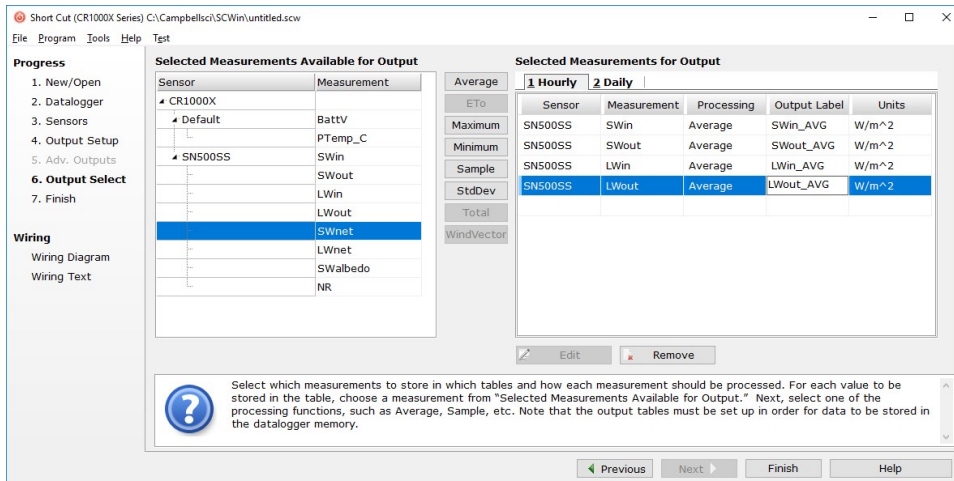
- Repeat steps three and four for other sensors.
- In **Output Setup**, type the scan rate, meaningful table names, and **Data Output Storage Interval**.

**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.



- Click **Finish** and save the program. Send the program to the data logger if the data logger is connected to the computer.
- 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, CR1000X, CR800-series, CR300-series, CR1000



# 6. Specifications

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Pyranometer spectral response:	385 to 2105 nm (upward-looking) 295 to 2685 nm (downward-looking)
Pyranometer sensitivity range:	0.057 mV per W/m <sup>2</sup> (upward-looking) 0.15 mV per W/m <sup>2</sup> (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 <sup>2</sup>
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: <a href="http://www.campbellsci.com/sn500ss">www.campbellsci.com/sn500ss</a> 

# 7. Installation

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If you are programming your data logger with *Short Cut*, skip [Wiring to the data logger](#) (p. 6) 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 <sup>1</sup>
Clear	Shield	G
Red	Power	12V
Black	Power ground	G

<sup>1</sup> 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](http://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 quotes (for example, “A”). Also enclose the **SDICommand** in quotes 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 CRBasic 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)).

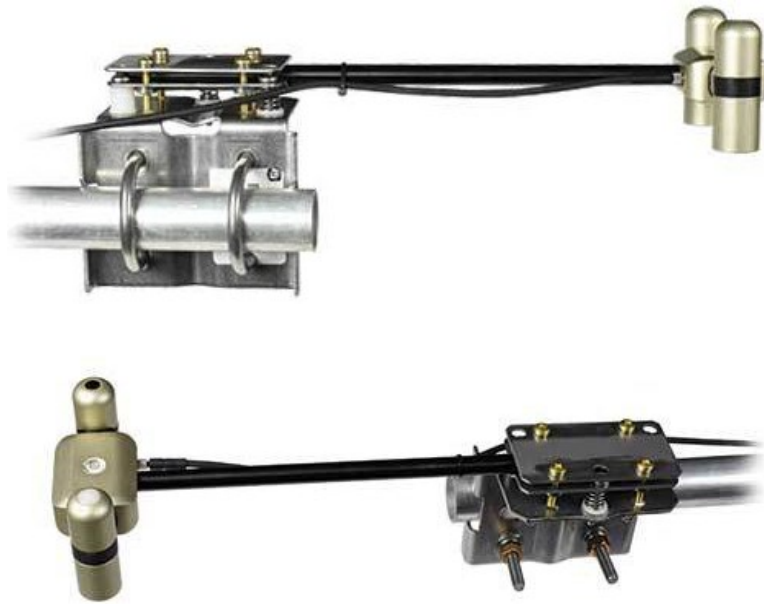


*FIGURE 7-1. Back of SN500SS shows the mounting rod port (left) and cable connector*



*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.

# 8. Operation


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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](http://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.

SI-12 command ( <i>a</i> is the sensor address)	Values returned or function	Units
<i>aM!</i> , <i>aC!</i> , <i>aMC!</i> , or <i>aCC!</i>	<ol style="list-style-type: none"> <li>1. Incoming short-wave (SW) radiation</li> <li>2. Outgoing SW radiation</li> <li>3. Incoming long-wave (LW) radiation</li> <li>4. Outgoing LW radiation</li> </ol>	$W m^{-2}$ $W m^{-2}$ $W m^{-2}$ $W m^{-2}$
<i>aM1!</i> , <i>aC1!</i> , <i>aMC1!</i> , or <i>aCC1!</i>	<ol style="list-style-type: none"> <li>1. Net SW</li> <li>2. Net LW</li> <li>3. Total Net Radiation</li> </ol>	$W m^{-2}$ $W m^{-2}$ $W m^{-2}$
<i>aM2!</i> , <i>aC2!</i> , <i>aMC2!</i> , or <i>aCC2!</i>	<ol style="list-style-type: none"> <li>1. Voltage signal for incoming LW</li> <li>2. Sensor body temperature for incoming LW</li> <li>3. Voltage signal for outgoing LW</li> <li>4. Sensor body temperature for outgoing LW</li> </ol>	mV °C mV °C
<i>aM4!</i> , <i>aC4!</i> , <i>aMC4!</i> , or <i>aCC4!</i>	Albedo	$W m^{-2}$
<i>aXHON!</i>	Turn heater on	
<i>aXHOFF!</i>	Turn heater off	
<i>?!</i>	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

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## 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 at the end of this manual 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](http://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  $\pm 4\%$  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*

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*Short Cut* creates a .DEF file that contains wiring information and a program file that can be imported into the *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. After saving the *Short Cut* program, click the **Advanced** tab then the **CRBasic Editor** button. A program file with a generic name will open in CRBasic. 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 it created.

2. To add the *Short Cut* wiring information into the new CRBasic program, open the .DEF file located in the C:\campbellsci\SCWin folder, and copy the wiring information, which is at the beginning of the .DEF file.
3. Go into the CRBasic program and paste the wiring information into it.
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

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SDI-12, Serial Data Interface at 1200 baud, 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](http://www.sdi-12.org) .

For additional information, refer to the [SDI-12 Sensors | Transparent Mode](#) and [SDI-12 Sensors | Watch or Sniffer Mode](#) videos.

## 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 upper case 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).

Name	Command	Response <sup>1</sup>
Acknowledge Active	a!	a<CR><LF>
Send Identification	aI!	allccccccmmmmmmvwx...xx <CR> <LF>
Start Verification	aV!	attn <CR> <LF>

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

Name	Command	Response <sup>1</sup>
Address Query	?!	a<CR><LF>
Change Address	aAb!	b<CR><LF>
Start Measurement	aM! aM1! . . . aM9!	attn<CR><LF>
Start Measurement and Request CRC	aMC! aMC1! . . . aMC9!	attn <CR><LF>
Start Concurrent Measurement	aC! aC1! . . . aC9!	attnn<CR><LF>
Start Concurrent Measurement and Request CRC	aCC! aCC1! . . . aCC9!	attnn<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>
<sup>1</sup> 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’s name, and sensor model information. Serial number or other sensor specific information may also be included.

aI!	allccccccmmmmmmvvvxxx...xx<CR><LF>
a	Sensor SDI-12 address
ll	SDI-12 version number (indicates compatibility)

ccccccc	8-character vendor identification
mmmmmm	6 characters specifying the sensor model
vvv	3 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
Source: SDI-12: A Serial-Digital Interface Standard for Microprocessor-Based Sensors (see References).	

### 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: *attn*<CR><LF>

*a* = sensor address

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

*n* = the 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 *attn*<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* = the 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 the **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. In this case make sure your scan interval is longer than the longest measurement time (*ttt*).

Table B-2: Example aM! sequence	
<b>0M!</b>	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.
<b>0D0!</b>	The data logger immediately issues the first <b>D</b> 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 *attn*<CR><LF>, where

*a* = the sensor address

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

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

See the following example. 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	
<b>XC!</b>	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 5 (05) values ready for collection within the next 30 (030) seconds.
<b>YC!</b>	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 6 (06) values ready for collection within the next 40 (040) seconds.
<b>ZC!</b>	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 10 values ready for collection within the next 20 (020) seconds.
<b>ZD0!</b>	After 20 seconds have passed, the data logger starts the process of collecting the data by issuing the first <b>D</b> 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 10 values.
<b>XD0!</b>	10 seconds later, after a total of 30 seconds have passed, the data logger starts the process of collecting data from sensor X by issuing the first <b>D</b> command.
X+1+2+3+4+5<CR><LF>	The sensor immediately responds with the sensor address and the 5 values.

Table B-3: Example aC! sequence	
YD0!	Ten seconds later, after a total of 40 seconds have 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 6 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 3 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](http://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. 22)), 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* = the 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 the **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 by navigating to the **Tools** list in *PC400* or the **Datalogger** list in the **Connect** screen of *LoggerNet*.

Watch [videos/sdi12-sensors-transparent-mode](#)  from our website.

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

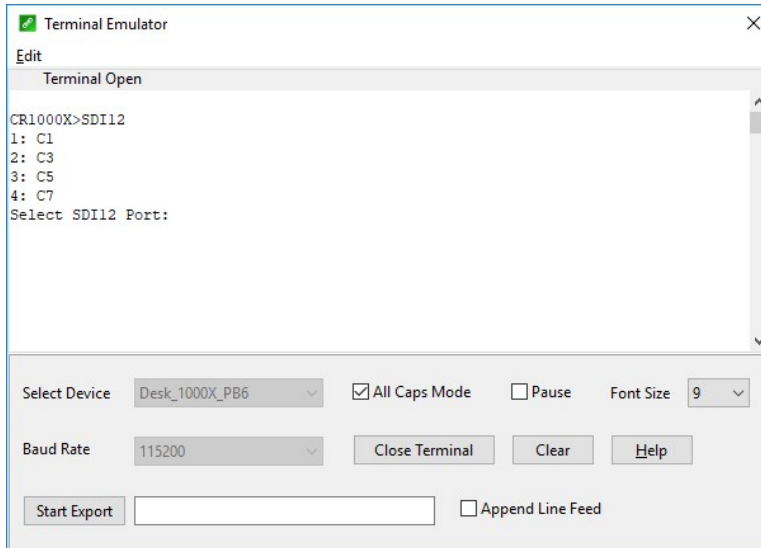
The following examples show how to enter transparent mode and change the SDI-12 address of an SDI-12 sensor. The steps shown in [Changing an SDI-12 address](#) (p. 23) are used with most Campbell Scientific data loggers.

## B.2.1 Changing an SDI-12 address

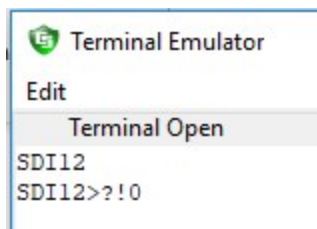
This example was done with a CR1000X, but the steps are only slightly different for CR6, CR3000, CR800-series, CR300-series, CR1000 data loggers.

1. Connect an SDI-12 sensor to the CR1000X.
2. In **LoggerNet Connect**, under **Datalogger**, click **Terminal Emulator**. The terminal emulator window opens.
3. Under **Select Device**, located in the lower left side of the window, select the **CR1000X**
4. Click **Open Terminal**.
5. Select **All Caps Mode**.
6. Press Enter until the data logger responds with the **CR1000X>** prompt.

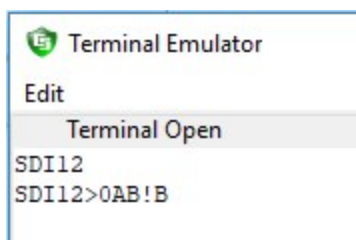
7. Type **SDI12** and press Enter.



8. At the **Select SDI12 Port** prompt, type the number corresponding to the control port where the sensor is connected and press Enter. The response **Entering SDI12 Terminal** indicates that the sensor is ready to accept SDI-12 commands.
9. 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.



10. 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.




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

**NOTE:**

The transparent mode for the CR6, CR3000, CR800-series, CR300-series, and CR1000 data loggers is similar to that shown for the CR1000X.

## B.3 References

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

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## 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.
- 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.

## 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.

## 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.

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