Product Manual

SN500SS

Net Radiometer

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MONITORING

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Guarantee

This equipment is guaranteed against defects in materials and workmanship. We will repair or replace products which prove to be defective during the guarantee period as detailed on your invoice, provided they are returned to us prepaid. The guarantee will not apply to:

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

- Batteries

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Note that goods sent air freight are subject to Customs clearance fees which Campbell Scientific will charge to customers. In many cases, these charges are greater than the cost of the repair.

PLEASE READ FIRST

About this manual

Please note that this manual was originally produced by Campbell Scientific Inc. primarily for the North American market. Some spellings, weights and measures may reflect this origin.

Some useful conversion factors:

Area: 1 in^2 (square inch) = 645 mm^2

Length:
1 in. (inch) = 25.4 mm
1 ft (foot) = 304.8 mm
1 yard = 0.914 m
1 mile = 1.609 km

Mass:
1 oz. (ounce) = 28.35 g
1 lb (pound weight) = 0.454 kg

Pressure: 1 psi (lb/in^2) = 68.95 mb

Volume:
1 UK pint = 568.3 ml
1 UK gallon = 4.546 litres
1 US gallon = 3.785 litres

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 it will be suitable for use in your country.*

Reference to some radio transmitters, digital cell phones and aerials 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. Details of the alternatives will be covered in separate manuals.

Part numbers prefixed with a "#" symbol are special order parts for use with non-EU variants or for special installations. Please quote the full part number with the # when ordering.

Recycling information

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.

Campbell Scientific Ltd 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 advice or support, please contact Campbell Scientific Ltd, or your local agent.

CAMPBELL® SCIENTIFIC
WHEN MEASUREMENTS MATTER

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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.eu or by telephoning +44(0) 1509 828 888 (UK). 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
- 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, or 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.

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.

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.

Table of contents

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 analogue channels 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 (p. iii) section at the front 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.eu/videos/cr1000x-datalogger-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.eu. It is included in installations of LoggerNet, PC200W, PC400, or RTDAQ.

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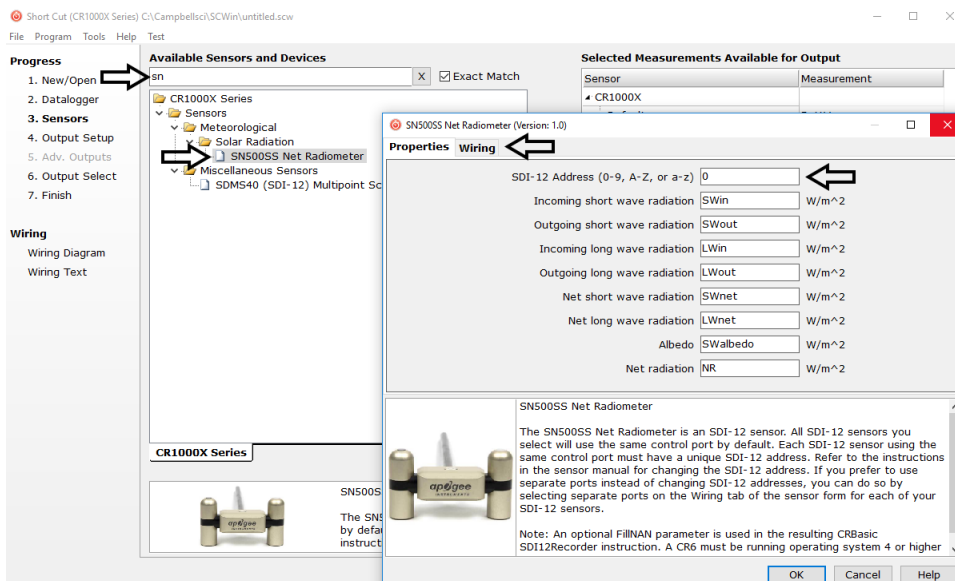
4. Click the **Wiring** tab to see how the sensor is to be wired to the data logger. Click **OK** after wiring the sensor.

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**.

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 logger support software data display in LoggerNet, PC400, RTDAQ, or PC200W 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 aluminium housing. Each radiometer is heated to minimize the effects of dew, frost, snow, and ice on the filter and sensor head. Analogue signals from each radiometer are measured with an onboard voltmeter and converted to SDI-12 outputs, eliminating the need for multiple analogue data logger channels 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.

6. Specifications

Features:

- Individual measurement of four net radiation components
- SDI-12 output, eliminating the need for multiple analogue channels 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: CR300 series, CR6, CR200(X) series, CR800 series, CR1000X, CR1000, CR3000, and CR5000

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

7. Installation

If you are programming your data logger with Short Cut, skip Wiring to the data logger (p. 9) and Programming (p. 10). Short Cut does this work for you. See QuickStart (p. 1) for a tutorial.

7.1 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.

7.2 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. 7) and FIGURE 7-2 (p. 8)).

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. 8)). If mounted to a vertical pipe, ensure that the pipe does not cast a reflection on the sensor. This includes both the incoming and out-going 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. 8)). 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 levelling 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. 8)).

> **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 levelling using the three spring-loaded levelling 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.

7.3 Wiring to the data logger

Connect the SN500SS to the data logger in the order shown in Table 7-1 (p. 9).

Table 7-1: Wire colour, function, and data logger connection		
Wire colour	**Wire function**	**Data logger connection**
White	SDI-12 signal	**C**, **SDI-12**, or **U** configured for SDI-12[1]
Clear	Shield	⏚ (analogue ground)
Red	Power	12V
Black	Power ground	G
[1] **U** and **C** terminals are automatically configured by the measurement instruction.		

For the CR6 and CR1000X dataloggers, 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.

7.4 Programming

Short Cut is the best source for up-to-date data logger programming code. 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. Complete program examples for select CRBasic data loggers can be found in Example program (p. 17).

7.4.1 SDI-12 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).

8. Operation

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. 19), 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 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. 19) 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 "Declaration of Hazardous Material and Decontamination" form. Refer to the Please Read First (p. ii) page at the beginning 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) 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 Please Read First (p. ii) 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. 19).

Appendix A. Importing Short Cut code into CRBasic Editor

This tutorial shows:

- Importing a Short Cut program into a program editor for additional refinement
- Importing a wiring diagram from Short Cut into the comments of a custom program

Short Cut creates files, which can be imported into CRBasic Editor. Assuming defaults were used when Short Cut was installed, these files reside in the C:\campbellsci\SCWin folder:

- .DEF (wiring and memory usage information)
- .CR2 (CR200(X)-series datalogger code)
- .CR300 (CR300-series datalogger code)
- .CR6 (CR6-series datalogger code)
- .CR8 (CR800-series datalogger code)
- .CR1 (CR1000 datalogger code)
- .CR1X (CR1000X-series datalogger code)
- .CR3 (CR3000 datalogger code)
- .CR5 (CR5000 datalogger code)
- .CR9 (CR9000(X) datalogger code)

Import Short Cut code and wiring diagram into CRBasic Editor:

1. Create the Short Cut program following the procedure in QuickStart (p. 1). Finish the program. On the **Advanced** tab, click the **CRBasic Editor** button. The program opens in CRBasic with the name **noname.CR_**. Provide a name and save the program.

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

2. The program can now be edited, saved, and sent to the data logger.

3. Import wiring information to the program by opening the associated .DEF file. By default, it is saved in the c:\campbellsci\SCWin folder. Copy and paste the section beginning with heading "–Wiring for CRXXX–" into the CRBasic program, usually at the head of the file. After pasting, edit the information such that an apostrophe (') begins each line. This

character instructs the data logger compiler to ignore the line when compiling. You can highlight several lines of CRBasic code then right-click and select **Comment Block**. (This feature is demonstrated at about 5:10 in the CRBasic | Features video.)

Appendix B. Example program

CRBasic Example 1:

```
'CR1000X Series Datalogger

'Explanation of Constants and Variables Used in Data logger Program
'BattV = data logger battery voltage
'PanelT = data logger panel temperature
'Net(4) = Array to hold output from SDI12Recorder function;
'          Location 1 = incoming SW, Location 2 = outgoing SW,
'          Location 3 = incoming LW, Location 4 = outgoing LW
'Incoming_SW = downwelling shortwave radiation in Watts per square metre
'Outgoing_SW = upwelling (reflected) shortwave radiation in Watts per
'square metre
'Incoming_LW = downwelling longwave radiation in Watts per square metre
'Incoming_LW = upwelling (emitted) longwave radiation in Watts per
'square metre

'Declare Public Variables
Public BattV, PanelT
Public Net(4)

'Rename Variables
Alias Net(1) = Incoming_SW
Alias Net(2) = Outgoing_SW
Alias Net(3) = Incoming_LW
Alias Net(4) = Outgoing_LW

'Define Data Tables
DataTable (Net_Rad,1,-1)
  DataInterval (0,1,Min,10)
  Minimum(1,BattV,IEEE4,0,False)
  Sample(1,PanelT,IEEE4)
  Average(1,Incoming_SW,IEEE4,False)
  Average(1,Outgoing_SW,IEEE4,False)
  Average(1,Incoming_LW,IEEE4,False)
  Average(1,Outgoing_LW,IEEE4,False)
EndTable

'Main Program
BeginProg
  'The scan rate should not be less than 10 s; faster rates cause the
  'data table to fail to populate.
  Scan(10,Sec,0,0)
```

```
    Battery(BattV)
    PanelTemp(PanelT,60)

    'Measure Surface Temperature
    SDI12Recorder (Net(),C1,0,"MC!",1.0,0) 'refer to Table 8-1
    'for a list of relevant commands

    'Call Output Tables
    CallTable Net_Rad
  NextScan
EndProg
```

Appendix C. SDI-12 sensor support

C.1 Introduction

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.

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

C.2 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 C-1 (p. 19).

Table C-1: Campbell Scientific sensor SDI-12 command and response set		
Name	**Command**	**Response[1]**
Acknowledge Active	`a!`	a<CR><LF>
Send Identification	`aI!`	allccccccccmmmmmmvvvxxx...xx<CR><LF>

Table C-1: Campbell Scientific sensor SDI-12 command and response set		
Name	**Command**	**Response[1]**
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 Concurrent 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.

C.2.1 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.

C.2.2 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!`	allccccccccmmmmmmvvvxxx...xx<CR><LF>
a	Sensor SDI-12 address

ll	SDI-12 version number (indicates compatibility)
cccccccc	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).	

C.2.3 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: *atttn<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

C.2.4 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.

C.2.5 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.

C.2.6 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 = 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 C-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.

C.2.7 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 = 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 C-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 5 (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 6 (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 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 10 values.
XD0!	10 seconds later, after a total of 30 seconds have passed, the data logger starts the process of 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 5 values.

Table C-3: Example aC! sequence	
YD0!	Ten seconds later, after a total of 40 seconds have passed, the data logger starts the process of 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.

C.2.8 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 1.3 available at www.sdi-12.org to learn more about how the CRC code is developed.

C.2.9 Stopping a measurement command

A measurement command (**M!**) is stopped if it detects a break signal. 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.

C.2.10 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 a**M!** or a**MC!**, the data logger issues the **aD0!** command once a service request has been received from the sensor. 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 (SDI-12 transparent mode (p. 25)), 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.

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 a**MC!** or **aCC!**.

C.2.11 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.

C.2.12 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.

C.3 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 PC 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 **Datalogger** list in PC200W, the **Tools** list in PC400, or the **Datalogger** list in the **Connect** screen of LoggerNet.

▶   Watch the video: SDI-12 Sensors | 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. 26) are used with most Campbell Scientific data loggers. Changing an SDI-12 address — CR200(X) Series (p. 27) lists the steps used for CR200(X)-series dataloggers.

C.3.1 Changing an SDI-12 address

The example below was done with a CR1000, but the steps are only slightly different for CR1000X-series, CR300-series, CR6-series, CR800-series, and CR3000 dataloggers. For CR200(X)-series dataloggers, see Changing an SDI-12 address — CR200(X) Series (p. 27).

1. Connect an SDI-12 sensor to the CR1000.
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 **CR1000** station.
4. Click **Open Terminal**.
5. Select **All Caps Mode**.
6. Press Enter until the data logger responds with the **CR1000>** 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 above step and **b** is the new address (see FIGURE C-1 (p. 27). Press Enter. The sensor changes its address and responds with the new address.
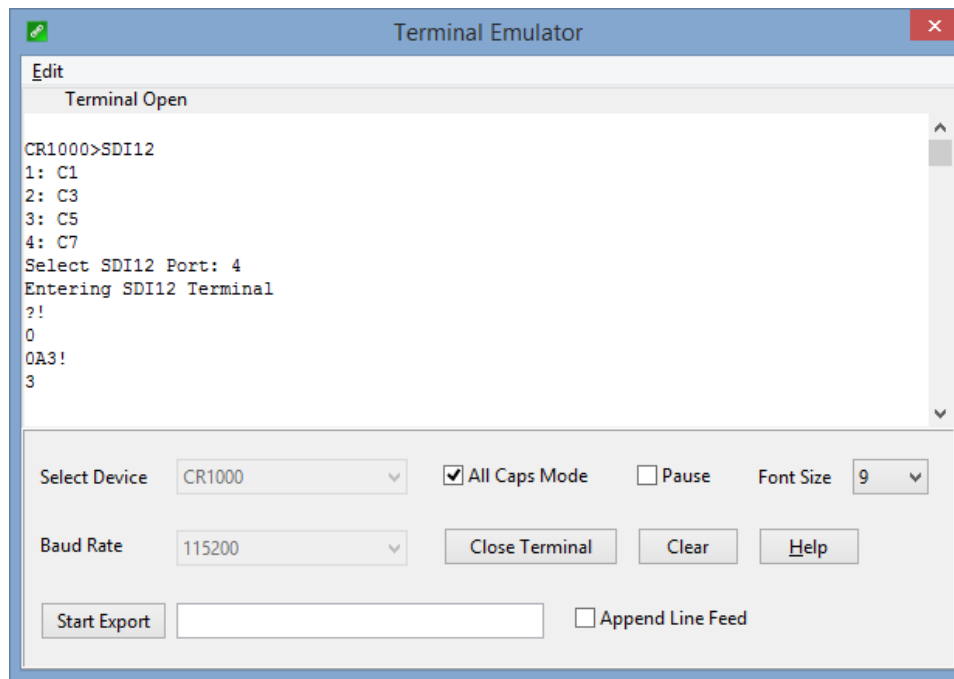11. To exit SDI-12 transparent mode, click **Close Terminal**.

FIGURE C-1. CR1000 example of using the SDI-12 transparent mode to change the SDI-12 address from 0 to 3. Sensor is connected to control port 1.

C.3.2 Changing an SDI-12 address — CR200(X) Series

1. Connect a single SDI-12 sensor to the CR200(X).
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 **CR200-Series** station.
4. Click **Open Terminal**.
5. Select **All Caps Mode**.
6. Press Enter until the data logger responds with the **CR2XX>** prompt.
7. Type **SDI12** and press Enter.
8. The response **SDI12>** 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 and press Enter.
10. To change the SDI-12 address, type **aAb!**, where **a** is the current address from the above step and **b** is the new address (see FIGURE C-2 (p. 28). Press Enter. The sensor changes its address and responds with the new address.
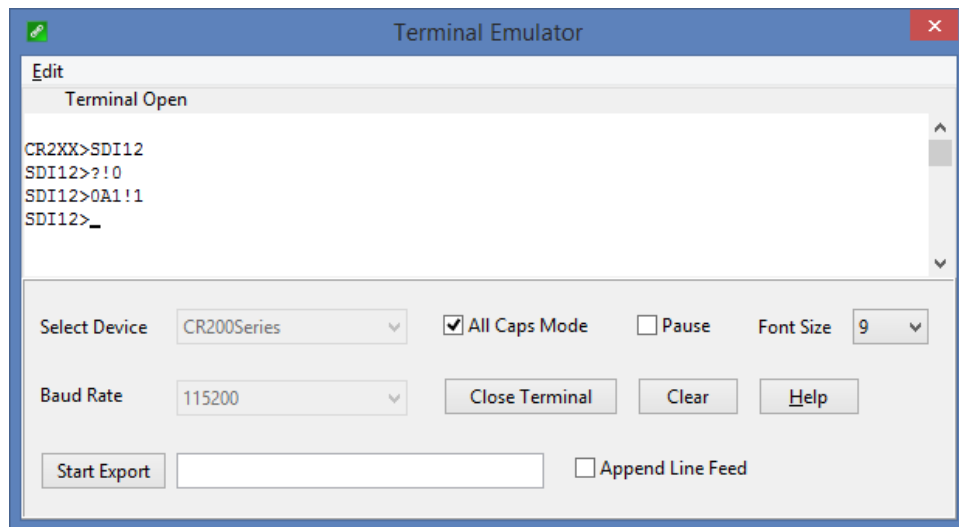11. To exit SDI-12 transparent mode, click **Close Terminal**.

FIGURE C-2. CR200(X) example of using the SDI-12 transparent mode to change the SDI-12 address from 0 to 1

C.4 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.

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