Wintersense SDI-12

Non-Invasive Surface Temperature Sensor

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1. About Wintersense SDI-12

Wintersense™ SDI-12 is an easy-to-deploy, non-invasive sensor for road temperature monitoring. This compact and light weight sensor is designed for mounting on existing roadside structures such as streetlight columns or RWIS towers. It has a cabled connection for power and communications with an RWIS station or data logger for data storage and forwarding.

> **NOTE:**
> The Wintersense SDI-12 is compatible with all data loggers that support SDI-12 communications. This manual focuses on Campbell Scientific data loggers.

2. Precautions

- READ AND UNDERSTAND the Safety section at the back of this manual.

- Use caution when working near roadways and moving vehicles. Coordinate with local traffic authorities and use appropriate traffic control measures.

- Although the Wintersense SDI-12 is rugged, it should be handled as a precision instrument.

- Do not use cable lengths greater than 60 m (200 ft).

- The black outer jacket of the cable is Santoprene® rubber. This compound was chosen for its resistance to temperature extremes, moisture, and ultraviolet (UV) degradation. However, this jacket will support combustion in air. It is rated as slow burning when tested according to U.L. 94 H.B. and will pass FMVSS302. Local fire codes may preclude its use inside buildings.

- Follow local regulations. See Compliance in Technical specifications (p. 6).

- IMPORTANT: Maintain a level of calibration appropriate to the application. Campbell Scientific recommends factory recalibration of the Wintersense SDI-12 every twelve months when installed within 100 km of a coast, otherwise every two years.

- Protect from ESD (electrostatic discharge).

3. Initial inspection

- Upon receipt of the Wintersense SDI-12, inspect the packaging and contents for damage. File any damage claims with the shipping company.

- The model number and cable length are printed on a label at the connection end of the cable. Check this information against the shipping documents to ensure the expected product and cable length are received.

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*.

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 **Wintersense**. You can also find the sensor in the **Sensors** > **Temperature** folder. Double-click the **Wintersense Road Surface Temperature Sensor**. **SDI-12 Address** defaults to 0. Type the correct **SDI-12 Address** if it has been changed from the factory-set default value.

   The default for units of measure are shown and can be changed by clicking the units of measure box and selecting another value.
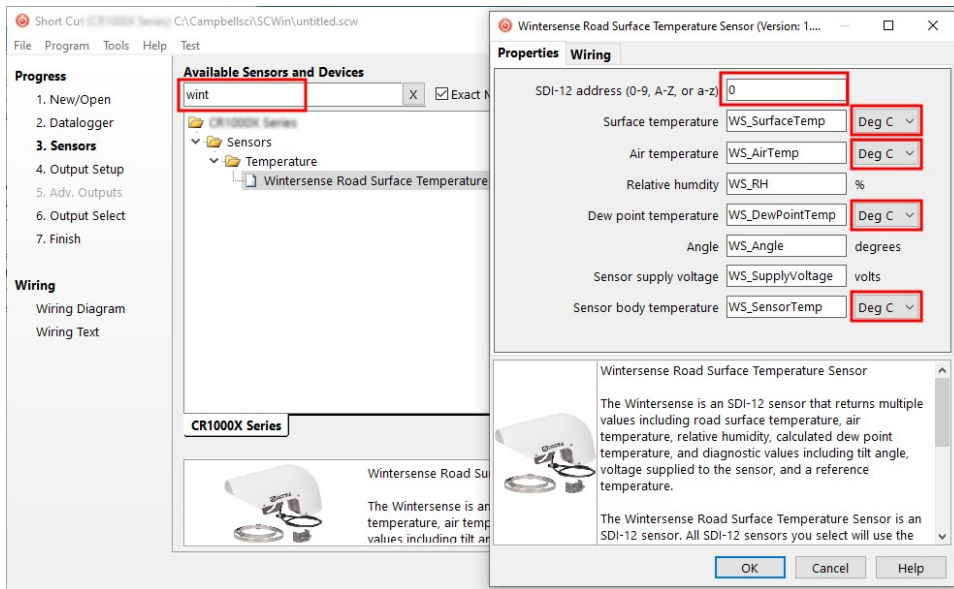
4. Click the **Wiring** tab to see how the sensor is to be wired to the data logger. Click **OK** after wiring the sensor.
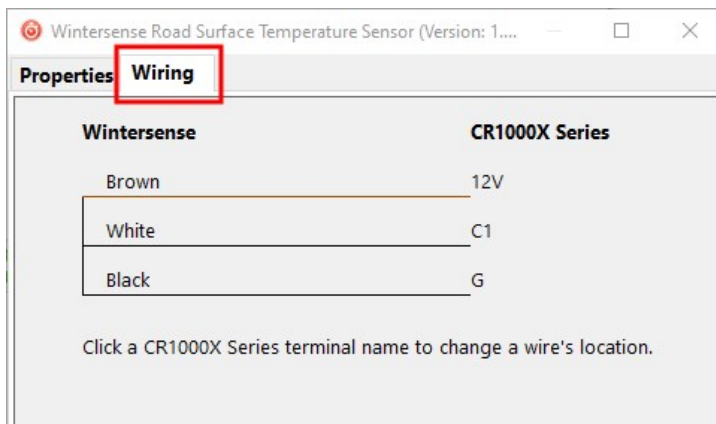
5. Repeat steps three and four for other sensors. Click **Next**.

6. In **Output Setup**, type the how often to measure the sensors (scan rate), meaningful table names, and **Data Output Storage Interval**.For this sensor, Campbell Scientific recommends measurement scans of 10 seconds or more.

> **NOTE:**
> When the scan rate is less than 20 seconds the Wintersense SDI-12 will be measured using a concurrent command. See Start concurrent measurement commands (aC!) (p. 32) for more information. Otherwise the measurement command is used. See Start measurement commands (aM!) (p. 31).

7. Click **Next**.

8. Select the output options.
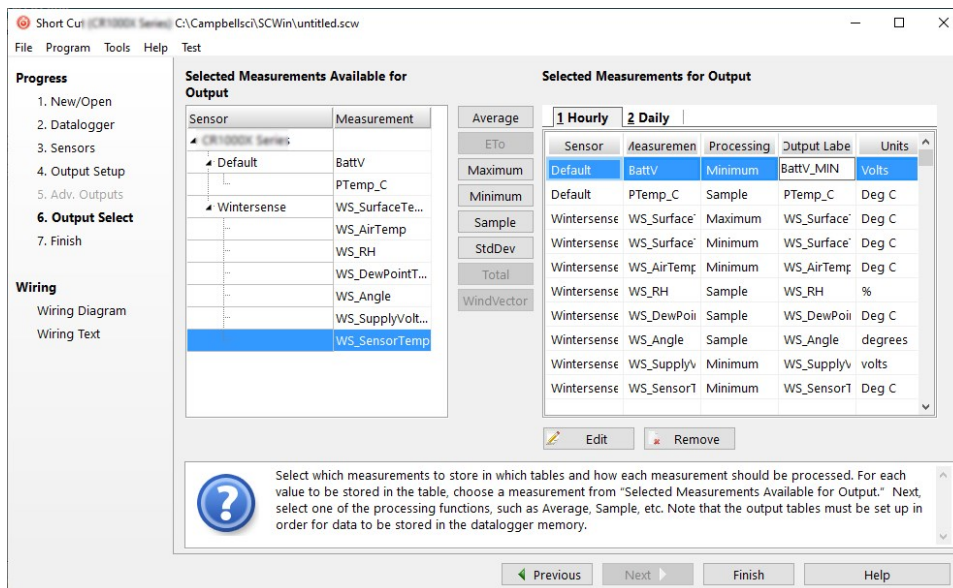
9. Click **Finish** and save the program. Send the program to the data logger if the data logger is connected to the computer.

10. 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

Wintersense SDI-12 smart sensors are simple to install. Each sensor is supplied with an integrated mounting bracket and two band clamps suitable for mounting the sensor to a vertical pole with diameters between 70 and 170 mm (3 and 7 in).

Features include:

- Accurate measurements
- Non-invasive
- Easy to install
- Simple to maintain
- Remote OS update via data logger
- Compatible with most data loggers and RWIS

- Monitor troublesome areas, such as bridge decks
- Ideal for multiple uses, including roads, parking lots, cycleways, and sidewalks

6. Technical specifications

Road surface temperature

Measurement range:	–40 to 70 °C (–40 to 160 °F)
Accuracy[1] –40 to 60 °C:	±0.5 °C
Resolution:	0.01 °C

Air temperature

Measurement range:	–40 to 70 °C (–40 to 160 °F)
Accuracy[2]:	±0.4 °C
Resolution:	0.01 °C

Relative humidity

Measurement range:	0 to 100%
Accuracy:	<±3%
Resolution:	0.1%

Dew point temperature (calculated)

Measurement range:	–40 to 70 °C (–40 to 160 °F)
Accuracy[3] –35 to 50 °C:	±1 °C
Resolution:	0.1 °C
Field of view (FOV):	10° (at 50% normalized signal)
	See Installation height and angle (p. 14) for more information.

Distance to target

Minimum:	2 m (6 ft)
Maximum:	15 m (50 ft)
Digital output:	SDI-12, v1.4 compliant
Default SDI-12 address:	0

Response time (to M!):	8 s
Sensor warm-up time:	If power is switched allow 3 seconds for warm up before taking a measurement
Dimensions, excluding band clamp (length x height x depth):	350 x 200 x 100 mm (13.8 x 7.9 x 4.0 in)
Weight:	1.4 kg (3 lb)
Supply voltage:	5 to 18 VDC
Power consumption at 12 VDC	
Idle:	<0.1 mA typical
Active:	<14 mA typical
Operating temperature:	−40 to 70 °C (−40 to 160 °F)
Operating humidity:	0 to 100%
Internal enclosure sealing:	IP65 (minimum)
Compliance:	View documents at: www.campbellsci.com/wintersense-sdi-12

[1] Temperature dependent – quoted accuracy is against a blackbody source within ambient temperature range of −20 to 50 °C and object temperature range of −40 to 60 °C.

[2] Accuracy may be reduced under moderate-to-high solar radiation.

[3] Calculated dew point temperature found from Tetens' equation solved for dew point with coefficients optimized for the temperature range −35 to 50 °C.

7. Site installation

Select a site away from intersections and where there is not regularly stopped traffic.

Tools required:

- Band clamp of suitable size for the vertical pole the sensor will be installed on. 70 to 120 mm (3 to 5 in) and 110 to 170 mm (4 to 7 in) band clamps are supplied with the sensor.
- 8 mm (5/16 in) hex tool or slotted screwdriver (not supplied) for adjusting band clamp
- 13 mm (1/2 in) spanner, wrench, or socket to allow sensor angle adjustment
- tin snips
- gloves

7.1 Wiring

The Wintersense SDI-12 cable has an M12 connector on one end and terminates in individual wires at the other. See Figure 7-1 (p. 8). Connect the wires in the order shown in the following table.

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

Wire color	Wire function	Data logger connection	Pin
White	SDI-12 signal	**C** or **U** configured for SDI-12[1]	6
Clear	Shield	**G**	None
Brown	Power	**12V**	5
Black	Power ground	**G**	8

[1]**C** and **U** terminals are automatically configured by `SDI12Recorder()`.

If multiple SDI-12 sensors are connected to a data logger, Campbell Scientific recommends using separate terminals when possible. However, multiple SDI-12 sensors can connect to the same data logger control or **U** terminal. Each must have a unique SDI-12 address. Valid addresses are 0 through 9, a through z, and A through Z.

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 Wintersense SDI-12 is connected to **C3** on a CR1000X, C4 cannot be used in the `TimerInput()`, `PulseCount()`, or `WaitDigTrig()` instructions.

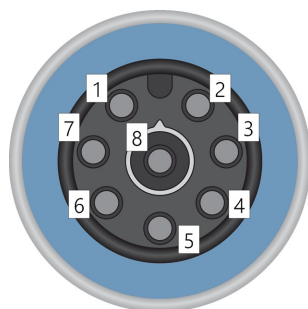*Figure 7-1. M12 connector pinout*

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. 2). 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. 27).

Programming basics for CRBasic data loggers are provided in the following section.

7.2.1 CRBasic programming

A downloadable example program is available at https://www.campbellsci.com/downloads/wintersense-sdi12-example-program⬈.

The `SDI12Recorder()` instruction sends a request to the sensor to make a measurement and then retrieves the measurement from the sensor. See SDI-12 measurements (p. 9) for more information.

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

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

Valid values for the `SDIAddress` are 0 through 9, A through Z, and a through z; 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 7-2 [p. 10]).

`FillNAN` and `WaitonTimeout` are optional parameters (refer to CRBasic Help for more information).

7.2.2 SDI-12 measurements

The Wintersense SDI-12 responds to the SDI-12 measurement commands shown in Table 7-2 (p. 10). When the data logger issues an `M!` command, the sensor should respond immediately indicating how long it will take to perform the measurement. The data logger then waits that amount of time or if the sensor finishes sooner, it will send a service request to the data logger indicating data can be collected. After receiving the service request or waiting the indicated time, the data logger will send the `D!` command to collect the data.

The C! command follows the same pattern as an M! 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 retrieves the data with the D! command on the next scan. Another measurement request is then sent so that data are ready on the next scan.

Wintersense SDI-12 supports cyclic redundancy checks (CRC) to enhance error detection. See Start measurement commands with cyclic redundancy check (aMC! and aCC!) (p. 33) for more information.

> **NOTE:**
> The Wintersense SDI-12 needs to be turned on for 3 seconds before it can receive an SDI-12 command.

Table 7-2: SDI-12 commands

SDI-12[1] command	Values returned or function	Units	Max. sensor response time (sec)
aM!, aC!	1. Surface temperature 2. Air temperature 3. Air relative humidity 4. Dew point temperature 5. Angle 6. Supply voltage 7. Sensor body temperature	1. °C 2. °C 3. % 4. °C 5. deg 6. V 7. °C	8
aM1!, aC1!	1. Surface temperature 2. Sensor body temperature	1. °C 2. °C	8
aM2!, aC2!	1. Air temperature 2. Air relative humidity	1. °C 2. %	0
aM3!, aC3!	Angle	deg	0
aM4!, aC4!	Supply voltage	V	0
aM5!, aC5!	Dew point temperature	°C	0

Table 7-2: SDI-12 commands			
SDI-12[1] command	Values returned or function	Units	Max. sensor response time (sec)
aI!	a14CampbellWtrSen SN=nnnnn SDI-12 address: a SDI-12 version: 14 (version 1.4) vendor: Campbell model: WtrSen SN = Serial number (5 digits)		0
aV!	1. Hardware version 2. Status	1. N/A 2. 0 = no error 1 = contact Campbell Scientific for repair	0
?!	SDI-12 address		0
aAb!	Change address command; b is the new address		0
aHA!, aHB!	a000000 High volume commands not supported		
aXWEM+nn.nn!	Write emissivity		
aXREM!	Read emissivity		1
aXLOADOS!	Sends the new OS to the sensor. Refer to Updating the operating system (OS) (p. 21).		
[1]Where a = address of SDI-12 device. In the SDI12Recorder() instruction, the command parameter does not include the SDI-12 address because the address is entered in a separate parameter.			

7.2.3 Identify measurement and measurement parameter commands

Version 1.4 compliant sensors must respond to identify commands for each type of measurement command and each parameter with a command. The identify commands return how many variables will be returned with a given measurement command and the time it will take the sensor to respond, without the time penalty of actually taking the measurement. The specific identify parameter commands will return a SHEF code, the measurement units, and the type of measurement (such as sample, count, or average).

Table 7-3: Identify commands for the Wintersense SDI-12			
SDI-12 command[1]	Description	Sensor response	Comment
`aIM!`, `aIMC!`	Identify measurement for **M** commands	`atttn`	`ttt`: response time (seconds) **n**: # of values returned
`aIM1!`… `aIM9!`	Identify measurement for **M** commands	`atttn`	`ttt`: response time (seconds) **n**: # of values returned
`aIC!`, `aICC!`	Identify measurement for **C** commands	`atttnn`	`ttt`: response time (seconds) **nn**: # of values returned
`aIC1!`… `aIC9!`	Identify measurement for **C** commands	`atttnn`	`ttt`: response time (seconds) **nn**: # of values returned
`aIV!`	Identify measurement for **V** command	`atttn`	`ttt`: response time (seconds) **n**: # of values returned
`aIM_001!`, … `aIMC_`, `aIC_`, `aICC_`	Identify measurement parameters	a, TR, C	TR = SHEF CODE for Temperature, road surface
`aIM_002!`, … `aIMC_`, `aIC_`, `aICC_`	Identify measurement parameters	a, TA, C	TA = SHEF CODE for Temperature, air
`aIM_003!`, … `aIMC_`, `aIC_`, `aICC_`	Identify measurement parameters	a, XR, %	XR = SHEF CODE for Humidity, relative

Table 7-3: Identify commands for the Wintersense SDI-12			
SDI-12 command[1]	Description	Sensor response	Comment
`aIM_004!`, ... `aIMC_`, `aIC_`, `aICC_`	Identify measurement parameters	a, TD, C	TR = SHEF CODE for Temperature, dew point
`aIM_005!`, ... `aIMC_`, `aIC_`, `aICC_`	Identify measurement parameters	a, angle, deg	
`aIM_006!`, ... `aIMC_`, `aIC_`, `aICC_`	Identify measurement parameters	a, VB, vdc	VB = SHEF CODE for Voltage, battery
`aIM_007!`, ... `aIMC_`, `aIC_`, `aICC_`	Identify measurement parameters	a, SBT, C	
[1]Where a = address of SDI-12 device. In the `SDI12Recorder()` instruction, the command parameter does not include the SDI-12 address because the address is entered in a separate parameter.			

7.3 Temperature and humidity cover

Wintersense SDI-12 ships with a small protective cover over the temperature and relative humidity sensor. While at ground level, gently pull the cover off. The white filter cap will be exposed; do not remove it.
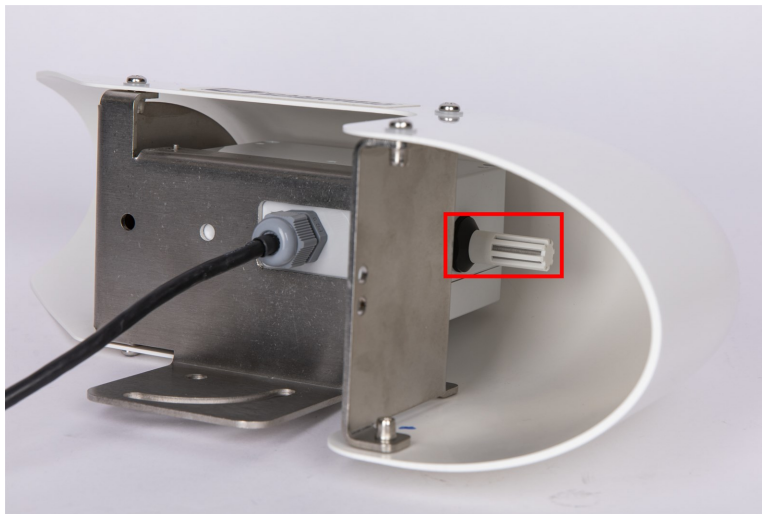

Figure 7-2. Sensor exposed after protective cover is removed

7.4 Install bracket

The included C-bracket, used for angle adjustment, attaches to the main sensor bracket.

1. Locate installation hardware which includes two bolts, spring (split) washers, and flat washers.

2. Slide one spring (split) washer onto each bolt.

3. Slide one flat washer, next to the spring washer, onto each bolt.

4. Insert one bolt through the main sensor bracket hole and screw into hole on C-bracket, ensuring the C-bracket tabs that accept the band-strap are pointing away from the sensor bracket.

5. Insert the other bolt through the slot on the main sensor bracket and screw into other hole on the C-bracket.

6. Secure C-bracket to main sensor bracket using a 13 mm (0.5 in) spanner, wrench, or socket.

7.5 Installation height and angle

Installation height and angle affect the surface measurement area. Use an online field of view tool https://docs.wintersense.com/field-of-view/ to see how these factors affect the field of view, and consequently the section of road surface being measured.

The recommended installation height for a Wintersense SDI-12 smart sensor is 3 to 5 meters (10 to 16 feet). Sensors can be installed higher if required. However, the higher the sensor is installed,

the larger the surface measurement area will be. This increases the risk of sensing the temperature of unwanted objects. In addition, a large measuring distance may result in reduced accuracy under certain atmospheric conditions.

The following table and figure show typical installation parameters and resulting target dimensions.

Installation parameters:	
Angle	45°
Sensor setback (B)	3 m (10 ft)
Sensor height (H)	4.6 m (15 ft)
Lane width	3 m (10 ft)
Calculated target dimensions:	
Distance to target (D)	6.5 m (21.4 ft)
Target coverage area (A)	6 m^2 (66 ft^2)
Major (long) diameter (L)	3.4 m (11.2 ft)
Minor (short) diameter (S)	2.3 m (7.7 ft)
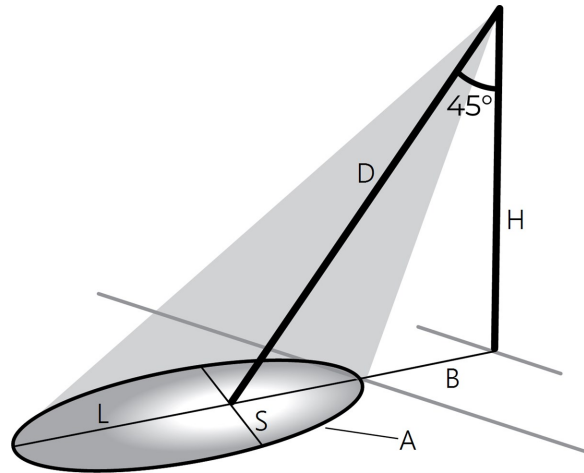
The recommended installation angle of a Wintersense SDI-12 sensor is 30 to 60° (from vertical). The following figure shows it at 45° from vertical.


Wintersense SDI-12 smart sensors contain a thermopile sensor which detects the presence of thermal radiation emitted from the target surface. With non-contact infrared thermopile sensors,

the greater the installation angle of the sensor from vertical, the greater the risk of sensing reflected radiation from other sources (such as long-wave infrared or reflected sunlight), which can affect sensor accuracy. The Wintersense SDI-12 unit contains an integrated optical filter (long-wave pass) that cuts off the visible and near-infrared radiant flux to provide optimum ambient and sunlight immunity. The wavelength pass band of this optical filter is from 5.5 to 14 μm. Therefore, if site restrictions dictate that an installation angle of greater than 45° is required, the Wintersense SDI-12 sensor will be less prone to errors from reflected radiation than other non-invasive sensors without these optical filters.

To adjust the sensor angle, slightly loosen both bolts in the bracket to allow rotation of the sensor around the bolt that is fitted in the round hole towards the front of the sensor. Once at the correct angle, tighten the bolts by hand until the spring washers are fully compressed.

Adjust the angle of the hood so it is between 30 and 60 ° from vertical. See the following figure.
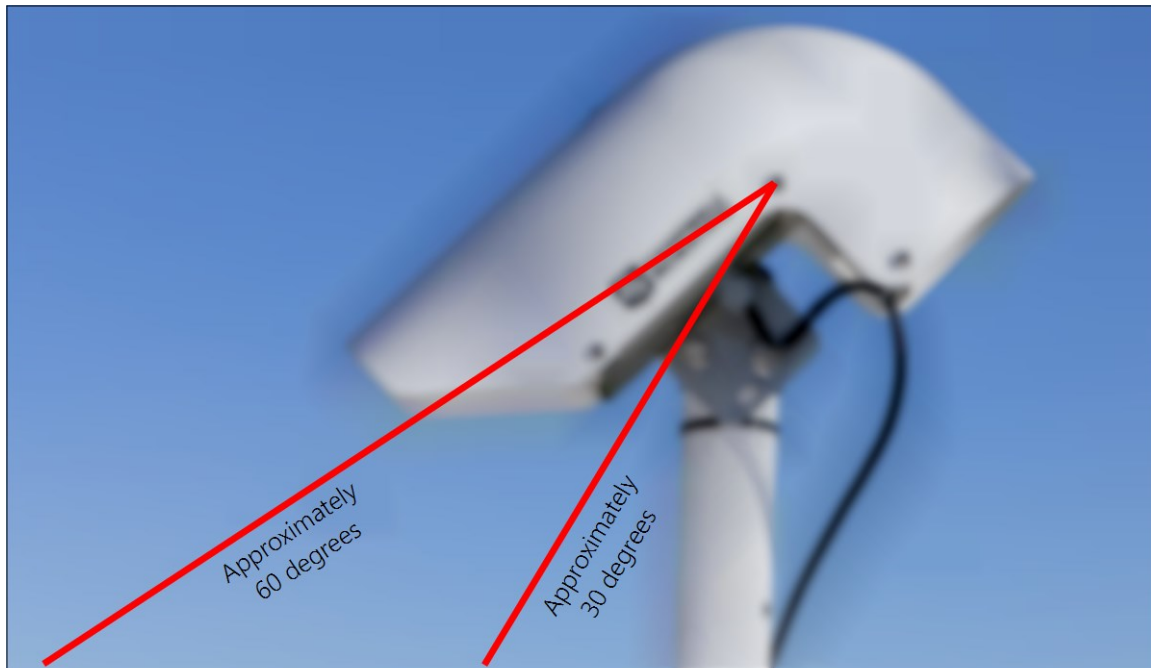
Figure 7-3. Recommended installation angle range

8. Maintenance

CAUTION:
Before proceeding with any maintenance, always retrieve the data first.

> **CAUTION:**
> Always disconnect the Wintersense SDI-12 from the data logger or the connector before disassembling.

Recommended equipment and supplies:

- 8 mm (5/16 in) hex tool or slotted screwdriver (not supplied) for adjusting band clamp
- 13 mm (1/2 in) spanner, wrench, or socket to allow sensor angle adjustment
- Clean lint-free cloths
- Air duster
- Cotton buds or swabs
- Electronics-grade alcohol

8.1 Clean the sensor

Wintersense SDI-12 smart sensors are designed to be low maintenance. Like any non-invasive sensor, however, objects in front of the sensing element can influence readings. Regularly check, and when necessary, clean the sensor to remove any dirt, insects, or spider webs that may block the sensing element.

To clean the sensor:

1. Remove the Wintersense SDI-12 unit from the mounting pole and take it down to ground level.
2. Remove the six screws attaching the sensor hood to the mounting bracket.
3. Lift the sensor hood up and off the mounting bracket.
4. Wipe down the hood to remove any dirt.
5. Use a clean cloth to wipe down the internal box, bracket, and front metal plate.
6. Use an air duster to clean dirt from within the sensing element. If there appears to be any deposits on the detector window, use a cotton bud (swab) dipped in electronics-grade alcohol to gently clean the detector window.
7. Remove the four screws attaching the electronics box inside the hood.
8. Replace old desiccant bags with new.
9. Replace the electronics box and secure the four screws.
10. Reattach the hood with the six mounting screws, making sure the anti-vibration spring washers are still in place.
11. Adjust the angle of the hood so it is between 30 and 60 ° from vertical.

8.2 Replace the temperature and humidity element

Replace the temperature and humidity element every 1 to 2 years to ensure accurate measurements. The element is pre-calibrated; so, changing the element will return the system to factory calibration accuracy. A replacement filter cap is supplied with the element; fit it to ensure adequate air flow to the sensor element.

To replace the element, the Wintersense SDI-12 unit must be brought down to ground level and the outer hood removed as discussed in Clean the sensor (p. 17). The temperature and humidity element is on the opposite end of the electronics box as the infrared sensor, which normally points down to the road. Unscrew the filter cap in an anticlockwise direction, by hand, to expose the sensor element.
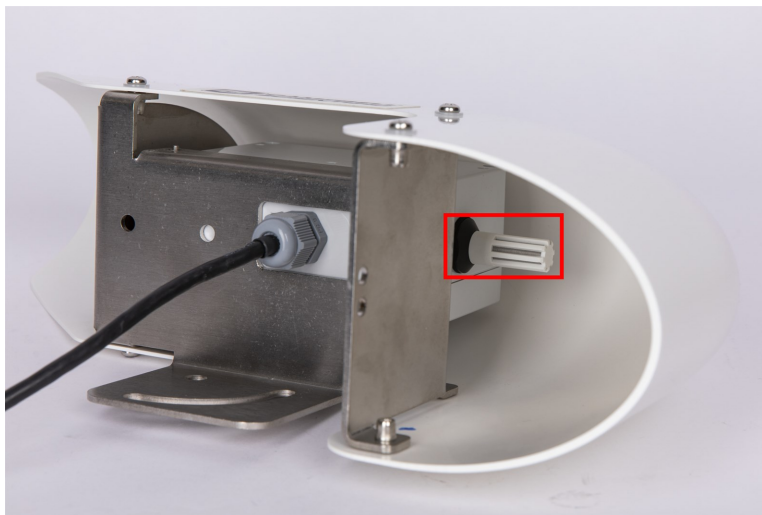
Figure 8-1. Sensor element with filter cap on
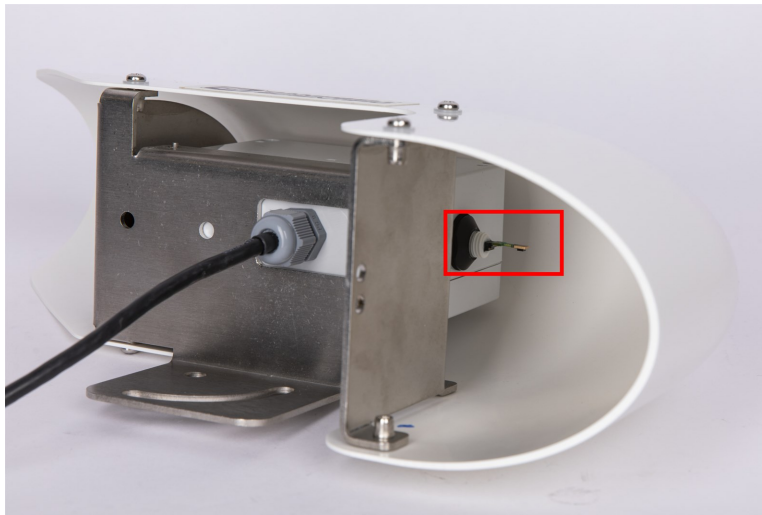
Figure 8-2. Sensor after filter cap has been removed
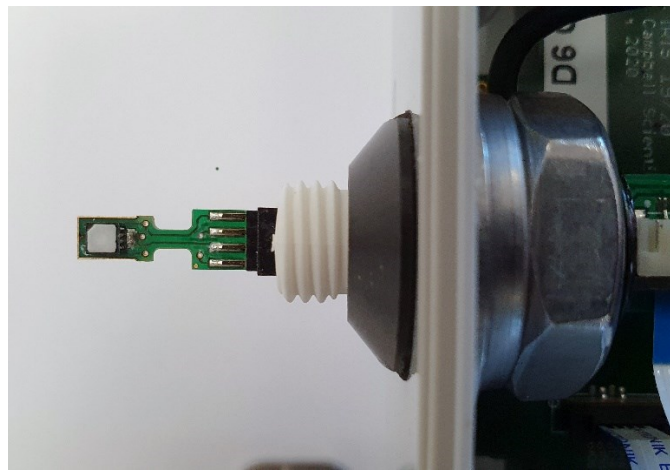
Figure 8-3. Exposed sensor element after filter cap has been removed

8.2.1 Replace sensor element

Campbell Scientific offers a replacement temperature/RH element and cap for the Wintersense SDI-12. The replacement element is only available from Campbell Scientific. It includes a small circuit board that is coated to ensure longer life at high humidity. A single row of four gold pins inserts into one side of an eight-way socket at the end of the sensor.

The replacement element must be correctly installed for the sensor to work properly. Follow these steps to correctly replace the element:

1. Wash your hands to avoid getting dirt or grease on the element. If possible, use cotton gloves and handle the element by the edges of the small circuit board. Avoid touching the square white filter on the surface of the small, black component on top of the circuit board.

> **CAUTION:**
> If dirt, salt, or grease are left on the face of the sensor element during the process of handling the element, it may influence the measurements made.

2. Ensure the Wintersense SDI-12 has been disconnected from the data logger.

3. Remove the filter cap by unscrewing it counter clockwise when looking towards the tip of the sensor.

> **CAUTION:**
> Only unscrew the filter cap. Attempting to pull the filter cap off the sensor may damage the filter cap.

4. Identify the sensor element. The element plugs into the black plastic socket that protrudes by about 2 mm from the end of the body of the sensor.
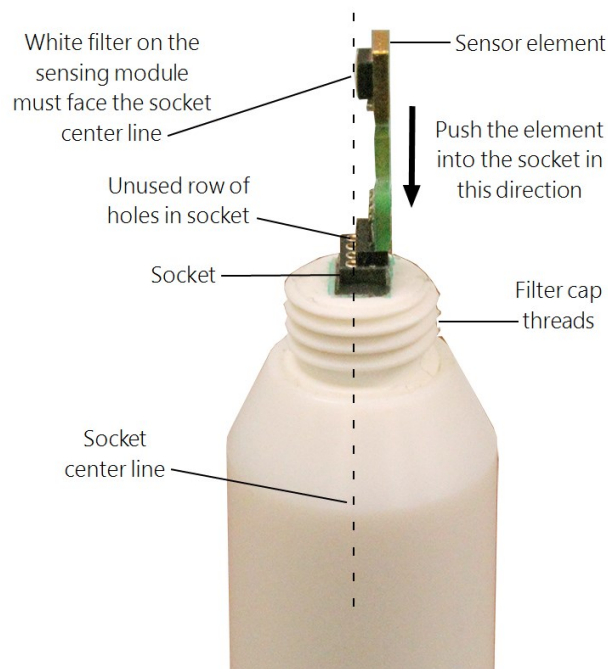
Figure 8-4. Correct fit of the 4-pin sensor element (side view)

5. Grasp the sensor body to ensure you are at the same electrical potential as the element. Hold the edge of the circuit board between your fingertips and pull the element out of the socket. Store the old element in electrostatic protective packaging if you wish to retain it.

> **CAUTION:**
> Avoid pink-colored electrostatic bags as they can emit chemicals which change the calibration of the sensor.

6. With the element removed, check for dirt and corrosion around the socket. Use a damp cloth to remove dirt or salts that might be there.

7. Hold the replacement element by the sides of the circuit board. The element has four gold pins. Carefully match the gold pins to a row of holes in the socket with the sensing module facing the socket center towards the empty row of holes (see Figure 8-4 [p. 20]). Gently push the pins down into the socket until they will not go in any further.

8. Before replacing the filter cap and connecting the sensor to a data logger, double-check that the element is seated correctly with the sensing module facing the socket center, towards the empty row of holes (see Figure 8-4 [p. 20]).

> **CAUTION:**
> Conditions that will cause the sensor to not work include an improperly oriented element, contamination, or water bridging the connections. The element may draw excessive power, possibly damaging the element, when powered under these conditions for more than a few seconds.

9. Screw the filter cap onto the sensor, ensuring it clears the sensor element. If the element appears too close to the filter cap, the element likely has been inserted in the incorrect orientation or the element gold pins are bent. Screw the filter onto the thread and gently finger tighten.

> **CAUTION:**
> Only finger tighten the filter approximately 1/8th of a turn after the filter is fully screwed onto the thread. Over-tightening the filter will damage it and cause problems in inserting and removing the sensor from some shields.

10. Reconnect theWintersense SDI-12 to the data logger.

8.3 Updating the operating system (OS)

The SDI-12 extended command **XLOADOS!** sends the new operating system (OS) to the sensor. **Only the CR6, CR1000X, CR350-series, and CR300-series data loggers are compatible with the**

XLOADOS! functionality. Verify that the data logger has been updated to the latest OS to ensure compatibility.

If a compatible data logger is not available to update the sensor, send the sensor to the factory to have Campbell Scientific update the OS. A returned material authorization (RMA) and completion of the "Statement of Product Cleanliness and Decontamination" form are required.

Refer to the Assistance page at the end of this manual for more information. The data loggers need the following OS versions:

- CR6 OS 11 or newer
- CR1000X OS 5.0 or newer
- CR350-Series OS 1 or newer
- CR300-Series OS 10.05 or newer

The XLOADOS OS update process requires access to the data logger terminal mode. Campbell Scientific *Device Configuration Utility* is recommended.

Although this update may be performed remotely, if the sensor is not communicating with the data logger, it must first be power cycled to regain communication and accept the new OS.

1. Download the update file from the Campbell Scientific website and run the self-extracting executable. The extraction takes only a moment, and a dialog box will indicate that the OS file has been saved to the computer. Take note of the directory where the Wintersense SDI-12 OS is saved on the computer: C:\Campbellsci\Lib\OperatingSystems.
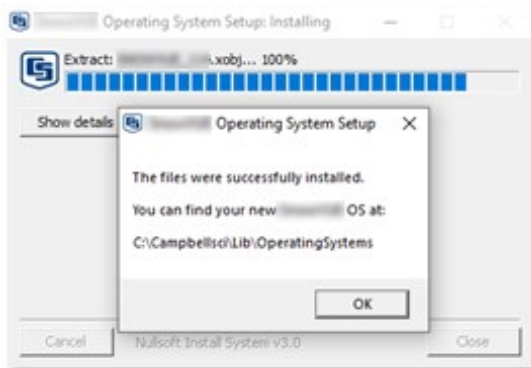
2. Upload the OS to the data logger CPU drive using *Device Configuration Utility*.
   - Connect to the data logger.
   - Open the **File Control** tab.

- Click the **Send** button and select the **WINTERSENSE_nnn.xobj** file from the C:\Campbellsci\Lib\OperatingSystems directory. File type needs to be changed to **All Files (*.*)** for the .xobj file to show up on the list.
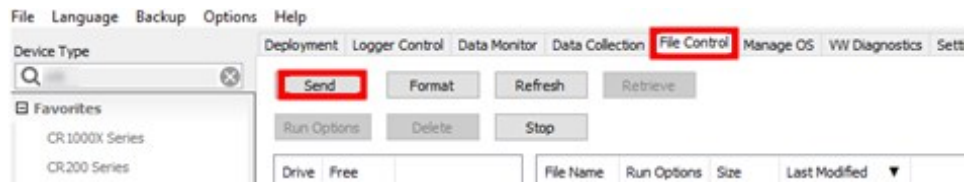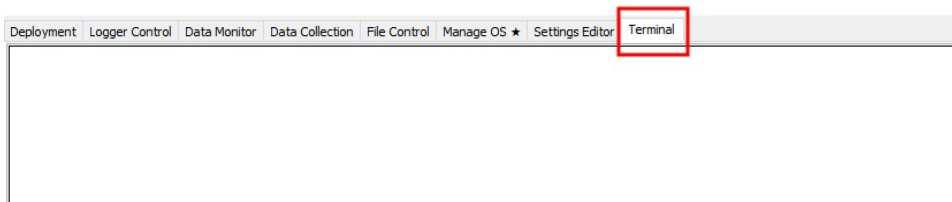

- Verify that the .xobj file is now on the data logger CPU drive.

3. Connect the sensor to the data logger digital and power terminals. Note the terminal the sensor is connected to. See Wiring (p. 8) for more information.

4. Open a terminal interface to the data logger. Press Enter twice within the terminal window to get a command prompt.

5. Within the terminal, run the following commands:

   - Type **SDI12** at the prompt and then enter the corresponding number assigned to the digital terminal the sensor is connected to.

   - Identify the SDI12 address of the sensor by typing `?!` at the prompt.

   - Verify that the responding sensor is the Wintersense SDI-12 that you want to update by using the SDI12 verify command `aI!`.

6. Send the OS to the sensor with the **XLOADOS** extended command in the following format:

   - `<address>XLOADOS <baud rate> <OS name>!`

   - For example, this update command would be entered as:

     `0XLOADOS 9600 CPU:WINTERSENSE_nnn.XOBJ!`

   > **NOTE:**
   > The CR300-series data loggers are case sensitive, and the file name must match the name used in the command. The All Caps checkbox on the bottom will need to be unchecked to allow lower cases.

7. It will take an additional 8 to 10 minutes to complete the loading process after the word **SUCCESS** is displayed.
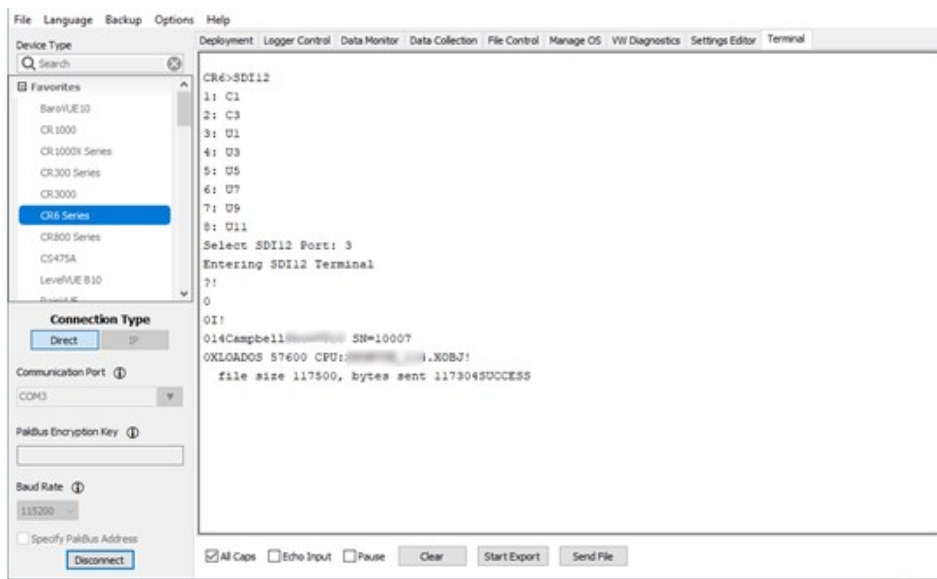
8. Verify the OS was updated with the verify command **aV!**, followed by the **aD0!** command to read the results.

8.4 Troubleshooting

Symptom:

On a CRBasic data logger, data values report NAN, or on a non-Campbell Scientific data logger, data values do not change when new measurement commands are issued.

Solution:

1. Verify the Wintersense SDI-12 is wired correctly. See Table 7-1 (p. 8).

   > **NOTE:**
   > Connect the power wire to the data logger **12V** terminal and not the **SW12** terminal.

2. Verify the power to the Wintersense SDI-12 is in the appropriate range (6 to 18 VDC).

3. Verify the correct SDI-12 address is being used when communicating with the Wintersense SDI-12. Use the transparent mode to verify the data logger can communicate with the it. For additional information, refer to SDI-12 transparent mode (p. 35).

   For more information refer to: www.campbellsci.com/videos/sdi12-sensors-transparent-mode ▶ and www.campbellsci.com/videos/sdi12-sensors-watch-or-sniffer-mode ▶.

Symptom:

Measurement values are inconsistent or erratic.

Solution:

1. Verify that the sensor angle has not changed.

2. Check that obstructions, such as vehicles, are not in the field of view.

Symptom:

Temperature and relative humidity measurement values are **-99.999**.

Solution:

1. Check the sensor element is properly plugged in, with the correct orientation. See Replace the temperature and humidity element (p. 18) for more information.

2. Check for water under the sensor element connector and ensure there is no corrosion of the sensor pins or the socket.

3. Check that the protective cap has been removed. See Temperature and humidity cover (p. 13) for more information.

4. Replace the element. See Replace the temperature and humidity element (p. 18) for more information.

5. If the above do not resolve the issue, the Wintersense SDI-12 requires factory repair. See Assistance for more information.

Symptom:

Temperature and relative humidity measurement values are inconsistent or slow to change.

Solution:

1. Check that the protective cap has been removed. See Temperature and humidity cover (p. 13) for more information.

Symptom:

Any other measurement value is **-99.999**.

Solution:

1. Wintersense SDI-12 requires factory repair. See Assistance page for more information.

Symptom:

Inaccurate temperature or relative humidity is reported.

Solution:

1. Clean the sensor tip with distilled water or replace it.

2. Check that the sensor is not installed too close to a radio transmitter or cell phone.

> **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.

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

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.

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. 29).

> **NOTE:**
> The Wintersense SDI-12 does not support all variants of the commands in the following table.

Table B-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>
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>
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'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).	

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: *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

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 = 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	
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 = 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	
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.

Table B-3: Example aC! sequence	
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 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 5 values.
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 ⬈ 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. 35]), 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.

In *Device Configuration Utility* connect to your data logger. Click the **Terminal** tab.

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. 35) 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, CR350-series, CR300-series, CR1000 data loggers.
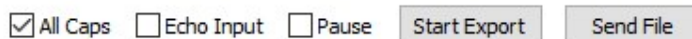
1. Connect an SDI-12 sensor to the CR1000X.

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**.
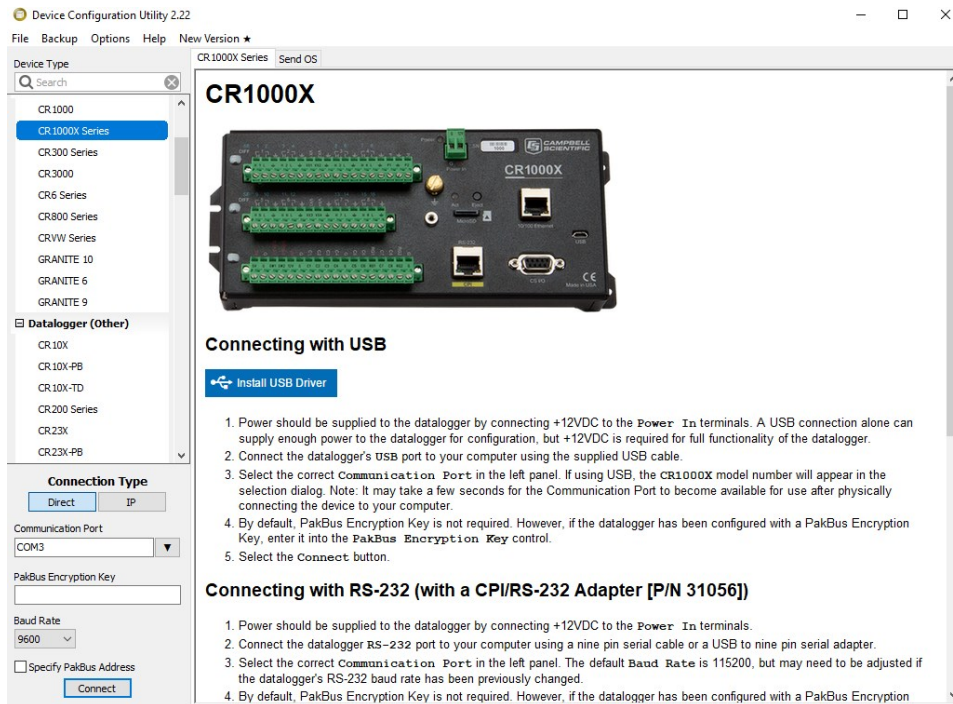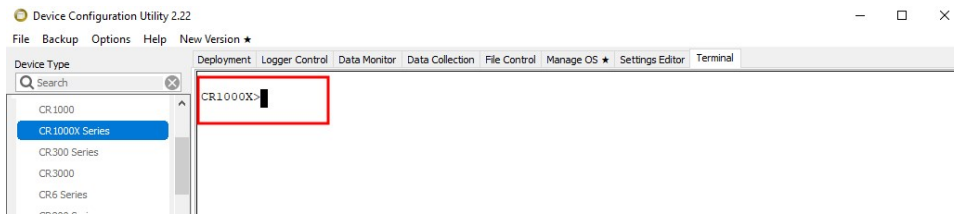

5. Click the **Terminal** tab.
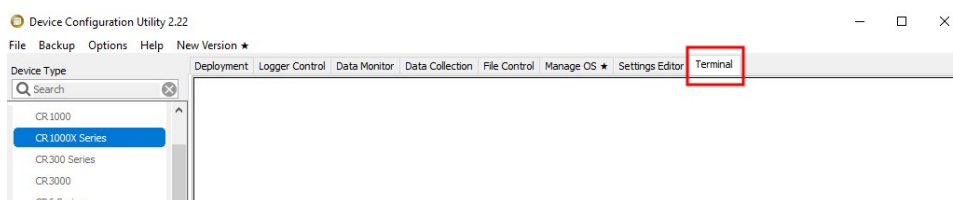
6. Select **All Caps Mode**.

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 CR6, CR3000, CR800-series, CR350-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. https://sdi-12.org/specification ↗.

Limited warranty

Products manufactured by Campbell Scientific are warranted by Campbell Scientific to be free from defects in materials and workmanship under normal use and service for twelve months from the date of shipment unless otherwise specified on the corresponding product webpage. See Product Details on the Ordering Information pages at www.campbellsci.com ⬀. 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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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.

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