

# CS230/CS231

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## Temperature Profilers



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# 1. Introduction

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The CS230/CS231 temperature profiler provides temperature measurements both in a rigid probe assembly and external probes using digital sensor technology. It uses the SDI-12 communication protocol to communicate with an SDI-12 recorder simplifying installation and programming.

**NOTE:**

SGB3 Surge Protectors were shipped with older CS230 temperature profilers (serial numbers < 1162). Newer CS230s (serial numbers  $\geq$  1162) and all CS231s include built-in surge protection, and therefore do not need the SGB3. For more information, refer to [SGB3 electrical surge protector](#) (p. 25).

## 2. Precautions

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- READ AND UNDERSTAND the [Safety](#) section at the back of this manual.
- Although the CS230/CS231 is designed to be a rugged and reliable device for field use, care should be taken when handling or moving it to avoid damage.
- There are no user-serviceable parts and disassembling the device will void the warranty.
- The black outer jacket of the cable is Santoprene® rubber. This compound was chosen for its resistance to temperature extremes, moisture, and 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.



## 3. Initial inspection

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- Upon receipt of the CS230/CS231, inspect the packaging and contents for damage. File 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 were received.

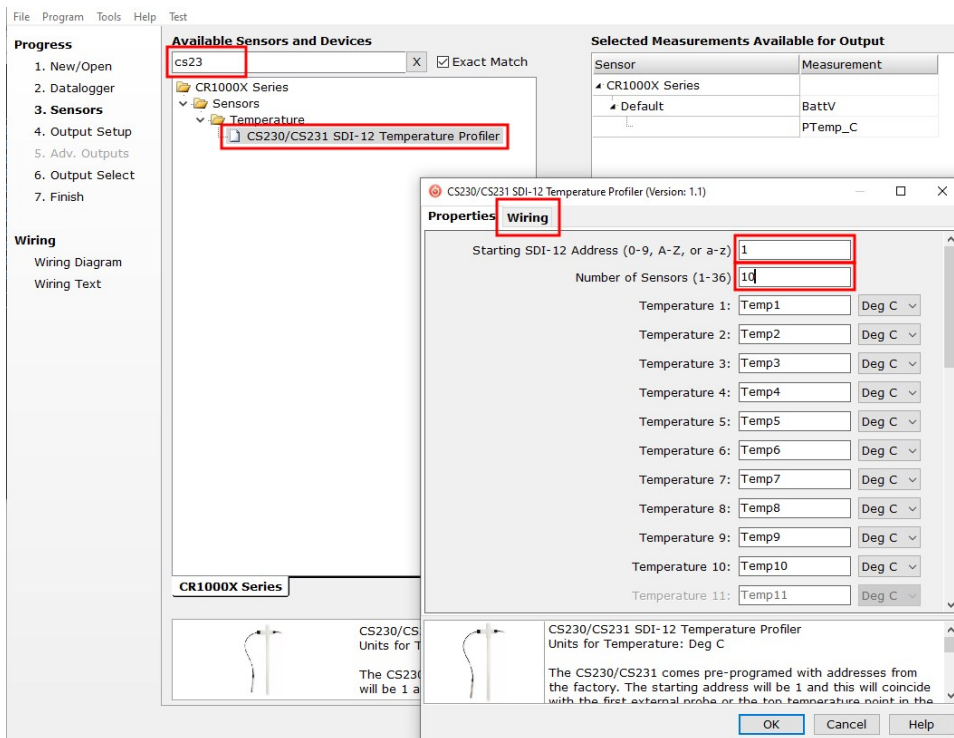
# 4. QuickStart

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

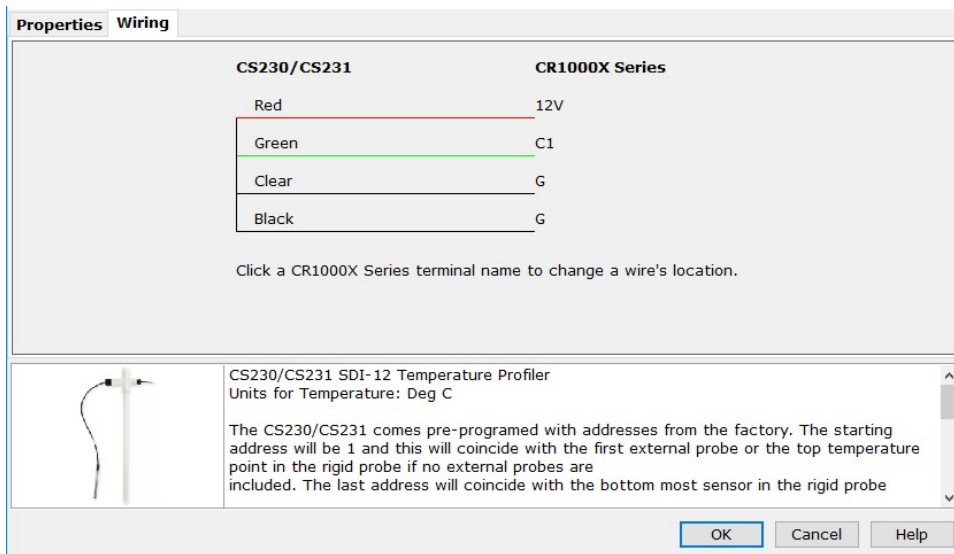
[www.campbellsci.com/videos/cr1000x-data-logger-getting-started-program-part-3](http://www.campbellsci.com/videos/cr1000x-data-logger-getting-started-program-part-3) . *Short Cut* is an easy way to program your data logger to measure the sensor and assign data logger wiring terminals. *Short Cut* is available as a download on [www.campbellsci.com](http://www.campbellsci.com) . It is included in installations of *LoggerNet*, *RTDAQ*, and *PC400*.

The following procedure also shows using Short Cut to program the CS230/CS231.

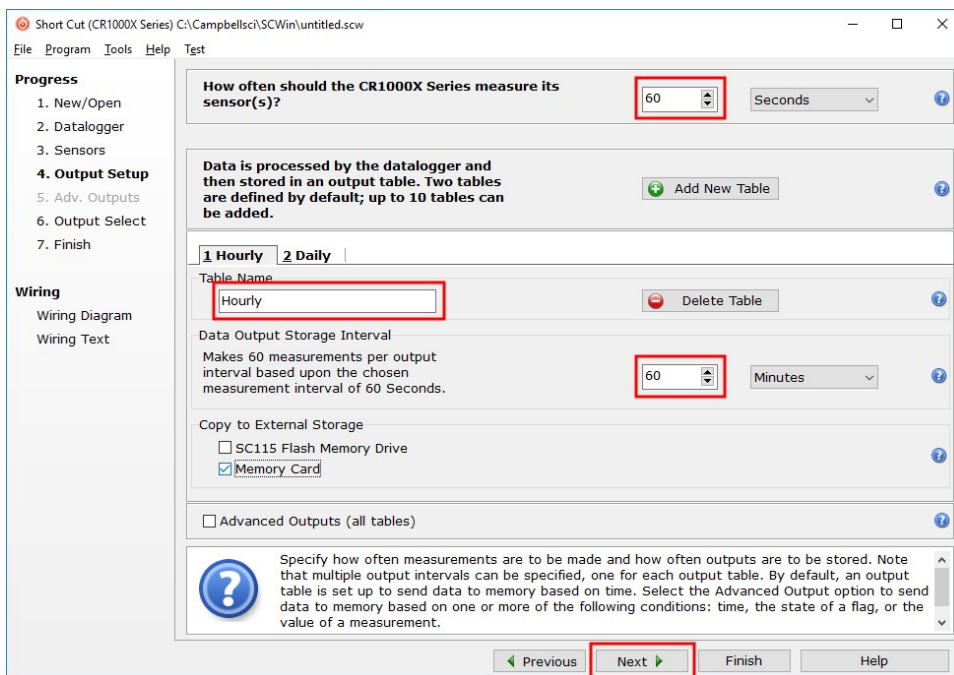
1. Open *Short Cut* and click **Create New Program**.
2. Double-click the data logger model.
3. In the **Available Sensors and Devices** box, type CS231 or locate the sensor in the **Sensors > Temperature** folder. Double-click **CS230/CS231 SDI-12 Temperature Profiler**. Type the correct **Starting SDI-12 Address** for the first external probe or the top temperature point in the rigid probe if no external probes are included ([SDI-12 addressing](#) (p. 11)). Type the **Number of Result Sensors**.



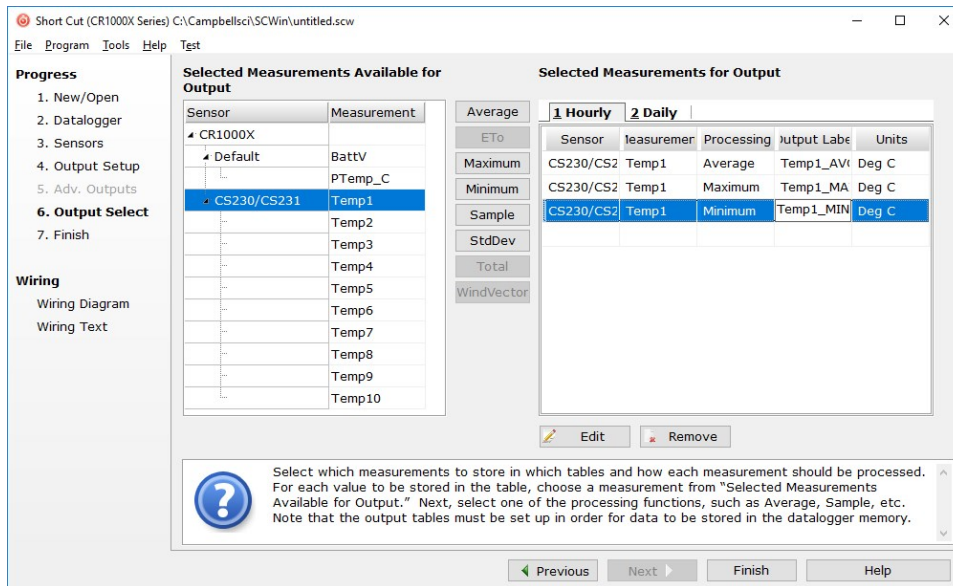
- Click the **Wiring** tab to see how the sensor is to be wired to the data logger. Click **OK** after wiring the sensor.



- Repeat steps 3 and 4 for other sensors.
- 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 display in *LoggerNet*, *RTDAQ*, or *PC400* to make sure it is making reasonable measurements.

## 5. Overview

The CS231 offers the same precise temperature profiling as our CS230 SDI-12 Temperature Profiler, but designed for easier use in borehole and road applications. The two profilers have the same programming, wiring, and measurement specifications.

The CS230/CS231 temperature profiler uses digital sensor technology allowing for a simple 3-wire integration. The CS230/CS231 consists of a rigid probe assembly and up to four optional external temperature probes. The rigid probe assembly maintains the precise position of the temperature points within the profile, while protecting the temperature sensors in all mediums.

The CS230/CS231 is suited for a wide variety of applications and environments. The completely sealed probe assembly and external probes permits the CS230/CS231 to be used in roadbeds, soils, and water (snow and ice).

Examples of some applications include spring load adjustment, frost and permafrost monitoring, soil and water temperature profiling, and snowpack temperature profiling.

## Features:

- Accurate and stable measurements
- Each sensor is individually addressed and referenced to its depth
- Low power consumption
- Digital SDI-12 output
- Compatible with the following data loggers: CR6, CR3000, CR1000X, CR800 Series, CR300 Series, CR1000

# 6. Specifications

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Operating range:	–55 to 85 °C
Accuracy	
Typical:	±0.2 °C over –40 to 85 °C,
Worst case:	±0.4 °C over –40 to 85 °C; ±0.5 °C over –55 to –40 °C (includes lifetime drift of sensor)
Resolution:	0.0078 °C
Output protocol:	SDI-12 1.3
Measurement update interval:	1 s (automatic), occurs in quiescent mode
Warm-up time:	10 s
Time constant (ice bath)	
External probe:	60 s
Tee sensor:	720 s
Second sensor from tee:	420 s
Remainder of profiler:	300 s
Maximum sensors per probe:	32 sensors in rigid probe assembly, 4 external sensors
External probe length:	45 cm (18 in)
Supply voltage:	9 to 28 VDC



## Current Consumption

Quiescent:	# sensors • 1.0 mA (max)
Active (during SDI-12 communications):	20 mA + (# sensors • 1.0 mA)
Main diameter:	2.13 cm (0.84 in)
Maximum length:	3.0 m (118 in)
Maximum cable length:	152 m (500 ft)
Minimum sensor spacing:	5 cm (1.97 in) in rigid probe assembly
EU Declaration of Conformity:	View at <a href="http://www.campbellsci.com/cs230-I">www.campbellsci.com/cs230-I</a> or <a href="http://www.campbellsci.com/cs231-I">www.campbellsci.com/cs231-I</a>

# 7. Installation

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If you are programming your data logger with *Short Cut*, skip [Wiring](#) (p. 8) and [Programming](#) (p. 9). *Short Cut* does this work for you. See [QuickStart](#) (p. 2) for a *Short Cut* tutorial.

## 7.1 Siting

Install the CS230/CS231 directly in the medium that is to be measured. The types of medium that can be measured are varied, including soils, roadbeds, and water. To make the most representative measurement, it is important that consistent contact be made between the temperature profiler and the medium.

The location of the temperature profiler should be representative of the intended application. Typically, the first measurement point in the rigid assembly should have a minimum burial depth of 20 cm. This helps protect the sensor from damage in roadbed applications, and helps secure the sensor against frost heaving. Use the external probes for measurements at shallower depths. The external probes are sheathed in a stainless-steel housing to protect them against possible damage.

The installation depth of the rigid assembly is referenced at the first measurement point in the assembly (shown in [FIGURE 7-1](#) (p. 7), Internal Sensor Position #4). This information needs to be addressed as part of the sensor configuration process.

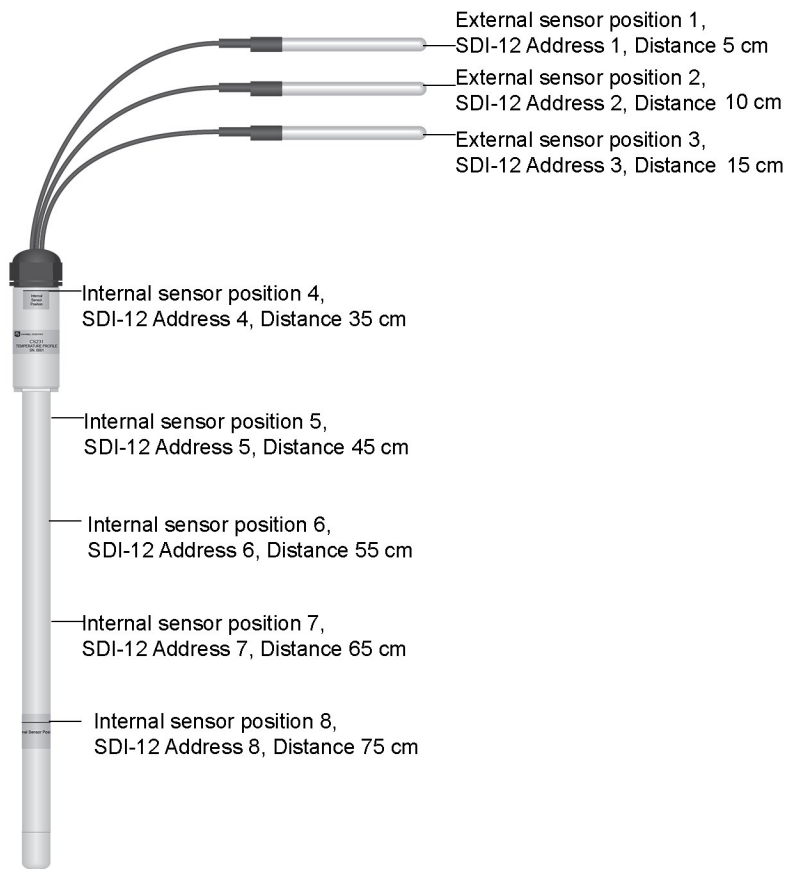


FIGURE 7-1. CS231 installation example with three external sensors and five internal sensors

**NOTE:**

FIGURE 7-1 (p. 7) is an example configuration with three external sensors and five internal sensors. Each profiler is custom built to the user's specific requirements.

FIGURE 7-2 (p. 7) shows the label for the first and last internal sensor locations.



FIGURE 7-2. Internal sensor label

## 7.2 Mounting

Orient and secure the CS230/CS231 in the measurement medium. Keep materials removed during installation and use that material as backfill.

While installing the CS230/CS231, the depth must be referenced between the surface of the medium and the first measurement point in the assembly (shown in [FIGURE 7-1](#) (p. 7), Internal Sensor Position #4). If the rigid assembly is not placed at the correct depth, all measurement depths will be out of place.

Install the external probes horizontally in the measurement medium. This helps ensure that the most representative measurement is taken at the given depth, and will not interfere with other nearby measurements.

Orient the signal and power cable of the CS230/CS231 towards the data logger to avoid loops or strain on the cable. Also use a suitable trench or conduit to protect the signal and power cable from damage.

## 7.3 Wiring

[Table 7-1](#) (p. 8) provides the connections for the CS230/CS231 and Campbell Scientific data loggers. Refer to [SGB3 electrical surge protector](#) (p. 25) if the CS230 serial number is less than 1162.

Wire color	Function	Data logger connection terminal
Red	Power	12V
Green	SDI-12 Signal	C or U <sup>1</sup> terminal configured for SDI-12
Black	Power Ground	G
Clear	Shield	G

<sup>1</sup> U terminals are automatically configured by the measurement instruction.


If multiple SDI-12 sensors are connected to a data logger, Campbell Scientific recommends using separate terminals when possible. For the CR6 and CR1000X, triggering conflicts may occur when a companion terminal is used for a triggering instruction such as [TimerInput\(\)](#), [PulseCount\(\)](#), or [WaitDigTrig\(\)](#). For example, if the CS230/CS231 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 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. 16). Programming basics for CRBasic data loggers are provided in the following section. Downloadable example programs are available at [www.campbellsci.com/downloads/cs230-cs231-example-programs](http://www.campbellsci.com/downloads/cs230-cs231-example-programs) .

### 7.4.1 SDI12Recorder() instruction

The **SDI12Recorder()** instruction is used to measure the temperature sensors in the CS230/CS231. This instruction sends a request to the sensor to make a measurement and then retrieves the measurement from the sensor. See [Sensor measurements](#) (p. 10) for more information.

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


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

Each temperature sensor in the CS230/CS231 needs a unique SDI-12 address. 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 ([Table 8-1](#) (p. 10)).

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

### 7.4.2 Slow sequence program instructions

Use the slow sequence program instructions when the CS230/CS231 measurements will exceed the program scan interval of the additional instruments included in the station. For example, if a CS230/CS231 consists of 17 or more temperature sensors, the time required to poll all sensors and receive data can be greater than 5 seconds based on the 300 ms execution time for the

**aR0!** command. For more details on the use of the slow sequence program instructions, reference the related *LoggerNet Help*, data logger manual, or the slow sequence program at [www.campbellsci.com/downloads/cs230-cs231-example-programs](http://www.campbellsci.com/downloads/cs230-cs231-example-programs) .

# 8. Operation

## 8.1 Sensor measurements

The CS230/CS231 responds to the SDI-12 commands shown in [Table 8-1](#) (p. 10). When power is supplied to the CS230/CS231, the internal electronics continuously measure temperature at a rate of approximately once per second. Every output measurement (**aR0!** or **aM0!**) obtained from the sensor is a running average of 10 consecutive readings. The accuracy specification is based on an average of 10 consecutive readings. Therefore, after initial power up, a delay of 10 s is recommended to obtain the best accuracy.

As the sensor is obtaining a measurement every second, Campbell Scientific recommends using the continuous measurement command (**aR0!**) to obtain the temperature readings. Using the **aR0!** commands reduces the time taken in comparison to the **aM0!** to obtain a reading via the SDI-12 protocol.

Outputs of both lifetime and user resettable minimum and maximum temperatures are also available during powered operation from each temperature point in the CS230/CS231. The user-resettable minimum and maximum temperatures can be used to monitor specific seasons or periods of measure, without having to review the entire data set. The lifetime minimum and maximum temperatures are used for maintenance and warranty records. The lifetime and user-resettable minimum and maximum temperature values are single 1-second readings.

SDI-12 command	Variable name	Description
<b>aR0!</b>	Temperature value	Temperature – floating point (°C)
<b>aR1!</b>	Serial number, location number, depth value (in cm)	Serial number, location number, depth value (in cm)
<b>aR2!</b>	Read user resettable min temperature	Min. temperature – floating point (°C)
<b>aR3!</b>	Read user resettable max temperature	Max. temperature – floating point (°C)
<b>aR4!</b>	Read lifetime min temperature	Min. temperature – floating point (°C)

Table 8-1: SDI-12 commands		
SDI-12 command	Variable name	Description
<b>aR5!</b>	Read lifetime max temperature	Max. temperature – floating point (°C)
<b>aR6!</b>	Read and reset user resettable min temperature	Min. temperature – floating point (°C). This value constitutes the minimum of all 1-second measurements taken since the previous <b>aR6!</b> command.
<b>aR7!</b>	Read and reset user resettable max temperature	Max. temperature – floating point (°C). This value constitutes the maximum of all 1-second measurements taken since the previous <b>aR7!</b> command.
<b>aV!</b>	Verification command	S1 = BootRom Signature S2 = Firmware Signature
<b>aAb!</b>	Change Address command	Valid addresses in sequence are: 1–9 / A–Z / a–z (no Address 0) Sending a broadcast message with the address change “{” can correct units that have conflicting addresses.
<b>aI!</b>	SDI-12 Identification command	X13CAMPBELLCS230 1.0 SN:XXXXX

## 8.1.1 SDI-12 addressing

Each temperature sensor has a different default SDI-12 address. The starting addresses is 1 and coincides with the first external probe or the top temperature point in the rigid probe if an external probe is not included. The last address coincides with the bottom sensor in the rigid probe assembly.

If multiple SDI-12 sensors are connected to the data logger, Campbell Scientific recommends using separate terminals when possible. However, multiple SDI-12 sensors or multiple CS230/CS231 sensors can connect to the same data logger control or **U** terminal if they have different SDI-12 addresses. If changing the SDI-12 addresses, Campbell Scientific recommends starting the readdressing process with the largest temperature sensor address to avoid duplicate addresses. [Table 8-2](#) (p. 12) provides the SDI-12 addresses and positions.

**NOTE:**

Use the default SDI-12 addresses when possible. Inadvertently giving multiple sensors the same SDI-12 address will prevent the sensors from communicating. Use the **aA{!** command, where *a* is the affected address to reset the affected sensors to their factory configured address value.

Numeric set	Uppercase set	Lowercase set
1 / 1	A / 10	a / 36
2 / 2	B / 11	b / 37
3 / 3	C / 12	c / 38
4 / 4	D / 13	d / 39
5 / 5	E / 14	e / 40
6 / 6	F / 15	f / 41
7 / 7	G / 16	g / 42
8 / 8	H / 17	h / 43
9 / 9	I / 18	i / 44
	J / 19	j / 45
	K / 20	k / 46
	L / 21	l / 47
	M / 22	m / 48
	N / 23	n / 49
	O / 24	o / 50
	P / 25	p / 51
	Q / 26	q / 52
	R / 27	r / 53
	S / 28	s / 54
	T / 29	t / 55
	U / 30	u / 56
	V / 31	v / 57

Numeric set	Uppercase set	Lowercase set
	W / 32	w / 58
	X / 33	x / 59
	Y / 34	y / 60
	Z / 35	a / 61
		{ – reset to factory address

## 8.1.2 Metadata

Every temperature point in a probe includes the following metadata, which can be retrieved using the **aR1!** SDI-12 command. This information can be used to identify details of the temperature probe and its individual temperature points.

Name	Value range	Description
Serial Number	0 to 65534	The serial number that is unique to each probe unit.
Location Number	1 to 255	Each temperature sensor within a probe is assigned its own unique location number which by default is in relation to the SDI-12 address (see <a href="#">Table 8-1</a> (p. 10)).
Depth Value	0 to 65535 cm	The distance values in centimeters (cm). These are intended to reflect the profile distances. Typically, the top most temperature point would be designated as 0 cm and if the next temperature point below was 10 cm away, then its distance value would be 10 cm. Users may designate other starting values. These can be configured at the time of ordering.

## 8.2 Long cables

As the measurement data is transferred between the temperature profiler and data logger digitally, there are no offset errors incurred with increasing cable length as seen with analog sensors. However, with long enough cable lengths, the digital communications will break down, resulting in either no response from the sensor or corrupted readings. The original SDI-12 standard specifies the maximum total cable length for the cable as being 61 m (200 ft), but we are able to exceed this limit by:



- Using low capacitance, low resistance, screened cable
- Ensuring that the power ground cable has low resistance and is connected to the same ground reference as the data logger control or U terminals

## 8.3 Power conservation

The CS230/CS231 draws less than 1 mA of current per sensor between polling sessions from its 12 V supply. In many applications, this is minimal compared to overall system power use, so the sensor can be permanently powered to avoid the warm-up period.

In low power applications, you can switch the power on a minimum of 10 s (allowing for the warm-up period) before polling the CS230/CS231. This switching can be achieved in different ways depending on the type and model of your data logger. If available, the switched 12 V output of the data logger can be used.

# 9. Maintenance, calibration, and troubleshooting

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The CS230/CS231 probe requires no maintenance nor calibration. The following are symptoms and possible corrections.

Symptom: -9999 or NAN for temperature

1. Verify the green wire is connected to the control terminal specified by the SDI-12 measurement instruction.
2. Verify the red power wire is connected to a 12V terminal; check the voltage with a digital volt meter. If a switched 12V terminal is used, temporarily connect the red wire to a 12V terminal (non-switched) for test purposes.

Symptom: Sensor won't respond to command

1. Expected address not used or has been changed.
  - a. Confirm all addresses in use with the **aI!** command to determine the individual addresses of each temperature sensor.

2. Expected sensor address has been to match another sensor address already in use.
  - a. When readdressing temperature sensors, you must avoid giving multiple sensors the same address. If this does occur, you will no longer be able to communicate with these sensors. Use the `aA{!` command, where a is the affected address. This will reset the affected sensors to their factory configured address value. For example, if two sensors have address 2, sending `2A{!` will reset both sensors to the original addresses.

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

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

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

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

**NOTE:**

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

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

# Appendix B. SDI-12 sensor support

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

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

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

## B.1 SDI-12 command basics

SDI-12 commands have three components:

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

An active sensor responds to each command. Responses have several standard forms and always terminate with <CR> <LF> (carriage return and line feed). Standard SDI-12 commands are listed in [Table B-1](#) (p. 17).

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

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

Name	Command	Response <sup>1</sup>
Address Query	?!	a<CR> <LF>
Change Address	aAb!	b<CR> <LF>
Start Measurement	aM! aM1! . . . aM9!	attn<CR> <LF>
Send Data	aD0! . . . aD9!	a<values> <CR> <LF> or a<values> <CRC> <CR> <LF>

<sup>1</sup> Information on each of these commands is given in the following sections.

### B.1.1 Acknowledge active command (a!)

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

### B.1.2 Send identification command (aI!)

Sensor identifiers are requested by issuing command aI!. The reply is defined by the sensor manufacturer but usually includes the sensor address, SDI-12 version, manufacturer’s name, and sensor model information. Serial number or other sensor specific information may also be included.

<b>aI!</b>	allccccccmmmmmmvvvxxx...xx<CR> <LF>
a	Sensor SDI-12 address
ll	SDI-12 version number (indicates compatibility)
ccccccc	8-character vendor identification
mmmmmm	6 characters specifying the sensor model
vvv	3 characters specifying the sensor version (operating system)
xxx...xx	Up to 13 optional characters used for a serial number or other specific sensor information that is not relevant for operation of the data logger
<CR> <LF>	Terminates the response

Source: *SDI-12: A Serial-Digital Interface Standard for Microprocessor-Based Sensors* (see References).

## B.1.3 Start verification command (aV!)

The response to a Start Verification command can include hardware diagnostics, but like the **aI!** command, the response is not standardized.

Command: **aV!**

Response: *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	
<b>OM!</b>	The data logger makes a request to sensor 0 to start a measurement.
00352<CR><LF>	Sensor 0 immediately indicates that it will return two values within the next 35 seconds.
0<CR><LF>	Within 35 seconds, sensor 0 indicates that it has completed the measurement by sending a service request to the data logger.
<b>OD0!</b>	The data logger immediately issues the first <b>D</b> command to collect data from the sensor.
0+.859+3.54<CR><LF>	The sensor immediately responds with the sensor address and the two values.

## B.1.7 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.1.8 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. 21)), 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.1.9 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.2 SDI-12 transparent mode

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

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

The terminal emulator is accessed by navigating to the **Tools** list in **PC400** or the **Datalogger** list in the **Connect** screen of **LoggerNet**.

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

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

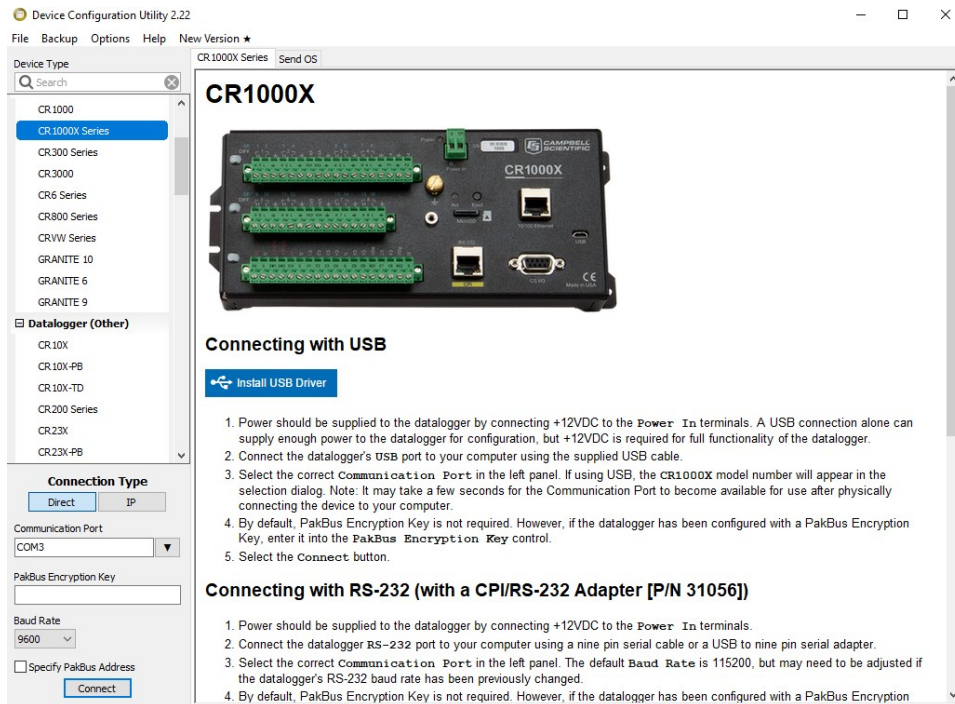
The following examples show how to enter transparent mode and change the SDI-12 address of an SDI-12 sensor. The steps shown in [Changing an SDI-12 address](#) (p. 21) are used with most Campbell Scientific data loggers.

### B.2.1 Changing an SDI-12 address

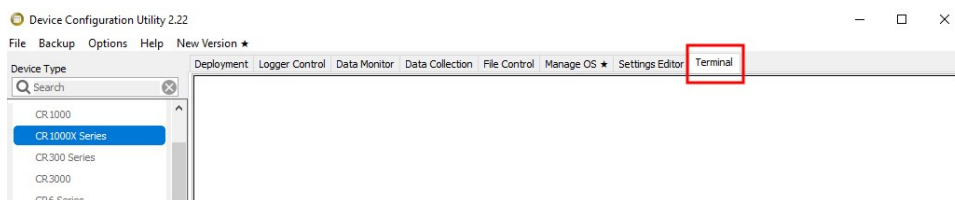
This example was done with a CR1000X, but the steps are only slightly different for CR6, CR3000, CR800-series, CR300-series, CR1000 data loggers.



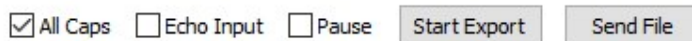
1. Connect an SDI-12 sensor to the CR1000X.
2. Open *Device Configuration* utility.
3. Under **Device Type**, type the data logger model and double-click on the model type. This example uses a CR1000X directly connected to the computer USB port.
4. Select the correct **Communication Port** and click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



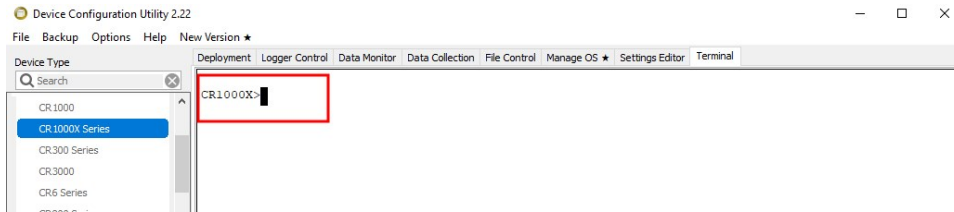
5. Click the **Terminal** tab.



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, 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> .

# Appendix C. SGB3 electrical surge protector

---

SGB3 Surge Protectors (FIGURE C-1 (p. 25)) were required with older CS230 temperature profilers (serial numbers < 1162). Newer CS230 (serial numbers  $\geq 1162$ ) and all CS231 profilers include built-in surge protection, and therefore do not need the SGB3.



FIGURE C-1. SGB3 3-line surge protector

## C.1 SGB3 3-line surge protector specifications

- Operating range:**  $-55$  to  $85$  °C
- Maximum voltage:**  $\pm 28$  VDC / 20 VAC  
(L1, L2, L3 with respect to G terminals)
- Maximum current:** 2 A per terminal, 4 A total  
(requires both ground terminals for return current)
- Maximum rated surge:** 1200 A (8/20  $\mu$ s)

## C.2 SGB3 3-line surge protector mounting and wiring

Older CS230 profilers were shipped with the SGB3, a 2-ft cable for connecting the SGB3 to the data logger, and two pan Phillips screws and two grommets for mounting the SGB3 to an

enclosure backplate. The case of the SGB3 is suited for mounting to a back plate with 1 inch on center spacing.

Table C-1 (p. 26) provides the connections for the SGB3 surge protector, CS230, and Campbell Scientific data loggers.

Table C-1: Wire color, function, and connections to the SGB3 and data logger			
CS230 wire color	Function	SGB3 connection terminal	Data logger connection terminal <sup>1</sup>
Red	Power	L1	12V
Green	SDI-12 Signal	L2	C or U <sup>2</sup> terminal configured for SDI-12
Black	Power Ground	G	G
Clear	Shield	G	G

<sup>1</sup> The SGB3 connects to the data logger using the 2 ft cable shipped with the CS230.

<sup>2</sup> U terminals are automatically configured by the measurement instruction.

If multiple SDI-12 sensors are connected to a data logger, Campbell Scientific recommends using separate terminals when possible. For the CR6 and CR1000X, triggering conflicts may occur when a companion terminal is used for a triggering instruction such as [TimerInput\(\)](#), [PulseCount\(\)](#), or [WaitDigTrig\(\)](#). For example, if the CS230/CS231 is connected to C3 on a CR1000X, C4 cannot be used in the [TimerInput\(\)](#), [PulseCount\(\)](#), or [WaitDigTrig\(\)](#) instructions.

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# Safety

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**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](http://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.
- Use only qualified personnel for installation, use, and maintenance of tripods and towers, and any attachments to tripods and towers. The use of licensed and qualified contractors is highly recommended.
- Read all applicable instructions carefully and understand procedures thoroughly before beginning work.
- Wear a **hardhat** and **eye protection**, and take **other appropriate safety precautions** while working on or around tripods and towers.
- **Do not climb** tripods or towers at any time, and prohibit climbing by other persons. Take reasonable precautions to secure tripod and tower sites from trespassers.
- Use only manufacturer recommended parts, materials, and tools.

## Utility and Electrical

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

## Elevated Work and Weather

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

## Maintenance

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

## Internal Battery

- Be aware of fire, explosion, and severe-burn hazards.
- Misuse or improper installation of the internal lithium battery can cause severe injury.
- Do not recharge, disassemble, heat above 100 °C (212 °F), solder directly to the cell, incinerate, or expose contents to water. Dispose of spent batteries properly.

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