PRODUCT MANUAL

Sensor

CS225

Temperature String

Revision: 10/2024

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Please read first

About this manual

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

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

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

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

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1. Introduction

The CS225 Temperature String uses SDI-12 digital technology for simple integration and reliability. The CS225 consists of an arrangement of temperature sensors mounted in rugged steel reinforced cable. Temperature points are over molded to provide long-term connection in all mediums. Each CS225 is manufactured to the client's specific requirements and includes the SGB3 to provide electrical surge protection.

> **NOTE:**
> This manual provides information only for CRBasic data loggers. For retired Edlog data logger support, see an older manual at www.campbellsci.com/old-manuals.

2. Precautions

- READ AND UNDERSTAND the Safety section at the back of this manual.
- Although the CS225 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.

- CAUTION—Do not make tight bends near the temperature sensor(s). Doing so has the potential to damage the sensor assembly. The minimum bend radius at any sensor location is 15 cm (6 in). See following image.

3. Initial inspection

- Upon receipt of the CS225, 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.

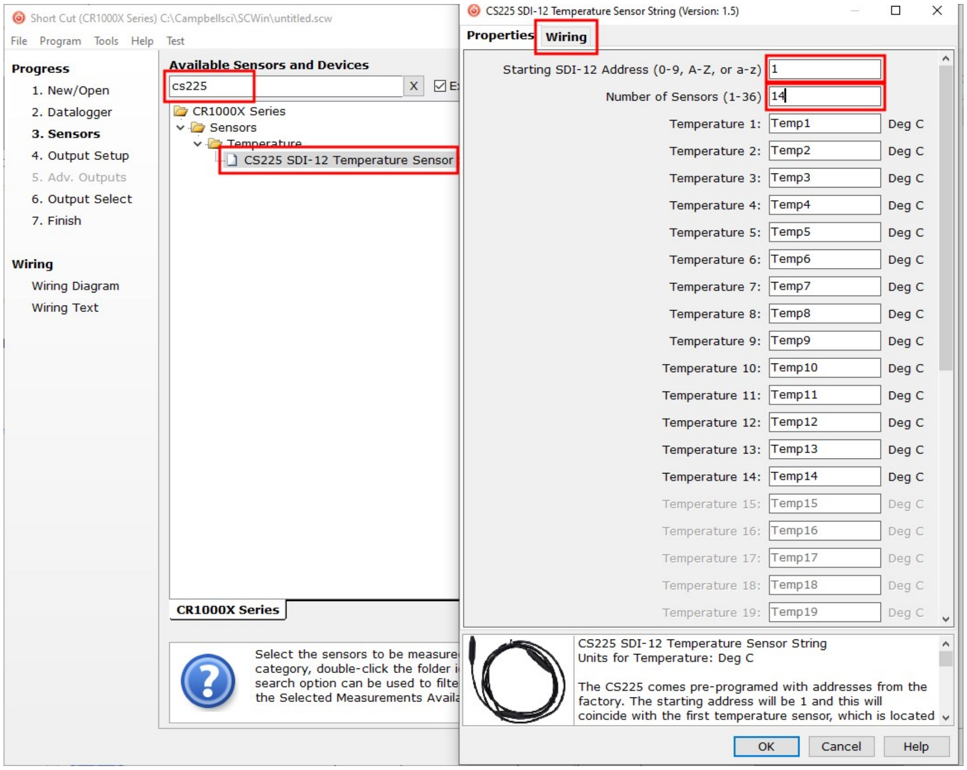
4. QuickStart

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. ***Short Cut*** is an easy way to program your data logger to measure the sensor and assign data logger wiring terminals. ***Short Cut*** is available as a download on www.campbellsci.com. It is included in installations of ***LoggerNet***, ***RTDAQ***, and ***PC400***.

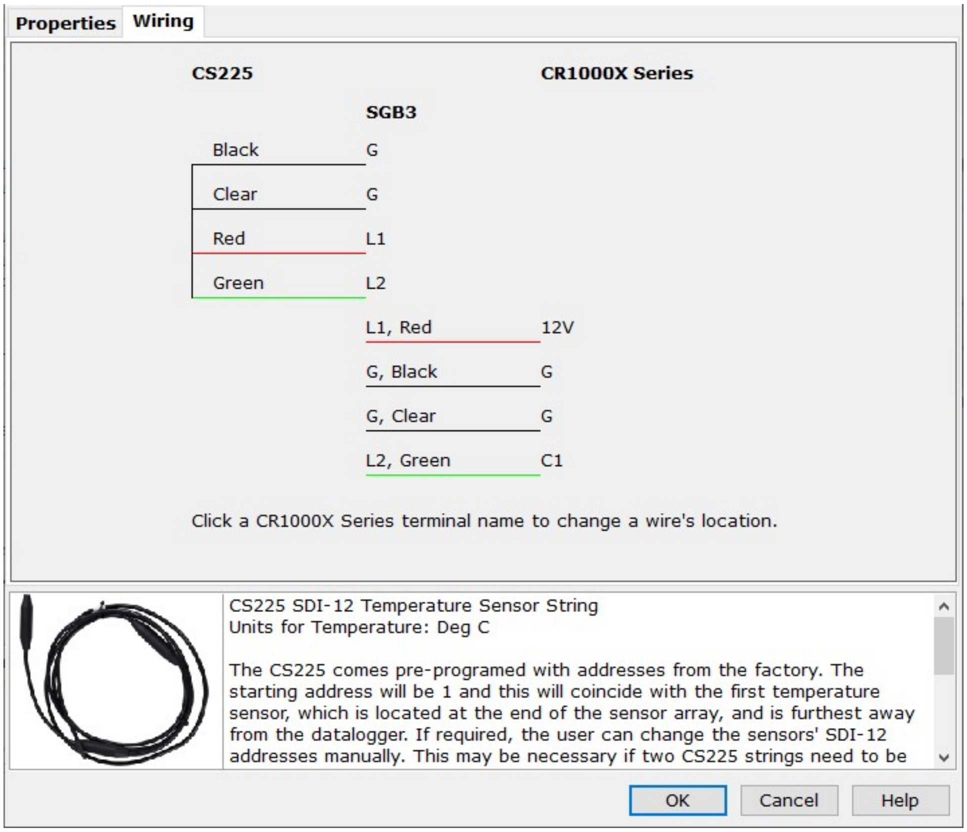
The following procedure also shows using Short Cut to program the CS225.

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 CS225 or locate the sensor in the **Sensors** > **Temperature** folder. Double-click **CS225 SDI-12 Temperature Profiler**. Type the correct **Starting SDI-12 Address** for the first sensor (SDI-12 addressing [p. 12]). Type the **Number of Result Sensors**.

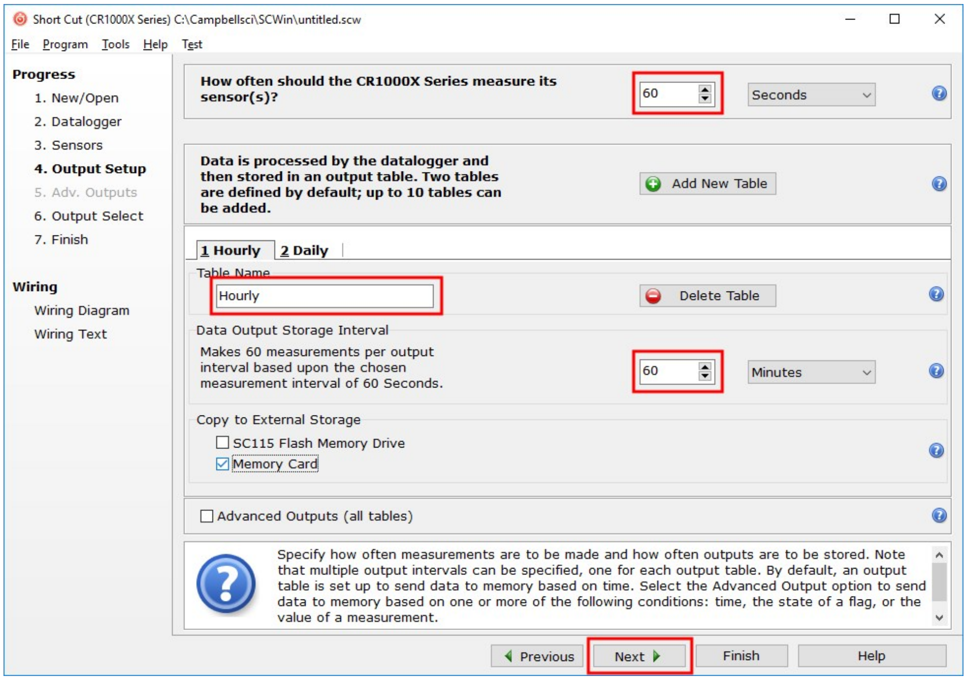


4. Click the **Wiring** tab to see how the sensor is to be wired to the data logger. Click **OK** after wiring the sensor.

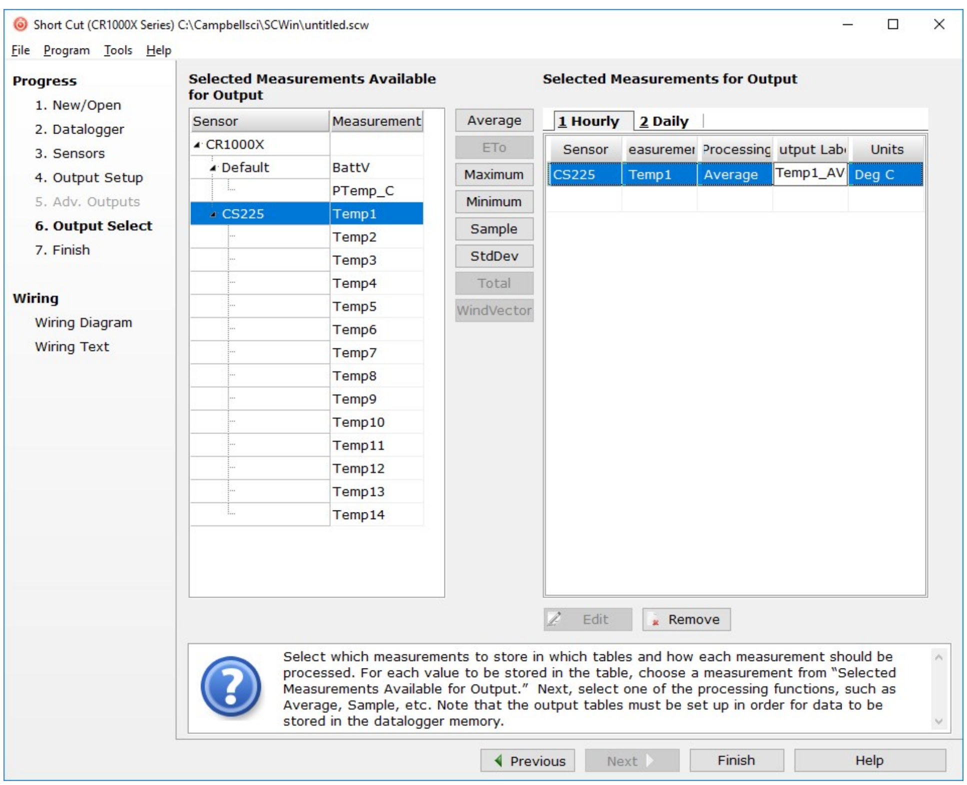


5. Repeat steps 3 and 4 for other sensors.

6. In **Output Setup**, type the scan rate, meaningful table names, and **Data Output Storage Interval**.



7. Select the measurement and its associated output option.



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

5. Overview

The CS225 Temperature String uses digital sensor technology allowing for a simple three-wire integration. The CS225 consists of an arrangement of over molded temperature points mounted in a rugged steel reinforced cable. Each CS225 is manufactured to the client's specific requirements.

The CS225 is suited to a wide variety of applications and environments that require temperature profiling. The completely sealed cable assembly permits the CS225 to be buried, submerged, or integrated directly into structures. Examples of applications include temperature profiling in boreholes, soils, water, and frost and permafrost monitoring.

The SGB3 provides surge protection for the CS225 Temperature String. The SGB3 case can be mounted to the backplate of a Campbell Scientific enclosure.

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

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
Maximum sensors per probe:	36
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)
Temperature point diameter:	2.22 cm (0.88 in)
Maximum cable length:	152 m (500 ft)
Minimum sensor spacing:	15 cm (6 in)
EU Declaration of Conformity:	View at www.campbellsci.com/cs225-l

6.1 SGB3 3-line surge protector

Operating range:	–55 to 85 °C
Maximum voltage:	±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 µs)

7. Installation

If you are programming your data logger with ***Short Cut***, skip Wiring (p. 9) and Programming (p. 10). ***Short Cut*** does this work for you. See QuickStart (p. 2) for a ***Short Cut*** tutorial.

7.1 Siting

Install the CS225 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.

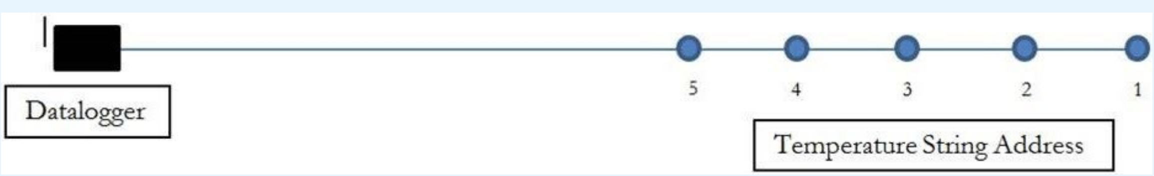
The CS225 consists of the lead cable and the sensor array. The lead cable length is the length between the data logger and sensor array. The sensor array length is the length of cable that incorporates all temperature sensors in their specified configuration. The installation position of the string and its measurement points are referenced from the first sensor position at the end of the sensor array. This information is needed for the sensor configuration process.

7.2 Mounting

Orient and secure the CS225 in the measurement medium. Keep materials removed during installation and use that material as backfill.

If a burial depth is required for each temperature sensor, you need to know the length of the sensor array, the "measurement from end" metadata of each sensor in the array, and any offset used during installation of the string. You will also need to calculate the depth of each temperature sensor.

> **NOTE:**
> The furthest temperature point from the data logger (or the temperature point at the end of the string) is addressed starting at '1'. Each temperature point going up the string towards the data logger changes by one address number/letter.



Orient the lead cable of the CS225 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.

The SGB3 is required to protect against electrical surges (Figure 7-1 [p. 9]). The CS225 is 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.

Figure 7-1. SGB3 3-line surge protector

7.3 Wiring

Table 7-1 (p. 9) provides the connections for the SGB3 surge protector, CS225, and Campbell Scientific data loggers.

Table 7-1: Wire color, function, and connections to the SGB3 and data logger

CS225 wire color	Function	SGB3 connection terminal	Data logger connection terminal[1]
Red	Power	**L1**	**12V**
Green	SDI-12 Signal	**L2**	**C** or **U**[2] terminal configured for SDI-12
Black	Power Ground	**G**	**G**
Clear	Shield	**G**	**G**

[1] The SGB3 connects to the data logger using the 2 ft cable shipped with the CS225.

[2] **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 CS225 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. 17). Programming basics for CRBasic data loggers are provided in the following section. Downloadable example programs are available at www.campbellsci.com/downloads/cs225-example-programs.

7.4.1 `SDI12Recorder()` instruction

The `SDI12Recorder()` instruction is used to measure the temperature sensors in the CS225. This instruction sends a request to the sensor to make a measurement and then retrieves the measurement from the sensor. See Sensor measurements (p. 11) for more information.

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

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

Each temperature sensor in the CS225 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. 11]).

`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 CS225 measurements will exceed the program scan interval of the additional instruments included in the station. For example, if a CS225 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/cs225-example-programs.

8. Operation

8.1 Sensor measurements

The CS225 responds to the SDI-12 commands shown in Table 8-1 (p. 11). When power is supplied to the CS225, 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 CS225. 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.

Table 8-1: SDI-12 commands

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

Table 8-1: SDI-12 commands		
SDI-12 command	Variable name	Description
aR5!	Read lifetime max temperature	Max. temperature – floating point (°C)
aR6!	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 **aR6!** command.
aR7!	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 **aR7!** command.
aV!	Verification command	S1 = BootRom Signature S2 = Firmware Signature
aAb!	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.
aI!	SDI-12 Identification command	X13CAMPBELLCS225 1.0 SN:XXXXX

8.1.1 SDI-12 addressing

Each temperature sensor has a different default SDI-12 address. The starting address is 1 and coincides with the bottom temperature point. The last address coincides with the top sensor, which is closest to the data logger.

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 CS225 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. 13) 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.

Table 8-2: SDI-12 addresses and positions

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

Table 8-2: SDI-12 addresses and positions		
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.

Table 8-3: Metadata details		
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 Table 8-1 [p. 11]).
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 CS225 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 CS225. 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.

8. Maintenance, calibration, and troubleshooting

The CS225 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*

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 and the SDI-12 Sensors Troubleshooting Tips application note.

B.1 SDI-12 command basics

SDI-12 commands have three components:

- **Sensor address (a)** – a single character and the first character of the command. Use the default address of zero (0) unless multiple sensors are connected to the same port.
- **Command body** – an 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. 18).

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>

Table B-1: Campbell Scientific sensor SDI-12 command and response set		
Name	Command	Response[1]
Address Query	`?!`	a<CR><LF>
Change Address	`aAb!`	b<CR><LF>
Start Measurement	`aM!` `aM1!...aM9!`	atttn<CR><LF>
Send Data	`aD0!...aD9!`	a<values><CR><LF> or a<values><CRC><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 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 a`M!` or a`MC!`, the data logger issues the **aD0!** command once a service request has been received from the sensor or the reported time has expired. When the data logger is issuing concurrent commands (**aC!** or **aCC!**), the Send Data command is issued after the required time has elapsed (no service request will be sent by the sensor). In transparent mode (see SDI-12 transparent mode [p. 22]), the user asserts this command to obtain data.

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

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

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

where:

a = the sensor address

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

<CR><LF> = terminates the response

<CRC> = 16-bit CRC code appended if data was requested with a`MC!` 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***.

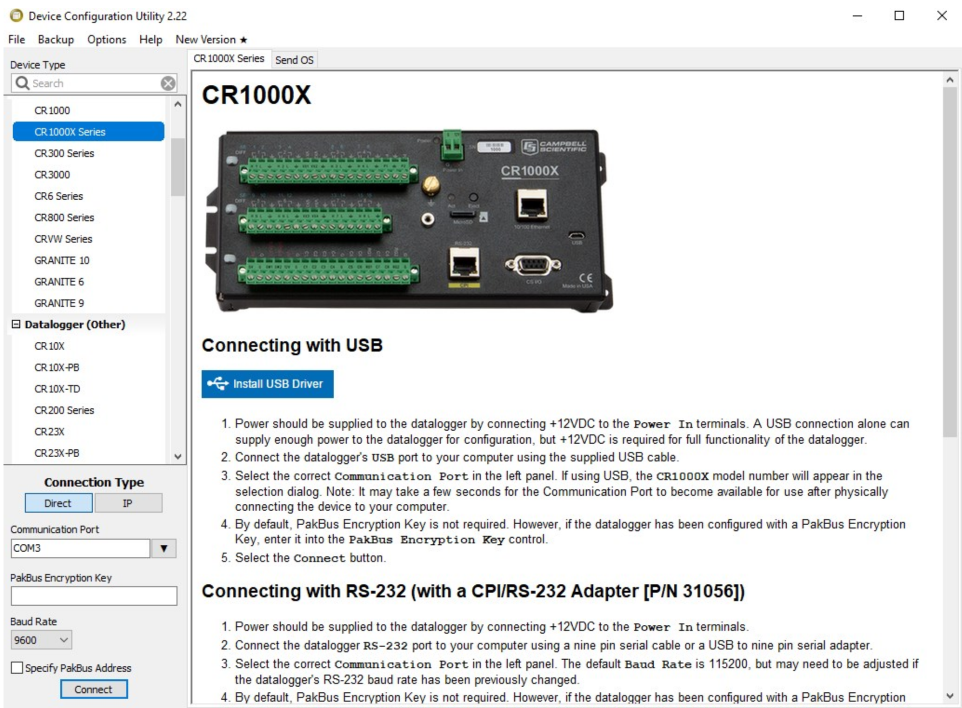
Watch videos/sdi12-sensors-transparent-mode from our website.

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

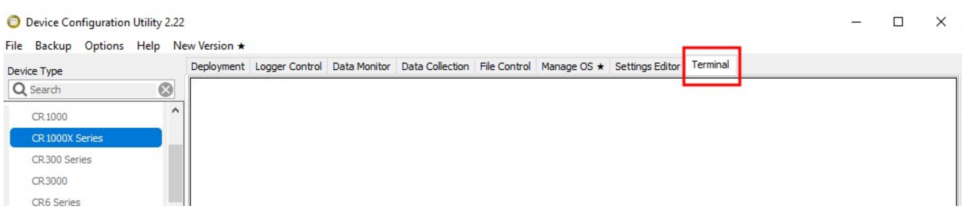
The following examples show how to enter transparent mode and change the SDI-12 address of an SDI-12 sensor. The steps listed are used with most Campbell Scientific data loggers.

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

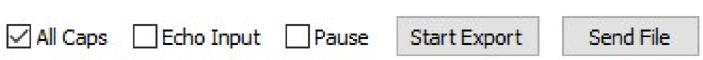
1. Connect an SDI-12 sensor to the CR1000X.
2. Open ***Device Configuration*** utility.
3. Under **Device Type**, type the data logger model and double-click on the model type. This example uses a CR1000X directly connected to the computer USB port.
4. Select the correct **Communication Port** and click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



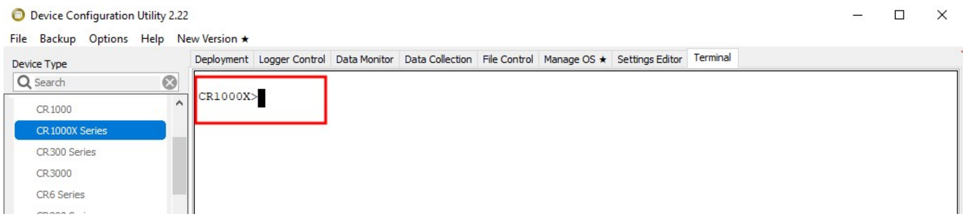
5. Click the **Terminal** tab.



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.

Limited warranty

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

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

2. The defect cannot be the result of misuse.

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

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

The following is not covered:

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

2. Batteries; and

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

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

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

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Campbell Scientific will, as a default, return warranted equipment by surface carrier prepaid. However, the method of return shipment is at Campbell Scientific's sole discretion. Campbell Scientific will not reimburse the claimant for costs incurred in removing and/or reinstalling equipment. This warranty and the Company’s obligation thereunder is in lieu of all other warranties, expressed or implied, including those of suitability and fitness for a particular purpose. Campbell Scientific is not liable for consequential damage.

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

Assistance

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

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

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

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

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

Safety

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

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

General

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

Utility and Electrical

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

Elevated Work and Weather

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

Internal Battery

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

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

Use and disposal of batteries

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

Avoiding unnecessary exposure to radio transmitter radiation

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

Maintenance

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

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

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