PRODUCT MANUAL

Sensor

CS451/CS456

Submersible Pressure Transducers

Revision: 05/2025

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RELIABLE MONITORING SINCE 1974

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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 CS451/CS456 Submersible Pressure Transducer provides pressure and temperature measurements. It uses the SDI-12 or RS-232 communications protocols to communicate with an SDI-12 or RS-232 recorder, simplifying installation and programming.

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

2. Precautions

- READ AND UNDERSTAND the Safety section at the back of this manual.
- Sensor will be damaged if it is encased in frozen liquid.
- Although the CS451/CS456 is rugged, it is also a highly precise scientific instrument and should be handled as such. There are no user-serviceable parts and any attempt to disassemble the device will void the warranty.
- Dropping the instrument or allowing it to "free fall" down a well may damage the transducer.
- Never suspend the CS451/CS456 from the connections at the top end of the cable. Sharp bends or excessive pinching of the cable can cause damage and may pinch off the vent tube causing measurement errors.
- Danger: Do not use pliers when installing the sensor to a pressurized pipe. Pliers can damage the case, compromising the seal, resulting in a possible explosion.
- The desiccant tube must always be attached to the CS451/CS456, and the desiccant tube must be housed in an environmental enclosure.
- Confirm the compatibility of the sensor and cable to non-water environments before installation.
- The CS456, instead of the CS451, should be used in harsh water applications, including salt water.

3. Initial inspection

- Upon receipt of the CS451/CS456, inspect the packaging for any signs of shipping damage and, if found, report the damage to the carrier in accordance with policy. Also inspect the contents of the package and file a claim if shipping related damage is discovered.
- The model number and pressure range is etched on the housing, and the cable length is printed on the label near the connection end of the cable. Check this information against the shipping documentation to ensure that the expected product was received.
- Ensure the desiccant tube is attached to the vent tube on the cable. Desiccant should be orange or blue. Replace it if the desiccant is green or pale pink.

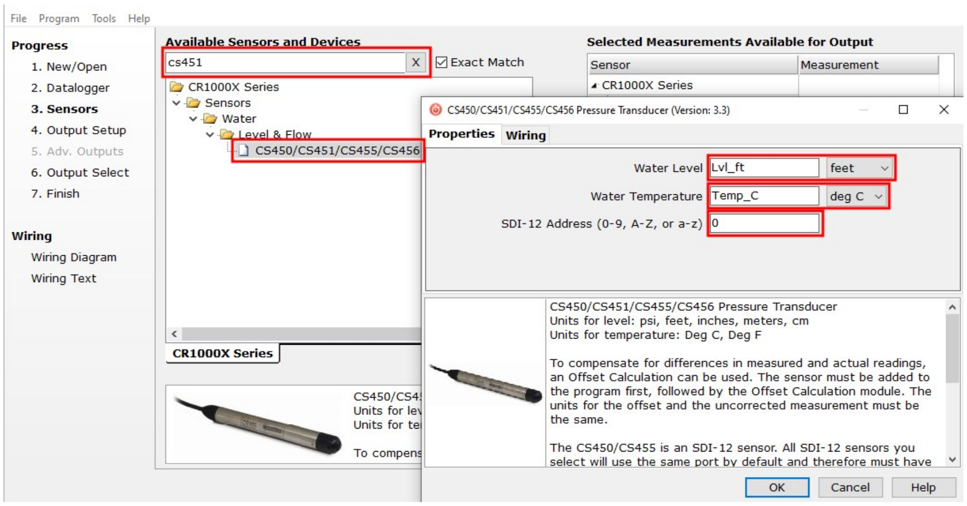
4. QuickStart

A video that describes data logger programming using ***Short Cut*** is available at: www.campbellsci.com/videos/cr1000x-datalogger-getting-started-program-part-3. ***Short Cut*** is an easy way to program your data logger to measure the sensor and assign data logger wiring terminals. ***Short Cut*** is available as a download on www.campbellsci.com. It is included in installations of ***LoggerNet***, ***RTDAQ***, or ***PC400***.

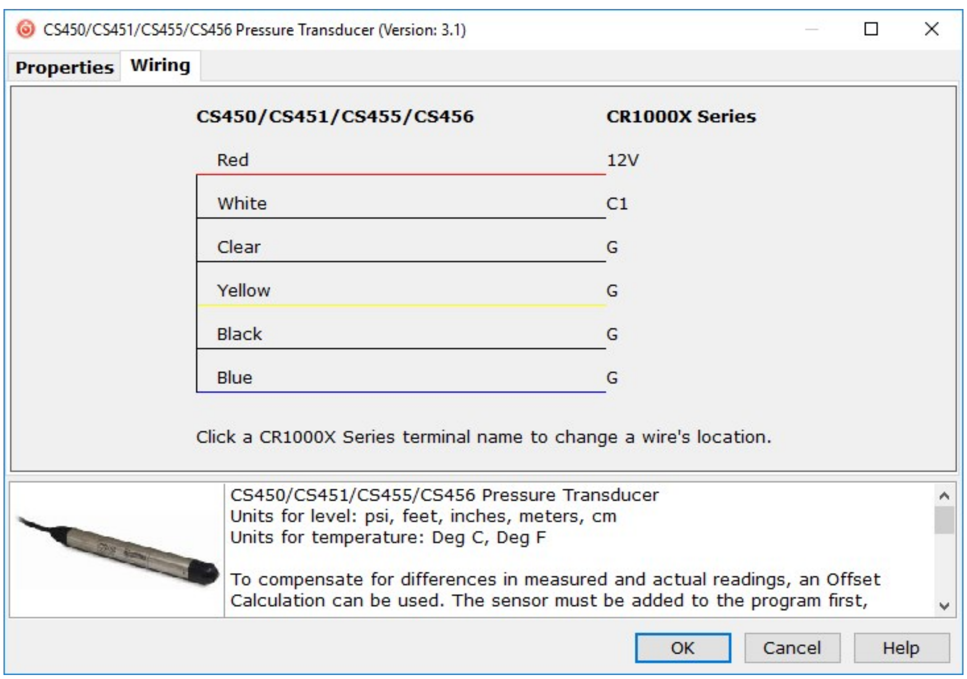
The following procedure also describes programming with ***Short Cut***.

1. Open ***Short Cut*** and click **Create New Program**.
2. Double-click the data logger model.

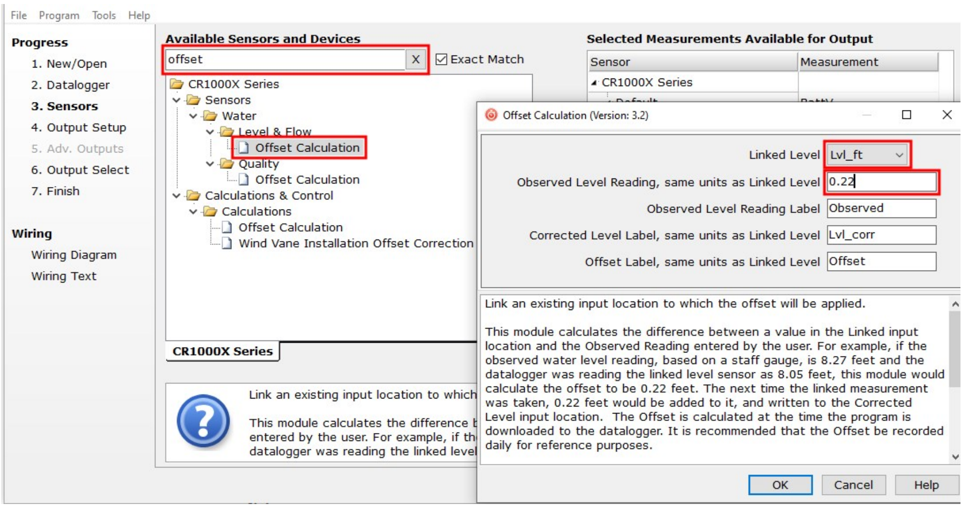
3. In the **Available Sensors and Devices** box, type CS451 or locate the sensor in the **Sensors** > **Water** > **Level & Flow** folder. Double-click **CS450/CS451/CS455/CS456 Pressure Transducer**. Water level defaults to feet and temperature defaults to degrees Celsius. These can be changed by clicking the **Water Level** or **Temperature** box and selecting a different option. Type the correct **SDI-12 Address** for the CS451.



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

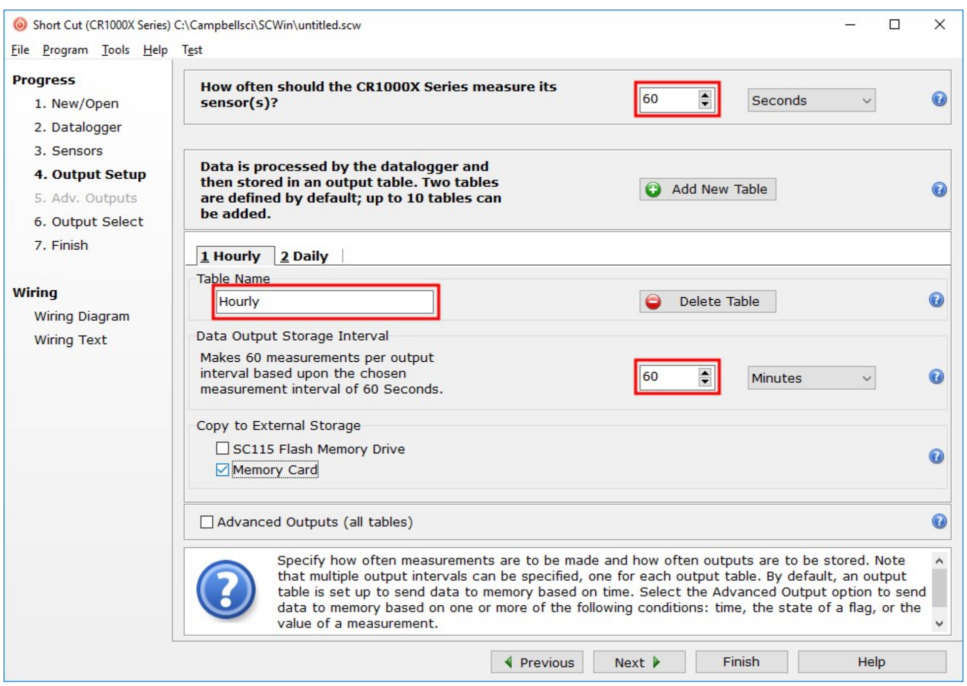


5. In the **Available Sensors and Devices** box, type **Offset** and double-click the **Offset Calculation** under the **Sensors** > **Water** > **Level & Flow** folder. For the Linked Level parameter, select the variable that stores the level measurement (typically **Lvl_ft** or **Lvl_m**). Type the initial water level in the **Observed Level Reading** box.

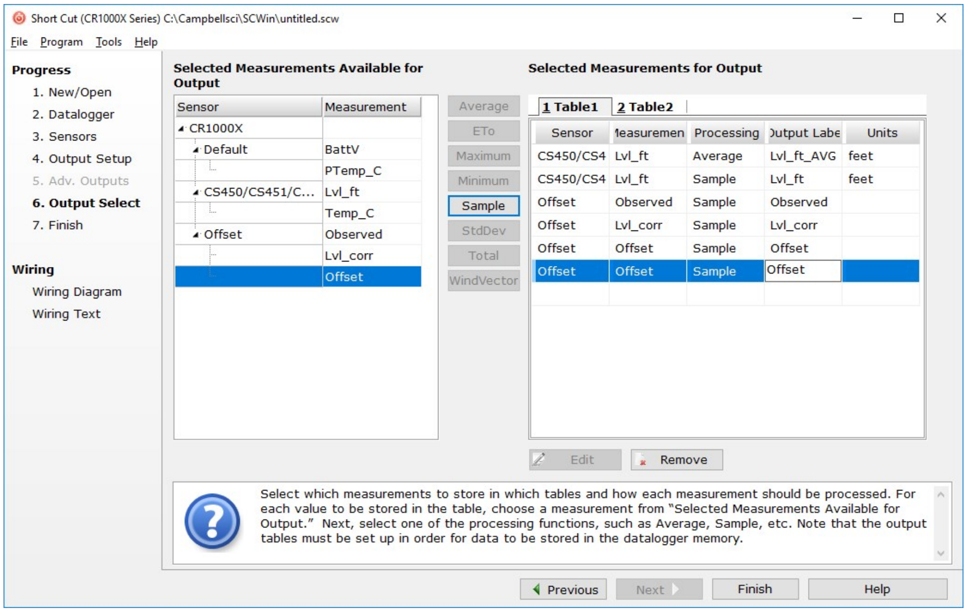


6. Repeat steps three and four for other sensors being measured. Click **Next**.

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



8. Select the measurement and its associated 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 logger support software data display in ***LoggerNet***, ***RTDAQ***, or ***PC400*** to make sure it is making reasonable measurements.

5. Overview

The CS451/CS456 pressure transducer provides a reliable, accurate pressure/level measurement that is fully temperature compensated. Its 24-bit A/D has simultaneous 50/60 Hz rejection and automatic calibration for each measurement.

A number of additional advanced measurement techniques are employed to harness the best possible performance available from today's state-of-the-art pressure transducer technology. The transducer reverts to a low power sleep state between measurements. A series of measurements are performed, yielding a temperature and pressure value. This measurement cycle takes less than 1.5 s. The transducer can also be configured to output pressure only in less than 1 s. The measurement cycle is activated using SDI-12 or RS-232 commands.

The transducer consists of a piezoresistive sensor housed in a 316L stainless-steel (CS451) or titanium (CS456) package to enhance reliability. The rugged construction makes the CS451/CS456 suitable for water level measurement in irrigation applications, water wells, lakes, streams, and tanks. The titanium package of the CS456 makes it ideal for salt water or other harsh environments. The cable incorporates a vent tube to compensate for atmospheric pressure fluctuations and the jacket is made of rugged Hytrel®, designed to remain flexible and tough, even under harsh environmental conditions.

The CS451/CS456 has two communication options: SDI-12 and RS-232. The CS451/CS456 is shipped from the factory with both communications options enabled. As an SDI-12 sensor, the CS451/CS456 is shipped with an address of 0.

Two values are output by the CS451/CS456—pressure/level and temperature. By default, the sensor outputs pressure in pounds per square inch gage (psig), which is the pressure relative to atmospheric pressure. By default, the sensor outputs temperature in degrees Celsius.

The CS451/CS456 has three nose cone options. Figure 5-1 (p. 6) shows the nose cone options. The weighted nose cone makes the transducer easier to submerge to depth. The 1/4-inch NPT nose cone allows the transducer to be used in closed-pipe applications. Nose cones can be switched out later. The nose cones are available separately from Campbell Scientific, allowing the nose cone to be changed to a different style at a later date, if desired.

Figure 5-1. CS451 nose cone options

Features:

- Output acceptable for recording devices with SDI-12 or RS-232 capability including Campbell Scientific data loggers
- Quality construction ensures product reliability
- Rugged stainless steel or titanium case protects piezoresistive sensor
- Fully temperature compensated
- Low power sleep state between measurements reduces power consumption
- Weighted nose cone offered adds 0.2 kg (7.4 oz) to the transducer weight. Additional weight makes submersion of the transducer easier
- Compatible with Campbell Scientific CRBasic data loggers: CR6, CR3000, CR1000Xe, CR1000X, CR800 series, CR300 series, CR1000

6. Specifications

Power requirements:	5 to 18 VDC
Power consumption	
Idle current:	< 50 µA
Measurement/communication current:	8 mA for 1-s measurement
Maximum peak current:	40 mA
Measurement time:	Less than 1.5 s
Outputs:	SDI-12 (version 1.3) 1200 bps RS-232 9600 bps, 8 data bits, no parity, 1 stop bit, no flow control

Measurement ranges:

Pressure (psig)	Pressure (kPa)	Depth of fresh water
0 to 2.9	0 to 20	0 to 2 m (6.7 ft)
0 to 7.25	0 to 50	0 to 5.1 m (16.7 ft)
0 to 14.5	0 to 100	0 to 10.2 m (33.4 ft)
0 to 29	0 to 200	0 to 20.4 m (67 ft)
0 to 72.5	0 to 500	0 to 50.9 m (167 ft)
0 to 145	0 to 1000	0 to 102 m (334.5 ft)

Accuracy:	±0.1% full scale range TEB[1] or ±0.05% full scale range TEB[2]
Water-level resolution:	0.0035% full scale range
Worst-case temperature resolution:	0.006 °C
Overpressure:	Twice the pressure range
Dry storage temperature:	–40 to 100 °C

> **CAUTION:**
> Sensor will be damaged if it is encased in frozen liquid.

Operating temperature:	0 to 60 °C
Temperature accuracy:	±0.2 °C
Maximum cable length	
SDI-12 (one transducer connected to a single terminal):	~475 m (1500 ft)
SDI-12 (10 transducers connected to a single terminal[3]):	60 m (200 ft)
RS-232:	60 m (200 ft)
Cable type:	5 Conductor, 26 AWG Hytrel jacket
Body material:	CS451 – 316L stainless steel CS456 – titanium
Element material:	CS451 – 316L stainless steel CS456 – Hastelloy
Standard nose cone material:	Delrin
Length:	213.36 mm (6.875 in)
Diameter:	21.34 mm (0.84 in)
Cable outer diameter:	0.589 cm (0.232 in) nominal 0.599 cm (0.236 in) maximum
Distance from pressure sensor interface (black line etched on housing) to:	
End of NPT fitting:	2.54 cm (1 in)
End of standard nose cone:	2.3 cm (0.9 in)

End of weighted nose cone:	9.9 cm (3.9 in)
Air gap	
Standard and weighted nose cone:	0.653 cm (0.257 in)
NPT fitting:	2.72 cm (1.07 in)
Weight:	
CS451:	0.17 kg (0.37 lb)
CS456:	0.10 kg (0.23 lb)
Cable:	0.421 kg/m (0.283 lb/ft)
Compliance:	View the EU Declaration of Conformity at: www.campbellsci.com/cs451 www.campbellsci.com/cs456

[1] Total Error Band (TEB) includes the combined errors due to nonlinearity, hysteresis, nonrepeatability, and thermal effects over the compensated temperature range, per ISA S51.1.

[2] 0.05% full scale range accuracy not available in the 0 to 2.9 psig range.

[3] Campbell Scientific recommends using separate terminals when possible.

7. Installation

If using ***Short Cut*** to program the data logger, skip Wiring (p. 13) and Programming (p. 14). ***Short Cut*** automatically performs these steps. See QuickStart (p. 2) for a ***Short Cut*** tutorial.

This section includes the following information:

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7.1 Installation considerations

The CS451/CS456 is designed for water level measurements. Typical applications include agricultural water level/flow, water wells, lakes, streams, and tanks. If the sensor is to be installed in a liquid other than water or in contaminated water, check the compatibility of the wetted material. For harsh environments, including saltwater, use the CS456 instead of the CS451.

7.1.1 Vent and desiccant tubes

A vent tube incorporated in the cable vents the sensor diaphragm to the atmosphere. This eliminates the need to compensate for changes in barometric pressure. To prevent water vapor from entering the inner cavity of the sensor, the vent tube opening terminates inside a desiccant tube.

> CAUTION:
> The desiccant tube is shipped with a black cap to cover the vent hole. This cap MUST be removed prior to installation.

Before installing the sensor, check the desiccant and replace it if the desiccant is green instead of orange.

> NOTE:
> Until August 2019, the CS451/CS456 used blue desiccant that turned pink when it became saturated.

The desiccant tube must always be attached to the CS451/CS456, and the desiccant tube must be housed in an environmental enclosure.

7.1.2 Appropriate water depth

The CS451/CS456 must be installed below the water at a fixed depth. This depth should be chosen so that the water pressure will never exceed the transducer's pressure range (twice its pressure rating).

CAUTION:
The output reading will not be correct, and the transducer can be damaged if pressure is twice its pressure rating.

Pressure can be converted to feet of fresh water using the following conversion:

1 psi = 2.31 feet of water

For example, the maximum depth with a pressure range of 0 to 7.25 psig is 16.748 feet of water.

7.1.3 Dislodge bubbles

While submersing the CS451/CS456, air bubbles may become trapped inside the nose cone, causing small, offset errors until the bubbles dissolve. Dislodge these bubbles by gently shaking the CS451/CS456 while under water.

CAUTION:
Hitting the instrument against the well casing or other solid surface could damage the CS451/CS456.

CAUTION:
If the bubbles are not removed by rotation and shaking underwater (or bleeding out the air in a closed system), the CS451/CS456 reading will drift lower by the distance of the gap as the air is slowly dissolved into the water over time.

7.2 Installing and securing the transducer

Lower the transducer to an appropriate depth. With long drops, it may be necessary to use the weighted nose cone (option -WN).

CAUTION:
Do not drop the instrument or allow it to free fall down a well as this may damage the sensor.

Secure the body using cable ties or tape. A Heyco cable grip can also be used to secure the transducer to a PVC pipe; see Heyco cable grip (p. 12) for more information. Secure and strain relief the cable using cable ties or the split mesh cable grip. If installing in a well, fasten the cable to the well head.

CAUTION:
Never suspend the CS451/CS456 from the connections at the top of the cable. Sharp bends or excessive pinching of the cable can cause damage and may pinch off the vent tube causing measurement errors.

After installation, take several readings to ensure proper operation.

7.2.1 Split mesh cable grip

The split mesh cable grip can be used to center the cable and to provide a method of suspending the cable-reducing cable stretch. It is often recommended for use in wells. Figure 7-1 (p. 12) shows a transducer cable suspended using the split mesh cable grip.

Figure 7-1. Transducer suspended with split mesh cable grip

7.2.2 Heyco cable grip

To protect your transducer during deployment, Campbell Scientific offers the Heyco cable grip (Figure 7-2 [p. 13]) to clamp the transducer to the submerged end of a 1-inch PVC pipe (Figure 7-3 [p. 13]). The PVC pipe will help protect the sensor and cable from debris and disturbances while also providing a more secure means of anchoring the sensor to minimize movement. The Heyco fitting is not meant to be water tight and water will likely fill the submerged pipe behind the fitting. A 1-inch female adapter socket with FPT threads is needed between the Heyco cable grip and 1-inch PVC pipe. This adapter socket is available at any store that sells PVC pipe.

Figure 7-2. Heyco Cable Grip

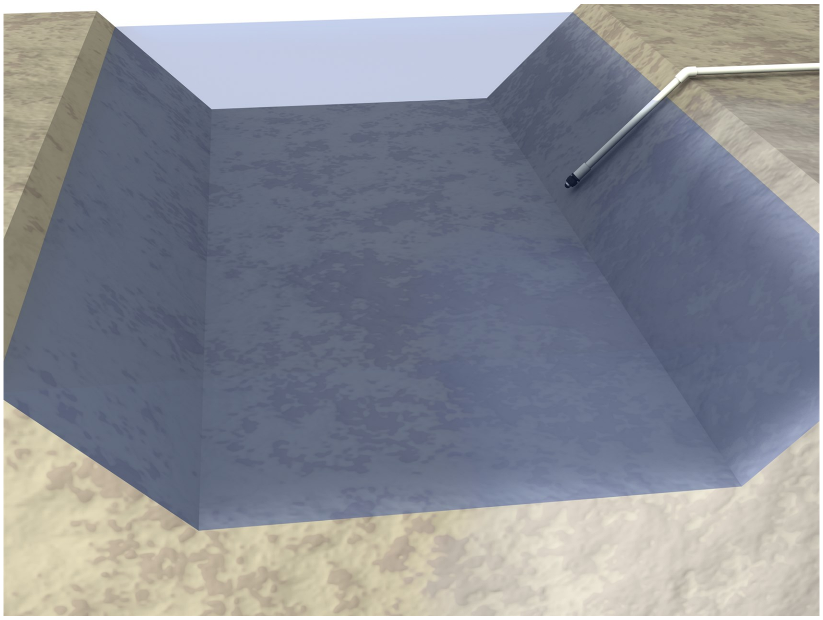

Figure 7-3. Transducer mounted in PVC pipe using the Heyco cable grip

7.3 Wiring

> **NOTE:**
> Power down the system before wiring the CS451/CS456.

Table 7-1 (p. 14) provides data logger connections when using SDI-12 and Table 7-2 (p. 14) provides data logger connections when using RS-232.

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

For the CR6 and CR1000X data loggers, triggering conflicts may occur when a companion terminal is used for a triggering instruction such as `TimerInput()`, `PulseCount()`, or `WaitDigTrig()`. For example, if the CS451 is connected to C3 on a CR1000X, C4 cannot be used in the `TimerInput()`, `PulseCount()`, or `WaitDigTrig()` instructions.

Table 7-2: Wire color, function, data logger connection, and RS-232 pin			
Wire color	**CS451/CS456 function**	**Data logger connection**	**RS-232 9-pin**
Red	+12vdc	**12V**, **Battery+**	
Black	Power ground	**G**	
White	RS-232 Tx (output)	Odd-numbered **C** terminal	Pin 2 Rx (input)
Blue	RS-232 Rx (input)	Even-numbered **C** terminal	Pin 3 Tx (output)
Yellow	Digital ground	**G**	Pin 5 GND
Clear	Shield GND	**G**	

7.4 Programming

Short Cut is the best source for up-to-date data logger programming code.

If data acquisition requirements are simple, a data logger program can probably be created and maintained 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). 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 sections. A complete program example for the CR1000X data logger can be found in Example program (p. 28). Programming basics and programming examples for Edlog data loggers are provided at www.campbellsci.com\old-manuals.

7.4.1 SDI-12 programming

The `SDI12Recorder()` instruction is used to measure a CS451/CS456 configured for SDI-12 measurements. This instruction sends a request to the sensor to make a measurement and then retrieves the measurement from the sensor. See SDI-12 commands (p. 20) for more information.

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

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

For the `SDIAddress`, alphabetical characters need to be enclosed in quotes (for example, “A”). Also enclose the `SDICommand` in quotes as shown. The `Destination` parameter must be an array. The required number of values in the array depends on the command (see Table 8-3 [p. 21]).

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

7.4.2 Offset calculation

The pressure created is directly proportional to the water column above the sensor. An offset is used to correct the final measurement to any error due to sensor zero offset or installation. The steps for calculating the offset:

1. Use a staff gage (or other device) to measure the initial elevation of water.
2. Measure the water pressure using the CS451/CS456.
3. Convert the pressure measurement to water level.
4. Subtract the CS451 level measurement from the initial elevation measurement.

For example, if the correct elevation of the water, as measured by a staff gage or other measurement device, is 20 feet, and the CS451 provides a reading of 5.76 psig, then:

5.76 psig • 2.31 ft/psig = 13.3056 ft.

So, the offset is the following:

20 ft – 13.3056 ft = 6.6944 ft

Include an expression in the CRBasic program to account for this offset.

7.5 Changing nose cones

The procedure to change or replace a nose cone follows:

1. Remove the two screws (Figure 7-4 [p. 16]).
2. Pull the nose cone away from the sensor housing.
3. Insert the new nose cone into the sensor housing.
4. Replace and tighten the screws.

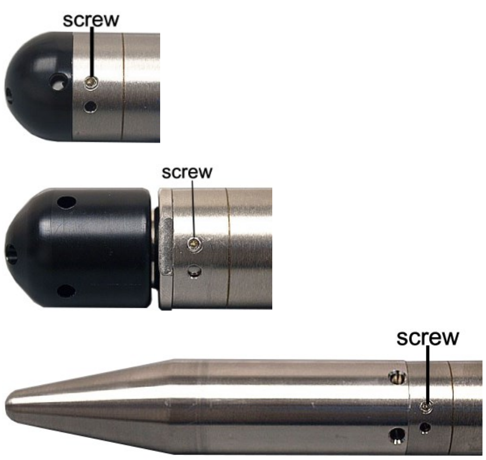

Figure 7-4. Screws on the standard nose cone (top), NPT nose cone (middle), and weighted nose cone (bottom)

8. Operation

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8.1 Configuration

Table 8-1 (p. 17) shows default settings of the CS451/CS456.

Table 8-1: Factory settings	
SDI-12 address	0
RS-232 baud rate	9600
Pressure/level units	psig
Temperature units	Celsius

Communicating with the CS451/CS456 requires the sensor to be either connected to a computer or to an SDI-12 recorder. The sensor typically connects to a computer via the A200 sensor to computer interface. Many SDI-12 recorders allow communication to the sensor via a terminal screen. Configurable settings can be changed via SDI-12 commands or by using Campbell Scientific software ***Device Configuration Utility***. Refer to the video SDI-12 Sensors | Transparent Mode.

8.1.1 Computer connection using the A200

The A200 or another device is required to connect the CS451/CS456 to a computer. This allows sensor settings to be changed using the ***Device Configuration Utility***.

8.1.1.1 Driver installation

If the A200 has not been previously plugged into your computer, the A200 driver needs to be loaded onto your computer.

> **NOTE:**
> Drivers should be loaded before plugging the A200 into the computer.

The A200 drivers can be downloaded, at no charge, from: www.campbellsci.com/downloads.

8.1.1.2 A200 wiring

One end of the A200 has a terminal block while the other end has a type B female USB port. The terminal block provides **12V**, **G**, **Tx**, and **Rx** terminals for connecting the sensor (see Figure 8-1 [p. 18] and Table 8-2 [p. 18]). The data cable shipped with the A200 has a USB type-A male connector that attaches to a computer USB port, and a type B male connector that attaches to the A200 USB port.

Figure 8-1. A200 Sensor-to-Computer Interface

Table 8-2: A200 wiring		
Color	Sensor cable label	A200 terminal
Red	12V	+12Vdc
Black	G	G
White	C	Tx
Blue	G	Rx
Yellow	G	G
Clear	Signal ground	G

8.1.1.3 Powering the sensor

The A200 provides power to the sensor when it is connected to a computer USB port. An internal DC/DC converter boosts the 5 VDC supply from the USB connection to a 12 VDC output is required to power the sensor.

8.1.1.4 Determining which COM port the A200 has been assigned

When the A200 driver is loaded, the A200 is assigned a COM port number. This COM port number is needed when using the ***Device Configuration Utility***.

Often, the assigned COM port will be the next port number that is free. However, if other devices have been installed in the past (some of which may no longer be plugged in), the A200 may be assigned a higher COM port number.

To check which COM port has been assigned to the A200, watch for the appearance of a new COM port in the list of COM ports offered in the software package (e.g., ***LoggerNet***) before and after the installation, or look in the Windows Device Manager list under the ports section (access via the control panel).

8.1.2 *Device Configuration Utility* (version 2.03 or higher)

Device Configuration Utility allows the settings of the CS451/CS456 to be changed. ***Device Configuration Utility*** is included in ***LoggerNet*** and is also available at www.campbellsci.com/downloads.

To use ***Device Configuration Utility***, the transducer needs to be connected to the computer via the A200 (see Computer connection using the A200 [p. 17]). After installing ***Device Configuration Utility*** and connecting the transducer to the computer, select **CS451** from the **Device Type** list on the left column of the screen.

In the **Communication Port** box, select the COM port that was assigned to the A200 (see Determining which COM port the A200 has been assigned [p. 18]). Click on the **Connect** button to enable communication with the sensor. Once successfully connected, the screen should look like Figure 8-2 (p. 20).

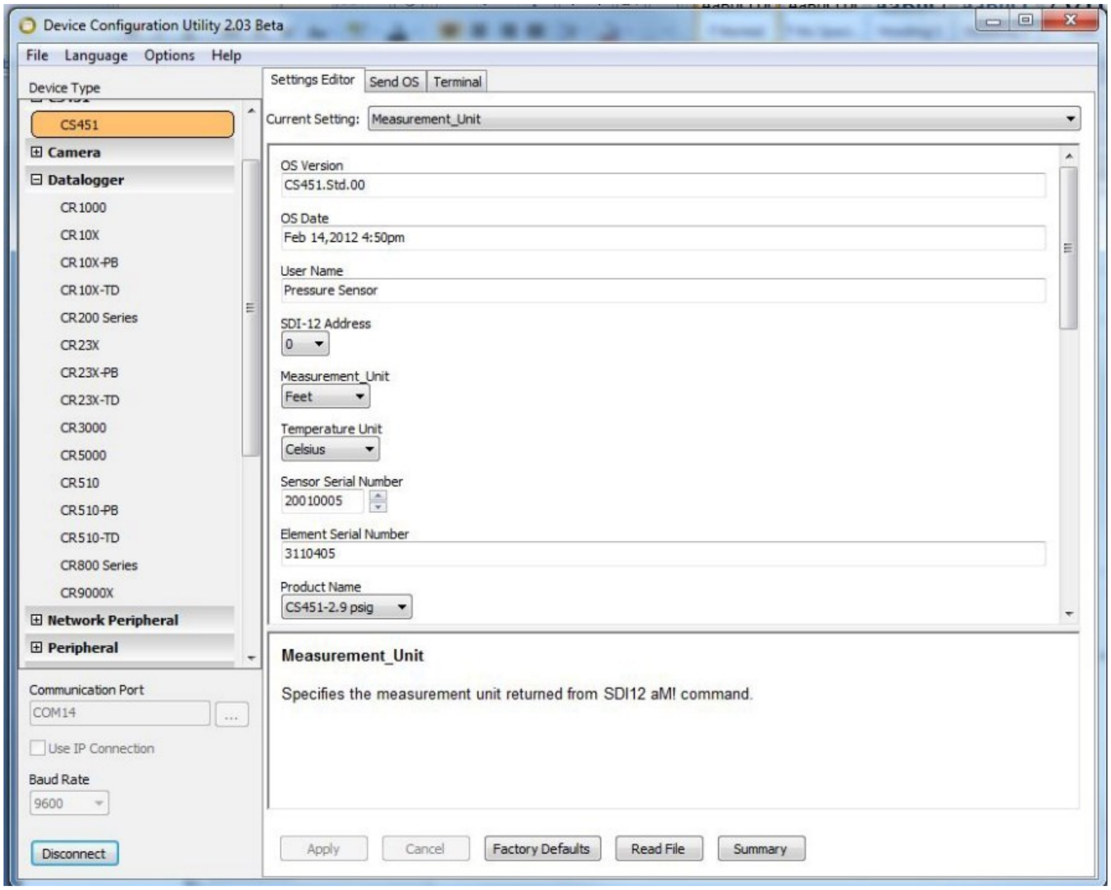


Figure 8-2. Connect screen

There are three settings that can be changed: SDI-12 address, Pressure/Level Units, and Temperature Units. Double-click on the window of the units to be changed. This will open a pick menu box. Select the desired units and **Apply** the changes.

8.2 SDI-12 commands

> **NOTE:**
> This section briefly describes using the SDI-12 commands. For additional SDI-12 information, refer to SDI-12 sensor support (p. 31), www.sdi-12.org, or the videos SDI-12 Sensors | Watch or Sniffer Mode and SDI-12 Sensors | Transparent Mode.

The CS451/CS456 supports the commands that are listed in Table 8-3 (p. 21). When using an `M!` command, the data logger waits for the time specified by the sensor, sends the `D!` command, pauses its operation, and waits until either it receives the data from the sensor or the sensor timeout expires. If the data logger receives no response, it will send the command a total of three times, with three retries for each attempt, or until a response is received. Because of the delays this command requires, it is only recommended in measurement scans of 10 seconds or more.

A `C!` 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 picks up the data with the `D!` command on the next pass through the program. Another measurement request is then sent so that data are ready on the next scan.

Table 8-3: CS451/CS456 SDI-12 commands

SDI-12 command (*a* is the sensor address)	Values returned or function	Units
a`M!` or *a*`C!`	1. Pressure/Level 2. Temperature	Configured Settings
a`M1!` or *a*`C1!`	1. Pressure/Level 2. Temperature	PSIG °C
a`M2!` or *a*`C2!`	1. Pressure/Level 2. Temperature	PSIG °F
a`M3!` or *a*`C3!`	1. Pressure/Level 2. Temperature	kPa °C
a`M4!` or *a*`C4!`	1. Pressure/Level 2. Temperature	kPa °F
a`M5!` or *a*`C5!`	Sensor Serial Number	
a`M6!` or *a*`C6!`	1. ΔR 2. Rb 3. Temperature 4. IN – DAC counts single-ended measurement, IN+ DAC counts single-ended measurement 5. OUT DAC counts differential measurement	Ohms Ohms °C
a`M7!` or *a*`C7!`	1. Pressure/Level 2. Temperature	Configured Settings (provides data in less than 0.8 s)

Table 8-3: CS451/CS456 SDI-12 commands		
SDI-12 command (*a* is the sensor address)	Values returned or function	Units
*a*M8! or *a*C8!	1. Pressure/Level 2. Temperature	Configured Settings. Provides average of data based on user selected samples. Number of samples are entered with the aXCONFIG2=nnn! command.
*a*MC!, *a*MCn!, *a*CC! or *a*CCn! Where n =1 through 8	Same values returned as *a*M!, *a*M1! to *a*M8!, *a*C!, *a*C1! to *a*C8! commands, except a checksum is added	Same units as the *a*M!, *a*M1!, to *a*M8!, *a*C!, *a*C1!, to *a*C8! commands
*a*XCONFIG1=*t,p,mmm.mm,ooo.ooo*! Where, *t* = temperature units *p* = measurement unit *mmm.mm* = pressure/level multiplier (slope) *ooo.ooo* = pressure/level offset	Configures the output units for the *a*M! and *a*C! commands. Valid entries for *t* are: 0 = Celsius 1 = Fahrenheit Valid entries for *p* are: 0 = psig 1 = kPa 2 = Bar 3 = feet 4 = meter 5 = inch 6 = millimeter For example, aXCONFIG1=0,0,1,3.33! Configures the output as: Temperature units in Celsius (0) Measurement units in psig (0) Pressure/level multiplier of 1 Pressure/level offset of 3.33	

Table 8-3: CS451/CS456 SDI-12 commands		
SDI-12 command (*a* is the sensor address)	Values returned or function	Units
a`XCONFIG2`=*nnn*! Where, *nnn* = number of samples used with the *a*`M8!` or *a*`C8!` command.	Configures the number of samples used with the *a*`M8!` or *a*`C8!` command	
`?!`	Returns the SDI-12 Address	

As measurement data is transferred between the probe and data logger digitally, there are no offset errors incurred with increasing cable length as seen with analog sensors. However, with increasing cable length, there is still a point when digital communications break down, resulting in either no response or excessive SDI-12 retries and incorrect data due to noise problems. (Using SDI 12 commands like `MC!`, which adds a cyclic redundancy check (CRC), can significantly improve incorrect data issues.)

8.3 Measuring multiple SDI-12 sensors

Campbell Scientific recommends using separate terminals when possible. However, multiple CS451/CS456 sensors or other SDI-12 sensors can be connected to a single data logger control or U terminal. Each SDI-12 device must have a unique SDI-12 address. See SDI-12 sensor support (p. 31) for more information.

8.4 Unit command

An extended SDI-12 command is used to select the temperature units (Celsius or Fahrenheit), pressure/level units (psig, kPa, bar, feet, meter, inches, millimeter, multiplier (slope), and offset. This command is in the form of *a*`XCONFIG1`=*t,p,mmm.mm,ooo.ooo*`!`, where *a* = the SDI-12 address of the sensor, *t* = temperature units, *p* = measurement unit, *mmm.mm* = multiplier (slope), and *ooo.ooo* = offset.

Valid entries for *tt* (temperature) are:

0 = Celsius

1 = Fahrenheit

Valid entries for *pp* (pressure/level) are:

0 = psig

1 = kPa

2 = Bar

3 = Feet

4 = Meter

5 = Inch

6 = Millimeter

The level units are for level of fresh water. The multiplier (slope) and offset are used to correct for relative density of water. Only SDI-12 instructions `M!`, `M7!`, `M8!`, `C!`, `C7!`, and `C8!` output the results obtained when using the multiplier and offset. The offset and multiplier are only applied to the pressure/level value, not to the temperature.

8.5 Sample number command

An extended SDI-12 command is used to enter a sample number for the `M8!` and `C8!` commands. This command is in the form of `XCONFIG2=`*nnn*`!`, where *nnn* is the number of samples that will be measured to obtain the final output value, which is an average of the samples taken. The integration time can be derived by adding 2 seconds to the number of samples. For example, if *nnn* = 50, then 50 samples are averaged. The integration time for this process is 50 plus 2, or 52 seconds.

9. Maintenance

NOTE:
For all factory calibrations and repairs, customers must get an RMA number. Customers must also properly fill out a "Declaration of Hazardous Material and Decontamination" form and comply with the requirements specified in it. Refer to the Assistance page for more information.

Campbell Scientific recommends that the CS451/CS456 be factory recalibrated and checked every 24 months.

The CS451/CS456 has no user-serviceable parts. Cable can be damaged by abrasion, rodents, sharp objects, twisting, crimping or crushing, and pulling. Carefully handle the cable to avoid damage. If the cable is damaged, send the sensor to Campbell Scientific for repairs.

Periodic evaluation of the desiccant is vital for keeping the vent tube dry. The CS451/CS456 ships with the desiccant tube attached. To assess the effectiveness of the desiccant, use one of the following:

- Desiccant in the tube changes color from orange to green when the drying power is lost.

  > **NOTE:**
  > Until August 2019, the CS451/CS456 used blue desiccant that turned pink when it became saturated.

- Enclosure Accessory Humidity Indicator Card changes from blue to pink when the desiccant needs to be replaced.

Every visit:

- Collect data.
- Visually inspect wiring and physical conditions.
- Check indicating desiccant or enclosure humidity indicator; service if necessary.
- Check battery condition (inspect physical appearance and use a keyboard display or computer to view the battery voltage).
- Check all sensor readings; adjust transducer offsets if necessary.
- Check recent data.

Every two years:

- Send the CS451/CS456 to the factory for recalibration and inspection.

10. Troubleshooting

The most common causes for erroneous pressure transducer data include:

- poor sensor connections to the data logger
- damaged cables
- damaged transducers
- moisture in the vent tube

Problem:

Unit will not respond when attempting serial communications.

Suggestion:

Check the power (red is +V and black is ground) and signal (white is SDI-12 data) lines to ensure proper connection to the data logger. Check the data logger program to ensure that the same terminal the SDI-12 data line is connected to is specified in the measurement instruction.

Problem:

Transducer appears to be operating properly but water level data show cycles in fluctuation not attributable to water level changes.

Suggestion:

A kinked or plugged vent tube will not effectively vent the pressure transducer to atmospheric pressure. Normal changes in barometric pressure will appear as water level fluctuations and these types of errors are typically on the order of 1 foot of water level. If the desiccant chamber has not been properly maintained, water may have condensed in the vent tube and the device should be returned to the factory for service.

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. Example program

CRBasic Example 1: CS451 SDI-12 program for CR1000X data logger

```
'CR1000X Series

'Declare Variables and Units
Dim FRun
Dim Old
Dim Changed
Public BattV
Public PTemp_C
Public CS451(2)
Public Observed
Public Lvl_corr
Public Offset

Alias CS451(1)=Lvl_ft
Alias CS451(2)=Temp_C

Units BattV=Volts
Units PTemp_C=Deg C
Units Lvl_ft=feet
Units Temp_C=deg C

'Define Data Tables
  DataTable(Hourly,True,-1)
  DataInterval(0,60,Min,10)
  Maximum(1,Lvl_ft,FP2,False,True)
  Minimum(1,Lvl_ft,FP2,False,True)
  Maximum(1,Temp_C,FP2,False,True)
  Minimum(1,Temp_C,FP2,False,True)
EndTable

DataTable(Daily,True,-1)
  DataInterval(0,1440,Min,10)
  Minimum(1,BattV,FP2,False,False)
EndTable

PreserveVariables

'Main Program
BeginProg
  'Main Scan
  Scan(60,Sec,1,0)
```

CRBasic Example 1: CS451 SDI-12 program for CR1000X data logger

```
    'Default CR1000X Data Logger Battery Voltage measurement 'BattV'
    Battery(BattV)
    'Default CR1000X Data Logger Wiring Panel Temperature measurement 'PTemp_C'
    PanelTemp(PTemp_C,60)
    'CS451 Pressure Transducer measurements 'Lvl_ft' and 'Temp_C'
    SDI12Recorder(Lvl_ft,C1,"0","M1!",1,0,-1)
    Lvl_ft=Lvl_ft*2.30666
    'Offset calculation 'Offset'
    If FRun=0 Then
      Observed=NAN
      FRun=1
    EndIf
    Changed=Observed-Old
    If Changed=0 Then
      Lvl_corr=Lvl_ft+Offset
    Else
      Offset=Observed-Lvl_ft
      Lvl_corr=Lvl_ft+Offset
      Old=Observed
    EndIf
    'Call Data Tables and Store Data
    CallTable Hourly
    CallTable Daily
  NextScan
EndProg
```

Appendix C. Calibration certificate

Each CS451/CS456 has been calibrated to meet printed accuracy specification at multiple temperature and pressure ranges. If additional verification is required, a Calibration Certificate for each CS451/CS456 Submersible Pressure Transducer can be downloaded from www.campbellsci.com/customer-center. You must be logged in to order the calibration certificates. The calibration is done using NIST-traceable instruments.

The *Instrument Data Report* provides a list of the pressure and temperature at which the sensor was tested.

Pressure [kPa] is the pressure applied (listed in kilopascals) to the sensor. Temperature [°C] is the temperature inside the test chamber at the time of testing. Pressure After [kPa] represents the resulting measurement output by the CS451/CS456 at the give pressure and temperature. Finally, Deviation After [%F.S.], provides the difference between the actual pressure applied to the sensor and the pressure measurement output by the sensor. This value is listed as a percentage of the full scale range of the sensor.

When a CS451/CS456 is returned to Campbell Scientific for calibration, the sensor will be returned with an Instrument Data Report. This report will include values in the Pressure Before [kPa] column. These values represent the measured pressure the sensor returns at the specified pressure and temperature, before calibration.

Appendix D. 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.

D.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 D-1 (p. 32).

> **NOTE:**
> The CS451/CS456 does not support all variants of the commands in the following table.

Table D-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>
Continuous Measurement	`aR0!...aR9!`	a<values><CR><LF>
Continuous Measurement and Request CRC	`aRC0!...aRC9!`	a<values><CRC><CR><LF>
Extended Commands	`aXNNN!`	a<values><CR><LF>

[1] Information on each of these commands is given in the following sections.

D.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.

D.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).	

D.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

D.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.

D.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.

D.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 D-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.

D.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 D-3: Example aC! sequence	
XC!	The data logger makes a request to sensor X to start a concurrent measurement.
X03005<CR><LF>	Sensor X immediately indicates that it will have 5 (05) values ready for collection within the next 30 (030) seconds.
YC!	The data logger makes a request to sensor Y to start a concurrent measurement.
Y04006<CR><LF>	Sensor Y immediately indicates that it will have 6 (06) values ready for collection within the next 40 (040) seconds.
ZC!	The data logger makes a request to sensor Z to start a concurrent measurement.
Z02010<CR><LF>	Sensor Z immediately indicates that it will have 10 values ready for collection within the next 20 (020) seconds.
ZD0!	After 20 seconds have passed, the data logger starts the process of collecting the data by issuing the first **D** command to sensor Z.
Z+1+2+3+4+5+6+7+8+9+10<CR><LF>	Sensor Z immediately responds with the sensor address and the 10 values.

Table D-3: Example aC! sequence	
`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.

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

D.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.

D.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 (SDI-12 transparent mode [p. 38]), 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!.

D.1.11 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.

D.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.

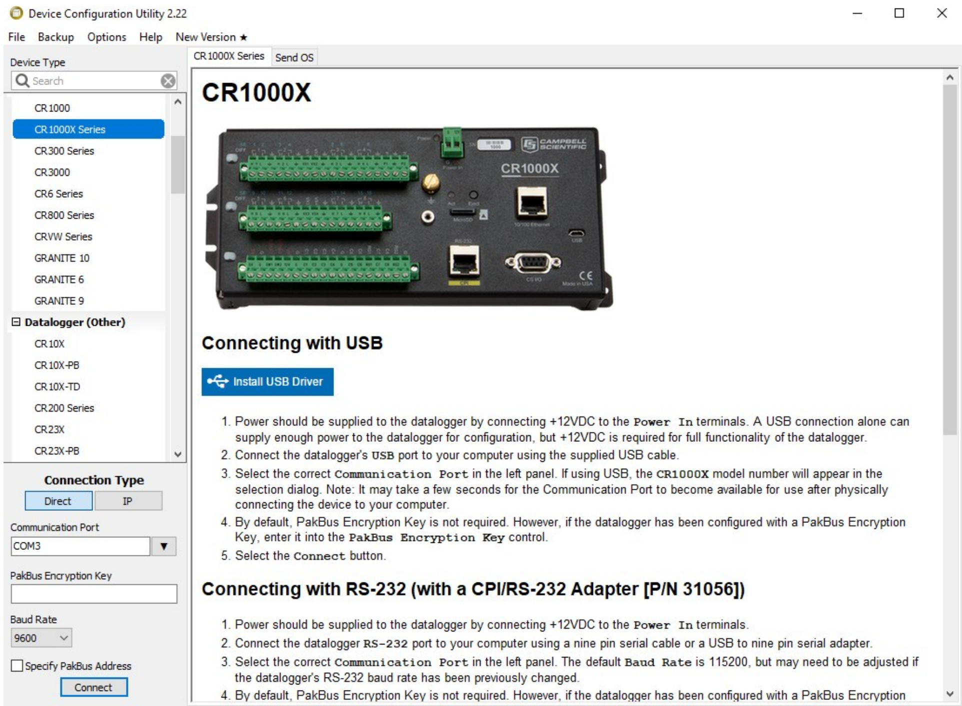
The following examples show how to enter transparent mode and change the SDI-12 address of an SDI-12 sensor. The steps shown in Changing an SDI-12 address (p. 38) are used with most Campbell Scientific data loggers.

D.2.1 Changing an SDI-12 address

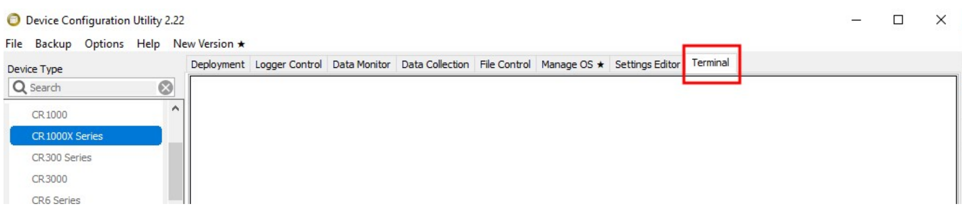
This example was done with a CR1000X, but the steps are only slightly different for CR6, CR3000, CR800-series, CR300-series, CR1000 data loggers.

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.

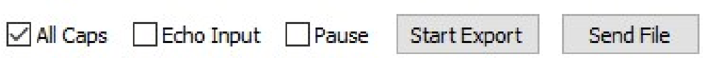
4. Select the correct **Communication Port** and click **Connect**.



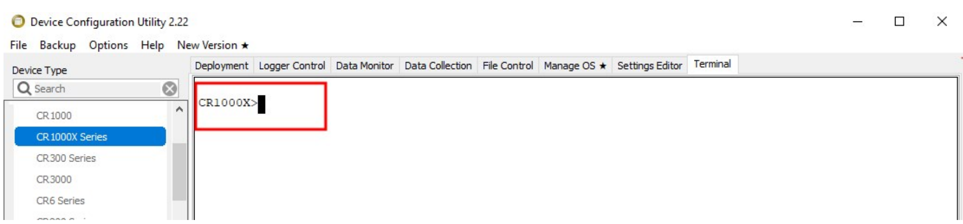
5. Click the **Terminal** tab.



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.

D.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/current_specification/SDI-12_version-1_4-Jan-30-2021.pdf.

Appendix E. RS-232 connection via computer terminal software

Computer terminal software can be used to communicate with the CS451/CS456 via the RS-232 communication mode.

The CS451/CS456 is connected to the computer using the A200 (see Computer connection using the A200 [p. 17]).

Upon setup, the terminal emulator software will request you enter the **Communication** connection; defaults to a phone connection. Change the communication to appropriate **Com** in the **Connect Using** box (see Determining which COM port the A200 has been assigned [p. 18] to determine the COM port that was assigned to the A200). The software will then prompt for the proper **Port Settings**. Table E-1 (p. 41) shows the RS-232 settings.

Table E-1: RS-232 settings	
Bits per second	9600
Data bits	8
Parity	None
Stop bits	1
Flow control	None

You will now be able to communicate with the CS451/CS456. At the prompt, press the **<Enter>** key several times. This will wake-up the RS-232 mode of the sensor. Table E-2 (p. 42) shows the RS-232 commands that can be entered once it is in the RS-232 mode.

> **NOTE:**
> By default, the CS451/CS456 is in the SDI-12 mode for communication. Once in the RS-232 mode, if there is no communication for 20 s, the sensor will return to the SDI-12 mode.

Table E-2: RS-232 terminal commands	
Terminal commands	Values returned
1	Serial number, pressure/level, temperature (in configured units)
2	Serial number, pressure (kPa), temperature (°C)
3	Serial number, DR(ohms), Rb(ohms), temperature (°C), element serial number, product name
5	Copyright information, OS version and date, serial number, element serial number, product name, user defined name (station name), SDI-12 address
H or h	Help menu

Appendix F. FAQs

Frequently asked questions

Can I repair or replace the cable on my CS45x sensor if it gets damaged?

The CS451/CS456 has no user-serviceable parts. Cable can be damaged by abrasion, rodents, sharp objects, twisting, crimping or crushing, and pulling. Carefully handle the cable to avoid damage. If the cable is damaged, send the sensor to Campbell Scientific for repairs.

Can the CS45x do event based measurements?

Yes, but a data logger is required. The CS45x-series pressure transducers are not autonomous. They require a data logger to initiate and retrieve a measurement. The data logger can initiate an event-based measurement. In contrast, the CRS45x-series water-level recording sensors support event-based recording using built-in data-collection features.

Can the CS45x measure water level at high elevations?

The CS45x-series pressure transducers are suitable for monitoring high-altitude lake levels. However, be sure to submerge the pressure transducer below the frost line. If ice forms against the diaphragm, it will deform the diaphragm and cause permanent damage.

Is it possible to winterize the CS45x for year-round-in-stream-monitoring?

No. To prevent damage to the pressure transducer, it must be removed if freezing is anticipated.

What is the difference between the CS451 and CS456?

- **CS451**: Made of stainless steel, which is durable and corrosion-resistant but may not be ideal for highly saline or aggressive environments.

- **CS456:** Made of titanium, which provides superior corrosion resistance, making it suitable for harsh environments such as saltwater applications or areas with high chemical exposure.

When should dessicant be changed?

The desiccant is orange when dry and turns green as it absorbs moisture. Replace the desiccant when it becomes predominantly green.

Why does data show a periodic or cyclic fluctuation not attributable to water level changes?

A kinked or plugged vent tube will not effectively vent the pressure transducer to atmospheric pressure. Normal changes in barometric pressure will appear as water level fluctuations and these types of errors are typically on the order of 1 foot of water level. If the desiccant chamber has not been properly maintained, water may have condensed in the vent tube and the device should be returned to the factory for service.

Why does the cable have a vent tube?

The vent tube serves a crucial role in barometric compensation. It allows the sensor to compensate for changes in atmospheric pressure, ensuring accurate water level or depth measurements. Without this venting, atmospheric pressure variations could introduce errors in the sensor's readings.

The vent tube runs through the cable and connects to a desiccant to prevent moisture from affecting the sensor's internal electronics.

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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MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE. Campbell Scientific hereby disclaims, to the fullest extent allowed by applicable law, any and all warranties and conditions with respect to the products, whether express, implied, or statutory, other than those expressly provided herein.

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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