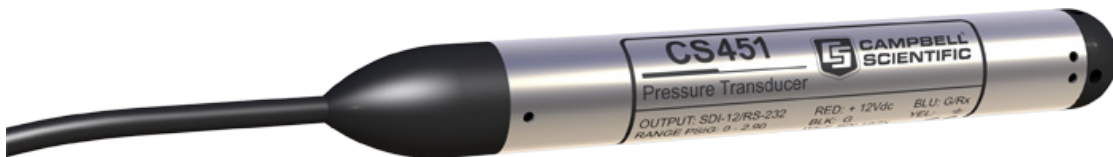


# CS451/CS456

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## Submersible Pressure Transducer





# Guarantee

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

- Equipment which has been modified or altered in any way without the written permission of Campbell Scientific
- Batteries
- Any product which has been subjected to misuse, neglect, acts of God or damage in transit.

Campbell Scientific will return guaranteed equipment by surface carrier prepaid. Campbell Scientific will not reimburse the claimant for costs incurred in removing and/or reinstalling equipment. This guarantee and the Company's obligation thereunder is in lieu of all other guarantees, expressed or implied, including those of suitability and fitness for a particular purpose. Campbell Scientific is not liable for consequential damage.

Please inform us before returning equipment and obtain a Repair Reference Number whether the repair is under guarantee or not. Please state the faults as clearly as possible, and if the product is out of the guarantee period it should be accompanied by a purchase order. 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 a "Declaration of Hazardous Material and Decontamination" form will be issued for completion.

When returning equipment, the Repair Reference Number must be clearly marked on the outside of the package. Complete the "Declaration of Hazardous Material and Decontamination" form and ensure a completed copy is returned with your goods. Please note your Repair may not be processed if you do not include a copy of this form and Campbell Scientific Ltd reserves the right to return goods at the customers' expense.

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



Campbell Scientific Ltd,  
80 Hathern Road,  
Shepshed, Loughborough, LE12 9GX, UK  
Tel: +44 (0) 1509 601141  
Fax: +44 (0) 1509 270924  
Email: [support@campbellsci.co.uk](mailto:support@campbellsci.co.uk)  
[www.campbellsci.co.uk](http://www.campbellsci.co.uk)



# PLEASE READ FIRST

---

## About this manual

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

Some useful conversion factors:

**Area:** 1 in<sup>2</sup> (square inch) = 645 mm<sup>2</sup>

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

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

**Pressure:** 1 psi (lb/in<sup>2</sup>) = 68.95 mb

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

In addition, while most of the information in the manual is correct for all countries, certain information is specific to the North American market and so may not be applicable to European users.

Differences include the U.S standard external power supply details where some information (for example the AC transformer input voltage) will not be applicable for British/European use. *Please note, however, that when a power supply adapter is ordered it will be suitable for use in your country.*

Reference to some radio transmitters, digital cell phones and aerials may also not be applicable according to your locality.

Some brackets, shields and enclosure options, including wiring, are not sold as standard items in the European market; in some cases alternatives are offered. Details of the alternatives will be covered in separate manuals.

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

## Recycling information



At the end of this product's life it should not be put in commercial or domestic refuse but sent for recycling. Any batteries contained within the product or used during the products life should be removed from the product and also be sent to an appropriate recycling facility.

Campbell Scientific Ltd can advise on the recycling of the equipment and in some cases arrange collection and the correct disposal of it, although charges may apply for some items or territories.

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



Campbell Scientific Ltd, 80 Hathern Road, Shepshed, Loughborough, LE12 9GX,  
UK Tel: +44 (0) 1509 601141 Fax: +44 (0) 1509 270924  
Email: [support@campbellsci.co.uk](mailto:support@campbellsci.co.uk)  
[www.campbellsci.co.uk](http://www.campbellsci.co.uk)



# Safety

---

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

Use tripods, towers, and attachments to tripods and towers only for purposes for which they are designed. Do not exceed design limits. Be familiar and comply with all instructions provided in product manuals. Manuals are available at [www.campbellsci.eu](http://www.campbellsci.eu) or by telephoning +44(0) 1509 828 888 (UK). You are responsible for conformance with governing codes and regulations, including safety regulations, and the integrity and location of structures or land to which towers, tripods, and any attachments are attached. Installation sites should be evaluated and approved by a qualified engineer. If questions or concerns arise regarding installation, use, or maintenance of tripods, towers, attachments, or electrical connections, consult with a licensed and qualified engineer or electrician.

## General

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

## Utility and Electrical

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

## Elevated Work and Weather

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

## Maintenance

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

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



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# CS451/CS456 Submersible Pressure Transducer

---

## 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](http://www.campbellsci.com/old-manuals).

## 2. Precautions

- READ AND UNDERSTAND the *Safety* section at the front 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.
- 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

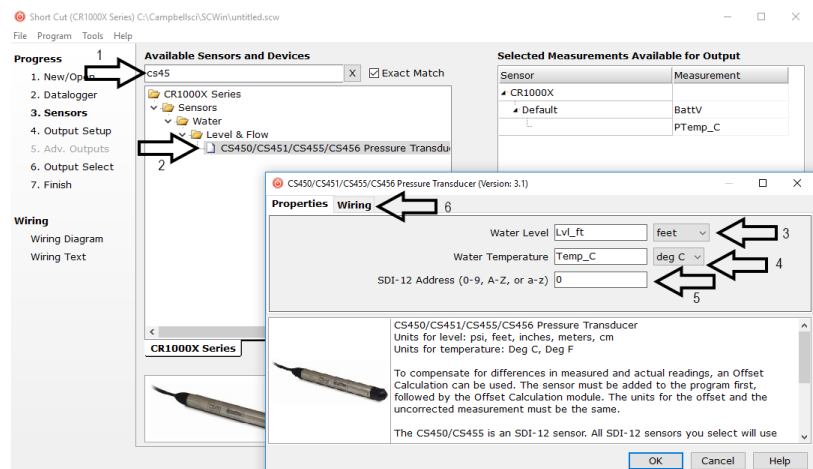
- Upon receipt of the CS451/CS456, inspect the packaging for any signs of shipping damage and, if found, report the damage to the carrier in accordance with policy. Also inspect the contents of the package and file a claim if shipping related damage is discovered.
- The model number and pressure range 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.

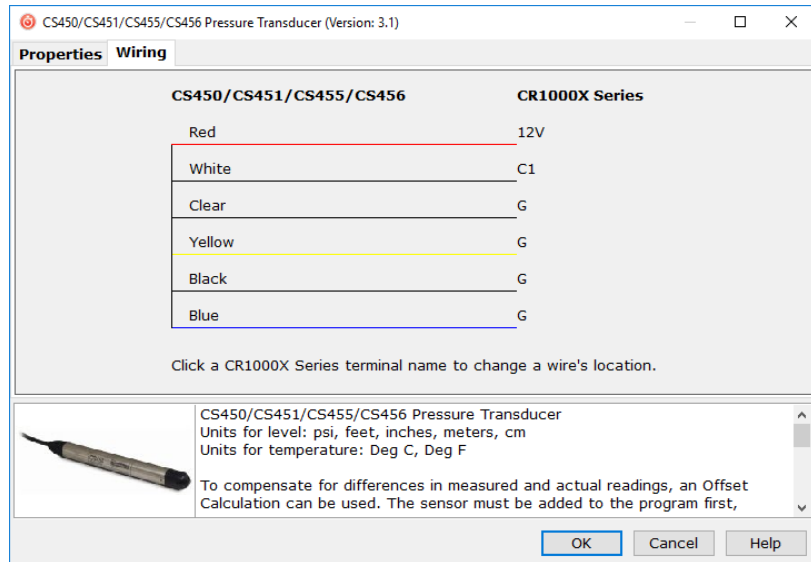
## 4. QuickStart

A video that describes data logger programming using *Short Cut* is available at: [www.campbellsci.eu/videos/cr1000x-datalogger-getting-started-program-part-3](http://www.campbellsci.eu/videos/cr1000x-datalogger-getting-started-program-part-3). *Short Cut* is an easy way to program your data logger to measure the sensor and assign data logger wiring terminals. *Short Cut* is available as a download on [www.campbellsci.eu](http://www.campbellsci.eu). It is included in installations of *LoggerNet*, *PC200W*, *PC400*, or *RTDAQ*.

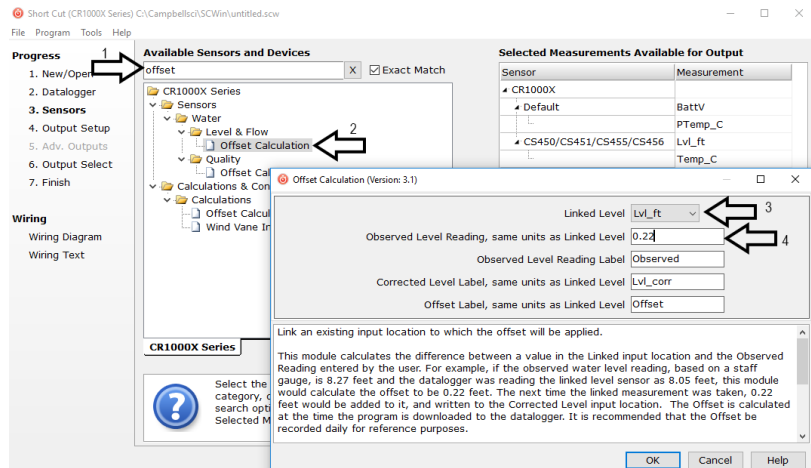
The following procedure also describes programming with *Short Cut*.

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 (1). You can also locate the sensor in the **Sensors | Water | Level & Flow** folder. Double-click **CS450/CS451/CS455/CS456 Pressure Transducer** (2). Water level defaults to feet and temperature defaults to degrees Celsius. These can be changed by clicking the **Water Level** (3) or **Temperature** (4) box and selecting a different option. Type the correct **SDI-12 Address** (5) for the CS451. After entering the **Properties**, click on the **Wiring** (6) tab to see how the sensor is to be wired to the data logger.



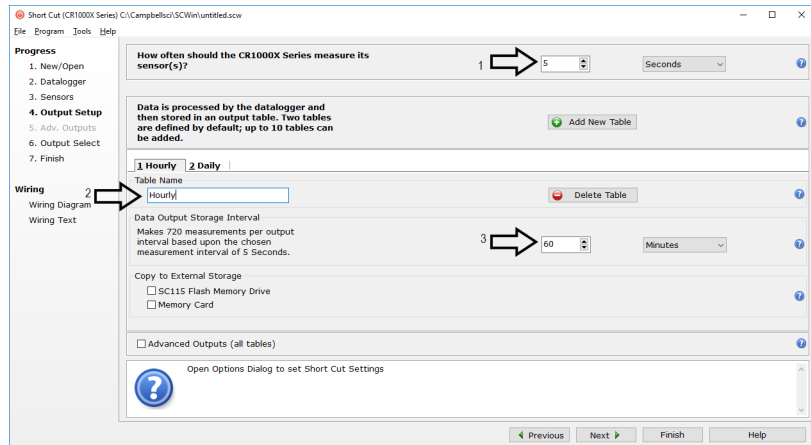


4. In the **Available Sensors and Devices** box, type **Offset** (1) and double-click the **Offset Calculation** (2) under the **Sensors | Water | Level & Flow** folder. For the **Linked Level** parameter (3), select the variable that stores the level measurement (typically **Lvl\_ft** or **Lvl\_m**). Type the initial water level in the **Observed Level Reading** box (4).

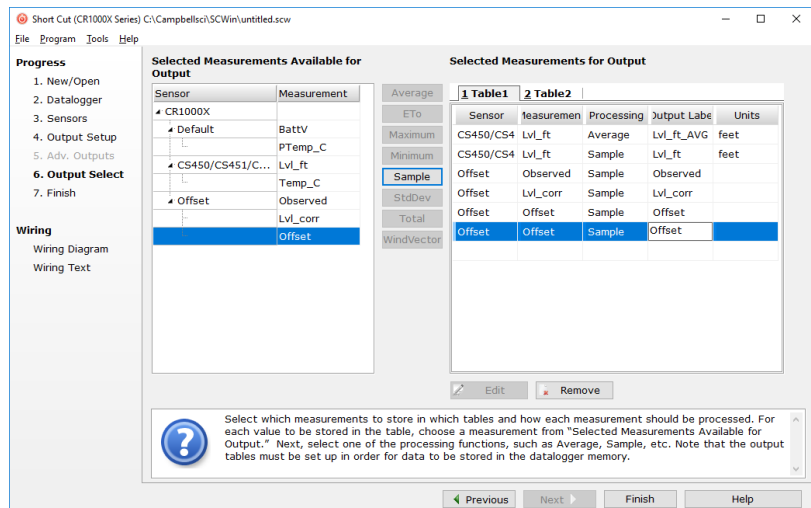


5. Repeat step three for other sensors being measured.

6. In **Output Setup**, enter the scan rate (1), **Data Output Storage Intervals** (2), and meaningful table names (3).



7. Select the measurement and its associated output options.



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*, *PC400*, *RTDAQ*, or *PC200W* 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 gauge (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 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

## 6. Specifications

### 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: CR1000X, CR300 series, CR6, CR200(X) series, CR800 series, CR1000, CR3000, and CR5000

**Power Requirements:** 5 to 18 VDC

**Power Consumption:** Quiescent current < 50  $\mu$ A  
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:**  $\pm 0.1\%$  full scale range TEB<sup>1</sup> or  
 $\pm 0.05\%$  full scale range TEB<sup>2</sup>

**Water-Level Resolution:** 0.0035% full scale range

**Worst-Case  
Temperature Resolution:** 0.006 °C

**Overpressure:** Twice the pressure range

**Dry Storage Temperature:** -10 to 80 °C

### CAUTION

Sensor will be damaged if it is encased in frozen liquid.

**Operating Temperature:** 0 to 60 °C

<b>Temperature Accuracy:</b>	±0.2 °C
<b>Maximum Cable Length:</b>	
SDI-12 (one transducer connected to a single terminal):	~475 m (1500 ft)
SDI-12 (10 transducers connected to a single terminal <sup>3</sup> ):	60 m (200 ft)
RS-232:	60 m (200 ft)
<b>Cable Type:</b>	5 Conductor, 26 AWG Hytrek Jacket
<b>Body Material:</b>	CS451 – 316L Stainless Steel CS456 – Titanium
<b>Element Material:</b>	CS451 – 316L Stainless Steel CS456 – Hastelloy
<b>Standard Nose Cone Material:</b>	Delrin
<b>Length:</b>	213.36 mm (6.875 in)
<b>Diameter:</b>	21.34 mm (0.84 in)
<b>Cable Outer Diameter:</b>	0.589 cm (0.232 in) nominal 0.599 cm (0.236 in) maximum
<b>Distance from pressure sensor interface (black line etched on housing) to:</b>	
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)
<b>Air Gap</b>	
Standard and weighted nose cone:	0.653 cm (0.257 in)
NPT fitting:	2.72 cm (1.07 in)
<b>Weight:</b>	CS451: 0.17 kg (0.37 lb) CS456: 0.10 kg (0.23 lb) Cable: 0.421 kg/m (0.283 lb/ft)
<b>Compliance:</b>	View the EU Declaration of Conformity at: <a href="http://www.campbellsci.eu/cs451">www.campbellsci.eu/cs451</a> <a href="http://www.campbellsci.eu/cs456">www.campbellsci.eu/cs456</a>

<sup>1</sup> 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.

<sup>2</sup> 0.05% full scale range accuracy not available in the 0 to 2.9 psig range.

<sup>3</sup> Campbell Scientific recommends using separate terminals when possible.

## 7. Installation

If using *Short Cut* to program the data logger, skip Section 7.3, *Wiring* (p. 11), and Section 7.4, *Programming* (p. 12). *Short Cut* automatically performs these steps. See Section 4, *QuickStart* (p. 2), for a *Short Cut* tutorial.

### 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 device is to be installed in a liquid other than water or in contaminated water, check the compatibility of the wetted material. The CS456 should be used in harsh water applications, including salt water.

#### 7.1.1 Vent Tube

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 vapour 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.

#### 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 the water pressure will never exceed the transducer overpressure range (twice the pressure range).

---

**CAUTION**

The output reading will not be correct, and the transducer can be damaged if pressure is excessive (twice the pressure range).

---

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

$$1 \text{ psi} = 2.31 \text{ feet of water}$$

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

### 7.1.3 Dislodging Bubbles

While submersing the transducer, air bubbles may become trapped between the pressure plate and the water surface, causing small offset errors until the bubbles dissolve. Dislodge these bubbles by gently shaking the CS451/CS456 while under water.

#### CAUTION

If 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 bubbles are slowly dissolved into the water over time.

#### CAUTION

Hitting against the well casing or other solid surface could damage the transducer.

## 7.2 Installation Procedure

### 7.2.1 Lower to Depth

Lower the transducer to an appropriate depth.

#### CAUTION

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

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

### 7.2.2 Secure the Transducer

#### 7.2.2.1 Tie Wrap/Tape

The transducer body can be strapped with cable ties or tape. Campbell Scientific offers cable ties that can be used to secure and strain relief the cable. 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.

#### 7.2.2.2 Split Mesh Cable Grip

The Split Mesh Cable Grip can be used to centre 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 shows a transducer cable suspended using the split mesh cable grip.



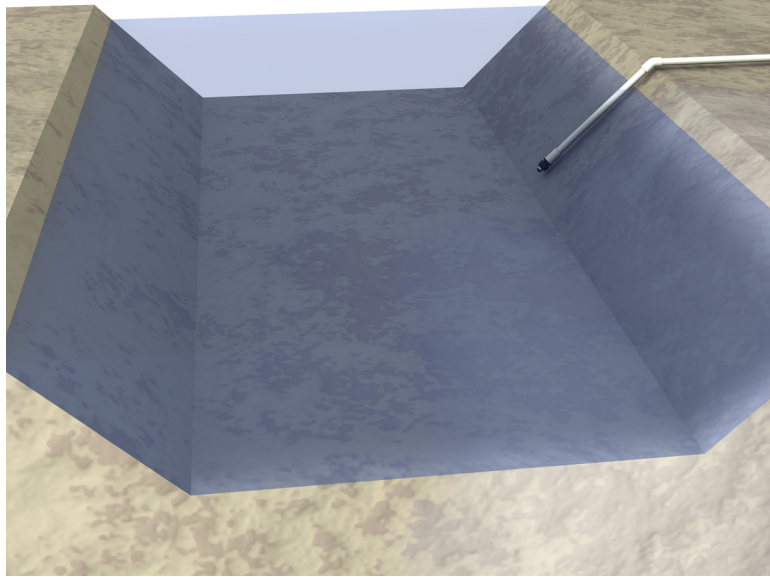
*FIGURE 7-1. Transducer suspended with split mesh cable grip*

#### **7.2.2.3 Heyco Cable Grip**

To protect your transducer during deployment, Campbell Scientific offers the Heyco cable grip (FIGURE 7-2) to clamp the transducer to the submerged end of a 1-inch PVC pipe (FIGURE 7-3). 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

### 7.2.3 Measure the Initial Elevation

Use a staff gauge (or other device) to measure the initial elevation of water. This value is used to calculate an offset that corrects the final measurement for errors due to zero offset or installation. *Short Cut* will make the offset calculation. Refer to Section 7.2.4, *Offset Calculation (p. 11)*, if not using *Short Cut* to calculate the offset.

After installation, several readings should be taken to ensure proper operation.

### 7.2.4 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.

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

$$5.76 \text{ psig} \cdot 2.31 \text{ ft/psig} = 13.3056 \text{ ft.}$$

So, the offset is calculated:

$$20 \text{ ft} - 13.3056 \text{ ft} = 6.6944 \text{ ft}$$

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

## 7.3 Wiring

### NOTE

---

Power down the system before wiring the CS451/CS456.

---

### 7.3.1 SDI-12 Data Logger Connections

TABLE 7-1. Wire Colour, Function, and Data Logger Connection for SDI-12 Measurements		
Wire Colour	Wire Function	Data Logger Connection
White	SDI-12 Signal	C terminal <sup>1</sup> or U configured for SDI-12 <sup>2</sup>
Clear	Shield	⏏ (analogue ground)
Red	Power	12V, Battery+
Black	Power Ground	G
Blue	Ground	⏏ (analogue ground)
Yellow	Ground	⏏ (analogue ground)
<sup>1</sup> Dedicated SDI-12 port on CR5000.		
<sup>2</sup> 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.

### 7.3.2 RS-232 Connections

TABLE 7-2. Wire Colour, Function, Data Logger Connection, and RS-232 Pin			
Wire Colour	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	⏏ (analogue ground)	Pin 5 GND
Clear	Shield GND	⏏ (analogue ground)	

## 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 Section 4, *QuickStart* (p. 2). To import *Short Cut* code into *CRBasic Editor* to create or add to a customized program, follow the procedure in Appendix A, *Importing Short Cut Code into CRBasic Editor* (p. A-1). Programming basics for CRBasic data loggers are provided in the following sections. Complete program examples for select CRBasic data loggers can be found in Appendix B, *Example Programs* (p. B-1). Programming basics and programming examples for Edlog data loggers are provided at [www.campbellsci.com/old-manuals](http://www.campbellsci.com/old-manuals).

The **SDI12Recorder()** measurement instruction programs CRBasic data loggers to measure the CS451/CS456 sensor.

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

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

For some of the SDI-12 commands, the **Destination** parameter must be an array. The required number of values in the array depends on the command (TABLE 8-3).

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

Section 8.2, *SDI-12 Commands* (p. 17), lists the SDI-12 commands, the returned data, and other information about the SDI-12 instruction.

## 7.5 Changing Nose Cones

The procedure to change or replace a nose cone follows:

1. Remove the two screws (FIGURE 7-4).
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.

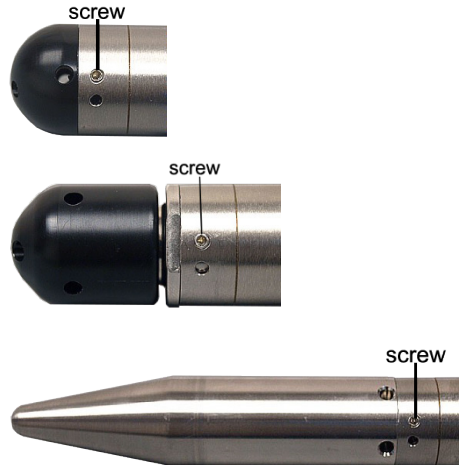


FIGURE 7-4. Screws on the standard nose cone (top), NPT nose cone (middle), and weighted nose cone (bottom)

## 8. Operation

### 8.1 Configuration

TABLE 8-1 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's software *Device Configuration Utility (DevConfig)*. (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 via *DevConfig*.

##### 8.1.1.1 Driver Installation

If the A200 has not been previously plugged into your computer and your computer operating system is not Windows 7, the A200 driver needs to be loaded onto the 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.eu/downloads](http://www.campbellsci.eu/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 and TABLE 8-2). Use the data cable that ships with the A200 to connect it to the computer.



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

TABLE 8-2. Wire Colour, Function, and A200 Connection

Wire Colour	Wire Function	A200 Connection
Red	Power	+12Vdc
Black	Ground	G
White	RS-232 Tx (Output)	Tx
Blue	RS-232 Rx (Output)	Rx
Yellow	Ground	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 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 *DevConfig* or a computer terminal software such as *HyperTerminal*.

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 *LoggerNet* or other software package before and after the installation, or look in the Windows Device Manager list under the ports section (access using the control panel).

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

*Device Configuration Utility (DevConfig)* allows the settings of the CS451/CS456 to be changed. *DevConfig* is included in *LoggerNet* and is also available at [www.campbellsci.eu/downloads](http://www.campbellsci.eu/downloads).

To use *DevConfig*, the transducer needs to be connected to the computer via the A200 (see Section 8.1.1, *Computer Connection Using the A200* (p. 14)). After installing *DevConfig* 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 Section 8.1.1.4, *Determining which COM Port the A200 has been Assigned* (p. 16)). Click on the **Connect** button to enable communication with the sensor. Once successfully connected, the screen should look like FIGURE 8-2.

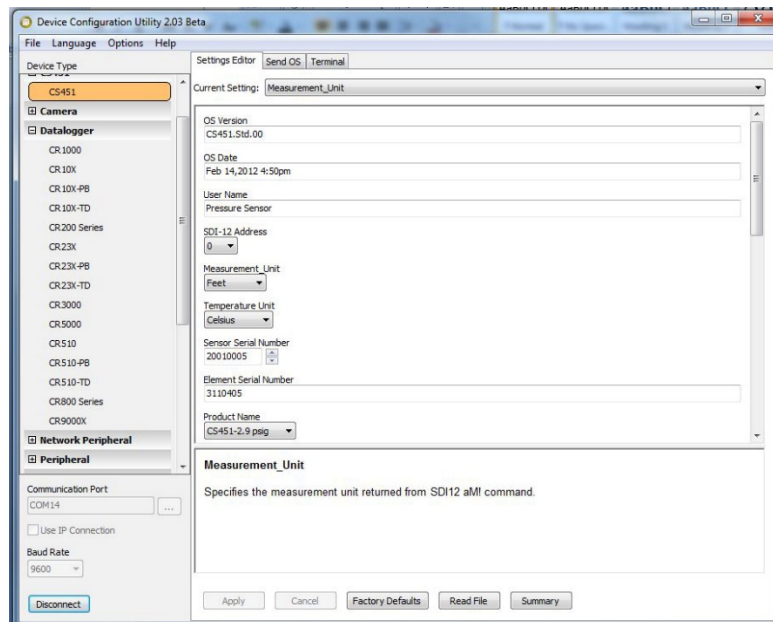


FIGURE 8-2. Connect screen

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 Appendix D, *SDI-12 Sensor Support (p. D-1)*, [www.sdi-12.org](http://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. 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 ( <i>a</i> is the sensor address)	Values Returned or Function	Units
<i>aM!</i> or <i>aC!</i>	1. Pressure/Level 2. Temperature	Configured Settings
<i>aM1!</i> or <i>aC1!</i>	1. Pressure/Level 2. Temperature	PSIG °C
<i>aM2!</i> or <i>aC2!</i>	1. Pressure/Level 2. Temperature	PSIG °F
<i>aM3!</i> or <i>aC3!</i>	1. Pressure/Level 2. Temperature	kPa °C
<i>aM4!</i> or <i>aC4!</i>	1. Pressure/Level 2. Temperature	kPa °F
<i>aM5!</i> or <i>aC5!</i>	Sensor Serial Number	

TABLE 8-3. CS451/CS456 SDI-12 Commands

<b><i>aM6!</i> or <i>aC6!</i></b>	<ol style="list-style-type: none"> <li>1. <math>\Delta R</math></li> <li>2. <math>R_b</math></li> <li>3. Temperature</li> <li>4. IN – DAC counts single-ended measurement, IN+ DAC counts single-ended measurement</li> <li>5. OUT DAC counts differential measurement</li> </ol>	Ohms Ohms °C
<b><i>aM7!</i> or <i>aC7!</i></b>	<ol style="list-style-type: none"> <li>1. Pressure/Level</li> <li>2. Temperature</li> </ol>	Configured Settings (provides data in less than 0.8 s)
<b><i>aM8!</i> or <i>aC8!</i></b>	<ol style="list-style-type: none"> <li>1. Pressure/Level</li> <li>2. Temperature</li> </ol>	Configured Settings.  Provides average of data based on user selected samples. Number of samples are entered with the <b><i>aXCONFIG2=nnn!</i></b> command.
<b><i>aMC!</i>, <i>aMCn!</i>, <i>aCC!</i> or <i>aCCn!</i></b>  Where n = 1 through 8	Same values returned as <b><i>aM!</i>, <i>aM1!</i> – <i>aM8!</i>, <i>aC!</i>, <i>aC1!</i> – <i>aC8!</i></b> commands, except a checksum is added	Same units as the <b><i>aM!</i>, <i>aM1!</i> – <i>aM8!</i>, <i>aC!</i>, <i>aC1!</i> – <i>aC8!</i></b> commands
<b><i>aXCONFIG=tt,pp,mmm.mm,ooo.oo!</i></b>  Where, <i>tt</i> = temperature units <i>pp</i> = measurement unit <i>mmm.mm</i> = multiplier (slope) <i>ooo.oo</i> = offset	Configures the output units for the <b><i>aM!</i></b> and <b><i>aC!</i></b> commands.  Valid entries for <i>tt</i> are: 0 = Celsius 1 = Fahrenheit  Valid entries for <i>pp</i> are: 0 = psig 1 = kPa 2 = Bar 3 = feet 4 = metre 5 = inch 6 = millimetre  The offset and multiplier are only applied to the pressure/level value, not to the temperature.	

TABLE 8-3. CS451/CS456 SDI-12 Commands

<b><i>aXCONFIG2=nnn!</i></b>  Where, <i>nnn</i> = number of samples used with the <b><i>aM8!</i></b> or <b><i>aC8!</i></b> command.	Configures the number of samples used with the <b><i>aM8!</i></b> or <b><i>aC8!</i></b> command	
<b><i>?!</i></b>	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 analogue 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 Appendix D, *SDI-12 Sensor Support (p. D-1)*, 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, metre, inches, millimetre, multiplier (slope), and offset. This command is in the form of ***XCONFIG1=tt,pp,mmm.mm,ooo.oo!***, where *a* = the SDI-12 address of the sensor, *tt* = temperature units, *pp* = measurement unit, *mmm.mm* = multiplier (slope), and *ooo.oo* = 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 = Metre
- 5 = Inch
- 6 = Millimetre

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 at the front of this manual 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 colour 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.

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

### 9.1 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.

## 9.2 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 port the SDI-12 data line is connected to is specified in the measurement instruction.

*Problem:*

Transducer appears to be operating properly but data shows a periodic or cyclic 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

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

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


1. Create the *Short Cut* program following the procedure in Section 4, *QuickStart* (p. 2). After saving the *Short Cut* program, click the **Advanced** tab then the **CRBasic Editor** button. A program file with a generic name will open in CRBasic. Provide a meaningful name and save the CRBasic program. This program can now be edited for additional refinement.

---

## NOTE

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

---

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



# Appendix B. Example Programs

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CRBasic Example B-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)
'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

```

#### CRBasic Example B-2. CS451 SDI-12 Program for CR200(X)-Series Data Logger

```

'CR200(X) Series

'Declare the variable for the water level measurement
Public CS451(2)

'Rename the variable names
Alias CS451(1)=Level
Alias CS451(2)=Temp_C

'Define a data table for 60 minute maximum and minimums
DataTable(Hourly,True,-1)
  DataInterval(0,60,Min)
  Maximum(1,Level,0,0)
  Minimum(1,Level,0,0)
  Maximum(1,Temp_C,0,0)
  Minimum(1,Temp_C,0,0)
EndTable

'Read sensor every 60 seconds
BeginProg
  Scan(60,sec)

  'Code for SDI-12 measurements:
  SDI12Recorder(CS451,0M!,1,0)

  'Call the data table:
  CallTable(Hourly)

  NextScan
EndProg

```

## Appendix C. Calibration Certificate

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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-centre](http://www.campbellsci.com/customer-centre). 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

## D.1 Introduction

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

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

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

## D.2 SDI-12 Command Basics

SDI-12 commands have three components:

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

*Command body* – an upper case letter (the “command”), optionally followed by one or more alphanumeric qualifiers.

*Command termination (!)* – an exclamation mark.

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

TABLE D-1. Campbell Scientific Sensor SDI-12 Command and Response Set		
Name	Command	Response <sup>1</sup>
Acknowledge Active	<b>a!</b>	a<CR><LF>
Send Identification	<b>aI!</b>	allccccccmmmmmmvvvxxx...xx<CR><LF>
Start Verification	<b>aV!</b>	atttn <CR><LF>
Address Query	<b>?!</b>	a<CR><LF>
Change Address	<b>aAb!</b>	b<CR><LF>
Start Measurement	<b>aM!</b> <b>aM1!...aM9!</b>	atttn<CR><LF>
Start Measurement and Request CRC	<b>aMC!</b> <b>aMC1!...aMC9!</b>	atttn <CR><LF>
Start Concurrent Measurement	<b>aC!</b> <b>aC1!...aC9!</b>	atttn<CR><LF>

TABLE D-1. Campbell Scientific Sensor SDI-12 Command and Response Set		
Name	Command	Response <sup>1</sup>
Start Concurrent Measurement and Request CRC	<b>aCC!</b> <b>aCC1!...aCC9!</b>	attnn<CR><LF>
Send Data	<b>aD0!...aD9!</b>	a<values><CR><LF> or a<values><CRC><CR><LF>
Extended Commands	<b>aXNNN!</b>	a<values><CR><LF>
<sup>1</sup> Information on each of these commands is given in following sections.		

### D.2.1 Acknowledge Active Command (a!)

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

### D.2.2 Send Identification Command (a!)

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

<b>a!</b>	alccccccmmmmmmvvvxxx...xx<CR><LF>
a	Sensor SDI-12 address
ll	SDI-12 version number (indicates compatibility)
ccccccc	8-character vendor identification
mmmmmm	6 characters specifying the sensor model
vvv	3 characters specifying the sensor version (operating system)
xxx...xx	Up to 13 optional characters used for a serial number or other specific sensor information that is not relevant for operation of the data logger
<CR><LF>	Terminates the response
Source: <i>SDI-12: A Serial-Digital Interface Standard for Microprocessor-Based Sensors</i> (see Appendix D.4, References (p. D-8)).	

### D.2.3 Start Verification Command (aV!)

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

Command: **aV!**

Response: attn<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.2.4 Address Query Command (?!)

Command **?!** requests the address of the connected sensor. The sensor replies to the query with the address,  $a$ . This command should only be used with one sensor on the SDI-12 bus at a time.

### D.2.5 Change Address Command (aAb!)

Multiple SDI-12 sensors can connect to a single SDI-12 terminal on a data logger. Each device on a single terminal must have a unique address.

A sensor address is changed with command **aAb!**, where  $a$  is the current address and  $b$  is the new address. For example, to change an address from 0 to 2, the command is **0A2!**. The sensor responds with the new address  $b$ , which in this case is 2.

### D.2.6 Start Measurement Commands (aM!...aM9!)

A measurement is initiated with the **M!** command. The response to each command has the form *attn*<CR><LF>, where

$a$  = sensor address

*t* = 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, *t*, 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 (*t*).

**TABLE D-2. Example aM! Sequence**

<b>0M!</b>	The data logger makes a request to sensor 0 to start a measurement.
00352<CR><LF>	Sensor 0 immediately indicates that it will return two values within the next 35 seconds.
0<CR><LF>	Within 35 seconds, sensor 0 indicates that it has completed the measurement by sending a service request to the data logger.
<b>0D0!</b>	The data logger immediately issues the first <b>D</b> command to collect data from the sensor.
0+.859+3.54<CR><LF>	The sensor immediately responds with the sensor address and the two values.

## D.2.7 Start Concurrent Measurement Commands (**aC!**...**aC9!**)

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 *attnn*<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 <b>aC!</b> Sequence	
<b>XC!</b>	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.
<b>YC!</b>	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.
<b>ZC!</b>	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.
<b>ZD0!</b>	After 20 seconds have passed, the data logger starts the process of collecting the data by issuing the first <b>D</b> command to sensor Z.

TABLE D-3. Example aC! Sequence	
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.
<b>XD0!</b>	10 seconds later, after a total of 30 seconds have passed, the data logger starts the process of data from sensor X by issuing the first <b>D</b> command.
X+1+2+3+4+5<CR><LF>	The sensor immediately responds with the sensor address and the 5 values.
<b>YD0!</b>	Ten seconds later, after a total of 40 seconds have passed, the data logger starts the process of data from sensor Y by issuing the first <b>D</b> command.
Y+1+2+3+4+5+6<CR><LF>	The sensor immediately responds with the sensor address and the 6 values.

## D.2.8 Start Measurement Commands with Cyclic Redundancy Check (aMC! and aCC!)

Error checking is done by using measurement commands with cyclic redundancy checks (**aMC!** or **aCC!**). This is most commonly implemented when long cable lengths or electronic noise may impact measurement transmission to the data logger. When these commands are used, the data returned in response to **D** or **R** commands must have a cyclic redundancy check (CRC) code appended to it. The CRC code is a 16-bit value encoded within 3 characters appended before the <CR><LF>. This code is not returned in the data table but checked by the data logger as it comes. The code returned is based on the SDI-12 protocol. See the SDI-12 communication specification for version 1.3 available at [www.sdi-12.org](http://www.sdi-12.org) to learn more about how the CRC code is developed.

## D.2.9 Stopping a Measurement Command

A measurement command (**M!**) is stopped if it detects a break signal. A break signal is sent by the data logger before most commands.

A concurrent measurement command (**C!**) is aborted when another valid command is sent to the sensor before the measurement time has elapsed.

## D.2.10 Send Data Command (aD0! ... aD9!)

The Send Data command requests data from the sensor. It is issued automatically with every type of measurement command (**aM!**, **aMC!**, **aC!**, **aCC!**). When the measurement command is **aM!** or **aMC!**, the data logger issues the **aD0!** command once a service request has been received from the sensor. When the data logger is issuing concurrent commands (**aC!** or **aCC!**), the Send Data command is issued after the required time has elapsed (no service request will be sent by the sensor). In transparent mode (Appendix D.3, *SDI-12 Transparent Mode (p. D-6)*), the user asserts this command to obtain data.

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

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

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

where:

*a* = the sensor address

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

*<CR><LF>* = terminates the response

*<CRC>* = 16-bit CRC code appended if data was requested with **aMC!** or **aCC!**.

## D.2.11 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.3 SDI-12 Transparent Mode

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

Transparent mode is entered while the 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 **Datalogger** list in *PC200W*, the **Tools** list in *PC400*, or the **Datalogger** list in the *Connect* screen of *LoggerNet*.



Watch the video: [SDI-12 Sensors | Transparent Mode](#).

The following examples show how to enter transparent mode and change the SDI-12 address of an SDI-12 sensor. The steps shown in Appendix [D.3.1](#),

*Changing an SDI-12 Address* (p. D-7), are used with most Campbell Scientific data loggers. Appendix D.3.2, *Changing an SDI-12 Address – CR200(X) Series* (p. D-7), lists the steps used for CR200(X)-series data loggers.

### D.3.1 Changing an SDI-12 Address

The example below was done with a CR1000, but the steps are only slightly different for CR1000X-series, CR300-series, CR6-series, CR800-series, and CR3000 data loggers. For CR200(X)-series data loggers, see Appendix D.3.2, *Changing an SDI-12 Address – CR200(X) Series* (p. D-7).

1. Connect an SDI-12 sensor to the CR1000.
2. In *LoggerNet Connect*, under **Datalogger**, click **Terminal Emulator**. The terminal emulator window opens.
3. Under **Select Device**, located in the lower left side of the window, select the **CR1000** station.
4. Click **Open Terminal**.
5. Select **All Caps Mode**.
6. Press Enter until the data logger responds with the *CR1000>* prompt.
7. Type **SDI12** and press Enter.
8. At the *Select SDI12 Port* prompt, type the number corresponding to the control port where the sensor is connected and press Enter. The response *Entering SDI12 Terminal* indicates that the sensor is ready to accept SDI-12 commands.
9. To query the sensor for its current SDI-12 address, type **?!**  and press Enter. The sensor responds with its SDI-12 address. If no characters are typed within 60 seconds, the mode is exited. In that case, simply type **SDI12** again, press Enter, and type the correct control port number when prompted.
10. To change the SDI-12 address, type **aAb!**, where *a* is the current address from the above step and *b* is the new address. Press Enter. The sensor changes its address and responds with the new address.
11. To exit SDI-12 transparent mode, click **Close Terminal**.

### D.3.2 Changing an SDI-12 Address – CR200(X) Series

1. Connect a single SDI-12 sensor to the CR200(X).
2. In *LoggerNet Connect*, under **Datalogger**, click **Terminal Emulator**. The terminal emulator window opens.
3. Under **Select Device**, located in the lower left side of the window, select the **CR200Series** station.
4. Click **Open Terminal**.

5. Select **All Caps Mode**.
6. Press Enter until the data logger responds with the *CR2XX>* prompt.
7. Type **SDI12** and press Enter.
8. The response *SDI12>* indicates that the sensor is ready to accept SDI-12 commands.
9. To query the sensor for its current SDI-12 address, type **?!** and press Enter. The sensor responds with its SDI-12 address. If no characters are typed within 60 seconds, the mode is exited. In that case, simply type **SDI12** again and press Enter.
10. To change the SDI-12 address, type **aAb!**, where *a* is the current address from the above step and *b* is the new address. Press Enter. The sensor changes its address and responds with the new address.
11. To exit SDI-12 transparent mode, click **Close Terminal**.

## D.4 References

SDI-12 Support Group. *SDI-12: A Serial-Digital Interface Standard for Microprocessor-Based Sensors – Version 1.4*. River Heights, UT: SDI-12 Support Group, 2017. [www.sdi-12.org/specification.php?file\\_id=1](http://www.sdi-12.org/specification.php?file_id=1).

# Appendix E. RS-232 Connection Via Computer Terminal Software

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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 Section 8.1.1, *Computer Connection Using the A200* (p. 14)).

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 Section 8.1.1.4, *Determining which COM Port the A200 has been Assigned* (p. 16), to determine the COM port that was assigned to the A200). The software will then prompt for the proper “Port Settings”. TABLE E-1 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, push the <Enter> key several times. This will wake-up the RS-232 mode of the sensor. TABLE E-2 shows the RS-232 commands that can be entered once it is in the RS-232 mode.

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**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.

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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, $\Delta R$ (ohms), $R_b$ (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





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*Location:* Garbutt, QLD Australia  
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*Website:* [www.campbellsci.com.au](http://www.campbellsci.com.au)

## Brazil

*Location:* São Paulo, SP Brazil  
*Phone:* 11.3732.3399  
*Email:* [vendas@campbellsci.com.br](mailto:vendas@campbellsci.com.br)  
*Website:* [www.campbellsci.com.br](http://www.campbellsci.com.br)

## Canada

*Location:* Edmonton, AB Canada  
*Phone:* 780.454.2505  
*Email:* [dataloggers@campbellsci.ca](mailto:dataloggers@campbellsci.ca)  
*Website:* [www.campbellsci.ca](http://www.campbellsci.ca)

## China

*Location:* Beijing, P. R. China  
*Phone:* 86.10.6561.0080  
*Email:* [info@campbellsci.com.cn](mailto:info@campbellsci.com.cn)  
*Website:* [www.campbellsci.com](http://www.campbellsci.com)

## Costa Rica

*Location:* San Pedro, Costa Rica  
*Phone:* 506.2280.1564  
*Email:* [info@campbellsci.cc](mailto:info@campbellsci.cc)  
*Website:* [www.campbellsci.cc](http://www.campbellsci.cc)

## France

*Location:* Vincennes, France  
*Phone:* 0033.0.1.56.45.15.20  
*Email:* [info@campbellsci.fr](mailto:info@campbellsci.fr)  
*Website:* [www.campbellsci.fr](http://www.campbellsci.fr)

## Germany

*Location:* Bremen, Germany  
*Phone:* 49.0.421.460974.0  
*Email:* [info@campbellsci.de](mailto:info@campbellsci.de)  
*Website:* [www.campbellsci.de](http://www.campbellsci.de)

## South Africa

*Location:* Stellenbosch, South Africa  
*Phone:* 27.21.8809960  
*Email:* [sales@campbellsci.co.za](mailto:sales@campbellsci.co.za)  
*Website:* [www.campbellsci.co.za](http://www.campbellsci.co.za)

## Southeast Asia

*Location:* Bangkok, Thailand  
*Phone:* 66.2.719.3399  
*Email:* [thitipongc@campbellsci.asia](mailto:thitipongc@campbellsci.asia)  
*Website:* [www.campbellsci.asia](http://www.campbellsci.asia)

## Spain

*Location:* Barcelona, Spain  
*Phone:* 34.93.2323938  
*Email:* [info@campbellsci.es](mailto:info@campbellsci.es)  
*Website:* [www.campbellsci.es](http://www.campbellsci.es)

## UK

*Location:* Shephed, Loughborough, UK  
*Phone:* 44.0.1509.601141  
*Email:* [sales@campbellsci.co.uk](mailto:sales@campbellsci.co.uk)  
*Website:* [www.campbellsci.co.uk](http://www.campbellsci.co.uk)

## USA

*Location:* Logan, UT USA  
*Phone:* 435.227.9120  
*Email:* [info@campbellsci.com](mailto:info@campbellsci.com)  
*Website:* [www.campbellsci.com](http://www.campbellsci.com)