INSTRUCTION MANUAL

CS451/CS456 Submersible Pressure Transducer

Revision: 5/18

®

WARRANTY AND ASSISTANCE

This equipment is warranted by CAMPBELL SCIENTIFIC (CANADA) CORP. ("CSC") to be free from defects in materials and workmanship under normal use and service for **twelve (12) months** from date of shipment unless specified otherwise. ******* Batteries are not warranted. ******* CSC's obligation under this warranty is limited to repairing or replacing (at CSC's option) defective products. The customer shall assume all costs of removing, reinstalling, and shipping defective products to CSC. CSC will return such products by surface carrier prepaid. This warranty shall not apply to any CSC products which have been subjected to modification, misuse, neglect, accidents of nature, or shipping damage. This warranty is in lieu of all other warranties, expressed or implied, including warranties of merchantability or fitness for a particular purpose. CSC is not liable for special, indirect, incidental, or consequential damages.

Products may not be returned without prior authorization. To obtain a Return Merchandise Authorization (RMA), contact CAMPBELL SCIENTIFIC (CANADA) CORP., at (780) 454-2505. An RMA number will be issued in order to facilitate Repair Personnel in identifying an instrument upon arrival. Please write this number clearly on the outside of the shipping container. Include description of symptoms and all pertinent details.

CAMPBELL SCIENTIFIC (CANADA) CORP. does not accept collect calls.

Non-warranty products returned for repair should be accompanied by a purchase order to cover repair costs.

Assistance

Products may not be returned without prior authorization. The following contact information is for Canadian and international clients residing in countries served by Campbell Scientific (Canada) Corp. directly. Affiliate companies handle repairs for clients within their territories. Please visit *www.campbellsci.ca* to determine which Campbell Scientific company serves your country.

To obtain a Returned Materials Authorization (RMA), contact CAMPBELL SCIENTIFIC (CANADA) CORP., phone (780) 454-2505. After a measurement consultant determines the nature of the problem, an RMA number will be issued. Please write this number clearly on the outside of the shipping container. Campbell Scientific's shipping address is:

CAMPBELL SCIENTIFIC (CANADA) CORP.
RMA#_____
14532 131 Avenue NW
Edmonton, Alberta T5L 4X4
Canada

For all returns, the client must fill out a "Statement of Product Cleanliness and Decontamination" form and comply with the requirements specified in it. The form is available from our web site at *www.campbellsci.ca/repair*. A completed form must be either emailed to *repair@campbellsci.ca* or faxed to (780) 454-2655. Campbell Scientific (Canada) Corp. is unable to process any returns until we receive this form. If the form is not received within three days of product receipt or is incomplete, the product will be returned to the client at the client's expense. Campbell Scientific (Canada) Corp.f reserves the right to refuse service on products that were exposed to contaminants that may cause health or safety concerns for our employees.

Precautions

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.ca or by telephoning (780) 454-2505 (Canada). 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 personnel (e.g. 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.
- 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.

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 CLIENT 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.

PLEASE READ FIRST

About this manual

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

Some useful conversion factors:

Area:	1 in^2 (square inch) = 645 mm^2
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/in2) = 68.95 mb
Volume:	1 US gallon = 3.785 litres

In addition, part ordering numbers may vary. For example, the CABLE5CBL is a CSI part number and known as a FIN5COND at Campbell Scientific Canada (CSC). CSC Technical Support will be pleased to assist with any questions.

About sensor wiring

Please note that certain sensor configurations may require a user supplied jumper wire. It is recommended to review the sensor configuration requirements for your application and supply the jumper wire is necessary.

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CRBasic Examples

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 dataloggers. For retired Edlog datalogger support, access a retired manual at *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. The desiccant should be blue; replace if it is another color.

4. QuickStart

A video that describes datalogger 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 datalogger to measure the sensor and assign datalogger wiring terminals. *Short Cut* is available as a download on *www.campbellsci.com*. 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 datalogger 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 datalogger.
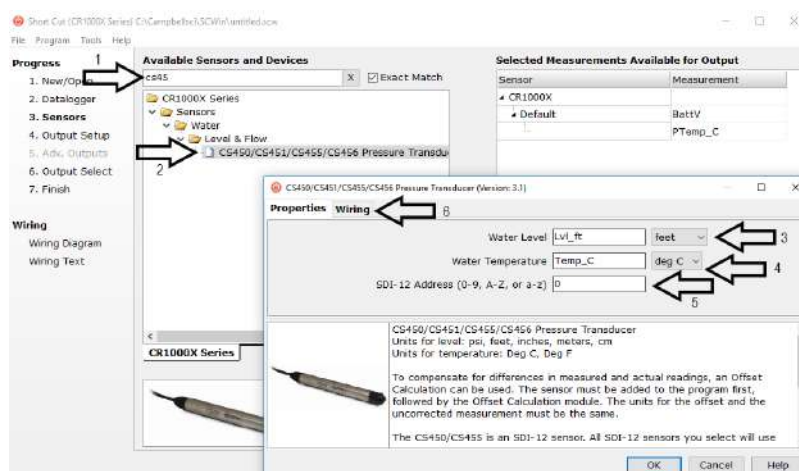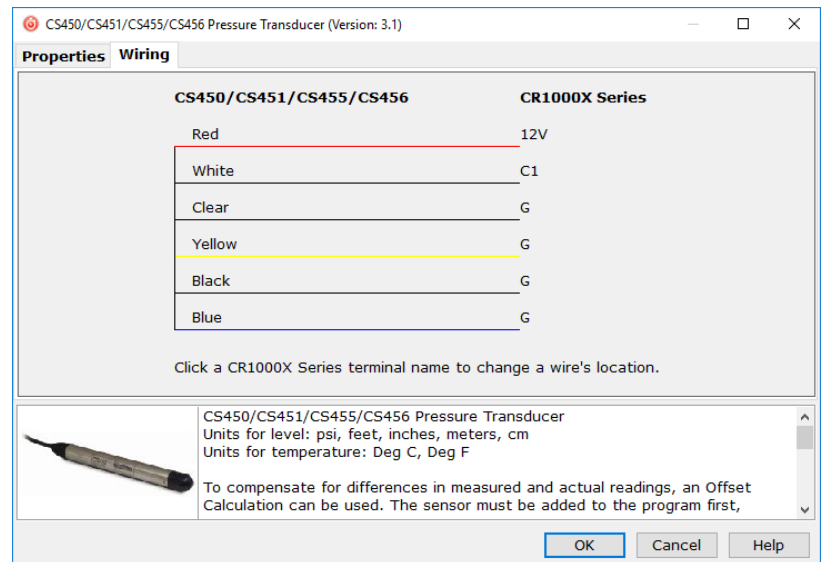
4. In the **Available Sensors and Devices** box, type **Offset** (1) and double-click the **Offset Calculation** (2) under the **Sensors | Water | Level & Flow** folder. For the **Linked Level** parameter (3), select the variable that stores the level measurement (typically **Lvl_ft** or **Lvl_m**). Type the initial water level in the **Observed Level Reading** box (4).
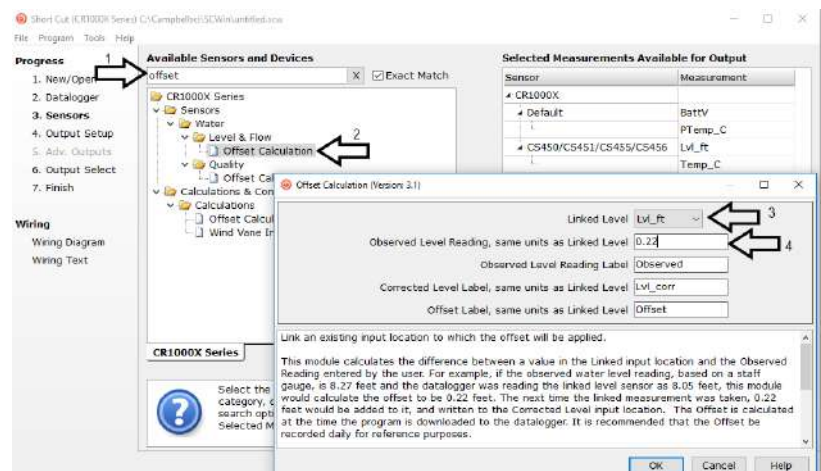
5. Repeat step three for other sensors being measured.

6. In **Output Setup**, enter the scan rate (1), **Data Output Storage Intervals** (2), and meaningful table names (3).
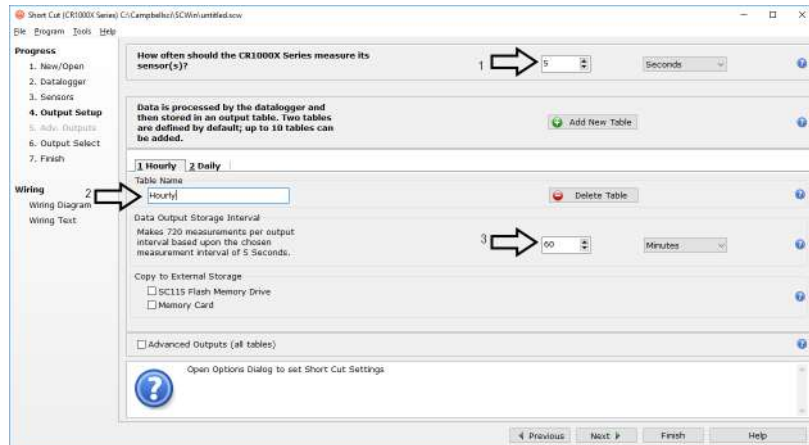
7. Select the measurement and its associated output options.
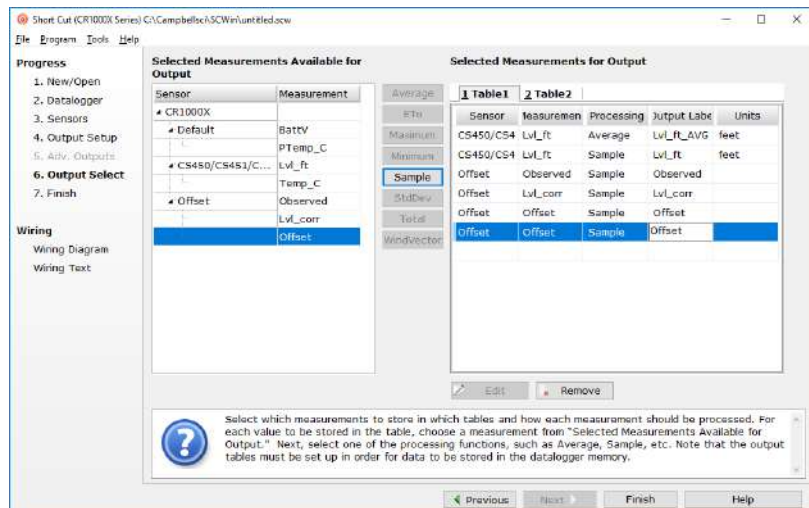
8. Click **Finish** and save the program. Send the program to the datalogger if the datalogger is connected to the computer.

9. If the sensor is connected to the datalogger, 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 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 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.

Standard Nose Cone

Weighted Nose Cone

1/4 inch NPT Nose Cone

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

Power Requirements: 5 to 18 Vdc

Power Consumption: Quiescent 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: –10 to 80 °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)
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 datalogger, 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 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, ensure the desiccant is blue; replace if not.

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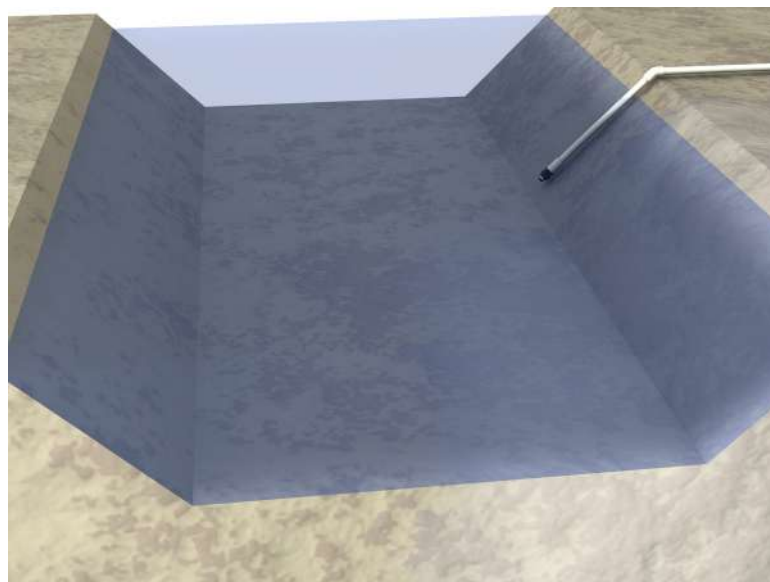
FIGURE 7-3. Transducer mounted in PVC pipe using the Heyco cable grip

7.2.3 Measure the Initial Elevation

Use a staff gage (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 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 calculated:

20 ft – 13.3056 ft = 6.6944 ft

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

7.3 Wiring

Power down the system before wiring the CS451/CS456.

7.3.1 SDI-12 Datalogger Connections

TABLE 7-1. Wire Color, Function, and Datalogger Connection for SDI-12 Measurements		
Wire Color	**Wire Function**	**Datalogger Connection**
White	SDI-12 Signal	**C** terminal[1] or **U** configured for SDI-12[2]
Clear	Shield	$\perp$ (analog ground)
Red	Power	**12V**, **Battery+**
Black	Power Ground	**G**
Blue	Ground	$\perp$ (analog ground)
Yellow	Ground	$\perp$ (analog ground)
[1] Dedicated SDI-12 port on CR5000. [2] **U** terminals are automatically configured by the measurement instruction.		

For the CR6 and CR1000X dataloggers, 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 Color, Function, Datalogger Connection, and RS-232 Pin			
Wire Color	**CS451/CS456 Function**	**Datalogger 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	$\pm$ (analog ground)	Pin 5 GND
Clear	Shield GND	$\pm$ (analog ground)	

7.4 Programming

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

If data acquisition requirements are simple, a datalogger 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 dataloggers are provided in the following sections. Complete program examples for select CRBasic dataloggers can be found in Appendix B, *Example Programs (p. B-1)*. Programming basics and programming examples for Edlog dataloggers are provided at *www.campbellsci.com\old-manuals*.

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

For most CRBasic dataloggers, 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).

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

Section 8.2, *SDI-12 Commands (p. 15)*, lists the SDI-12 commands, the returned data, and other information about the SDI-12 instruction.

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.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 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 Color, Function, and A200 Connection		
Wire Color	**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.com/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. 13)*). 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. 14)*). Click on the **Connect** button to enable communication with the sensor. Once successfully connected, the screen should look like FIGURE 8-2.
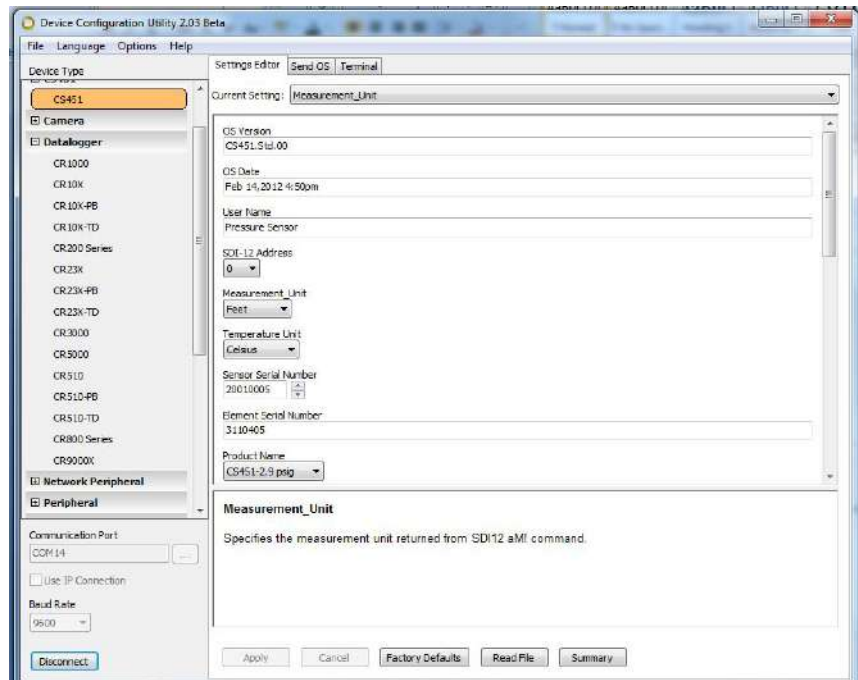
FIGURE 8-2. Connect screen

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*, 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 datalogger 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 datalogger 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 datalogger to pause its operation until the values are ready. Rather, the datalogger 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. SDI-12 Measurement Commands		
SDI-12 command ("a" is the sensor address)	**Command Function**	**Values Returned**
aM! or **aC!**	Configured Settings	Pressure/Level, Temperature
aM1! or **aC1!**	PSIG, °C	Pressure, Temperature
aM2! or **aC2!**	PSIG, °F	Pressure, Temperature
aM3! or **aC3!**	kPa, °C	Pressure, Temperature
aM4! or **aC4!**	kPa, °F	Pressure, Temperature
aM5! or **aC5!**	Sensor Serial Number	Serial Number
aM6! or **aC6!**	Ohms, ohms, °C	ΔR, Rb, Temperature (°C), IN – DAC counts single-ended measurement, IN+ DAC counts single-ended measurement, OUT DAC counts differential measurement
aM7! or **aC7!**	Configured Settings (provides data in less than 0.8 s)	Pressure/Level
aM8! or **aC8!**	Configured settings (provides average of data based on user selected samples)	Pressure/Level, Temperature

As measurement data is transferred between the probe and datalogger 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 **aMC!**, 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 datalogger 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.

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. Before a CS451/CS456 sensor is sent to Campbell Scientific, the customer must get an RMA (returned material authorization) number, and fill out the Declaration of Hazardous Material and Decontamination form.

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:

- The desiccant in the tube changes color from blue to pink when the drying power is lost.

- The 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 datalogger

- 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 datalogger. Check the datalogger 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

This tutorial shows:

- Importing a *Short Cut* program into a program editor for additional refinement

- Importing a wiring diagram from *Short Cut* into the comments of a custom program

Short Cut creates files, which can be imported into *CRBasic Editor*. Assuming defaults were used when *Short Cut* was installed, these files reside in the C:\campbellsci\SCWin folder:

- .DEF (wiring and memory usage information)
- .CR2 (CR200(X)-series datalogger code)
- .CR300 (CR300-series datalogger code)
- .CR6 (CR6-series datalogger code)
- .CR8 (CR800-series datalogger code)
- .CR1 (CR1000 datalogger code)
- .CR1X (CR1000X-series datalogger code)
- .CR3 (CR3000 datalogger code)
- .CR5 (CR5000 datalogger code)

Import *Short Cut* code and wiring diagram into *CRBasic Editor*:

1. Create the *Short Cut* program following the procedure in Section 4, *QuickStart (p. 2)*. Finish the program. On the **Advanced** tab, click the **CRBasic Editor** button. The program opens in CRBasic with the name **noname.CR_**. Provide a name and save the program.

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

2. The program can now be edited, saved, and sent to the datalogger.

3. Import wiring information to the program by opening the associated .DEF file. By default, it is saved in the c:\campbellsci\SCWin folder. Copy and paste the section beginning with heading "–Wiring for CRXXX–" into the CRBasic program, usually at the head of the file. After pasting, edit the information such that an apostrophe (') begins each line. This character instructs the datalogger compiler to ignore the line when compiling. You can highlight several lines of CRBasic code then right-click and select **Comment Block**. (This feature is demonstrated at about 5:10 in the *CRBasic | Features* video.)

Appendix B. Example Programs

CRBasic Example B-1. CS451 SDI-12 Program for CR1000X Datalogger

```
'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 Datalogger Battery Voltage measurement 'BattV'
    Battery(BattV)
    'Default CR1000X Datalogger 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 Datalogger

```
'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

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

D.1 Introduction

SDI-12, Serial Data Interface at 1200 baud, is a protocol developed to simplify sensor and datalogger 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 datalogger.

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.

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>
<tr><td colspan="3" align="center">TABLE D-1. Campbell Scientific Sensor SDI-12 Command and Response Set</td></tr>
<tr><td align="center">Name</td><td align="center">Command</td><td align="center">Response[1]</td></tr>
<tr><td align="center">Acknowledge Active</td><td align="center">a!</td><td align="center">a<CR><LF></td></tr>
<tr><td align="center">Send Identification</td><td align="center">aI!</td><td align="center">allccccccccmmmmmmvvvxxx...xx <CR><LF></td></tr>
<tr><td align="center">Start Verification</td><td align="center">aV!</td><td align="center">atttn <CR><LF></td></tr>
<tr><td align="center">Address Query</td><td align="center">?!</td><td align="center">a<CR><LF></td></tr>
<tr><td align="center">Change Address</td><td align="center">aAb!</td><td align="center">b<CR><LF></td></tr>
<tr><td align="center">Start Measurement</td><td align="center">aM!
aM1!...aM9!</td><td align="center">atttn<CR><LF></td></tr>
<tr><td align="center">Start Measurement and Request CRC</td><td align="center">aMC!
aMC1!...aMC9!</td><td align="center">atttn <CR><LF></td></tr>
</table>

<table>
<tr><td colspan="3" align="center">TABLE D-1. Campbell Scientific Sensor SDI-12 Command and Response Set</td></tr>
<tr><td align="center">Name</td><td align="center">Command</td><td align="center">Response[1]</td></tr>
<tr><td align="center">Start Concurrent Measurement</td><td align="center">aC!
aC1!...aC9!</td><td align="center">atttnn<CR><LF></td></tr>
<tr><td align="center">Start Concurrent Measurement and Request CRC</td><td align="center">aCC!
aCC1!...aCC9!</td><td align="center">atttnn<CR><LF></td></tr>
<tr><td align="center">Send Data</td><td align="center">aD0!...aD9!</td><td align="center">a<values><CR><LF>
or
a<values><CRC><CR><LF></td></tr>
<tr><td colspan="3">[1] Information on each of these commands is given in following sections.</td></tr>
</table>

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 (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 datalogger
<CR><LF>	Terminates the response
Source: *SDI-12: A Serial-Digital Interface Standard for Microprocessor-Based Sensors* (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 **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.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 datalogger. 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!)

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 datalogger, and the datalogger 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 datalogger 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 datalogger 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 datalogger 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 datalogger.
0D0!	The datalogger 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.2.7 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 datalogger 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 datalogger that the measurement is complete. The datalogger 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 datalogger has three sensors wired into terminal **C1**. The sensors are addresses X, Y, and Z. The datalogger will issue the following commands and receive the following responses:

TABLE D-3. Example aC! Sequence	
XC!	The datalogger 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 datalogger 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 datalogger 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 datalogger starts the process of collecting the data by issuing the first **D** 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.
XD0!	10 seconds later, after a total of 30 seconds have passed, the datalogger starts the process of 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 datalogger starts the process of 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.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 datalogger. 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 datalogger 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.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 datalogger 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 datalogger issues the **aD0!** command once a service request has been received from the sensor. When the datalogger 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 datalogger 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.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. Datalogger security may need to be unlocked before activating the transparent mode.

Transparent mode is entered while the computer is communicating with the datalogger through a terminal emulator program. It is accessed through Campbell Scientific datalogger support software or other terminal emulator programs. Datalogger 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-6)*, are used with most Campbell Scientific dataloggers. Appendix D.3.2, *Changing an SDI-12 Address – CR200(X) Series (p. D-7)*, lists the steps used for CR200(X)-series dataloggers.

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 dataloggers. For CR200(X)-series dataloggers, 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 datalogger 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 datalogger 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*.

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 Section 8.1.1, *Computer Connection Using the A200 (p. 13)*).

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. 14)*, 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.

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, ΔR(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

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