

ClariVUE™ 10

Side-Scatter Turbidity Sensor



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1. Introduction

The ClariVUE™10 is a submersible turbidity sensor that uses side-scatter technology to measure suspended solids and turbidity for applications ranging from water quality in aquatic ecosystems to sediment transport and dredge monitoring.



2. Precautions

- READ AND UNDERSTAND the [Safety](#) section at the back of this manual.
- The sensor may be damaged if it is encased in ice. Damages caused by freezing conditions will not be covered by the warranty.
- Campbell Scientific recommends removing the sensor from the water for the time period that the water is likely to freeze.
- ClariVUE 10 is a precision instrument that must be handled with care.
- IMPORTANT: Maintain a level of calibration appropriate to the application. Campbell Scientific recommends factory recalibration of the ClariVUE 10 every two years or when it varies by more than 5% in standard buffer within the 0 to 4000 TU range (see [Verification procedure](#) (p. 16)).



3. Initial inspection

- Upon receipt of the ClariVUE 10, inspect the packaging for any signs of shipping damage, and, if found, report the damage to the carrier in accordance with policy. The contents of the package should also be inspected and a claim filed if any shipping-related damage is discovered.

- When opening the package, take care to not damage or cut the cable jacket. If there is any question about damage having been caused to the cable jacket, a thorough inspection is prudent.
- The model number is on the housing. Check this information against the shipping documentation to ensure that the expected model number was received.

4. QuickStart

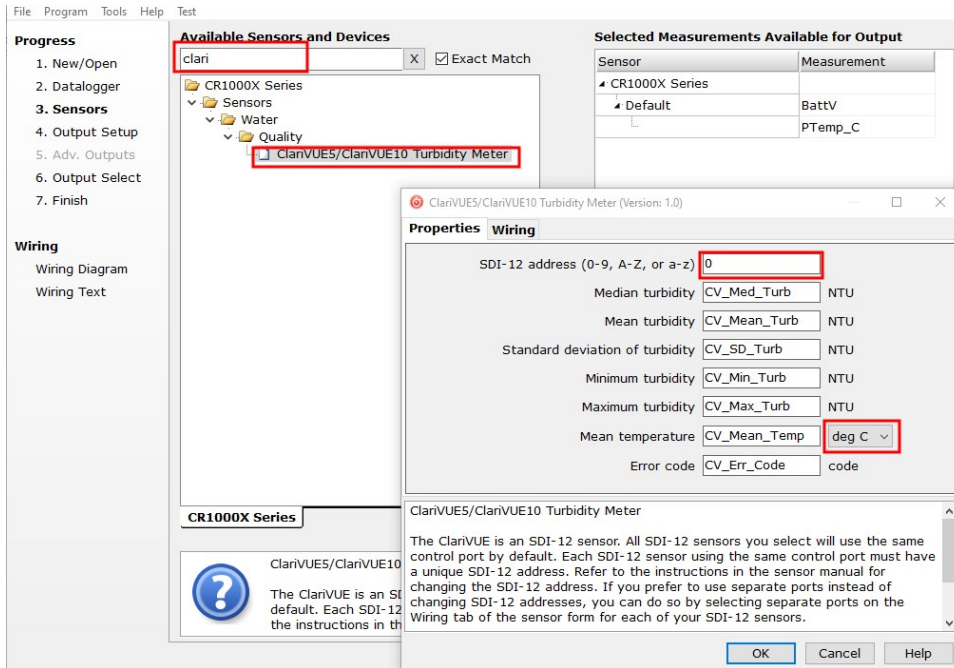
A video that describes data logger programming using *Short Cut* is available at:

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

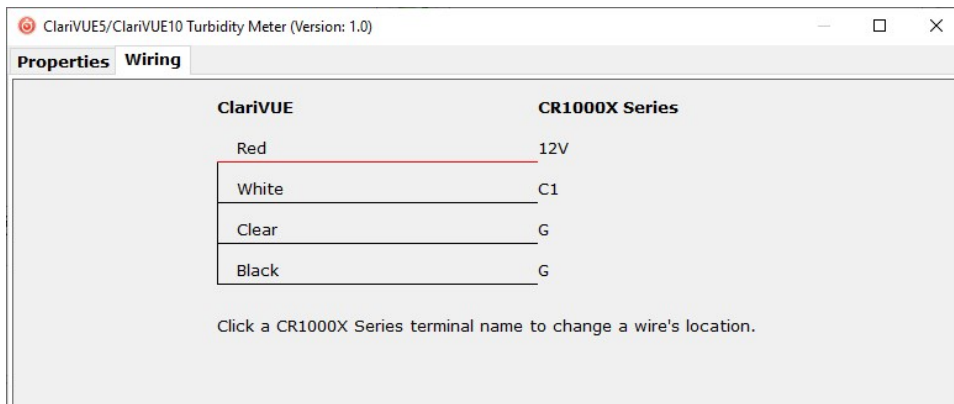
The following procedure also shows using *Short Cut* to program the ClariVUE 10.

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

- In the **Available Sensors and Devices** box, type ClariVUE or find the sensor in the **Sensors > Water > Quality** folder, and double-click **ClariVUE5/ClariVUE10. SDI-12 Address** defaults to 0. Enter the correct **SDI-12 Address** for the sensor if it has been changed from the factory default value. **Mean temperature** defaults to degrees Celsius. These can be changed by clicking the **Mean temperature** box and selecting a different option.



- Click the **Wiring** tab. Click **OK** after wiring the sensor.



- Repeat steps three and four for other sensors you want to measure. Click **Next**.

- In **Output Setup**, type the scan rate, a **Table Name**, and **Data Output Storage Interval**. Click **Next**.

File Program Tools Help Test

Progress

- New/Open
- Datalogger
- Sensors
- Output Setup**
- Adv. Outputs
- Output Select
- Finish

Wiring

- Wiring Diagram
- Wiring Text

How often should the CR1000X Series measure its sensor(s)? Minutes

Data is processed by the datalogger and then stored in an output table. Two tables are defined by default; up to 10 tables can be added. [Add New Table](#)

1 FifteenMin **2 Daily**

Table Name [Delete Table](#)

Data Output Storage Interval
Makes 4 measurements per output interval based upon the chosen measurement interval of 15 Minutes. Minutes

Copy to External Storage

SC115 Drive

Memory Card

Advanced Outputs (all tables)

Specify how often measurements are to be made and how often outputs are to be stored. Note that multiple output intervals can be specified, one for each output table. By default, an output table is set up to send data to memory based on time. Select the Advanced Output option to send data to memory based on one or more of the following conditions: time, the state of a flag, or the value of a measurement.

[Previous](#) [Next](#) [Finish](#) [Help](#)

NOTE:

Because of the sensor response time, Campbell Scientific recommends measurement scans of at least 30 seconds.

- Select the output options.

Progress

- New/Open
- Datalogger
- Sensors
- Output Setup
- Adv. Outputs
- Output Select**
- Finish

Wiring

- Wiring Diagram
- Wiring Text

Selected Measurements Available for Output

Sensor	Measurement
CR1000X Series	
Default	BattV
	PTemp_C
ClariVUE	CV_Med_Turb
	CV_Mean_Turb
	CV_SD_Turb
	CV_Min_Turb
	CV_Max_Turb
	CV_Mean_Temp
	CV_Err_Code

Selected Measurements for Output

1 FifteenMin **2 Daily**

Sensor	Measurement	Processing	Output Label	Units
ClariVUE	CV_Med_Turb	Sample	CV_Med_Turb	NTU
ClariVUE	CV_Mean_Tur	Sample	CV_Mean_Tur	NTU
ClariVUE	CV_SD_Turb	Sample	CV_SD_Turb	NTU
ClariVUE	CV_Min_Turb	Sample	CV_Min_Turb	NTU
ClariVUE	CV_Max_Turb	Sample	CV_Max_Turb	NTU
ClariVUE	CV_Mean_Ter	Sample	CV_Mean_Ter	deg C
ClariVUE	CV_Err_Code	Sample	CV_Err_Code	code

[Edit](#) [Remove](#)

Select which measurements to store in which tables and how each measurement should be processed. For each value to be stored in the table, choose a measurement from "Selected Measurements Available for Output." Next, select one of the processing functions, such as Average, Sample, etc. Note that the output tables must be set up in order for data to be stored in the datalogger memory.

[Previous](#) [Next](#) [Finish](#) [Help](#)

- Click **Finish** and save the program. Send the program to the data logger if the data logger is connected to the computer.

9. If the sensor is connected to the data logger, check the output of the sensor in the data display in *LoggerNet*, *RTDAQ*, or *PC400* to make sure it is making reasonable measurements.

5. Overview

The heart of the ClariVUE 10 is a near-infrared (NIR) laser and a photodiode for detecting the intensity of light scattered from suspended particles in water. The detector is positioned at 90 degrees to the emitter to measure the side-scatter energy. The ClariVUE 10 has two measurement ranges. The low range is from 0-400 TU and uses a transfer function to convert mV readings to turbidity units based on 4 calibration points in this range: 0, 20, 100, and 400 TU. The high range is from 401 to 4000 TU. The high range transfer function converts millivolt to turbidity units using seven calibration points across the full measurement range: 0, 20, 100, 400, 1000, 2500, and 4000 TU.

Turbidity sensors are used for a wide variety of monitoring tasks in riverine, oceanic, laboratory, and industrial settings. They can be integrated with water-quality monitoring systems, conductivity, temperature, and depth sensors (CTDs), laboratory instrumentation, and sediment-transport monitors.

Applications include:

- Compliance with permits, water-quality guidelines, and regulations
- Determination of transport and fate of particles and associated contaminants in aquatic systems
- Conservation, protection, and restoration of surface waters
- Assessing the effects of land-use management on water quality
- Monitoring waterside construction, mining, and dredging operations
- Characterization of wastewater and energy-production effluents

Features:

- Fitted with wet-pluggable connector—multiple mating cable length options available
- Accurate and rugged
- Compatible with any SDI-12 data logger/controller including Campbell Scientific GRANITE-series, CR6, CR3000, CR1000X, CR800-series, CR300-series, and CR1000

6. Specifications

Standards: Meets ISO 7027-1:2016 (side scatter) standard for turbidity measurements.

Compliance: SDI-12 v1.4

Operating temperature range: -2 to 40 °C

CAUTION:

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

Power requirements: 9.6 to 18 VDC

Power consumption

Idle: <300 µA

Measurement: <35 mA

Measurement range: 0 to 4000 FNU

Measurement response time: 9 to 22 s depending on the SDI-12 command (see [Table 8-1](#) (p. 13))

Resolution: 0.2 FNU

Particle size: 0.1 to 0.5 µm

Accuracy: ±2% or 0.5 FNU, whichever is greater

Housing material: Delrin® plastic

Head material: Marine-grade bronze

Optics: Sapphire lens

Connector description: MCBH-5-FS, marine-grade bronze, 3 gold-plated pins, wet-matable

Cable type: 3-conductor, polyurethane jacket with water block

Optical assembly: Sealed with double O-rings

Internal temperature measurement: ±0.2 °C accuracy

Maximum depth: 30 m (100 ft)

Diameter: 3.0 cm (1.2 in)
Length: 16.6 cm (6.5 in)

7. Installation

If you are programming your data logger with *Short Cut*, skip [Wiring](#) (p. 7) and [Programming](#) (p. 7). *Short Cut* does this work for you. See [QuickStart](#) (p. 2) for a tutorial.

7.1 Wiring

Connect the wires in the order shown in the following table.

Wire color	Wire function	Data logger connection
White	SDI-12 signal	C, SDI-12, or U configured for SDI-12 ¹
Red	Power	12V
Black	Power ground	G
Clear	Shield	G

¹U and C terminals are automatically configured by the measurement instruction.

If multiple SDI-12 sensors are connected to a data logger, Campbell Scientific recommends using separate terminals when possible. However, multiple SDI-12 sensors can connect to the same data logger control (C) or universal (U) terminal. Each must have a unique SDI-12 address. Valid addresses are 0 through 9, a through z, and A through Z.

For 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 this product is connected to C3 on a CR1000X, C4 cannot be used in the [TimerInput\(\)](#), [PulseCount\(\)](#), or [WaitDigTrig\(\)](#) instructions.


7.2 Programming

Short Cut is the best source for up-to-date programming code for Campbell Scientific data loggers. If your data acquisition requirements are simple, you can probably create and maintain a data logger program exclusively with *Short Cut*. If your data acquisition needs are more complex,

the files that *Short Cut* creates are a great source for programming code to start a new program or add to an existing custom program.

NOTE:

Short Cut cannot edit programs after they are imported and edited in *CRBasic Editor*.

A *Short Cut* tutorial is available in [QuickStart](#) (p. 2). If you wish to import *Short Cut* code into *CRBasic Editor* to create or add to a customized program, follow the procedure in [Importing Short Cut code into CRBasic Editor](#) (p. 25). Programming basics for CRBasic data loggers are provided in the following section. A downloadable example program is available at www.campbellsci.com/downloads/clarivue-example-program .

7.2.1 CRBasic programming

The `SDI12Recorder()` instruction is used to measure a ClariVUE 10. The `SDI12Recorder()` instruction sends a request to the sensor to make a measurement and then retrieves the measurement from the sensor. See [SDI-12 measurements](#) (p. 12) for more information.

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

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

Valid values for the `SDIAddress` are 0 through 9, A through Z, and a through z; alphabetical characters need to be enclosed in quotes (for example, "A"). Also enclose the `SDICommand` in quotes as shown. The `Destination` parameter must be an array. The required number of values in the array depends on the command (see [SDI-12 measurements](#) (p. 12)).

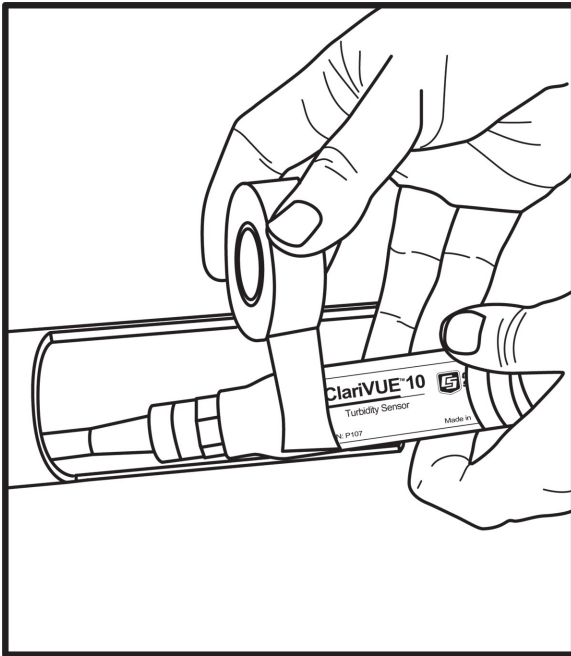
`FillNAN` and `WaitonTimeout` are optional parameters (refer to CRBasic Help for more information).

7.3 Mounting

Schemes for mounting the ClariVUE 10 will vary with applications; however, the same basic precautions should be followed to ensure the unit is able to make a good measurement and that it is not lost or damaged.

- Orient the unit so that the ClariVUE 10 looks into clear water without reflective surfaces. This includes any object such as a mounting structure, a stream bed, or sidewalls. The sidescatter sensor can see to about 5 cm (2 in) at 90°.

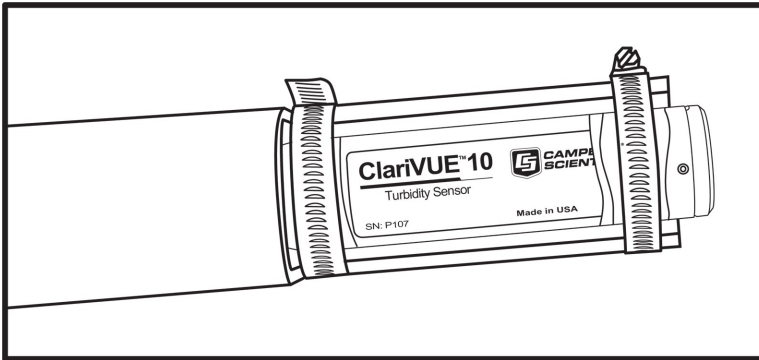
- Campbell Scientific recommends avoiding direct sunlight. The ClariVUE 10 measures any infrared light source pulsing at a 5 kHz rate that is in sync with the 5 kHz internal VCSEL light driver. Therefore, the combination of direct sunlight and a rippling water surface can affect turbidity measurements. Some installations may require shading to prevent sunlight interference.
- Always place electrical tape or 2 mm (1/16 in) neoprene sheet on the housing where the housing will contact metal or other hard objects.



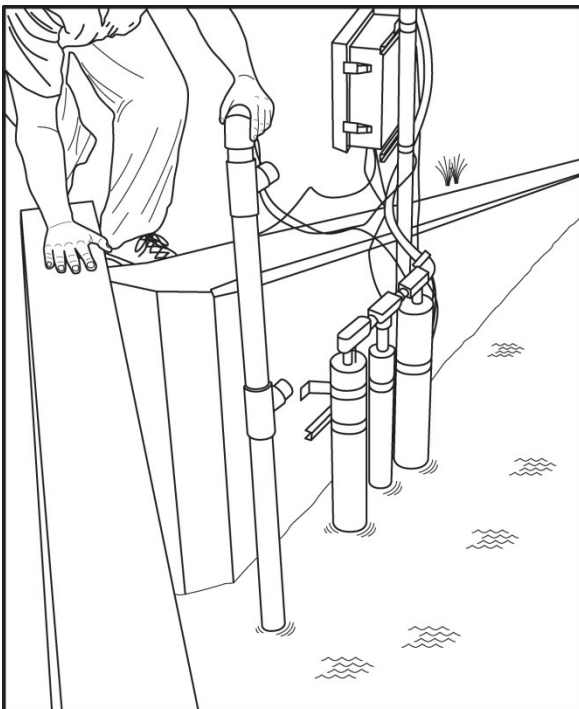
- The most convenient means for mounting the unit to a frame or wire is to use large, high-strength nylon cable ties (7.6 mm (0.3 in) width) or stainless steel hose clamps. First cover the area(s) to be clamped with electrical tape or 2 mm (1/16 in) neoprene sheet. Clamp the unit to the mounting frame or wire in the padded area.

CAUTION:

Lightly tighten the hose clamps. Overtightening may crack the pressure housing and cause a leak. Use spacer blocks when necessary to prevent chafing the unit with the frame or the wire.



- Mounting inside the end of a PVC pipe is a convenient way to provide structure and protection for deployments. The ClariVUE 10 fits inside a 2-in schedule 40 PVC pipe.



8. Operation

This section provides the following information:

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8.2 SDI-12 measurements	12
8.3 SDI-12 extended commands	14
8.4 Vertical-cavity surface-emitting laser diode	14

8.1 Turbidity units

Conceptually, turbidity is a numerical expression in turbidity units (TU) of the optical properties that cause water to appear hazy or cloudy as a result of light scattering and absorption by suspended matter. Operationally, a TU value is interpolated from neighboring light-scattering measurements made on calibration standards such as Formazin, StablCal®, or styrene divinylbenzene (SDVB) beads. Turbidity is caused by suspended and dissolved matter such as sediment, plankton, bacteria, viruses, and organic and inorganic dyes. In general, as the concentration of suspended matter in water increases, so will its turbidity; as the concentration of dissolved, light-absorbing matter increases, turbidity will decrease.


Descriptions of the factors that affect turbidity are given in [Factors that affect turbidity and suspended-sediment measurements](#) (p. 26). Like all other optical turbidity monitors, the response depends on the size, the composition, and the shape of suspended particles. For this reason, for monitoring concentrations, the sensor must be calibrated with suspended sediments from the waters to be monitored. There is no standard turbidimeter design or universal formula for converting TU values to physical units such as mg/l or ppm. TU values have no intrinsic physical, chemical, or biological significance. However, empirical correlations between turbidity and environmental conditions, established through field calibration, can be useful in water-quality investigations.

The USGS has an excellent chapter on turbidity measurements in their *National Field Manual for the Collection of Water-Quality Data*:

http://water.usgs.gov/owq/FieldManual/Chapter6/Section6.7_v2.1.pdf 

Historically, most turbidity sensor manufacturers and sensor users labeled the units NTUs, for Nephelometric Turbidity Units. The ASTM and the USGS unit classification for sidescatter is formazin nephelometric unit (FNU)

The following document, *U.S. Geological Survey Implements New Turbidity Data-Reporting Procedures*, describes the units:

<http://water.usgs.gov/owq/turbidity/TurbidityInfoSheet.pdf> 

8.2 SDI-12 measurements

The ClariVUE 10 responds to the SDI-12 commands shown in [Table 8-1](#) (p. 13). When the data logger issues an **M!** command, the sensor should respond immediately indicating how long it will take to perform the measurement. The data logger then waits that amount of time or if the sensor finishes sooner, it will send a service request to the data logger indicating data can be collected. After receiving the service request or waiting the indicated time, the data logger will send the **D!** command to collect the data.

NOTE:


[SDI-12 sensor support](#) (p. 28) describes the SDI-12 commands. Additional SDI-12 information is available at www.sdi-12.org .

Table 8-1: SDI-12 measurement commands

SDI-12 command ¹	Values Returned	Units	Sensor response time	Comments
<i>aM!</i> , <i>aMC!</i> , <i>aC!</i> , <i>aCC!</i>	<ol style="list-style-type: none"> Median turbidity (mmm.mm) Mean turbidity (nnn.nn) Standard deviation turbidity (sss.s) Minimum turbidity (lll.ll) Maximum turbidity (hhh.hh) Average temperature (ttt.tt) Error code (ee) 	<ol style="list-style-type: none"> FNU FNU FNU FNU FNU °C N/A 	9 s	Burst data. Sensor makes 30 measurements.
<i>aM1!</i> , <i>aMC1!</i> , <i>aC1!</i> , <i>aCC1!</i>	<ol style="list-style-type: none"> Median turbidity (mmm.mm) Mean turbidity (nnn.nn) Standard deviation turbidity (sss.s) Minimum turbidity (lll.ll) Maximum turbidity (hhh.hh) Average temperature (ttt.tt) Error code (ee) 	<ol style="list-style-type: none"> FNU FNU FNU FNU FNU °C N/A 	22 s	Burst data. Sensor makes 100 measurements.
<i>aM9!</i> , <i>aMC9!</i> , <i>aC9!</i> , <i>aCC9!</i>	<ol style="list-style-type: none"> Median turbidity Mean turbidity Standard deviation turbidity Minimum turbidity Maximum turbidity Error code (ee) 	<ol style="list-style-type: none"> mV mV mV mV mV N/A 	17 s	Raw burst data. Sensor makes 100 measurements and returns the raw millivolt readings without converting values to FNU.

¹a is the sensor address.

8.3 SDI-12 extended commands

Enter the following SDI-12 extended commands using the transparent mode 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. Refer to [SDI-12 transparent mode](#) (p. 34) for more information.

SDI-12 command ¹	Values Returned or Function
<i>a</i> XTEST!	Outputs 25 fitted measurement values
<i>a</i> XCAL!	Displays calibration values.
<i>a</i> XDEFAULT!	Reset probe to default production calibration.
<i>a</i> XSTATS!	<ol style="list-style-type: none">1. Serial number2. SDI-12 address3. Signature of the bootloader code4. Signature of the operating system5. Signature of the calibration data
<i>a</i> XHELP!	Lists the SDI-12 commands available for the ClariVUE 10.

¹a is the sensor address.

8.4 Vertical-cavity surface-emitting laser diode

The ClariVUE 10 sensor detects suspended matter in water and turbidity from the relative intensity of light side scattered at 90° in accordance with ISO7027. A 3D image of the main components of the sensor is shown in [FIGURE 8-1](#) (p. 15). The ClariVUE 10 light source is a vertical-cavity surface-emitting laser diode (VCSEL), which converts 7 mA of electrical current to 1500 µW of optical power. The detector is a low-drift silicon photodiode with enhanced NIR responsivity. NIR responsivity is the ratio of electrical current produced per unit of light power in air or water. A light baffle prevents direct illumination of the detector by the light source and in-phase coupling that would otherwise produce large signal biases. The silicon photodiode features a daylight blocking filter matched with 830 nm to 950 nm infrared emitters. The daylight blocking filter protects the photodiode from ambient light saturation.

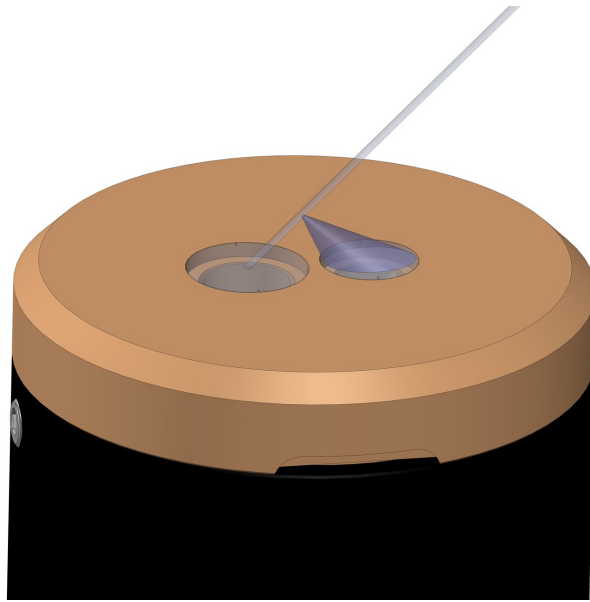


FIGURE 8-1. Sidescatter detector cones. The larger window is the VCSEL laser, and the smaller window is the photo diode detector.

9. Maintenance, troubleshooting, and calibration

NOTE:

All factory repairs and recalibrations require a returned material authorization (RMA) and completion of the "Statement of Product Cleanliness and Decontamination" form. Refer to the [Assistance](#) page at the end of this manual for more information.

9.1 Maintenance

CAUTION:

No user-serviceable parts are inside the sensor housing. Do not remove the sensor or connector from the pressure housing. This will void the warranty and could cause a leak.

Periodically clean the ClariVUE 10 window:

1. If encrusted organisms such as barnacles or tube worms are on the ClariVUE 10 window, use a flexible knife blade to gently scrape them off.
2. For other types of fouling, wet a scouring pad.
 - a. Place the scouring pad on a counter with a plastic-laminate top with the pad side aligned with the edge of the counter.
 - b. Rub the sensor window back and forth on the pad until it is clean.

Do the following to remove pits from the sensor face:

1. Tape a strip of 400 grit wet-or-dry abrasive cloth to the edge of a counter.
2. Add a few drops of water to the abrasive cloth.
3. Using the counter edge as a guide, rub the sensor window on the cloth in smooth one-way strokes until the sensor is shiny and pit free.

WARNING:

Do not use solvents such as methyl ethyl ketone (MEK), toluene, acetone, or trichloroethylene on the ClariVUE 10.

Verify sensor calibration ([Verification procedure](#) (p. 16)) when visiting site to clean the sensor. If sensors deviate more than 5% send to Campbell Scientific for factory calibration (refer to [Assistance](#) for more information).

9.2 Troubleshooting

1. Check the wiring to ensure the ClariVUE 10 wires are connected to the correct data logger terminals (see [Wiring](#) (p. 7)).
2. Check the data logger program scan rate is sufficient for the SDI-12 commands ([SDI-12 measurements](#) (p. 12)).
3. Check the data logger program to ensure that the SDI-12 address matches the ClariVUE 10 SDI-12 address and that the **SDIPort** matches the data logger connections.

9.3 Verification procedure

Campbell Scientific recommends checking the calibration in the field. This section explains how to verify the factory calibration is still within 5% or a user set threshold.

Supplies:

- Data logger
- ClariVUE 10 cable
- ClariVUE 10
- Computer with *Device Configuration Utility* installed
- Formazin or StableCal Turbidity standards of your choice between 0 to 4000 TU.
- DI water for rinsing sensor and 0.4 TU point for checking
- 8 liter (2 gallon) black plastic bucket if you are using DI water as one of your check points.
- 100 mm (4 in), black calibration cup for standards greater than 20 TU

Procedure:

1. Swab sensor with an alcohol-soaked towel to sterilize it.
2. Wire sensor to the data logger. Many data loggers offer a terminal mode to talk to SDI-12 sensors. This procedure requires an SDI-12 recorder/data logger that can return multiple lines for an extended SDI-12 command. For this example, the ClariVUE 10 is connected to the following terminals on a Campbell Scientific CR1000X data logger.

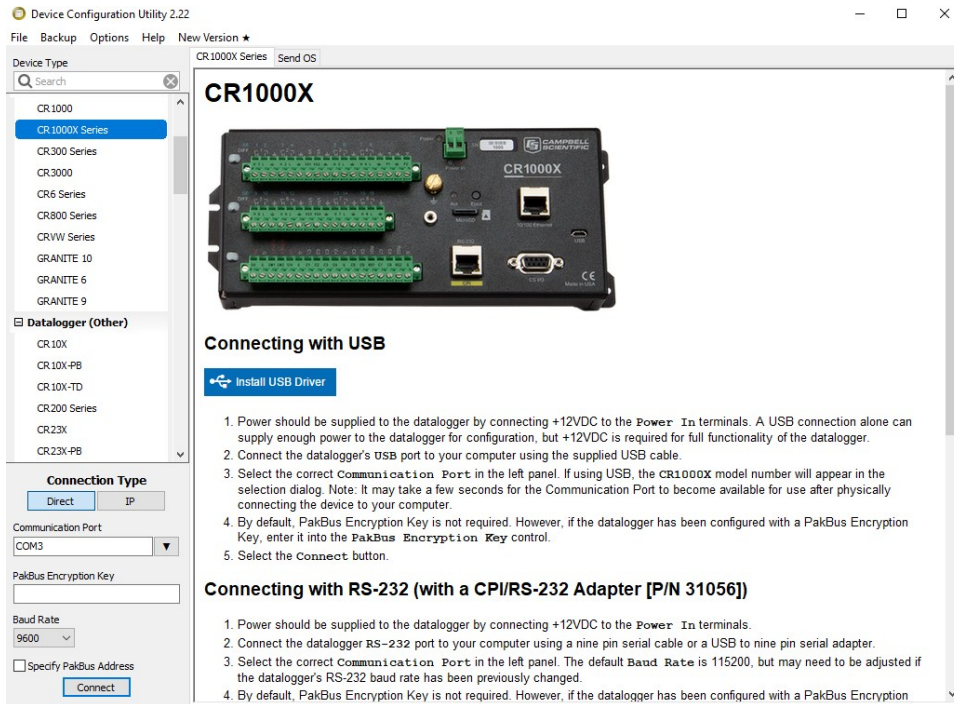
Wire color	CR1000X terminal
White	C3
Red	12V
Black	G
Clear	G

NOTE:

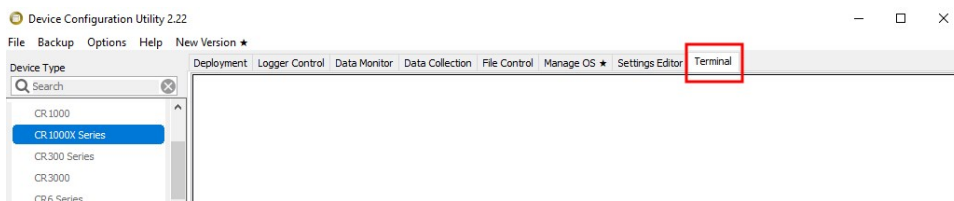
To verify the calibration, you do not need to have a program running on the data logger.

3. Open *Device Configuration* utility.
4. Under **Device Type**, type the data logger model and double-click on the model type. This example uses a CR1000X directly connected to the computer USB port.

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

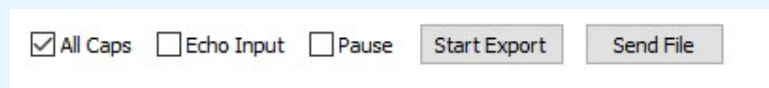


6. Click the **Terminal** tab.

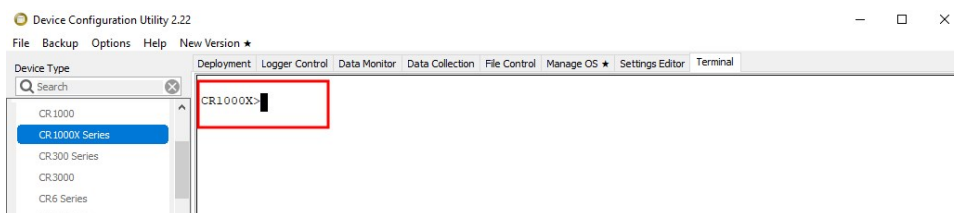


NOTE:

Click **Start Export** to save the 25 verification readings in a text editor. This log can be easily transferred to a spreadsheet. Select **All Caps** to simplify entering the SDI-12 commands.



7. Press Enter until the data logger responds with the data logger (**CR1000X>**) prompt.



- Type **SDI12** and press Enter.
- At the **Select SDI12 Port** prompt, type the number corresponding to the control port where the sensor is connected and press Enter. In this example the sensor is connected to C3. The response **Entering SDI12 Terminal** indicates that the sensor is ready to accept SDI-12 commands.

```
CR1000X>  
CR1000X>SDI12  
1: C1  
2: C3  
3: C5  
4: C7  
Select SDI12 Port: 2
```

- Type **?!** to determine the address of your sensor. The default sensor address is 0.

```
?!  
0
```

NOTE:

If the standards are cold or the sensor was recently removed from the water, the ClariVUE 10 will need to equilibrate to the ambient temperature before doing the next step.

- Submerge the ClariVUE 10 into the first calibration standard or DI water. Place the sensor vertically, in the middle of the calibration cup. If the first point is DI water or a turbidity standard less than 20 TU, use a black 8 liter (2 gallon) bucket, preferably tumbled so the inside of the bucket is not glossy/reflective.

12. Type *aXTEST!*, where *a* is the sensor address (0 in this example). This SDI-12 command collects 25 measurements, which is similar to running the *M!* command 25 times in rapid succession.

```
0XTEST!  
0 .....0 output 25 values of NTU readings  
0 .....  
0 0.273755 22.937300  
0 0.287878 22.946196  
0 0.271526 22.963276  
0 0.258146 22.986679  
0 0.238077 23.013351  
0 0.293824 23.041656  
0 0.676631 23.070333  
0 0.623111 23.098751  
0 0.310920 23.126926  
0 0.480394 23.154617  
0 0.328759 23.180658  
0 0.236591 23.206181  
0 0.255173 23.230719  
0 0.294567 23.254576  
0 0.287878 23.277170  
0 0.216522 23.298714  
0 0.243281 23.319822  
0 0.264836 23.340040  
0 0.235104 23.359821  
0 0.245510 23.378616  
0 0.269295 23.396957  
0 0.301257 23.414764  
0 0.298284 23.431765  
0 0.258146 23.448683  
0 0.324300 23.464485
```

13. If the values are stable, remove the sensor from standard 1. If you have it in DI water, cover the DI water bucket and go to the next step. If the calibration standard is greater than 0 TU, rinse the sensor with DI water to reduce contamination of standards. Dry the sensor to reduce dilution of the next standard. Pour the calibration standard into the bottle and cap it, or cover the bucket to reduce evaporation and cross contamination.

- Place the sensor in your second standard. If the turbidity value is greater than 20 TU, use a smaller calibration cup, preferably a black plastic container with a diameter greater than 4 inches.

NOTE:

The second standard should be within the range of the field site conditions or the range of turbidity in which you are most interested. For high turbidity waters, check at 1000 and 4000 TU. For less turbid bodies of water, check the 0 point and 250 TU.

In the following example, the turbidity standard is approximately 765 TU.

```
OXTEST!  
0 .....0 output 25 values of NTU readings  
0 .....  
0 780.742188 22.872490  
0 763.879028 22.881109  
0 766.559326 22.897186  
0 765.838989 22.918715  
0 764.279541 22.944286  
0 764.367065 22.971216  
0 765.166504 22.998585  
0 766.294800 23.026031  
0 766.044556 23.053076  
0 764.259399 23.079439  
0 762.503540 23.105286  
0 761.238525 23.129725  
0 760.520508 23.153858  
0 759.896606 23.177067  
0 759.733765 23.199064  
0 759.682983 23.220318  
0 760.502563 23.240923  
0 762.001343 23.260736  
0 763.672119 23.279921  
0 764.774292 23.298456  
0 765.240479 23.316216  
0 765.356323 23.333521  
0 765.721680 23.350586  
0 766.385986 23.366339  
0 766.896362 23.382288
```

- End the **Export** of the data.
- Open the text file in Excel to export the data for your records. The terminal data exported from the *Device Configuration* utility is a space-delimited file. The following shows the text file imported into Excel and post-processed.

Calibration point 1			0.4 FNU		
SDI-12 Address	Turbidity (FNU)	Temperature (°C)		Turbidity (FNU)	Temperature (°C)
0	0.273755	22.9373	Mean	0.31	23.21
0	0.287878	22.946196	Median	0.27	23.23
0	0.271526	22.963276	St dev	0.11	0.17
0	0.258146	22.986679			
0	0.238077	23.013351			
0	0.293824	23.041656			
0	0.676631	23.070333			
0	0.623111	23.098751			
0	0.31092	23.126926			
0	0.480394	23.154617			
0	0.328759	23.180658			
0	0.236591	23.206181			
0	0.255173	23.230719			
0	0.294567	23.254576			
0	0.287878	23.27717			
0	0.216522	23.298714			
0	0.243281	23.319822			
0	0.264836	23.34004			
0	0.235104	23.359821			
0	0.24551	23.378616			
0	0.269295	23.396957			
0	0.301257	23.414764			
0	0.298284	23.431765			
0	0.258146	23.448683			
0	0.3243	23.464485			

Calibration point 2			763 FNU 5% = 38.15		
SDI-12 Address	Turbidity (FNU)	Temperature (°C)		Turbidity (FNU)	Temperature (°C)
0	780.74	22.87	Mean	764.46	23.14
0	763.88	22.88	Median	764.37	23.15
0	766.56	22.90	St dev	4.13	0.17
0	765.84	22.92			
0	764.28	22.94			
0	764.37	22.97			
0	765.17	23.00			
0	766.29	23.03			
0	766.04	23.05			
0	764.26	23.08			
0	762.50	23.11			
0	761.24	23.13			
0	760.52	23.15			
0	759.90	23.18			
0	759.73	23.20			
0	759.68	23.22			
0	760.50	23.24			
0	762.00	23.26			
0	763.67	23.28			
0	764.77	23.30			
0	765.24	23.32			
0	765.36	23.33			
0	765.72	23.35			
0	766.39	23.37			
0	766.90	23.38			

10. References

Anderson, C.W., 2005, *Turbidity (ver. 2.1): U.S. Geological Survey Techniques of Water-Resources Investigations*, book 9, chap. A6., sec. 6.7, Sept 2005, accessed December 8, 2011, from <http://pubs.water.usgs.gov/twri9A6>.

Lewis, Jack. 1996. *Turbidity-controlled Suspended Sediment Sampling for Runoff-event Load Estimation*. *Water Resources Research*, 32(7), pp. 2299-2310.

U.S. Geological Survey Implements New Turbidity Data-Reporting Procedures. U.S. Geological Survey. <http://water.usgs.gov/owq/turbidity/TurbidityInfoSheet.pdf>.

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


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

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

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

NOTE:

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

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

Appendix B. Factors that affect turbidity and suspended-sediment measurements

This appendix summarizes some of the factors that affect turbidity measurements and shows how ignoring them can lead to erroneous data. If you are certain that the characteristics of suspended matter will not change during your survey and that your sensor was factory-calibrated with sediment from your survey site, you only need to skim this section to confirm that no problems have been overlooked.

B.1 Particle size

The size of suspended-sediment particles typically ranges from about 0.2 to 500 μm in surface water (streams, estuaries, and ocean). With size, shape, and color remaining constant, particle area normal to a light beam will determine the intensity of light scattered by a volume of suspended matter.

B.2 Suspensions with mud and sand

Light scattering from particles is inversely related to particle size on a mass concentration basis. This can lead to serious difficulties in flow regimes where particle size varies with time. For example, when sandy mud goes through a cycle of suspension and deposition during a storm, the ratio of sand to mud in suspension will change. A turbidity sensor calibrated for a fixed ratio of sand to mud will, therefore, indicate the correct concentration only part of the time. There are no simple remedies for this problem. One solution is to take many water samples and analyze them in the laboratory; however, this is not always practical during storms when the errors are likely to be largest. Do not rely solely on turbidity sensors to monitor suspended-sediment particles when particle size or composition is expected to change with time at a monitoring site.

B.3 Particle-shape effects

In addition to size and flocculation/aggregation, particle shape has a significant effect on the scattering intensity from a sample and calibration slope of a turbidity sensor. Plate-shaped particle (clay-mineral particles, for example) backscatter light about ten times more efficiently

than spherical particles, while angular shapes have intermediate scattering efficiency. Turbidity sensors are very sensitive to shape effects and this makes it very important to calibrate with material from the monitoring site. It is also essential that particle shape remains constant during the monitoring period.

B.4 High-sediment concentrations

At high sediment concentrations, particularly in suspensions of clay and silt, the infrared radiation from the emitter can be so strongly attenuated along the path connecting the emitter, the particle, and the detector, that backscatter decreases exponentially with increasing sediment concentration. For mud, this occurs at concentrations greater than about 5,000 mg/l. Do not exceed the specified turbidity or suspended-sediment ranges because the interpretation of the signal can be ambiguous.

B.5 Water color

Although organic and inorganic infrared-absorbing, dissolved matter has visible color, its effect on turbidity measurements is small unless the colored compounds are strongly absorbing at the sensor wavelength (850 nm) and are present in high concentrations. Only effluents from mine-tailings produce enough color to absorb measurable infrared. In river, estuary, and ocean environments, concentrations of colored materials are too low by at least a factor of ten to produce significant errors.

Appendix C. SDI-12 sensor support

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

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

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

C.1 SDI-12 command basics

SDI-12 commands have three components:

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

An active sensor responds to each command. Responses have several standard forms and always terminate with <CR> <LF> (carriage return and line feed). Standard SDI-12 commands are listed in [Table C-1](#) (p. 28).

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

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

Name	Command	Response ¹
Address Query	?!	a<CR><LF>
Change Address	aAb!	b<CR><LF>
Start Measurement	aM! aM1! . . . aM9!	attn<CR><LF>
Start Measurement and Request CRC	aMC! aMC1! . . . aMC9!	attn <CR><LF>
Start Concurrent Measurement	aC! aC1! . . . aC9!	attnn<CR><LF>
Start Concurrent Measurement and Request CRC	aCC! aCC1! . . . aCC9!	attnn<CR><LF>
Send Data	aD0! . . . aD9!	a<values><CR><LF> or a<values><CRC><CR><LF>
Continuous Measurement	aR0! . . . aR9!	a<values><CR><LF>
Continuous Measurement and Request CRC	aRC0! . . . aRC9!	a<values><CRC><CR><LF>
Extended Commands	aXNNN!	a<values><CR><LF>
¹ Information on each of these commands is given in the following sections.		

C.1.1 Acknowledge active command (a!)

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

C.1.2 Send identification command (aI!)

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

aI!	allccccccmmmmmmvvvxxx...xx<CR><LF>
a	Sensor SDI-12 address
ll	SDI-12 version number (indicates compatibility)

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

C.1.3 Start verification command (aV!)

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

Command: **aV!**

Response: *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

C.1.4 Address query command (?!)

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

C.1.5 Change address command (aAb!)

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

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

NOTE:

Only one sensor should be connected to a particular terminal at a time when changing addresses.

C.1.6 Start measurement commands (aM!)

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

a = sensor address

ttt = time, in seconds, until measurement data is available. When the data is ready, the sensor notifies the data logger, and the data logger begins issuing **D** commands.

n = the number of values returned when one or more subsequent **D** commands are issued. For the **aM!** command, *n* is an integer from 0 to 9.

When the **aM!** is issued, the data logger pauses its operation and waits until either it receives the data from the sensor or the time, *ttt*, expires. Depending on the scan interval of the data logger program and the response time of the sensor, this may cause skipped scans to occur. In this case make sure your scan interval is longer than the longest measurement time (*ttt*).

Table C-2: Example aM! sequence	
0M!	The data logger makes a request to sensor 0 to start a measurement.
00352<CR><LF>	Sensor 0 immediately indicates that it will return two values within the next 35 seconds.
0<CR><LF>	Within 35 seconds, sensor 0 indicates that it has completed the measurement by sending a service request to the data logger.
0D0!	The data logger immediately issues the first D command to collect data from the sensor.
0+.859+3.54<CR><LF>	The sensor immediately responds with the sensor address and the two values.

C.1.7 Start concurrent measurement commands (aC!)

A concurrent measurement (**aC!**) command follows the same pattern as the **aM!** command with the exception that it does not require the data logger to pause its operation, and other SDI-12 sensors may take measurements at the same time. The sensor will not issue a service request to notify the data logger that the measurement is complete. The data logger will issue the **aD0!** command during the next scan after the measurement time reported by the sensor has expired. To use this command, the scan interval should be 10 seconds or less. The response to each command has the form *attn*<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 C-3: Example aC! sequence	
XC!	The data logger makes a request to sensor X to start a concurrent measurement.
X03005<CR><LF>	Sensor X immediately indicates that it will have 5 (05) values ready for collection within the next 30 (030) seconds.
YC!	The data logger makes a request to sensor Y to start a concurrent measurement.
Y04006<CR><LF>	Sensor Y immediately indicates that it will have 6 (06) values ready for collection within the next 40 (040) seconds.
ZC!	The data logger makes a request to sensor Z to start a concurrent measurement.
Z02010<CR><LF>	Sensor Z immediately indicates that it will have 10 values ready for collection within the next 20 (020) seconds.
ZD0!	After 20 seconds have passed, the data logger starts the process of collecting the data by issuing the first D command to sensor Z.
Z+1+2+3+4+5+6+7+8+9+10<CR><LF>	Sensor Z immediately responds with the sensor address and the 10 values.
XD0!	10 seconds later, after a total of 30 seconds have passed, the data logger starts the process of collecting data from sensor X by issuing the first D command.
X+1+2+3+4+5<CR><LF>	The sensor immediately responds with the sensor address and the 5 values.

Table C-3: Example aC! sequence	
YD0!	Ten seconds later, after a total of 40 seconds have passed, the data logger starts the process of collecting data from sensor Y by issuing the first D command.
Y+1+2+3+4+5+6<CR><LF>	The sensor immediately responds with the sensor address and the 6 values.

C.1.8 Start measurement commands with cyclic redundancy check (aMC! and aCC!)

Error checking is done by using measurement commands with cyclic redundancy checks (**aMC!** or **aCC!**). This is most commonly implemented when long cable lengths or electronic noise may impact measurement transmission to the data logger. When these commands are used, the data returned in response to **D** or **R** commands must have a cyclic redundancy check (CRC) code appended to it. The CRC code is a 16-bit value encoded within 3 characters appended before the <CR><LF>. This code is not returned in the data table but checked by the data logger as it comes. The code returned is based on the SDI-12 protocol. See the SDI-12 communication specification for version 1.4 available at www.sdi-12.org to learn more about how the CRC code is developed.

C.1.9 Stopping a measurement command

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

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

C.1.10 Send data command (aD0! ... aD9!)

The Send Data command requests data from the sensor. It is issued automatically with every type of measurement command (**aM!**, **aMC!**, **aC!**, **aCC!**). When the measurement command is **aM!** or **aMC!**, the data logger issues the **aD0!** command once a service request has been received from the sensor or the reported time has expired. When the data logger is issuing concurrent commands (**aC!** or **aCC!**), the Send Data command is issued after the required time has elapsed (no service request will be sent by the sensor). In transparent mode (see [SDI-12 transparent mode](#) (p. 34)), the user asserts this command to obtain data.

Depending on the type of data returned and the number of values a sensor returns, the data logger may need to issue **aD0!** up to **aD9!** to retrieve all data. A sensor may return up to 35

characters of data in response to a **D** command that follows an **M!** or **MC!** command. A sensor may return up to 75 characters of data in response to a **D** command that follows a **C!** or **CC!** command. Data values are separated by plus or minus signs.

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

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

where:

a = the sensor address

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

<CR><LF> = terminates the response

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

C.1.11 Continuous measurement command (aR0! ... aR9!)

Sensors that are able to continuously monitor the phenomena to be measured can be read directly with the **R** commands (**R0!** ... **R9!**). The response to the **R** commands mirrors the Send Data command (**aD0!**). A maximum of 75 characters can be returned in the <values> part of the response to the **R** command.

C.1.12 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.

C.2 SDI-12 transparent mode

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

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

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

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

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

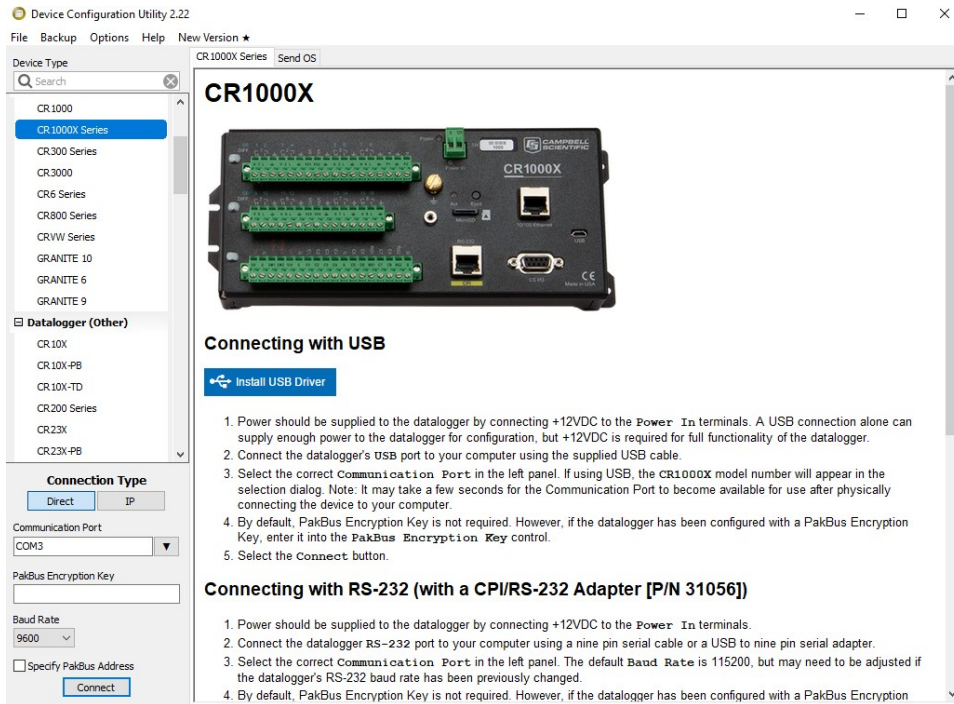
The following examples show how to enter transparent mode and change the SDI-12 address of an SDI-12 sensor. The steps shown in [Changing an SDI-12 address](#) (p. 35) are used with most Campbell Scientific data loggers.

C.2.1 Changing an SDI-12 address

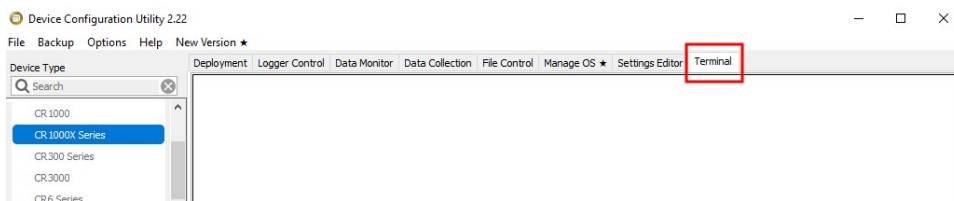
This example was done with a CR1000X, but the steps are only slightly different for CR6, CR3000, CR800-series, CR300-series, CR1000 data loggers.

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

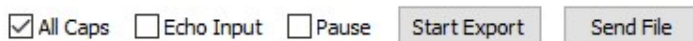
4. Select the correct **Communication Port** and click **Connect**.



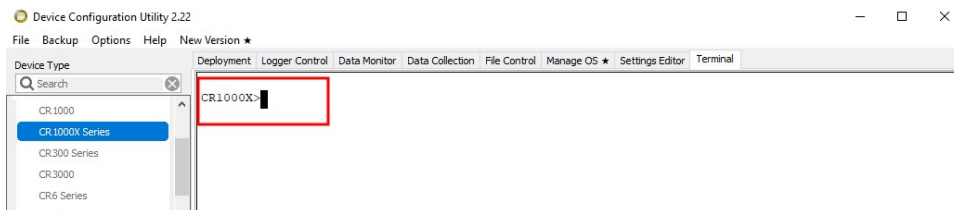
5. Click the **Terminal** tab.



6. Select **All Caps Mode**.



7. Press Enter until the data logger responds with the data logger (**CR1000X>**) prompt.



8. Type **SDI12** and press Enter.

9. At the **Select SDI12 Port** prompt, type the number corresponding to the control port where the sensor is connected and press Enter. In this example the sensor is connected to C3. The

response **Entering SDI12 Terminal** indicates that the sensor is ready to accept SDI-12 commands.

```
CR1000X>
CR1000X>SDI12
1: C1
2: C3
3: C5
4: C7
Select SDI12 Port: 2
```

10. To query the sensor for its current SDI-12 address, type **?!** and press Enter. The sensor responds with its SDI-12 address. If no characters are typed within 60 seconds, the mode is exited. In that case, simply type **SDI12** again, press Enter, and type the correct control port number when prompted.

```
?!
0
```

11. To change the SDI-12 address, type **aAb!**, where **a** is the current address from the previous step and **b** is the new address. Press **Enter**. The sensor changes its address and responds with the new address. In the following example, the sensor address is changed from 0 to B.

```
SDI12
SDI12>0AB!B
```

12. To exit SDI-12 transparent mode, click **Close Terminal**.

NOTE:

The transparent mode for the CR6, CR3000, CR800-series, CR300-series, and CR1000 data loggers is similar to that shown for the CR1000X.

C.3 References

SDI-12 Support Group. SDI-12: A Serial-Digital Interface Standard for Microprocessor-Based Sensors – Version 1.4. River Heights, UT: SDI-12 Support Group, 2017. <https://sdi-12.org/specification> .

Limited warranty

Products manufactured by Campbell Scientific are warranted by Campbell Scientific to be free from defects in materials and workmanship under normal use and service for twelve months from the date of shipment unless otherwise specified on the corresponding product webpage. See Product Details on the Ordering Information pages at www.campbellsci.com[↗]. Other manufacturer's products, that are resold by Campbell Scientific, are warranted only to the limits extended by the original manufacturer.


Refer to www.campbellsci.com/terms#warranty[↗] for more information.

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Safety

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

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

General

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

Utility and Electrical

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

Elevated Work and Weather

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

Maintenance

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

Internal Battery

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

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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