CS475, CS476 & CS477
Radar
Water Level Sensor

User Manual

Issued 8.4.13

CSL 855

Guarantee

This equipment is guaranteed against defects in materials and workmanship. This guarantee applies for twelve months from date of delivery. We will repair or replace products which prove to be defective during the guarantee period provided they are returned to us prepaid. The guarantee will not apply to:

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- Batteries
- Any product which has been subjected to misuse, neglect, acts of God or damage in transit.

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PLEASE READ FIRST

About this manual

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

Some useful conversion factors:

Area:	1 in^2 (square inch) = 645 mm^2	**Mass:**	1 oz. (ounce) = 28.35 g 1 lb (pound weight) = 0.454 kg
Length:	1 in. (inch) = 25.4 mm 1 ft (foot) = 304.8 mm 1 yard = 0.914 m 1 mile = 1.609 km	**Pressure:**	1 psi (lb/in^2) = 68.95 mb
		Volume:	1 UK pint = 568.3 ml 1 UK gallon = 4.546 litres 1 US gallon = 3.785 litres

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

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

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

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

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

Recycling information

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

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

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

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CS475, CS476, and CS477 Radar Water Level Sensor

1. Introduction

The CS475, CS476, and CS477 are radar-ranging sensors that monitor the water level of rivers, lakes, tidal seas, and reservoirs. They output a digital SDI-12 signal to indicate distance and stage. Many of our dataloggers can read the SDI-12 signal.

Before using these radar sensors, please study

- Section 2, *Cautionary Statements*
- Section 3, *Initial Inspection*
- Section 4, *Quickstart*

2. Cautionary Statements

- Follow country-specific installation standards, prevailing safety regulations, accident prevention rules, and this manual's safety instructions.
- Depending on the model, the emitting frequencies of these radar sensors are either in the C or K band range. Their low transmitting power is well below the internationally permitted limits. When used correctly, the radar sensors present no danger to people.
- Do not attempt to install the sensor unless you are qualified to perform the installation.
- Care should be taken when opening the shipping package to not damage or cut the cable jacket. If damage to the cable is suspected, consult with a Campbell Scientific applications engineer.
- Handle the sensor carefully, since it is a precision instrument.
- Since the sensor is commonly installed over water from tall structures, use appropriate safety equipment such as a safety harness or a life preserver when installing or performing maintenance on the sensor.
- It is the responsibility of the user to ensure that the sensors are maintained and functioning properly.
- The sensor is designed for safe operations in accordance with the current technical, safety, and ANSI standards.

3. Initial Inspection

When unpacking the equipment, do the following:

- Unpack the unit in a clean, dry area.
- Inspect the equipment for any damage that occurred during shipping or storage.
- If the equipment is damaged, file a claim against the carrier and report the damage in detail.

4. Quickstart

This Quickstart uses the default settings (see Table 4-1), which are used in most circumstances.

Table 4-1. Default Settings

Setting	**Default**
SDI-12 Address	0 (change only if two sensors are connected to the same port; valid addresses are 0 through 9, A through Z, and a through z; see Appendix B.1.3, *Query/Set the Address)*
Units of Measure	1 = feet (see Appendix B.1.4, *Set Units*)
Water Conditions	1 = smooth (typical peak to trough of wave ≤ 4 inches; see Appendix B.1.5, *Set Water Conditions*)
Power Operation Mode	1 = on (sensor is always on until new power operation mode command received; see Appendix B.1.6, *Set Power Operation Mode*)

NOTE Detailed information about all of the settings and information on changing the settings are provided in Appendix B.

4.1 Step 1 — Mount and Align the Sensor

1. Choose an appropriate site away from obstructions and over the smoothest part of the water (see Section 7.1, *Site Selection*).

2. Centre the sensor beam a minimum of 2.5 m from any obstruction in the measurement range. Obstructions to be aware of include excessive waves, splashing, pipes, wires, and logs. Note that the radiation beam spreads as it leaves the sensor (see Table 4-2 and Table 4-3).

NOTE Usually the beam path is 10° for the CS475, and 8° for the CS476/CS477.

Table 4-2. Radiation Beam Spread for CS475 (10° Beam Angle)	
Distance in Metres	**Diameter of Footprint in Metres**
1	0.18
5	0.87
10	1.76
15	2.64
20	3.53

Table 4-3. Radiation Beam Spread for CS476/CS477 (8° Beam Angle)	
Distance in Metres	**Diameter of Footprint in Metres**
1	0.14
5	0.70
10	1.41
15	2.11
20	2.81
30	4.216
70 (CS477 only)	9.84

3. Securely mount the sensor.

4. Use a user-supplied bubble level or the #25619 bubble level to make certain the antenna horn is aligned within 1° of vertical. The cap needs to be removed when using the #25619. If the antenna is not vertical, a trigonometric measurement error can occur with respect to the water. The maximum range is reduced because of the off-axis return signal.

5. Orient the sensor such that one of its polarization markings is aligned towards the wall or pier (see Figure 4-1 and Table 4-4).

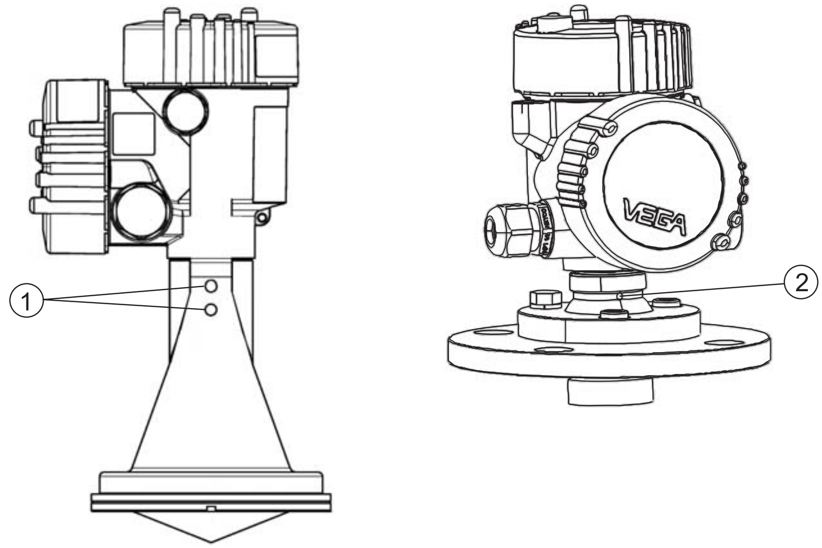


Figure 4-1. Polarization markings (see Table 4-4 for label descriptions)

Table 4-4. Description of Polarization Markings Labels

	Sensor	Description
1	CS475	Polarization marks are designated by the mounting loop screws.
2	CS476/CS477	Polarization mark is machine-tooled.

4.2 Step 2 — Do a False Echo Learn Command

Use the 25616, *Adjustment/Display Module*, or the terminal emulator in LoggerNet or PC400 to do a *Start False Echo Learn* command followed by a *Send Data* command (see Table 4-4). To start false echo learn, do the **aXSFEL+nnn.nnn!** command (where nnn.nnn = the actual distance to the water) followed by the **aD0!** (*Send Data*) command. Table 4-5 shows an example of the command and response.

Any echo occurring 0.5 m (1.6 ft) short of the distance you entered will be considered noise.

Appendix B describes this command in further detail.

Table 4-5. Example of a Start False Echo Learn Command

Initial Command	**Response**
0XSFEL+2.500! Where (from left to right), 0—sensor's address; 2.500—the water surface distance.	**02001<cr><If>** Where (from left to right), 0—sensor's address; 200—the amount of time (in seconds) that you must wait before sending the send data command; 1—the number of values that will be placed in the buffer.
Subsequent Command	**Response**
0D0! Where the first zero is the sensor address. This is the send data command.	**0+2.500<cr><lf>** Where (from left to right), 0—sensor's address; 2.500—the water surface distance.

4.3 Step 3 — Do a Set Water Stage Command

Use the 25616, *Adjustment/Display Module*, or the terminal emulator in LoggerNet or PC400 to do a *Set Water Stage* command followed by a *Send Data* command (see Table 4-6). To set the water stage, do an **aXSS+nnn.nnn!** command (where nnn.nnn = the initial water depth) followed by the **aD0!** (*Send Data*) command. Table 4-6 shows an example of the command and response for entering this setting.

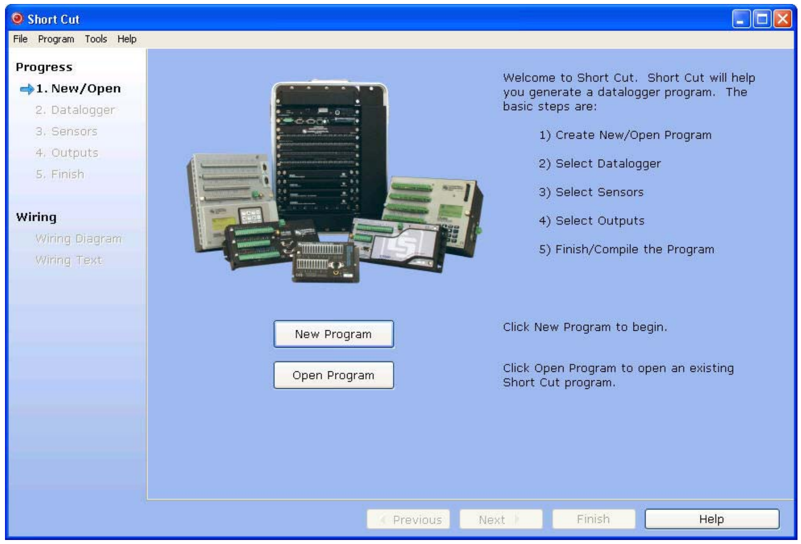
Appendix B describes this command in further detail.

Table 4-6. Example for Setting Water Stage

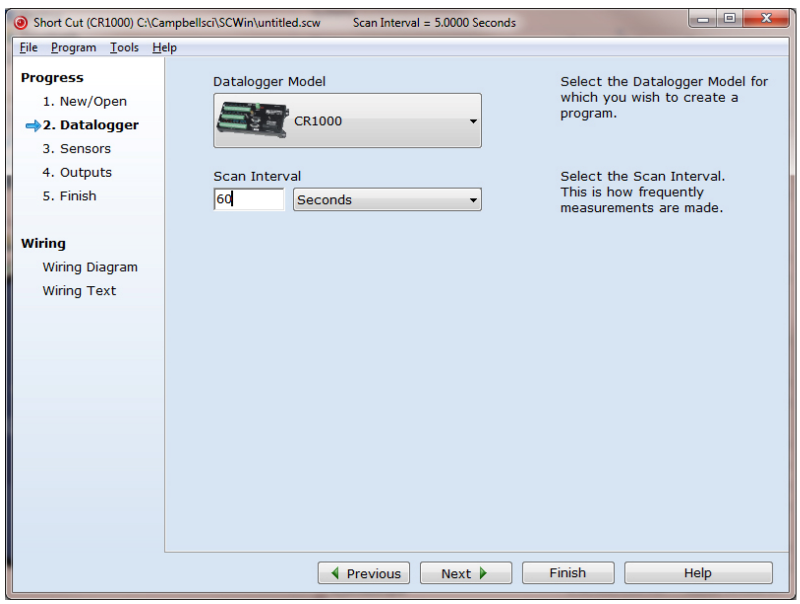
Initial Command	**Response**
0XSS+7.010! Where (from left to right), 0—sensor's address; 7.010—the initial water depth value used to calculate subsequent stage measurements.	**00011<cr><If>** Where (from left to right), 0—sensor's address; 001—the amount of time (in seconds) that you must wait before sending the send data command; 1—the number of values that will be placed in the buffer.
Subsequent Command	**Command Response**
0D0! Where the first zero is the sensor address. This is the send data command.	**0+7.010<cr><If>** Where (from left to right), 0—sensor's address; 7.010—the initial water depth value used to calculate subsequent stage measurements.

4.4 Step 4 — Use SCWin Short Cut to Program Datalogger and Generate Wiring Diagram

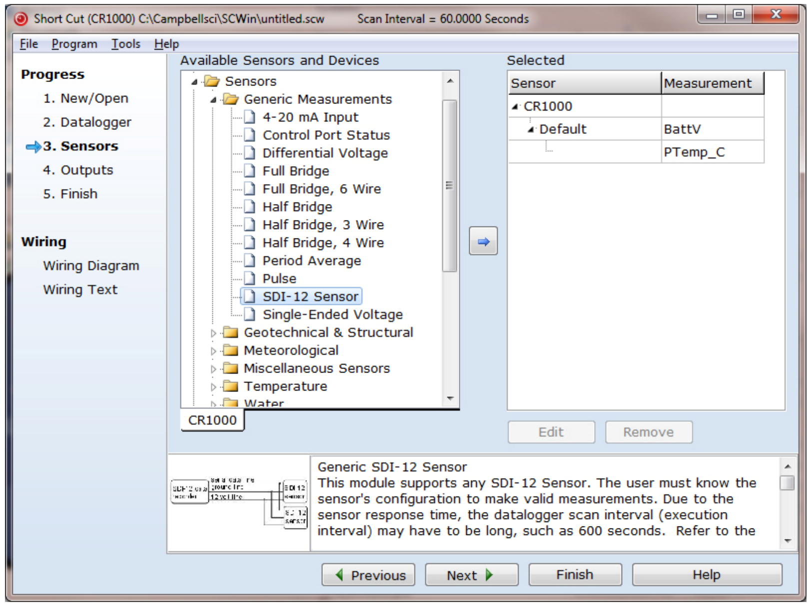
1. Open Short Cut and click on **New Program**.



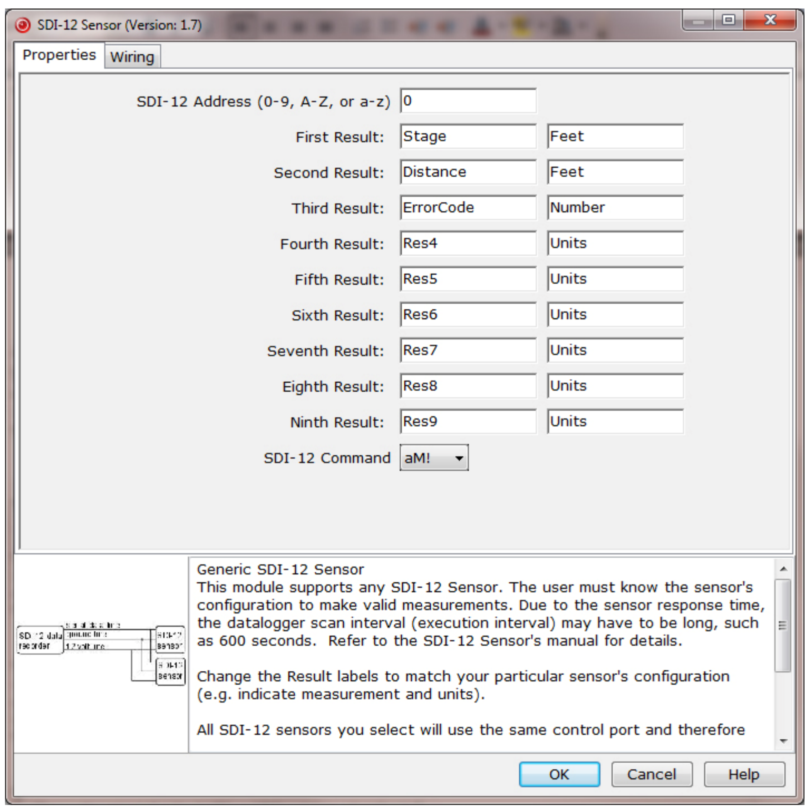
2. Select a datalogger and scan interval.



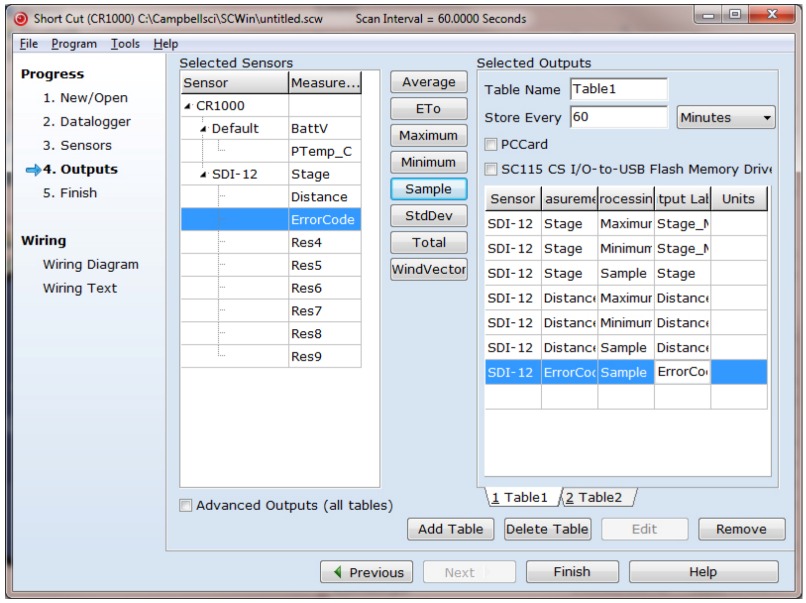
3. Under **Generic Measurements**, select **SDI-12 Sensor** then click the **right arrow** to add it to the list of sensors to be measured.



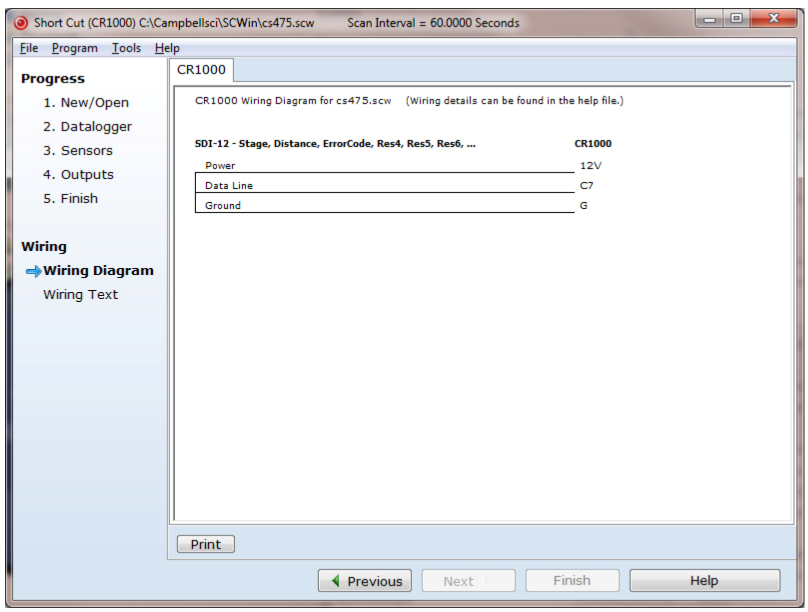
4. A properties window will appear. In this window, enter *Stage* and *Feet* for the **First Result**; *Distance* and *Feet* for the **Second Result**, and *ErrorCode* for the **Third Result**.



5. Choose the outputs and then select **Finish**.



6. Wire according to the wiring diagram generated by Short Cut.



5. Overview

The CS475, CS476, and CS477 emit short microwave pulses and measure the elapsed time between the emission and return of the pulses. The elapsed time measurement is used to calculate the distance between the sensor face and the target (for example, water, grain, slurry). The distance value can be used to determine depth.

These radar sensors output a digital SDI-12 signal to indicate distance and stage. This output is acceptable for recording devices with SDI-12 capability including Campbell Scientific dataloggers.

Three sensor models are available that differ in their measurement range and accuracy. The CS475 can measure distances up to 65 feet with an accuracy of ±0.2 inches; the CS476 can measure up to 98 feet with an accuracy of ±0.1 inches; and the CS477 can measure up to 230 feet with an accuracy of ±0.6 inches.

Figure 5-1. CS475, CS476, and CS477

5.1 Components and Hardware

The radar sensor consists of an integrated microwave transmitter and sensor together with a horn antenna (see Figure 5-2 and Table 5-1). The horn antenna serves to focus the transmitted signal and to receive the reflected echo. A built-in SDI-12 interface provides data processing and SDI-12 communications with the datalogger.

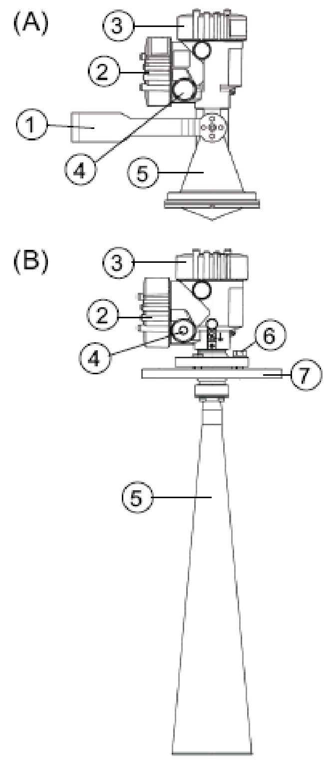


Figure 5-2. Components and hardware (see Table 5-1 for description of labels)

Table 5-1. Description of Components and Hardware Labels

(A)	CS475
(B)	CS476 or CS477
1	Mounting Loop
2	PULS Housing Side Cap
3	PULS Housing Cap
4	PULS Unit Secondary 1/2" NPT Cable Port, Primary Port on Opposite Side
5	PULS Instrument Horn
6	5/8" Hex Head Cap Screw and Lock Washer
7	Swivel Mounting Flange

6. Specifications

Features:

- FCC compliant
- Ideal for areas where submersed sensors can be damaged due to corrosion, contamination, flood-related debris, lightning, or vandalism
- Compatible with most Campbell Scientific dataloggers (including the CR200(X) series)

- Low maintenance—no moving parts significantly reduces maintenance cost and time
- Low power consumption
- Rugged enough for harsh environments—NEMA rated 4X
- Individual FCC license not required

Compatibility

Dataloggers:	CR200(X) series CR800 series CR1000 CR3000 CR5000 CR500 CR510 CR10(X) CR23X

Measurement Range (see Figure 6-1)

CS475:	50 mm to 20 m (2 in to 65 ft)
CS476:	50 mm to 30 m (2 in to 98 ft)
CS477:	400 mm to 70 m (16 in to 230 ft)

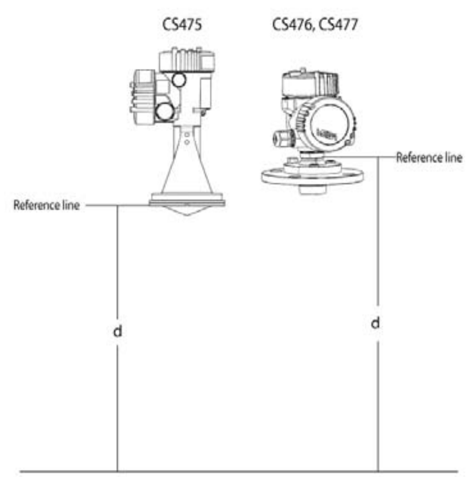


Figure 6-1. Reference line for measurement range

Accuracy

CS475:	±5 mm (±0.2 in)
CS476:	±3 mm (±0.1 in)
CS477:	±15 mm (±0.6 in)

Resolution:	1 mm (0.0033 ft)
Output Protocol:	SDI-12

6.1 Radar Unit

Frequency:	~26 GHz
Electromagnetic Compatibility:	Emission to EN 61326; Electrical Equipment Class B
Pulse Energy:	1 mW maximum
Beam Angle	
CS475:	10° (3-in dia horn)
CS476, CS477:	8° (4-in dia horn)
Power Requirements	
Input Voltage:	9.6 to 16 Vdc
Surge Protection:	1.5 KVA
Typical Current Drain with 12 V Power Supply	
Sleeps:	4.7 mA
Measurement:	14 mA

6.2 Environmental

Operating Temperature Range:	–40° to +80°C
Storage Ranges	
Temperature:	–40° to +80°C
Relative Humidity:	20% to 80% RH
Temperature Sensitivity:	average TK: 2 mm/10 K, max 5 mm over the entire temperature range of –40°to +80°C
Vibration Resistance:	Mechanical vibrations with 4 g and 5 to 100 Hz

6.3 Physical

See Figure 6-2 and Figure 6-3 for dimensions.

Rating:	NEMA 4x
Housing Material:	Aluminium, coated IP66/68
Horn Material:	316L stainless steel
Weight	
CS475:	2 kg (4 lb)
CS476/CS477:	4.3 kg (9.4 lb)

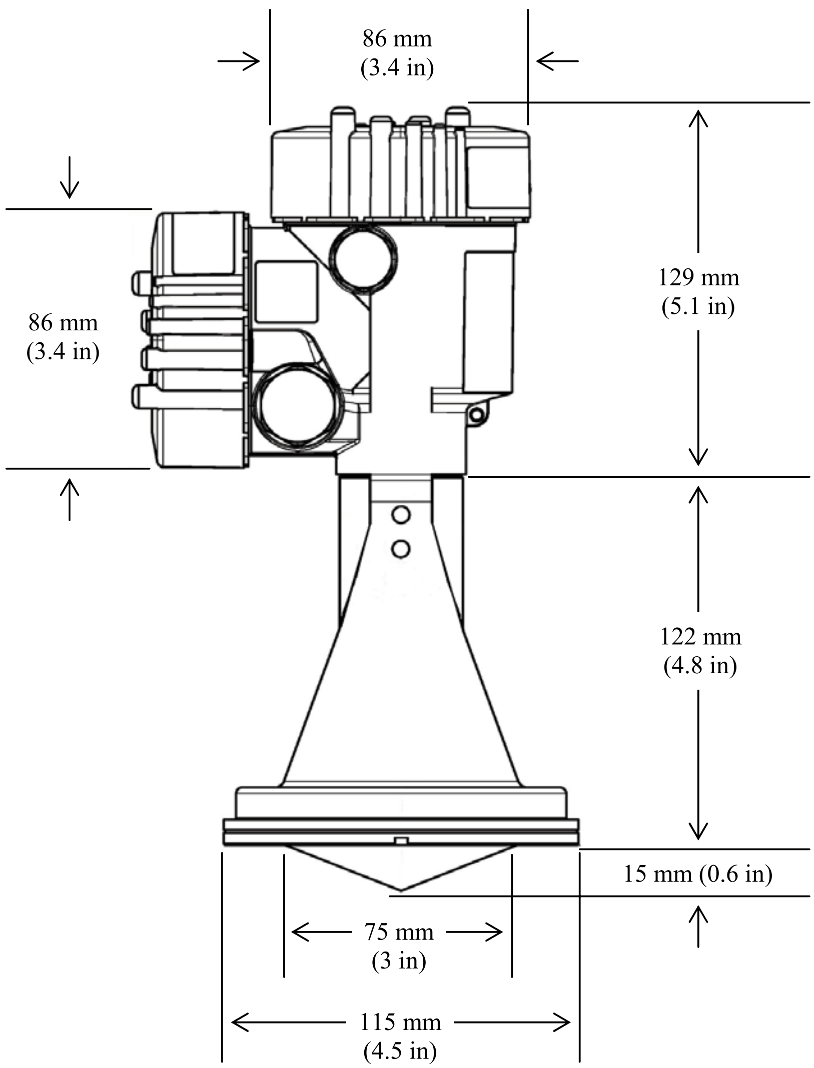


Figure 6-2. CS475 dimensions

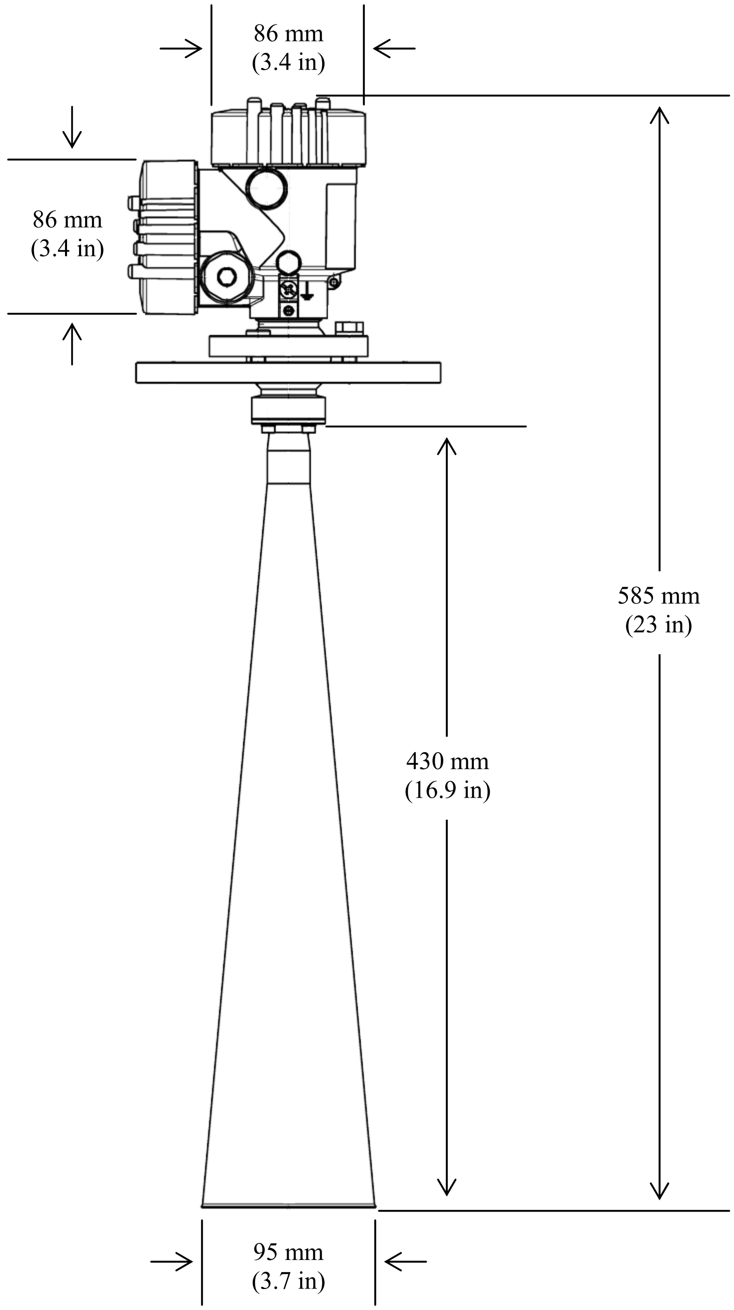


Figure 6-3. CS476/CS477 dimensions

7. Installation

Before installing the radar sensor, you must consider all the suggested guidelines for site and maintenance issues. Do not attempt to install the sensor unless you are qualified to perform the installation. The sensor is designed for safe operation in accordance with the current technical, safety, and ANSI standards.

CAUTION If you are uncertain of the safe installation and operation of this unit, read and understand all the instructions included in this manual before attempting any installation or operation.

7.1 Site Selection

1. Mount the sensor high enough to prevent submersion during flooding conditions.

WARNING **Since the sensor is commonly installed over water from tall structures, use appropriate safety equipment such as a safety harness or a life preserver when installing or performing maintenance on the sensor.**

2. Install the sensor above the smoothest part of the water surface.

NOTE The smoothest part of the water surface is typically found halfway between bridge piers. However, bridges with long spans between the piers experience more vibration. For these bridges, vibration can be minimized by mounting the sensor a quarter to a third of the distance to the next pier.

3. Avoid mounting near horizontal structural surfaces such as beams, brackets, and sidewall joints because these surfaces reflect a strong signal. If these structures cannot be avoided, use the *False Echo Learn* command to map out the interfering structures in the beam profile (see Appendix B.1.1, *Start False Echo Learn*).

4. Center the sensor beam a minimum of 2.5 m from any obstruction in the measurement range. Obstructions to be aware of include excessive waves, splashing, pipes, wires, and logs. Note that the radiation beam spreads as it leaves the sensor (see Table 4-2 and Table 4-3 in Section 4, *Quickstart*).

NOTE Usually the beam path is 10° for the CS475, and 8° for the CS476/CS477.

5. Be aware that bridges contract and expand with temperature changes. Traffic loads or trucks can also cause changes to the bridge height.

6. Do not install the sensor where submerged obstructions such as rocks or bridge piers can distort or disturb water level.

7.2 Sensor Alignment

7.2.1 Vertical

Use a user-supplied bubble level or the #25619 bubble level to make certain the antenna horn is aligned within 1° of vertical. The cap needs to be removed when using the #25619. If the antenna is not vertical, a trigonometric measurement error can occur with respect to the water. The maximum range is reduced because of the off-axis return signal.

7.2.2 Azimuth

The sensor's radar beam is polarized so it emits radar waves in an elliptical or football shape. You should orient the unit so the lobes are parallel to, and do not intersect, the pier when installing on a wall or close to a bridge pier. The radar housing has a large hex nut on its mount stem. Two drill marks below the hex nut indicate which direction the lobes extend the least. Orient the sensor such that one of the marks is aligned towards the wall or pier (see Figure 4-1 and Table 4-4 in Section 4, *Quickstart*).

7.3 Instrument Housing Adjustment

After mounting, you can rotate the housing up to 350° to simplify access to the conduit entry and terminal compartment. Proceed as follows to rotate the housing to the desired position:

1. Loosen the set screw on the housing.
2. Rotate the housing as desired.
3. Tighten the set screw.

7.4 Wiring

7.4.1 Datalogger Connection

As shipped from Campbell Scientific, the sensor is fitted with a cable for connection with the datalogger. Appendix A describes replacing this cable.

Connections to Campbell Scientific dataloggers are given in Table 7-1. The sensor should be wired to the channels shown on the wiring diagram created by Short Cut.

CAUTION Connect the wires in the order shown in Table 7-1.

Table 7-1. Wiring Diagram						
Colour	**Description**	**CR800, CR850, CR1000, CR3000,**	**CR10(X), CR510, CR500**	**CR23X**	**CR5000**	**CR200(X)**
White	SDI-12 Signal	Odd Numbered Control Port (C1, C3…)	Odd Numbered Control Port (C1, C3…)	Odd Numbered Control Port (C1, C3…)	SDI-12	C1/SDI-12
Clear	Chassis Ground	⏚	G	⏚	⏚	⏚
Red	+12V (Power Supply for Sensor)	12V	12V	12V	12V	Battery+
Black	Ground	G	G	⏚	G	G

7.4.2 Multiple Sensors Connection

To use more than one probe per datalogger, you can either connect the different probes to different SDI-12 compatible ports on the datalogger or change the SDI-12 addresses of the probes and let them share the same connection. Using the SDI-12 address minimizes the use of ports on the datalogger and also allows probes to be connected in a daisy-chain fashion which can minimize cable runs in some applications.

7.4.3 Built-in Self Test (BIST)

After connecting the sensor to the datalogger's power terminals, the sensor performs a BIST (built-in self test) for approximately 80 seconds (factory default). During this self-check, an internal check of the electronics occurs.

7.5 Programming

NOTE This section is for users who write their own datalogger programs. A datalogger program to measure this sensor can be created using Campbell Scientific's Short Cut Program Builder software. These sensors are not listed in the sensor list in Short Cut. Instead, select SDI-12 sensor under General Measurements (see Section 4.4, *Step 4 — Use SCWin Short Cut to Program Datalogger and Generate Wiring Diagram*, for more information about using Short Cut). You do not need to read this section to use Short Cut.

The radar sensor's output is measured using a standard SDI-12 instruction to read the data from an SDI-12 sensor. If using the sensor with other SDI-12 recorders, please refer to your system's documentation. Further details of the SDI-12 commands can be found in Appendix B and at: *www.sdi-12.org*.

7.5.1 CRBasic

Dataloggers that are programmed with CRBasic include the CR200(X) series, CR800, CR850, CR1000, CR3000, and CR5000. These dataloggers use the **SDI12Recorder()** instruction to read the sensor. The **SDI12Recorder()** instruction should only be ran in the sequential mode.

The values returned from the **SDI12Recorder()** instruction are different depending on the SDI-12 measurement command issued. The **SDI12Recorder()** instruction sends the command specified by the *SDI12Command* parameter as *(address)SDI12Command!*.

SDI12Recorder(*Dest, SDIPort, SDIAddress, "SDICommand", Multiplier, Offset***)**

The **SDI12Recorder()** instruction has the following parameters:

Dest The *Dest* parameter is a variable in which to store the results of the measurement. *Dest* must have enough elements to store all the data that is returned by the sensor or a 'variable out of range' error will result during the execution of the instruction.

SDIPort The *SDIPort* parameter is the port to which the SDI-12 sensor is connected. A numeric value is entered:

Code	Description
1	Control Port 1
3	Control Port 3
5	Control Port 5
7	Control Port 7

SDIAddress The *SDIAddress* parameter is the address of the sensor that will be affected by this instruction. Valid addresses are 0 through 9, A through Z, and a through z. Alphabetical characters should be enclosed in quotes (for example, "0").

SDICommand The *SDICommand* parameter is used to specify the command strings that will be sent to the sensor. The command should be enclosed in quotes. Table 7-2 shows the specific SDI-12 Command Codes and their returned values.

Table 7-2. SDI-12 Command Codes

SDI12 Measurement Command	Returned Values
M!	1) Stage in metres or feet 2) Distance in metres or feet 3) Error Code (see Section 8, *Diagnostics, Repair, and Maintenance*)

7.5.1.1 Example Program

```
'CR1000 Series Datalogger

'Declare the variable for the water level measurement

Public CS475(3)

'Rename the variable names
Alias CS475(1)=Stage
Alias CS475(2)=Distance
Alias CS475(3)=Error_Code

'Define a data table for 60 minute maximum and minimums
DataTable (Hourly,True,-1)
  DataInterval(0,60,Min,10)
  Maximum(1,Distance,FP2,0,0)
```

```
  Minimum(1,Distance,FP2,0,0)
  Average(1,Distance,FP2,False)
  StdDev(1,Distance,FP2,False)
  Maximum(1,Stage,FP2,0,0)
  Minimum(1,Stage,FP2,0,0)
  Average(1,Stage,FP2,False)
  StdDev(1,Stage,FPs,False)
  Sample (1,Error_Code,UINT2)
EndTable

'Read sensor every 60 seconds
BeginProg
  Scan(60,sec,1,0)

  'Code for SDI-12 measurements:
  SDI12Recorder(CS475,1,0,"M!",1,0)

  'Call the data table:
  CallTable(Hourly)

NextScan

EndProg
```

7.5.2 Edlog

Dataloggers that are programmed with Edlog include the CR500, CR510, CR10(X), and CR23X. These dataloggers use Instruction 105 to read the sensor.

Instruction 105 allows data to be collected from the radar sensor; each sensor requires a separate Instruction 105.

Instruction 105 has the following parameters:

Parameter 1 — Address. Valid addresses are 0 through 9; 65 through 90 (decimal value for ASCII upper-case letters); and 97 through 122 (decimal values for ASCII lower-case letters).

Parameter 2 — Command. Refer to the Edlog help for the command codes used with this instruction.

Parameter 3 — Port. Enter the datalogger port in which the datalogger is connected.

Parameter 4 — Location. Enter the input location in which to store the results.

Parameter 5 — Multiplier

Parameter 6 — Offset

NOTE Edlog allocates only one of the input locations needed for this instruction. Three input locations are required for this sensor. The additional input locations must be inserted manually using the Input Location Editor. For information on manually inserting input locations, refer to Manually Inserting Input Locations in the Edlog help.

7.5.2.1 Example Program

Below is a portion of a CR10X program that measures the radar sensor.

NOTE The instructions below do not store data in final storage. Instruction 92, Instruction 77 and processing instructions such as Instruction 70 are required to store the data permanently.

```
;{CR10X}
;
*Table 1 Program
01:    60            Execution Interval (seconds)

1: SDI-12 Recorder (P105)
  1:   0             SDI-12 Address
  2:   0             Start Measurement (aM0!)
  3:   1             Port ;this is where the white wire is connected
  4:   1             Loc[Data_1 ]
  5:   1.0           Mult
  6:   0.0           Offset

*Table 2 Program
  02:  0.000         Execution Interval (seconds)

*Table 3 Subroutines

End Program
```

After Instruction 105 is executed, the input location called "Data_1" will hold the measured stage, reported in feet or metres (depending on the Unit of Measure setting). The input location called Data_2 will hold the distance measurement, reported in feet or metres (depending on the Unit of Measure setting). The input location called Data_3 will hold the error code; an error code of 0 indicates that the sensor is functioning properly (see Section 8, *Diagnostics, Repair, and Maintenance*).

Note that Port 1 specifies that the SDI-12 data line is to be connected to the Port C1.

8. Diagnostics, Repair, and Maintenance

8.1 Testing Procedure

The test procedures for the sensor require the following steps:

1. Double check all wiring connections.

2. Connect the sensor to your datalogger and apply +12V power.

3. Compare the Output Stage versus the Actual Stage using the *Start Measurement* command followed by the *Send Data* command (see Section 8.1.1, *Start Measurement Command*).

4. Send the *Acknowledge Active* command (see Section 8.1.2, *Check Unit Response*). This command is used to check the presence of the sensor on the bus. Only the address is sent back in response.

5. Send the *Identification* command (see Section 8.1.3, *Check for Valid Data*).

6. Send the *Start Verification* command followed by the *Get Data* command (see Section 8.1.4, *Cyclic Redundancy Check*).

7. Use the *Get Unit* command to ensure the units are what you want (see Section 8.1.5, *Get Units*).

8. Use the *Get Water Condition* command to ensure that the water condition fit the body of water you are monitoring (see Section 8.1.6, *Get Water Conditions*).

9. Use the *Get Power Operation Mode* to ensure that the power mode is what you want (see Section 8.1.7, *Get Power Operation Mode*).

10. Use the *False Echo Learn* command if you encounter a problem that could be caused by noise (see Section 4.2, *Step 2 — Do a False Echo Learn Command*).

8.1.1 Start Measurement Command

NOTE The 25616, *Adjustment/Display Module*, or the terminal emulator in LoggerNet or PC400 can be used to enter this command. The *Start Measurement* command is also used in CRBasic or Edlog programming. Refer to the Edlog help for the appropriate command code entry.

The **aM!** command requests measurement values from the sensor. This command is always followed by the **aD0!** (*Send Data*) command (see Table 8-1). As a response of the *Send Data* command, the following information will be returned.

- Stage—the water level as measured in metres or feet. This measurement is calculated using the Water Stage Setting and the Units setting.
- Distance—the distance between the sensor and water surface. This value will be reported in either metres or feet, depending on the Units setting.
- Diagnostic Values—an error code. For example, Code 0 = OK, Code 13 = error E013 (see Section 8.2, *Diagnostics and Repair*).

Table 8-1. Example of Start Measurement Command

Initial Command	**Response**
0M! Where zero is the sensor address.	**00023<cr><lf>** Where (from left to right), 0—sensor's address; 002—the amount of time (in seconds) that you must wait before sending the send data command; 3—the number of values that will be placed in the buffer.
Subsequent Command	**Response**
0D0! Where the first zero is the sensor address.	**0+100.050+25.000+0<cr><lf>** Where (from left to right), 0—sensor's address; 100.050—the stage in metres or feet; 25.000—the distance in metres or feet; 0—error code.

8.1.2 Check Unit Response

The *Acknowledge Active* command is used to check the presence of the sensor on the bus (see Table 8-2).

Table 8-2. Acknowledge Active Command

Initial Command	**Response**
a!	**a<cr><If!>** Only the address is sent back in response.

8.1.3 Check for Valid Data

The **aI!** command gets the following identification information in response to sending **aI!** (see Table 8-3).

- Compatibility level: Version of SDI-12 protocol version; for example, 1.3.
- Manufacturer's Name: VEGA
- Manufacturer's Model Number: PS61 (CS475), PS62 (CS476), or PS63 (CS477)
- Three Digit Firmware Version Number.
- Eight Digit Serial Number of Sensor.

Table 8-3. Send Identification Command

Initial Command	**Response**
aI!	**a13VEGAbbbbPS6233212345678<cr><If>** Where (from left to right), a—sensor address; 13—SDI-12 compatibility number; VEGA = Manufacturer's Name; PS62 = Manufacturer's Model Number; 3.32 = Sensor Version Number; Serial Number = 12345678.

8.1.4 Cyclic Redundancy Check

A cyclic redundancy check (CRC) is used to produce and send a small, fixed-size checksum of a larger block of data to the datalogger. This checksum detects errors after transmission or storage. The CRC is computed and added before any transmission or storage. The CRC is also authenticated by the recipient, after the transmission, to confirm that no alterations occurred. CRCs are very good at identifying errors caused by noise in transmission channels.

8.1.4.1 Check CRC for Valid Data

The **aV!** command requests three verification values from the sensor. This command is always followed by the **aD0!** (*Send Data*) command.

The verification values that will be returned are:

- CRC check (error check)—values are 0 (OK) or 1 (failed)
- SDI-12 Radar firmware version number
- HART Sensor firmware version

Table 8-4 shows an example of checking the CRC.

Table 8-4. Checking CRC Example

Initial Command	**Response**
0V! Where 0 is the sensor's address.	**00013<cr><If>** Where (from left to right), 0—sensor's address; 001—the amount of time (in seconds) that you must wait before sending the send data command; 3—the number of values that will be placed in the buffer.
Subsequent Command	**Response**
0D0! Where the first zero is the sensor's address.	**0+0+1610000+3320000<cr><If>** Where (from left to right), 0—sensor's address; 0—CRC check (0 = OK); 1610000—adapter version (1.61.00.00); 3320000—sensor version (3.32.00.00).

8.1.5 Get Units

Use the **aXGU!** command to get the current units setting of the sensor. If the units are feet, a 1 will be returned, and if the units are metres, a 0 will be returned.

8.1.6 Get Water Conditions

The **aXGWC!** command returns the current setting of the water conditions. Possible water conditions are:

1 = smooth (default)

2 = medium

3 = rough

0 = undefined (custom settings)

8.1.7 Get Power Operation Mode

The **0XGPOM!** command provides the current power operation mode setting of the sensor.

8.2 Diagnostics and Repair

The radar sensor is extremely reliable, but problems can occur during operation. Most of these problems are caused by the following:

- Sensor
- Environmental conditions
- Power supply
- Signal processing

When you encounter a problem with the radar sensor, check the error messages from the aM!, followed by the aD0! command to help evaluate the issue.

NOTES

1. During the initial power up or resumption of supply voltage to the sensor, some SDI-12 commands, such as the **I** command, will not yield the expected responses.

2. A typical response to the **aD0!** command results in a response of **108003** where approximately 80 seconds is the required time to complete the BIST (Built In Self Test) of the instrument. After power up is complete, normal SDI-12 communication starts.

8.2.1 No Measured Value Available — Error E013

If you are unable to find a measured value, check the following:

- Sensor in boot phase
- Update the *Start False Echo Learn* (**aXSFEL**).

8.2.2 No Measured Value Available — Error E041, E042, E043

If you have a hardware error or have defective electronics, try cycling the power to the sensor. If the sensor recovers, no further steps are required. If the sensor does not recover, do one of the following:

- Exchange the electronics module (see Section 8.2.2.1, *Exchange Electronics Module*)
- Return the equipment for repair (an RMA number is required)

8.2.2.1 Exchange Electronics Module

If you do not have an electronics module onsite, order one from Campbell Scientific.

The electronics module is replaced by doing the following steps (see Figure 8-1 and Table 8-5):

1. Unscrew the housing cap (cap is not shown in Figure 8-1).

2. Remove all wires that are attached or plugged into the electronics and note their location for reassembly.

3. Loosen the two screws securing the electronics to the housing (3 in Figure 8-1). These screws are captive screws and will remain nested with the electronics.

4. Gently remove the electronics from the housing (4 in Figure 8-1).

NOTE Some friction is normal when removing the electronics because a seal is between the electronics and the lower portion of the housing.

5. Replace the electronics with a new module.

NOTE Make sure the two (2) screws holding the electronics module in are tight, but do not over tighten. Over tightening these screws can strip the threads.

6. Tighten the two screws to secure the electronics to the housing (3 in Figure 8-1).

7. Re-assemble all wires that were originally attached or plugged into the electronics.

8. Tighten the housing cap.

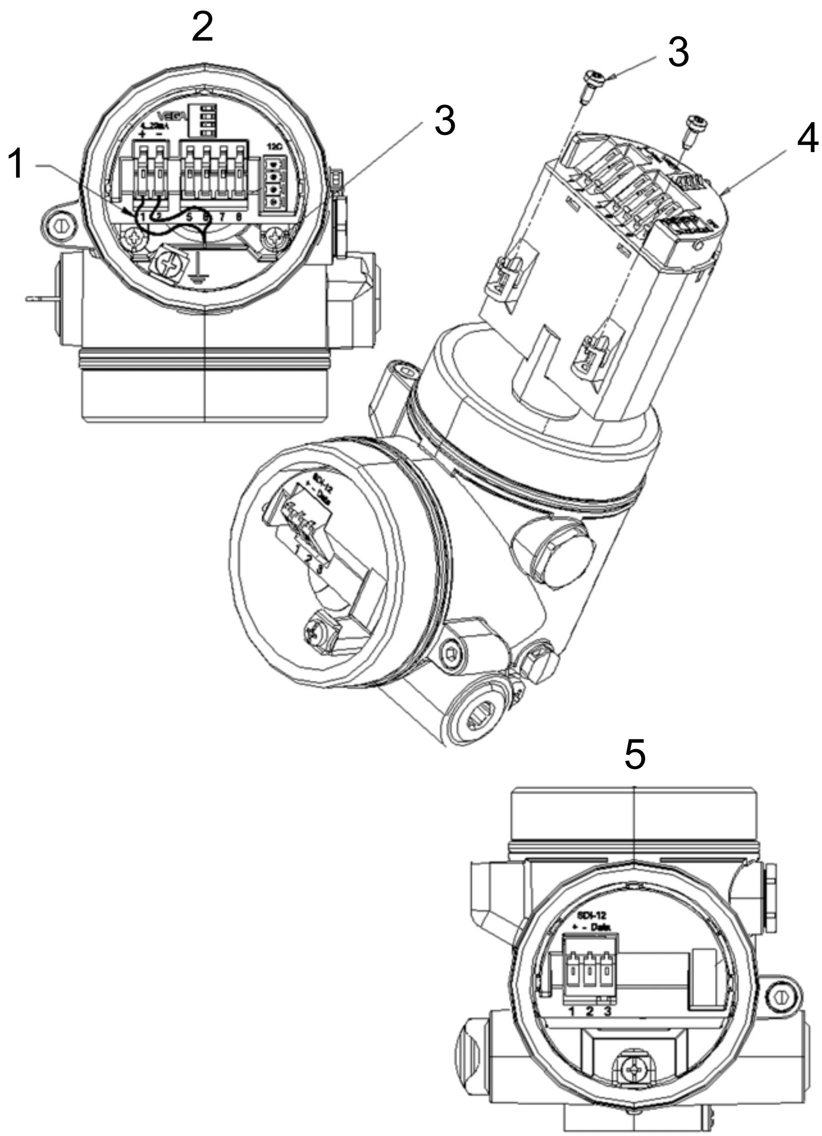


Figure 8-1. Changing the electronics (see Table 8-5 for label descriptions)

Table 8-5. Description of Changing the Electronics Labels	
	Description
1	Red Wire
2	Housing Top View
3	Screws to Secure Electronics to Housing
4	Electronics
5	Housing Side View

8.3 Maintenance

The sensors are maintenance free under normal operation.

Appendix A. Replacing the Cable

The sensor is fitted with a cable for connection to the datalogger. The following procedure is for replacing the original cable (see Figure A-1 and Table A-1).

1. Unscrew the housing side compartment screw cap.

2. Loosen the cord grip on the cable entry.

3. Remove approximately 10 cm (4 inches) of the cable mantle.

4. Strip approximately 1 cm (0.4 inches) of the insulation from the end of the individual wires.

5. Insert the cable into the sensor through the cable entry.

6. Lift the opening levers of the terminals with a screwdriver.

7. Insert the wire ends into the open terminals.

   - Connect the Power Supply +12 Vdc to the terminals marked 1 (+).

   - Connect the Power Supply Ground to the terminals marked 2 (–).

   - Connect the Data Line to the terminals marked 3 (data).

8. Press the opening lever of the terminal down. You will hear the terminal spring closed.

9. Check that the wires are firmly connected in the terminal by lightly pulling on them.

10. Connect the screen to the internal ground terminal and the external ground terminal to potential equalization (ground).

11. Tighten the cord grip on the cable entry. The seal ring must completely encircle the cable.

12. Place the housing side compartment screw cap on and tighten to ensure a mechanical seal.

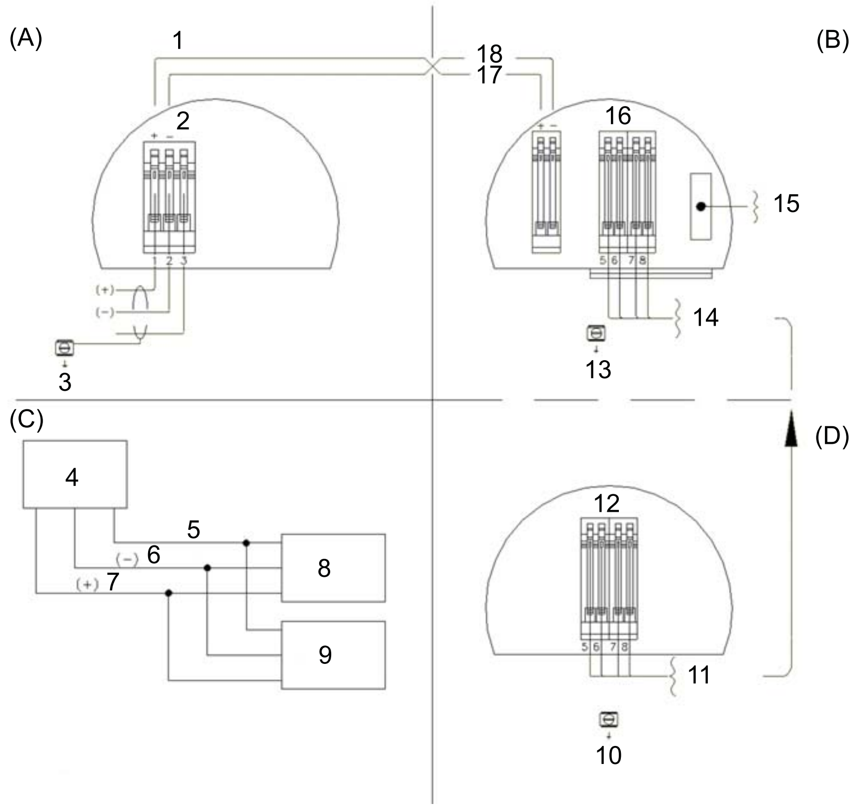


Figure A-1. Connecting the instrument housing (see Table A-1 for description of labels)

Table A-1. Description of Instrument Housing Labels

Connections	Description
(A)	Side Chamber SDI-12 Wiring
(B)	Top Chamber Inner Housing Connections
(C)	Typical SDI-12 Network Configuration
(D)	DIS61 (Optional) (Reference V-2799S0)
1	Inner Housing Connections (Modular Plug Mounted in Dual Chamber Housing), Plugs into Back of SDI-12 Board
2	SDI-12 Data
3	Ground Connection
4	Data Acquisition Device
5	Serial Data Line
6	12V (–) Ground
7	12V (+) Line
8	SDI-12 Sensor #1
9	SDI-12 Sensor #2
10	Ground Connection
11	To Instrument
12	Remote Display
13	Ground Connection
14	Digital Output (To Optional Remote Display)
15	Plug for Laptop Connection
16	Remote Display
17	Red
18	Other

Appendix B. SDI-12 Commands/ Changing Settings

The SDI-12 commands are entered using the #25616, *Adjustment/Display Module*, or the terminal emulator in LoggerNet or PC400. These commands are also used in CRBasic or Edlog programming (see Section 7.5, *Programming*).

During normal communication, the datalogger sends the address, together with a command, to the sensor. The sensor then replies with a “response”.

SDI-12 command codes used with the radar sensor are listed in Table B-1. The SDI-12 address and the command/response terminators have the following rules:

- The sensor address is an ASCII character. Valid addresses are: 0–9, A–Z, a–z, *, ?. Sensors are initially programmed at the factory with the address of 0 for use in single sensor systems. Addresses 1 to 9 and A to Z or a to z are used for additional sensors connected to the same port.
- All commands/responses are upper-case printable ASCII characters.
- Commands must be terminated with a ! character.
- Responses are terminated with <cr><lf> characters.
- The command string must be transmitted in a contiguous block with no gaps of more than 1.66 milliseconds between characters.

Table B-1. SDI-12 Commands

Function	**SDI-12 Command**
Address Query	**?!**
Send Identification	**aI!**
Acknowledge Active	**a!**
Change Address	**aAb!** Where a is the current address and b is the new address.
Start Verification	**aV!**
Start Measurement	**aM!**
Start Measurement and Request CRC	**aMC!**
Send Data	**aD0!...aD9!**
Additional Measurements	**aM1!...aM9!**
Additional Measurement and Request CRC	**aMC1!...aMC9!**
Start Concurrent Measurement	**aC!**
Start Concurrent Measurement and Request CRC	**aCC!**
Additional Concurrent Measurements	**aC1!...aC9!**
Additional Concurrent Measurements and Request CRC	**aCC1!...aCC9!**
Start False Echo Learn	**aXSFEL+n!** *n* = distance necessary to clear the obstruction
Set Power n Operation Mode	**aXSPOM+n!** *n* = 2 (auto), 1 (on), or 0 (off)
Get Power Operation Mode	**aXGPOM!** 2 = auto; 1=on; 0=off
Get Water Conditions	**aXGWC!** n = 0 (auto), 1 (smooth) 2 (medium), or 3 (rough)
Set Water Conditions	**aXSWC+n!** n = 0 (auto), 1 (smooth) 2 (medium), or 3 (rough) Where n is the new water condition.
Set Water Stage	**aXSS+n!** n = floating point number that is the initial stage or level of the water surface above the reference. Where n is the new water stage.
Get Unit	**aXGU!** 0 = metres; 1=feet
Set Unit	**aXSU+n!** n = 0 (metres) or 1 (feet) Where n is the new unit of measurement.
Reset Sensor	**aXRS!** 0 = reset unsuccessful; 1=reset successful Resets the sensor to its factory settings.

B.1 SDI-12 Command Descriptions

B.1.1 Start False Echo Learn

The *Start False Echo Learn* command is an essential function during the start-up of the sensor. It is also used during testing if a problem is encountered. The command allows the unit to learn about false echoes (noise) in the area. With the *False Echo Learn* command, you enter the actual distance to the water surface, as measured in metres or feet, depending on the unit setting. The radar sensor then emits the short microwave pulses. Any echo occurring 0.5 m (1.6 ft) short of the distance you entered will be considered noise.

To start *False Echo Learn*, do the **aXSFEL+nnn.nnn!** command (where nnn.nnn = the actual distance to the water) followed by the **aD0!** (*Send Data*) command. Table 4-5 in Section 4, *Quickstart*, shows an example of the command and response.

B.1.2 Set Water Stage

With the *Set Water Stage* command, you enter the initial depth of the water, and the sensor will automatically measure the distance between the sensor and the water surface. The water stage setting and the initial distance measurement are used to calculate subsequent water stage measurements. Correct stage measurements require that the water stage setting be in the same units as the Units of Measure setting. You can find out if the sensor is set to metres or feet by using the **aXGU!** (*Get Unit*) command.

To set the water stage, do an **aXSS+nnn.nnn!** command (where nnn.nnn = the initial water depth) followed by the **aD0!** (*Send Data*) command. Table 4-6 in Section 4, *Quickstart*, shows an example of the command and response for entering this setting.

B.1.3 Query/Set the Address

Valid addresses are 0 to 9; A through Z; and a through z. The factory default address is set to 0. The address can be verified by sending the sensor the *Address Query* command (see Table B-2).

Table B-2. SDI-12 Command for Querying the Address

Initial Command	Response
?!	**a<cr><lf>** Where a is the current address of the sensor.

Change the sensor's address by sending the sensor the **aAb!** command, where "a" is the original address and "b" is the new address. Table B-3 shows an example of the command and response for setting the address.

Table B-3. Example of Setting Address

Initial Command	**Response**
0A1! Where 0 is the original address and 1 is the new address.	**1<cr><If>** The new address (1) is set in response.

B.1.4 Set Units

The distance measurement can be reported in feet (default) or metres. Change the units by first using the **aXSU+n!** command (where n = 1 (feet) or 0 (metres)) followed by the **aXGU!** (*Get Units*) command. Table B-4 shows an example of the command and response for changing this setting.

Table B-4. Example of Setting Units

Initial Command	**Response**
0XSU+0! Where the first zero is the sensor address and the second zero sets the units to metres.	**00011<cr><If>** Where (from left to right), 0—sensor’s address; 001—the amount of time (in seconds) that you must wait before sending another command; 1—the number of values that will be placed in the buffer.
Subsequent Command	**Response**
0XGU! Where zero is the sensor address. This is the get units command.	**0+0<cr><If>** Where the first zero is the sensor address and the second zero indicates that the units are now metres.

B.1.5 Set Water Conditions

The *Set Water Conditions* command adapts the sensor to different water conditions.

There are four different settings:

- 0 (custom setting)
- 1 (smooth—typical peak to trough of wave < 4”)
- 2 (medium—typical peak to trough of wave < 8”)
- 3 (rough—typical peak to trough of wave > 8”)

The factory default water conditions are set to 1, which is smooth. The water condition settings should closely mimic the actual water conditions during normal river flow.

Change this setting by first using the **aXSWC+n!** command (where n=0 (custom), 1 (smooth), 2 (medium), or 3 (rough)) followed by the **aXGWC!** (*Get Water*

Conditions) command. Table B-5 shows an example of the command and response for changing this setting.

Table B-5. Example for Setting Water Conditions

Initial Command	**Response**
0XSWC+2! Where, 0—sensor's address; 2—the new water condition setting (2 = medium).	**00011<cr><lf>** Where (from left to right), 0—sensor's address; 001—the amount of time (in seconds) that you must wait before sending another command; 1—the number of values that will be placed in the buffer.
Subsequent Command	**Response**
0XGWC! Where zero is the sensor address. This is the send water conditions command.	**0+2<cr><lf>** Where, 0—sensor's address; 2—the new water condition setting (2 = medium).

B.1.6 Set Power Operation Mode

The following three power operation modes are available:

- 1 (ON—sensor is always on until a new set power command is received.)
- 2 (AUTO—sensor is powered by an incoming request from the SDI-12 bus and sends back a response including the information on power up time.)
- 0 (OFF—this mode is typically not recommended; sensor is completely off until a new set power command is received)

CAUTION The OFF power mode should only be used by advanced users who want to turn the sensor off for extended time periods. In this mode, the sensor is completely off and only responds to a new set power command.

The factory default *Power Operation Mode* is 1 (ON). In this mode of operation, the instrument is continuously making measurements and draws approximately 13.5 mA. The AUTO Power Operation Mode puts the instrument in quiescent mode between measurement request queries.

Change this setting by first using the **aXSPOM+n!** command (where n=1 (on), 2 (auto), or 0 (off)) followed by the **aXGPOM!** (*Get Power Mode*) command. Table B-6 shows an example of the command and response for changing this setting.

Table B-6. Example for Setting Power Operation Mode

Initial Command	Response
0XSPOM+2! Where, 0—sensor’s address; 2—the new power mode setting (2 = auto).	**00011<cr><lf>** Where (from left to right), 0—sensor’s address; 001—the amount of time (in seconds) that you must wait before sending another data command; 1—the number of values that will be placed in the buffer.
Subsequent Command	**Response**
aXGPOM! Where zero is the sensor address. This is the get power mode command.	**0+2<cr><lf>** Where, 0—sensor’s address; 2—the new power mode setting (2 = auto).

Appendix C. FCC/IC Equipment Authorization (USA/Canada only)

The CS475, CS476, and CS477 are FCC compliant (FCC IC # M01PULS616263). Modifications to the sensors must have express agreement from Campbell Scientific. Any modifications not approved by Campbell Scientific will cause the expiration of the operating license issued by the FCC/IC. The radar sensor is in conformity with Part 15 of the FCC directives and fulfils the RSS-210 regulations.

Regulations for operation include:

- These devices must not cause any interfering emissions.
- These devices must accept any interfering emissions received, including interference that may cause unwanted operating conditions.

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