SEA·BIRD SCIENTIFIC

User manual

Transmissometers

BAM, C-Star, C-Rover

Document No.	transmissometers20220706
Release Date:	2022-07-25
Version:	E

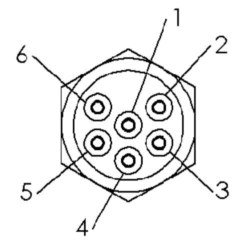
541-929-5650
seabird.com

Table of Contents

Section 1 Specifications

1.1 Mechanical

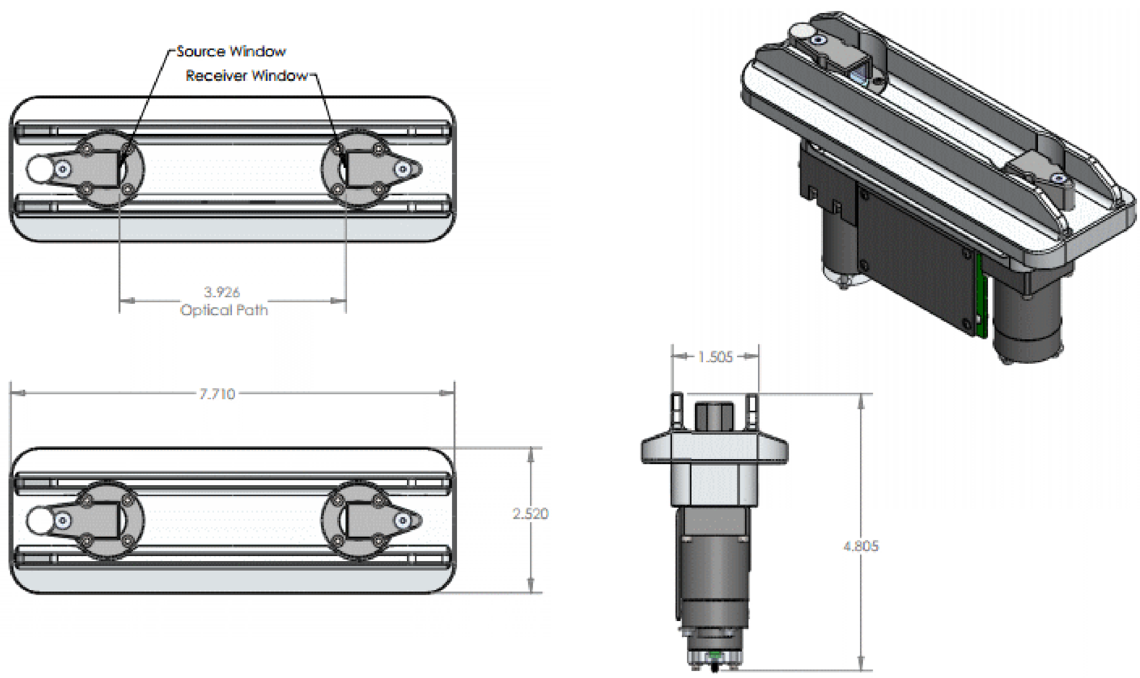
1.1.1 Bulkhead connector

Contact	Function	MCBH-6-MP
1	Ground	
2	RS232 RX	
3	Reserved	
4	Voltage in	
5	RS232 TX	
6	Reserved	

1.1.2 BAM

Length	19.56 cm
Height	12.2 cm
Width	6.35 cm
Weight in air	0.8 kg
Rated depth	1000 m
Temperature range, operation	-2–40 °C
Temperature range, storage	-40–70 °C
Temperature stability	0.02% FS/°C; 3.28 kg, 2.06 kg

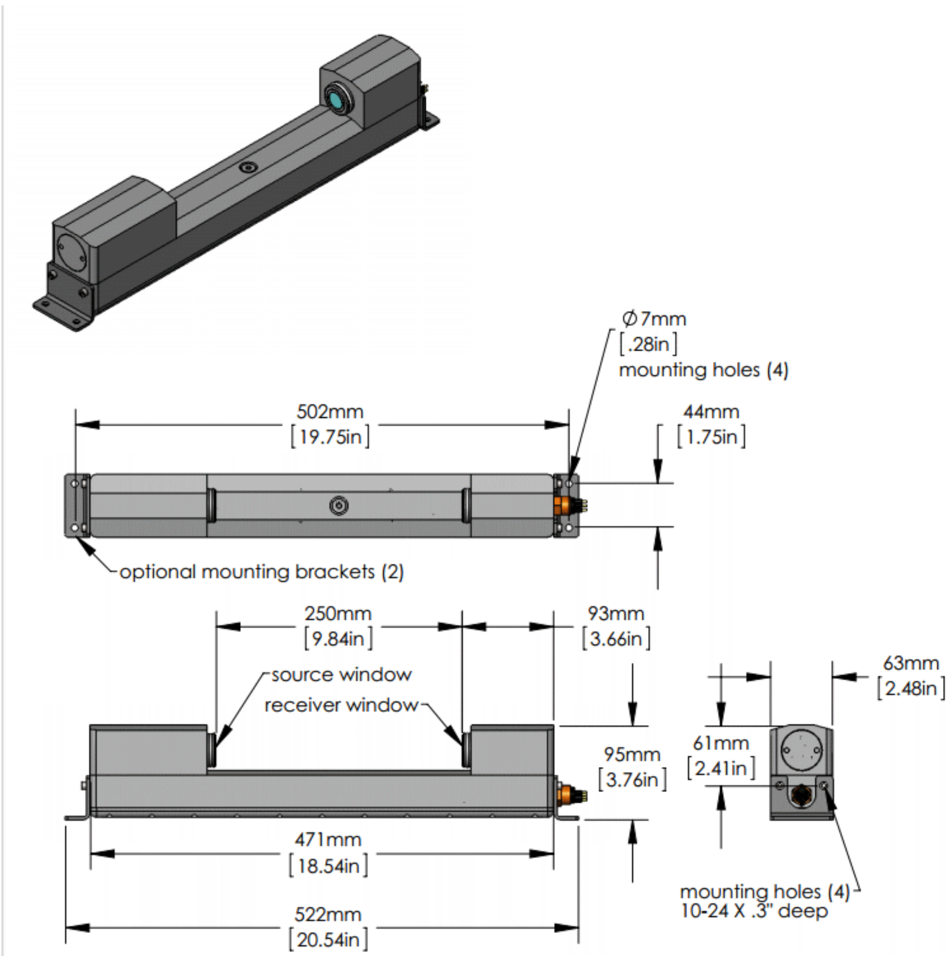
BAM SLK dimensions



1.1.3 C-Star

Dimensions	25 cm pathlength: 9.3 x 6.4 x 47 cm; 10 cm pathlength: 9.3 x 6.4 x 29.2 cm
Weight in air	25 cm pathlength: 2.2 kg; 3.6 kg (aluminum); 10 cm pathlength: 1.8 kg
Rated depth	600 m; 6000 m
Temperature range, operation	-2–40 °C
Temperature range, storage	-20–50 °C

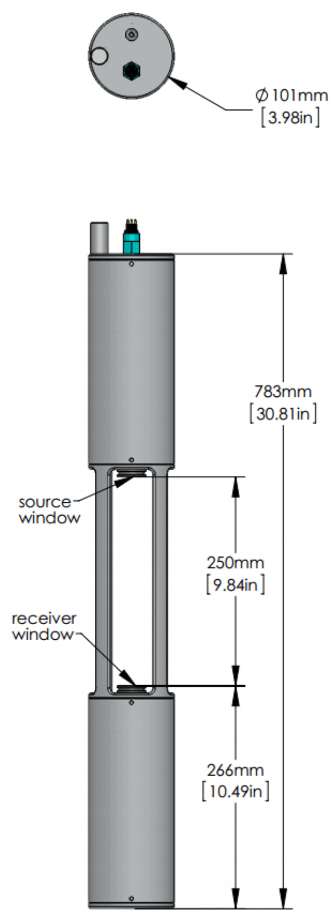
C-Star dimensions



1.1.4 C-Rover

Length	78.3 cm
Diameter	10.1 cm
Weight in air, water	4.11 kg, 0.028 kg
Displacement	4546 ml
Rated depth	2000 m
Temperature range, operation	-2–40 °C
Temperature range, storage	-20–50 °C

C-Rover dimensions



1.2 Electrical

Input	7–15 VDC
Current draw, typical	35 mA
Linearity	99%
Long-term stability	0.02% FS/hour, 6 hours
Short-term noise	0.027% FS Std dev over 1 minute

1.3 Communication

1.3.1 BAM

Sample rate	1 Hz (default) to 8 Hz
RS232 output rate	19200 baud
Data resolution	14 bit
Output maximum	~16380 counts

1.3.2 C-Star and C-Rover

Sample rate	1 Hz (default) to 8 Hz
RS232 output rate	19200 baud (default); Range 2400–115200
Data resolution	14 bit
Digital output maximum	~16380 counts
Analog output maximum	0–5 V (C-Star only)

1.4 Optical

Optical pathlength	25 cm C-Star, C-Rover; 10 cm BAM, (10 cm C-Star optional)
Acceptance angle	~1°
Precision	0.003 m^{-1} @ 1 Hz
Linearity	99%

1.4.1 BAM wavelengths

	Minimum	**Typical**	**Maximum**
"Blue" peak emission wavelength	460 nm	461 nm	465 nm
"Blue" dominant wavelength	463 nm	466 nm	469 nm
"Blue" spectral line half-width	—	22 nm	—
"Green" peak emission wavelength	517 nm	520 nm	523 nm
"Green" dominant wavelength	523 nm	526 nm	529 nm
"Green" spectral line half-width	—	32 nm	—
"Red" peak emission wavelength	—	652 nm	—
"Red" dominant wavelength	—	639 nm	—
"Red" spectral line half-width	—	21 nm	—

1.4.2 C-Star and C-Rover wavelengths

	Minimum	Typical	Maximum
C-Star only "UV" peak wavelength	405 nm	410 nm	415 nm
"Blue" peak emission wavelength	462 nm	465 nm	468 nm
"Blue" dominant wavelength	466 nm	468 nm	470 nm

"Blue" spectral line half-width	—	25 nm	—
"Green" peak emission wavelength		518 nm	
"Green" dominant wavelength	523 nm	526 nm	529 nm
"Green" spectral line half-width	—	32 nm	—
"Red" peak emission wavelength	—	652 nm	—
"Red" dominant wavelength	—	639 nm	—
"Red" spectral line half-width	—	21 nm	—

Section 2 Operation

2.1 Verify sensor operation

NOTICE

Do not supply more than 15 VDC to the sensor. More than 15 VDC will cause damage.

The manufacturer makes three types of transmissometers:

- Beam Attenuation Meter (BAM), designed for Autonomous Underwater Vehicles (AUVs) where size and drag are important.
- C-Star, designed for general purposes. It is available with a 6000 m rated depth. A titanium model is available for 6000 m non-trace metal studies. A 10 cm pathlength sensor is also available.
- C-Rover, designed for profiling floats. It is rated to 2000 m.

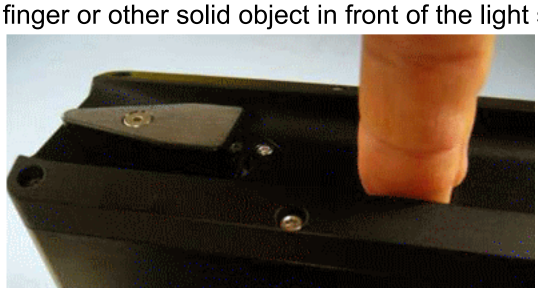
Each sensor has one of three wavelengths:

- "Red," best for particle dynamics, e.g. mass concentration studies.
- "Green," best for estimates of in-situ visibility.
- "Blue," best for estimates of blue light penetration.

Make sure that the sensor collects data and operates correctly before deployment.

1. Start a terminal communication program such as HyperTerminal® or Tera Term. Select:
   a. Bits per second: 19200
   b. Data bits: 8
   c. Parity: none
   d. Stop bits: 1
   e. Flow control: none.
2. Make sure that the sensor is connected to a PC and power supply.
3. Turn on the power supply if necessary.
4. Put a piece of paper in the light path.

   A circle of light shows.
5. Put a finger or other solid object in front of the light source.



6. Look at the data from the signal and the corrected signal. They are at or near 0.

2.2 Transmissometer operational criteria

The corrected signal (CSC_{sig}) is temperature-corrected output that is calculated from the raw signal and the manufacturer's thermal correction of the sensor. The thermistor output is not calibrated by the manufacturer and does not respond to external water temperature. This thermistor is located on the processor and is used to monitor the functionality of the sensor. Do not use the output from the thermistor (shown below in Column 6) for a secondary thermal correction.

The output from the sensor uses the format shown below.

Column	Value	Example output
1	Model-Serial Number-version	**xxx-0000-4.1** 11829 13838 13695 0.003 527
2	Reference	xxx-0000-4.1 **11829** 13838 13695 0.003 527
3	Signal	xxx-0000-4.1 11829 **13838** 13695 0.003 527
4	Corrected signal	xxx-0000-4.1 11829 13838 **13695** 0.003 527
5	Calculated beam c, m^{-1}	xxx-0000-4.1 11829 13838 13695 **0.003** 527
6	Thermistor	xxx-0000-4.1 11829 13838 13695 0.003 **527**

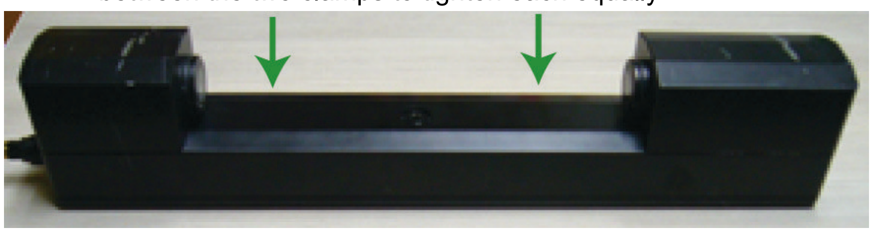
1. Look at a clear light path to make sure that the corrected signal is within 100 counts of the Corrected Signal Counts (CSC_{air}) value on the sensor's calibration page or the previous user-monitored value.
   a. The sensor operates correctly and the optical windows are clean.
   b. Record the output of the sensor and keep the information to compare to the next check.
2. If the corrected signal is more than 100 but less than 500 counts more than the CSC_{air}:
   a. Clean the optical windows. Refer to Clean the optics on page 13 for details.
   b. Clean the optical windows again if necessary, until the signal is either less than 100 counts different from CSC_{air} or stable between user-collected values.
   c. Record the output of the sensor and keep the information to compare to the next check.
3. If the output of the sensor is more than 500 corrected counts greater than CSC_{air}:
   a. Clean the optical windows. Refer to Clean the optics on page 13 for details.
   b. Clean the optical windows again if necessary, until the signal is either less than 100 counts different from CSC_{air} or stable between user-monitored values.
   c. Record the output of the sensor and keep the information to compare to the next check.
4. If the output of the sensor is still more than 500 counts greater than CSC_{air}, contact the manufacturer.

2.3 Transmissometer hardware setup

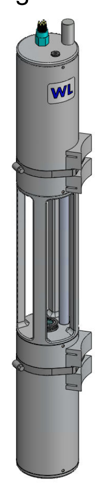
Attach sensor to frame

- Make sure to electrically isolate the sensor from any metal.
- Sensors that are depth-rated to 2,000 or 6,000 m have a zinc anode installed near the bulkhead connector to protect the sensor from normal corrosion.

- BAM: use the ½-20 threaded holes to attach the sensor to any frame.
- C-Star, C-Rover: the manufacturer recommends non-nylon cable ties or monofilament line to attach the sensor to a lowering frame or metal cage.
- C-Star, C-Rover: if the sensor is attached to a frame with hose clamps, Use a sheet of rubber or dielectric tape to prevent metal-to-metal contact. Use corrosion-resistant 316 stainless steel or titanium clamps.
- C-Star: make sure to attach hose clamps around the main mount (green arrows, below). Tighten one clamp approximately a quarter-turn, and tighten the other. Move between the two clamps to tighten each equally.



- C-Star, C-Rover: do not attach the hose clamps too tightly or the optical path of the sensor may twist, and the data collected may be incorrect.
- C-Star: operate the sensor with or without a pump. The manufacturer recommends the SBE-5T pump, which has an adjustable motor, so flow rates can accurately be controlled to 20–30 ml/sec to flush the flow tube. Attach the optional flow tube if the sensor is operated with a pump.
- C-Rover: Use the mounting blocks with hose clamps as shown below.



2.4 Deployment procedures

After the sensor is attached to the cage or frame on which it will be deployed, verify that it operates correctly with the power source to be used during the deployment.

- Do the steps in Transmissometer operational criteria on page 10 to verify the sensor operates correctly.

If the sensor will not be deployed within a short period of time:

- Do the steps in Transmissometer operational criteria on page 10 to verify the sensor operates correctly just before deployment.

1. Before deployment, put a drop of diluted detergent on the sensor optics to help keep the optics clean when the sensor is on the water's surface. Refer to Clean the optics on page 13 for details.
2. Deploy the sensor.
3. When the sensor is removed from the water, flush all of the surfaces with clean water to remove salt water and loose material.
4. Dry the windows with clean air.
5. Do the steps from the Maintenance section of this document to clean the sensor.
6. Verify that the output of the sensor meets the criteria in the Transmissometer operational criteria on page 10 section of this manual.

Section 3 Maintenance

⚠ WARNING

If the user thinks that a sensor has water in the pressure housing: Disconnect the sensor from any power supply. Put on safety glasses and make sure that the sensor is pointed away from the body and other people. In a well ventilated area, use the purge port (if the sensor is so equipped), or very SLOWLY loosen the bulkhead connector to let the pressure release.

3.1 Clean the sensor

Clean the sensor after each deployment.

1. Flush the sensor with clean fresh water.
2. Use soapy water to cut grease or oil on the sensor.
3. Make sure that saltwater does not dry on the optical windows of the sensor. Salt crystals are difficult to clean at a later date.
4. Flush the sensor with filtered, distilled water.
5. Clean the optics.

3.2 Clean the optics

Record and save the data that is collected by the sensor at regular intervals to monitor the performance of the sensor and to see if the optical windows need to be cleaned.

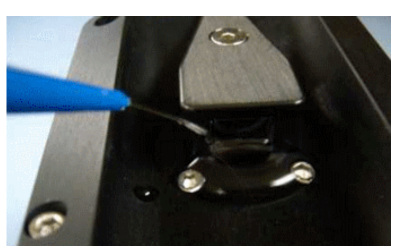
- It is not necessary to clean the windows if the data from the sensor is within 100 counts of the clean air value on the sensor-specific calibration page or the user-collected value.
- Clean the windows if the data from the sensor is more than 100 counts different from the clean air value on the sensor-specific calibration page or the user-collected value.

Do the steps below to clean the optical windows. Clean the optics until the data:

- is within 100 counts of the data output value on the manufacturer-supplied calibration page,
- is within 100 counts of the user-collected data output values, or
- is stable, between 100 and 500 counts of the calibration page or user-collected values.

1. Remove the protective cap(s) to clean the optical windows of the sensor.
2. Mix two drops of dilute unscented detergent with 0.2 or 0.4 μm filtered distilled water in a 500 ml bottle.
3. Put some soap solution on the optical window.

Figure 1 Apply detergent solution on window

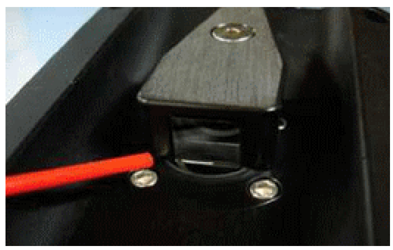


4. Use a lint-free tissue (e.g. Kimwipe or similar) or a swab to rub the optical window to remove particles and oil.

Figure 2 Rub window with lint-free tissue

5. Flush the detergent off of the windows with filtered distilled water.
6. Use compressed air to remove any particles that remain and to dry the optical window.

Figure 3 Dry window with compressed air



7. Wet, rub, flush, and dry each optical window two or three times to get a stable clean air value.

3.3 Clean bulkhead connectors

NOTICE

Do not use WD-40® or petroleum-based lubricants on bulkhead connectors. It will cause damage to the rubber.
Damaged connectors can cause a loss of data and additional costs for service.

Damaged connectors can cause damage to the sensor and make it unserviceable.

Examine, clean, and lubricate bulkhead connectors at regular intervals. Connectors that are not lubricated increase the damage to the rubber that seals the connector contacts. The incorrect lubricant will cause the failure of the bulkhead connector.

1. Apply isopropyl alcohol (IPA) as a spray or with a nylon brush or lint-free swab or wipes to clean the contacts.
2. Flush with additional IPA.
3. Shake the socket ends and wipe the pins of the connectors to remove the IPA.
4. Blow air into the sockets and on the pins to make sure they are dry.
5. Use a flashlight and a magnifying glass to look for:

Any corrosion.		
Cracks, scratches, or other damage on the rubber pins or in the sockets.		
Separation of the rubber from the pins.		
Swelled or bulging rubber pins.		

6. Use a silicone-based lubricant on each of the contacts of the bulkhead connector. The manufacturer recommends any of the products listed below.

   - 3M™ Spray Silicone Lubricant (3M ID# 62-4678-4930-3). Make sure to let it dry.
   - Dow Corning Molykote® III Compound (DC III)
   - Dow Corning High Vacuum Grease® (DC 976 V)
   - Dow Corning 4 Electrical Insulating Compound® (DC 4)
   - Dow Corning Molykote 44 High Temperature Grease® (DC 44)

   Use a finger to put a small quantity (approximately 1 cm in diameter) of silicone grease on the socket end of the connector and push as much of the lubricant as possible into each socket. Do not use too much lubricant, as that will prevent a good seal.

7. Connect the connectors.
8. Use a lint-free wipe to clean any unwanted lubricant from the sides of the connectors.

Section 4 Reference

4.1 Protective diode

The sensor has a protective diode to prevent damage to the sensor up to 30 volts in case power is supplied to the incorrect polarity.

4.2 Common terminal program commands

Command	Parameters	Description
!!!!!	none	Stops the data collected by the sensor. Lets the user to enter setup values. If the sensor is in a low-power mode, turn the power supply off for one minute, then turn the power on and push the "!" key 5 or more times.
$ave	1–255	The number of measurements that make up each row of collected data.
$mnu	—	Prints the menu of setup values to the PC screen.
$pkt	0–65535	Sets the number of rows of data that are collected between the specified time intervals.
$rls	none	Gets the settings from the flash memory.
$run	—	Uses the current setup values to operate.
$sto	—	Saves the desired setup values to the flash memory.

4.3 Calibration

The relationship between the calibrated output (CSC_{sig}) and clean water calibration (CSC_{cal}) is transmittance and will vary from 0 to 1, or 0 to 100%. The relation of transmittance to the beam attenuation coefficient (c) is $Tr = e^{-cx}$.

- Tr = transmittance
- e = natural logarithmic base, ~ 2.71828
- c = beam attenuation coefficient
- x = sensor pathlength

The manufacturer calibrates each sensor and records these values on the sensor-specific calibration page. The calibrated transmittance of the sensor is calculated below.

$\mathbf{Tr} = (CSC_{sig} - CSC_{dark}) \div (CSC_{cal} - CSC_{dark})$

- CSC_{sig} = the sensor-reported corrected signal.
- CSC_{dark} = the sensor-reported signal with the beam blocked.
- CSC_{cal}= the value of the output in optically clean water that is used for calibration.

The beam attenuation coefficient is calculated below.

$c = - 1/x \times \ln(\mathbf{Tr})$

$= - 1/x \times \ln [(CSC_{sig} - CSC_{dark}) \div (CSC_{cal} - CSC_{dark})]$

4.3.1 Verify analog data output

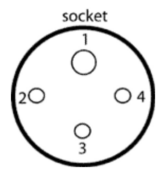
1. Connect the optional test cable to the sensor. Refer to the section on the test cable for details about test cables.
2. Use a regulated power supply to supply 12 VDC to the sensor or connect a 9V battery to the connectors on the test cable.
   The sensor comes on.
3. Use the probes on a digital multimeter (DMM) to touch the RCA connector on the auxiliary leg(s) of the test cable.
4. Put the red (signal) probe in the RCA connector and the black (ground) on the outside.

The DMM shows approximately 5 VDC.

5. Put a solid object near the light source of the sensor.
   The DMM shows approximately 0 VDC.

4.4 "Legacy" bulkhead connector

The oldest C-Star sensor models used the VSG-4 bulkhead connector shown below.

Analog		Connector diagram	Digital	
Contact	**Function**		**Contact**	**Function**
1	Ground		1	Ground
2	Analog out		2	Analog out
3	V+		3	V+
4	Analog return		4	RS232 TX

4.5 Digital data output types

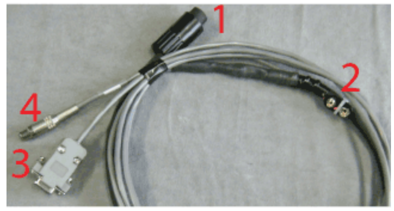
Data type	Description
AI	ASCII integer number
AF	ASCII floating point number
AS	ASCII string, text

Field	Length (bytes)	Data type	Description
Sensor	4	AS	Characters at the start of a row of data
Delimiter	1	AS	Hyphen delimiter
SN	4	AI	Serial number
Delimiter	1	AS	Tab delimiter
Ref raw	5	AI	Reference raw count value
Delimiter	1	AS	Tab delimiter
Sig raw	5	AI	Signal raw count value
Delimiter	1	AS	Tab delimiter
Corr Sig Raw	5	AI	Corrected signal raw count value, CSC_{sig}
Delimiter	1	AS	Tab delimiter
c	6	AF	Calculated beam attenuation coefficient in m,$^{-1}$
Delimiter	1	AS	Tab delimiter
Therm	3	AI	Internal thermistor raw count value
Delimiter	1	AS	Tab delimiter
Clean air	5	AI	Clean air value, counts
Delimiter	1	AS	Tab delimiter
Clean water	5	AI	Clean water value, counts
Delimiter	1	AS	Tab delimiter
Cal date	10	AS	Date of last calibration, YYYYMMDD format
Terminator	1	AS	Line feed pair ($0A_{hex}$), end of row.

Section 5 Optional equipment

5.1 Test cable

Use the optional test cable to set up and test the sensor before deployment.



1 six-contact connector	**3** db-9 serial port connector
2 9-volt battery connector	**4** RCA connector

1. Connect the six-contact connector to the sensor.
2. Connect the 9-volt connector to a 9-volt battery. As an alternative, it can be connected to a 12-volt regulated power supply.
3. Connect the db-9 connector to the host PC. Use a USB-to-RS232 adapter cable if necessary to see digital output.
4. Use the probes on a digital multimeter to see analog output. The inside of the RCA is power and the outside is ground.

5.2 Flow tube

The C-Star sensor can be equipped with a flow tube if the user has a flow-through application. This use requires a pump. The manufacturer recommends the SBE-05, which has an adjustable motor speed so the user can control the flow rate into the sensor.

Section 6 General information

⚠ WARNING

This product can expose the user to chemicals with silica, crystalline (airborne particles of respirable size), which is known to the State of California to cause cancer and birth defects or other reproductive harm. For more information, go to www.P65Warnings.ca.gov.

Revised editions of this user manual are on the manufacturer's website.

6.1 Warranty

Refer to the manufacturer's website for warranty information (seabird.com/warranty).

6.2 Service and support

The manufacturer recommends that sensors be sent back to the manufacturer annually to be cleaned, calibrated, and for standard maintenance.
Refer to the website for FAQs and technical notes, or contact the manufacturer for support at support@seabird.com. Do the steps below to send a sensor back to the manufacturer.

1. Complete the online Return Merchandise Authorization (RMA) form or contact the manufacturer.
   Note: *The manufacturer is not responsible for damage to the sensor during return shipment.*
2. Remove all batteries from the sensor, if so equipped.
3. Remove all anti-fouling treatments and devices.
   Note: *The manufacturer will not accept sensors that have been treated with anti-fouling compounds for service or repair. This includes AF 24173 devices, tri-butyl tin, marine anti-fouling paint, ablative coatings, etc.*
4. Use the sensor's original ruggedized shipping case to send the sensor back to the manufacturer.
5. Write the RMA number on the outside of the shipping case and on the packing list.
6. Use 3rd-day air to ship the sensor back to the manufacturer. Do not use ground shipping.
7. The manufacturer will supply all replacement parts and labor and pay to send the sensor back to the user via 3rd-day air shipping.

WET Labs, Inc.
620 Applegate Street
Philomath, OR 97370 U.S.A.
Tel. (541) 929-5650