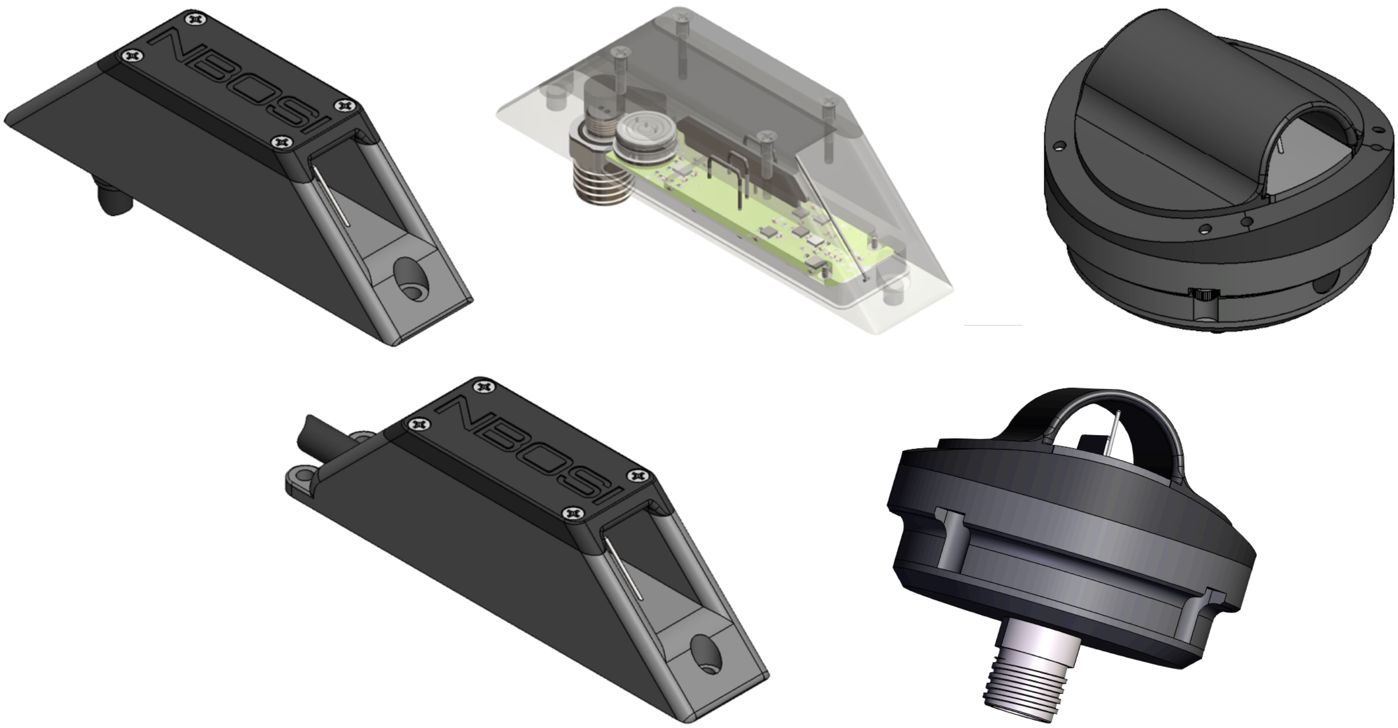
500 SERIES CTD SENSORS

Models 501, 511, 503, 513, 504



OPERATION AND CARE MANUAL

Revision 1.3, 07/2025

NBOSI ocean sensors

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All NBOSI products are designed, assembled and calibrated
in our Massachusetts, USA facility.

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CTD CARE

This Conductivity-Temperature-Depth (CTD) Sensor was designed to be rugged and capable of many years of service. Please remember the following to insure best performance and longest service life:

- Do NOT use your fingers, brushes or high-pressure water to clean the interior of the sensor. A light rinse with fresh water following deployment is recommended.

- Dried salt or organic matter within the CTD may result in spurious conductivity / salinity measurements. Soaking followed by gentle agitation of the cell in fresh water should resolve most issues. If the cell was exposed to a particularly oily environment, then soaking in water mixed with a small amount of dish soap may prove effective.

- The pressure sensor is protected beneath a plastic guard. Do not insert anything into the holes in this guard. Do not use high-pressure water to dislodge sediment or detritus.

- Occasional sensor recalibration is highly recommended to achieve the most accurate ocean measurements. Please contact NBOSI for fast-turnaround, low-cost sensor maintenance and calibration. Standard calibration can generally be completed within 2 weeks of receipt of the sensor in serviceable condition.

IMPORTANT: A CTD immersed in a non-conductive medium will not return a meaningful conductivity measurement. Air is non-conductive. Conductivity measurements performed in air (i.e. testing on deck or in the lab) have no relation to sensor performance when deployed underwater. Temperature and pressure measurements should always appear reasonable.

1. The NBOSI CTD Sensor

Overview

The NBOSI CTD Sensor consists of an internal field, four-electrode conductivity cell with an integral pressure-protected thermistor, a precision pressure sensor and a self-referencing electronics board. Optimized for use on mobile platforms, the NBOSI CTD cell is free-flushing, fast-responding, quiet, vibration-free, rugged, low-power and insensitive to mounting location. The sensor is fully potted and capable of operation beyond 6000 dbar. We regularly perform in-house pressure validation testing to 9,800 psi (6750 dbar) for customers operating under extreme conditions.

Theory of Operation

The salinity of seawater is a well-studied function of temperature and conductivity. Both properties must be measured very carefully to accurately determine salinity and related ocean parameters such as sound speed and ocean density.

Temperature is measured by the NBOSI CTD in a conventional manner using a pressure-protected, ultra-stable micro thermistor. The fast-responding temperature probe is located in the center of the sensor so that temperature, conductivity and pressure measurements are co-located and simultaneous. This arrangement results in accurate and stable real-time salinity measurements in the most complex and dynamic ocean environments.

Conductivity is a substantially more challenging measurement. Ohm's Law tells us that the current (I) that flows through a length of conducting material is proportional to the voltage (V) difference across the sample. The constant of proportionality is the resistance (R):

Ohm's Law: $V = I\,R$

The conductance (G) is simply the reciprocal of resistance:

$$G = 1/R = I/V$$

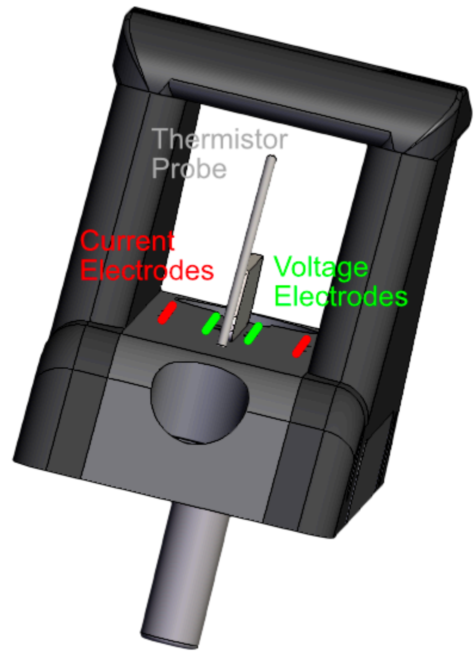
Unlike measuring the resistance of a length of wire using a multimeter, the conductance of a liquid sample depends not only on the relevant physical property of the liquid (its conductivity k) but also on the spacing (d) and surface area (A) of the electrodes used to supply current and measure voltage:

$$G = k\,A/d$$

The conductivity (*k*) can be expressed as the product of the measured conductance and the ratio of the electrode separation distance and area. This ratio is referred to as the cell constant (θ):

$$k = Gd/A = G\theta$$

The cell constant is a property of the measurement device (the conductivity cell) and not the fluid being measured – and it must be empirically determined for each individual sensor via a laboratory calibration procedure.



To measure conductivity using the 4-electrode NBOSI cell, a precisely known, small AC current is applied to one pair of platinum electrodes. Voltage is simultaneously measured across a second set of electrodes. The ratio of the applied current to the measured voltage (*I/V*) multiplied by the cell constant (θ) yields the conductivity:

$$k = G\theta = \theta(I/V)$$

Note that if there is no current through the medium there can be no voltage difference and hence no meaningful conductivity measurement.

The SI unit of conductance (*G*) is the Siemen (S). The cell constant is the ratio of a length to an area and has units of 1 / meter. Conductivity is therefore reported in Siemens / meter. Typical values range from 0 – 6 S/m (or equivalently, 0 – 60 mS/cm.) Because *G* is the reciprocal of *R* (measured in ohm) an occasionally used but non-recommended, non-SI unit for *G* is the *mho:* 1 mho = 1 S.

IMPORTANT: A CTD immersed in a non-conductive medium will not return a meaningful conductivity measurement. Air is non-conductive. Conductivity measurements performed in air (i.e. testing on deck or in the lab) have no relation to sensor performance when deployed underwater. Temperature and pressure measurements should always appear reasonable.

2. Specifications

Weights and dimensions will vary depending on connector and cabling configuration. All specifications are subject to change. Please visit nbosi.com for the most up-to-date information.

Model 501

Physical

Length	5.400 in (137.2 mm)
Width	1.159 in (29.4 mm)
Height	1.550 in (39.4 mm) [1]
Housing	Plastic, fully potted
Max Depth	6750 dbar (9800 psi) [2]
Weight (air)	Approx. 220 g [3]
Weight (water)	Approx. 140 g [3]
Connections	Power (2), Data (2)

[1] Not including bulkhead connector or hull penetrator
[2] Assumes selection of compatible-range pressure sensor
[3] Varies with customer-selected connector or penetrator

Electrical

Input Power	4.5 VDC to 28 VDC
Power Consumption	12 mA / 60 mW @ 5V
	13 mA / 156 mW @ 12V

Communications and Sampling

Protocol	RS-232, 8-N-1
Speed	9600 to 115,200 baud
Recursive Filtering	0 to 9 samples
Sample Output Rate	Standard 5 Hz
	Configurable 0.5 Hz - 10 Hz

Temperature

Standard Range	0°C to 30°C
Extended Range	-5°C to 60°C
Initial Accuracy	0.002°C
Resolution	0.0001°C
Time Constant	0.4 s

Conductivity

Standard Range	0 to 60 mS/cm
Initial Accuracy	0.005 mS/cm
Resolution	0.0001 mS/cm
Electrodes	99.95% pure platinum

Pressure

Sensor	Keller PA 7LD
Available Ranges	30 to 10,000 dbar
Initial Accuracy	0.15% of full-scale
Overpressure	4 x pressure range

Options

Modular Connectors	Impulse MKS(W)-307
	Impulse IE55-1206
	SubConn MC
	Others On Request
Hull Penetrator	Custom Engineered

Model 503

Physical

Diameter	3.000 in (76.2 mm)
Height	2.000 in (50.8 mm) [1]
Assumed Hull Diameter	7.5 in (190.5 mm) [2]
Housing	Plastic, fully potted
Max Depth	6750 dbar (9800 psi) [3]
Weight (air)	Approx. 232 g [4]
Weight (water)	Approx. 150 g [4]
Connections	Power (2), Data (2)

[1] Not including bulkhead connector or hull penetrator
[2] Shroud design can be adapted for other hull diameters
[3] Assumes selection of compatible-range pressure sensor
[4] Varies with customer-selected connector or penetrator

Electrical

Input Power	4.5 VDC to 28 VDC
Power Consumption	12 mA / 60 mW @ 5V
	13 mA / 156 mW @ 12V

Communications and Sampling

Protocol	RS-232, 8-N-1
Speed	9600 to 115,200 baud
Recursive Filtering	0 to 9 samples
Sample Output Rate	Standard 5 Hz
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Temperature

Standard Range	0°C to 30°C
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	SubConn MC
	Others On Request
Hull Penetrator	Custom Engineered

3. Setup and Operation

Installation

The CTD should be mounted on the exterior of the platform in an orientation that maximizes water flow through the cell. The stainless steel thermistor probe is located on the forward end of the sensor. For best performance the forward end of the sensor should align with and point towards the dominant direction of platform motion.

The sensor requires clean DC power at 4.5 – 28 VDC. The conductivity cell is in electrical contact with seawater but is DC isolated from the system power supply to avoid interfering with vehicle ground fault detection circuits. Wiring diagrams detailing the required connections are provided in Section 6 of this document.

Basic Operation

1. Connect the CTD following the appropriate diagram in Section 6.

2. Configure the host computer to communicate at 38,400 baud, no parity, 8 data bits, 1 stop bit.

3. Apply DC power being sure to observe the correct polarity.

Upon application of power data should start streaming immediately in fixed field format.

The data output mode can be identified and modified using the '*d*' command as described below in Section 5. If the sensor has been configured to output data in engineering units ('*d 3*' – see Section 5) and the default column selections have not been changed then the following columnar data should be expected:

Column 1: Temperature (deg C)
Column 2: Conductivity (mS/cm)
Column 3: Salinity
Column 4: Pressure (dbar)
Column 5: Pressure Sensor Temperature (deg C)
Column 6: Density (kg/m3)
Column 7: Sound Speed (m/s)
Column 8: Elapsed time (s)

Example:

```
23.5881 47.6256 31.993 0.31 23.40 1021.499 1527.720 810.20
23.5864 47.6289 31.996 0.34 23.40 1021.504 1527.725 810.70
```

The ‘*d 3* command may be further used to customize the content of this display by toggling the display of individual columns. See Section 5 for details.

In raw data mode (‘*d 1*’) the columnar data output reflects the A/D counts associated with several internal CTD measurements. These raw data are not generally of interest to the end user but may be helpful in diagnosing any irregularities in operation:

Column 1: Offset
Column 2: Temperature 1
Column 3: Temperature 2
Column 4: Conductivity 1
Column 5: Conductivity 2
Column 6: Pressure (dbar)
Column 7: Pressure Sensor Temperature (deg C)
Column 8: Elapsed time (s)

Example:

```
1517863 7332146 7852784 1505930 1517638 0.34 21.90 269.10
1517850 7332808 7852630 1506665 1517709 0.31 21.85 269.70
```

The default sampling / output rate is 5 Hz. This rate can be modified using the “s” command (see Section 5).

It is not necessary to halt the sensor output before removing power.

Flag Values in Engineering (‘d 3’) Output

The most commonly-used output (“d 3”) provides data in engineering units for use by the host platform. A very coarse internal QC is applied to the measured temperature (T) and conductivity (C) before these data are output. This QC corresponds to the following limit check:

```
-5 C        < T <      65 C
0 mS/cm     < C <      75 mS/cm
```

If a measured value is BELOW the lower limit of these ranges it is flagged as: `-11.11`
If a measured value is ABOVE the upper limit of these ranges it is flagged as: `-88.88`

Values derived from temperature and conductivity (salinity, density, sound speed) will be flagged with `-99.99` if either T or C are flagged.

4. Calibration

Temperature

The temperature sensor is calibrated in a high-stability temperature-controlled water bath. During calibration, the bath temperature is varied over the entire sensor operating range, typically 0-30 deg C. Samples of raw output from the CT Sensor are collected simultaneously with bath temperature as measured with a precision temperature bridge. The temperature data is then fit to the sensor raw output using a fourth-order Steinhart-Hart function. The results are plotted and residual errors are noted. The five Steinhart-Hart terms are then entered into the electronics board nonvolatile memory and the calibration is spot checked by running a single point bath comparison against the temperature bridge.

Conductivity / Salinity

The conductivity cell calibration is typically performed at 3 points in large, well-stirred saltwater tanks of known salinity plus a blank corresponding to fresh water. For each data point the sensor is lowered into the bath and allowed to equilibrate until the output is stable and no bubbles are present. A sample of CTD raw data is collected, the water temperature is measured and duplicate water samples are taken for processing with a laboratory salinometer. The results are plotted and residual errors are noted and he calculated coefficients are entered into nonvolatile memory. The calibration is spot checked by comparing against a precision conductivity transfer standard.

Pressure

The Keller pressure sensor was factory-calibrated and contains its own internal calibration constants. The pressure sensor uses its own internal reference thermistor to provide temperature compensation. Information about the pressure sensor including serial number, date of initial calibration and maximum measurement capability is available via the "p" command.

Example:

```
Keller Pressure Transmitter, LD Series
Unique product code: 246365185
Equipment#: 15
Place#: 1
File#: 3759
Mode#: = 1 [0=PR, 1=PA, 2=PAA, 3=undefined]
Date of calibration: 2023.8.31
Pmin: 0.000000 [bar]
Pmax: 100.000000 [bar]
```

5. CTD Command Summary

The commands described below provide interactive control of the sensor functions via serial communications. These operations allow control of baud rate, sample rate and data mode control.

Use the *h* command to halt data output. To restart use the *g* command or cycle the power to the sensor.

When power is applied the sensor will begin streaming data using parameters previously stored in persistent nonvolatile memory. Commands which result in settings that are persistent through power cycles are shown in **boldface**.

A space is required between the single-letter command and any argument. All commands must be terminated by a <CR>.

<u>Examples:</u>

1. List the available commands: `? <CR>`
2. Check the board firmware version: `v <CR>`
3. Change the output mode to raw counts: `d 1 <CR>`
4. Toggle the columnar output of density: `d 3 6 <CR>`
5. Change calibration constant 4 to a value of 1.23e-4: `c 4 1.23e-4 <CR>`
6. Change baud rate to 9600: `b 1 <CR>`

COMMAND	REPLY	FUNCTION
b [br]	None	Set serial baud rate. Default: 3=38,400 1=9,600; 2=19,200; 3=38,400; 4=57,600; 5=115,200
c	Calibration constants	Print list of all calibration constants
c [n] [k]	New c value	Change calibration constant n to value k
d	Data mode	Display current data mode and column assignments
d [mode] [T]	If d3, print list of available data output columns	Set data output mode: 1=raw counts, 2=resistance, 3=engineering units, 4=NMEA. The content of mode=3 output is user-configurable by toggling individual outputs. For example, to toggle output 4: *d34 <CR>*
g	None	GO: Start continuous scan mode
h	None	HALT: Stop continuous scan mode
n	Board S/N	Read board serial number
p	Pressure Sensor	Read the Keller pressure sensor information. Toggles activation of pressure sensor.
v	Firmware Version	Read firmware version
?	Help	Display a summary of available commands.

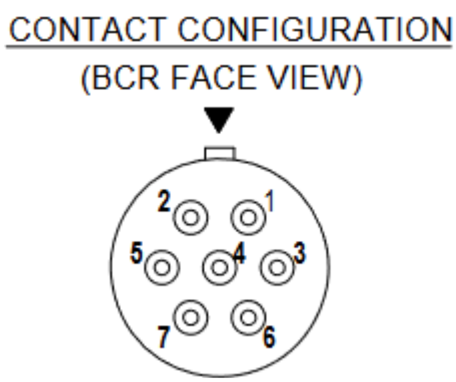
6. Firmware Updates

Coming soon…

The 500 Series CTD Sensors were designed to allow end-user-applied firmware updates utilizing the existing serial communications infrastructure. This capability has been successfully demonstrated and is used routinely in our laboratory. However, a rigorous firmware update procedure suitable for end-user execution is still under development and is not yet mature enough to document. When available, customers will be notified. Firmware updates will be disseminated by NBOSI via email and/or web download.

7. Wiring Diagrams and Pinouts

Impulse MKS(W)-307-CCP



(bulkhead view; male pins)

Pin	Function
1	+VDC (4.5V – 28V acceptable)
2	Ground
3	No Connection
4	Sensor Tx
5	Sensor Rx
6	No Connection
7	No Connection

SubConn MCIL6M

(cable end view; male pins)

Pin	Function
1	+VDC (4.5V – 28V acceptable)
2	Ground
3	No Connection
4	Sensor Tx
5	Sensor Rx
6	No Connection

MKS(W)-307 Lab Interface Cable

1	+VDC	White
2	Ground	Black
1	Sensor Tx	Pink
2	Sensor Rx	Grey
3	Ground	Black

MCIL6M Lab Interface Cable

1	+VDC	Various (check pin!)
2	Ground	Various (check pin!)
1	Sensor Tx	Green
2	Sensor Rx	Orange
3	Ground	White

***NOTE**: Wire colors are subject to change. Always confirm pinout on connector before applying power.*

8. Appendix A: SubConn Connector Care

MacArtney

COAX connector

- Only grease the rubber parts - do not grease coax pin and socket
- Do not mate under water. To be used with locking sleeves only

Bulkhead Connectors - Tightening force

Type	Material	Rec. Torque - Nm
3/8" - 24 UNF	Brass, aluminium	4.0
	Stainless steel, titanium	6.0
	PEEK	2.0
7/16" - 20 UNF	Brass, aluminium	10.0
	Stainless steel, titanium	14.0
	PEEK	4.2
1/2" - 20 UNF	Brass, aluminium	15.0
	Stainless steel, titanium	21.0
	PEEK	5.2
5/8" - 18 UNF	Brass, aluminium	29.0
	Stainless steel, titanium	41.0
	PEEK	10.0
3/4" - 16 UNF	Brass, aluminium	44.0
	Stainless steel, titanium	63.0
	PEEK	15.0
7/8" - 14 UNF	Brass, aluminium	60.0
	Stainless steel, titanium	80.0
	PEEK	20.0
1" - 14 UNF	Brass, aluminium	75.0
	Stainless steel, titanium	100.0
	PEEK	25.0

Recommended oil for pressure balanced systems

- MacArtney recommend DC-200/350 or PMX-200/350 in oil compensated systems

SubConn® Handling instructions

Follow these instructions carefully to ensure correct use of your SubConn® connectors.

Handling

- Connectors must be greased with Molykote 44 Medium before every mating
- Always grease O-rings on BH, BCR and FCR connectors with Molykote 111
- Disconnect by pulling straight out, not at an angle
- Do not pull on the cable and avoid sharp bends at cable entry
- When using a bulkhead connector, ensure that there are no angular loads
- Make sure to apply the recommended torque when tightening bulkhead nuts
- SubConn® connectors should not be exposed to extended periods of heat or direct sunlight. If a connector becomes very dry, it should be soaked in fresh water before use

Scan to access SubConn® greasing and cleaning instruction videos

Greasing products

Greasing and mating above water (dry mate)

- Connectors must be greased with Molykote 44 Medium before every mating
- A layer of grease corresponding to a minimum of 1/10 of the socket depth should be applied to the female connector
- The inner edge of all sockets should be completely covered, and a thin transparent layer of grease left visible on the face of the connector
- After greasing, fully mate the male and female connector in order to secure optimal distribution of grease on all pins and in the sockets
- To confirm that grease has been sufficiently applied, de-mate and check for grease on every male pin. Then re-mate the connector

Greasing and mating under water (wet mate)

- Connectors must be greased with Molykote 44 Medium before every mating
- A layer of grease corresponding to approximately 1/3 of a socket depth should be applied to the female connector
- All sockets should be completely sealed, and a transparent layer of grease left visible on the face of the connector
- After greasing, fully mate the male and female connector and remove any excess grease from the connector joint

Cleaning products

- * General cleaning and removal of any accumulated sand or mud on a connector should be performed using spray based contact cleaner (isopropyl alcohol)
- New grease must be applied again prior to mating

Use of Loctite

- Always use Loctite 5910 to lock non-metallic (PEEK) connectors
- For locking metallic connectors, the use of Loctite 243 is recommended

9. Revision History

REVISION	DATE	DESCRIPTION	APPROVED
1.0	04/2024	Initial	DF
1.1	04/2024	Updated UI menu items and examples	DF
1.2	05/2024	New section regarding future availability of firmware updates. New subsection describing flag values in engineering data output. Various changes to fonts and formatting for readability.	DF
1.3	07/2025	Added pinout for MCIL6M interface cable. Command for pressure sensor activation toggle added. Included additional sensor models covered by this document.	DF

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