100 SERIES CT SENSORS

Models 101, 102, 103

OPERATION AND CARE MANUAL

Revision 3.2, 03/2024

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

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CT SENSOR CARE

This Conductivity-Temperature 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 CT cell 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 CT Sensor consists of two components:

    - An electronics board located inside the vehicle pressure hull, and
    - The conductivity-temperature cell mounted on the vehicle exterior.

    These two sensor components were calibrated as a matched pair. Calibration information for the CT Sensor resides on the electronics board. Please return both components to NBOSI for service or calibration.

- Occasional 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 be completed within 2 weeks of receipt of both sensor components in serviceable condition.

IMPORTANT: A CT Sensor 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 performance when deployed. Temperature measurements should appear reasonable at all times.

1. The NBOSI CT Sensor

Overview

The NBOSI CT Sensor consists of an internal field, four-electrode conductivity cell with an integral pressure-protected thermistor and a self-referencing electronics board. Optimized for use on mobile platforms, the NBOSI CT cell is free-flushing, fast-responding, quiet, vibration-free, rugged, low-power and insensitive to mounting location. The conductivity cell 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 of these properties must be measured very carefully in order to accurately determine salinity and related ocean parameters such as sound speed and ocean density.

Temperature is measured by the NBOSI CT Sensor in a conventional manner using a pressure-protected, ultra-stable micro thermistor. The fast-responding temperature probe is located in the center of the conductivity cell so that temperature and conductivity 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:

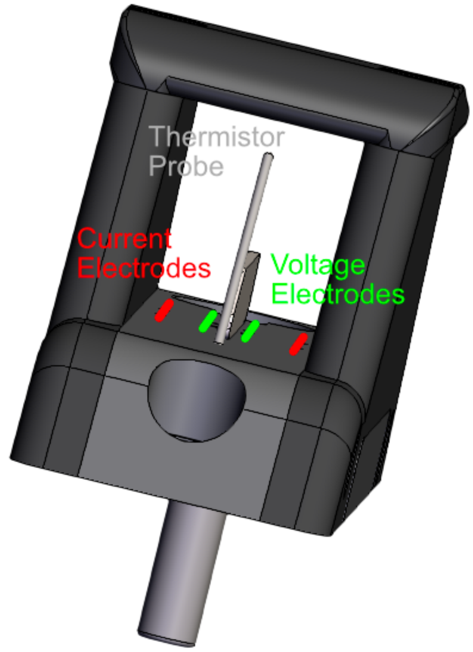
$$G = 1 / R = I / V$$

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):

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



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 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 CT Sensor immersed in a non-conductive medium will not return a meaningful conductivity measurement. <u>Air is non-conductive</u>. Conductivity measurements performed in air (i.e. testing on deck or in the lab) have no relation to performance when deployed. Temperature measurements should appear reasonable at all times.

2. Specifications

THE CTD FOR YOUR AUV

SMALL. ACCURATE. RUGGED. RELIABLE.

NBOSI ocean sensors

100 SERIES CT SENSORS

TEMPERATURE • SALINITY

Research-quality temperature and salinity measurements from a compact and rugged sensor designed specifically to integrate with your mobile platform. Our original conductivity-temperature (CT) sensor consists of an externally-mounted CT cell and an internally-mounted precision electronics board. Available in several rectangular and cylindrical form factors to suit your application. Connect via cable with a user-specified connector.

TECHNICAL SPECIFICATIONS

Physical

Housing	Plastic, fully potted
Max Depth	6750 dbar (9800 psi)
PCB Length	6.00 in (152.4 mm)
PCB Width	1.85 in (47.0 mm)
PCB Height	0.75 in (19.1 mm)
PCB Weight (air)	76 g

Model 101 Rectangular CT Sensor

Length	5.50 in (139.7 mm)
Width	1.20 in (30.5 mm)
Height	1.55 in (39.4 mm)
Typical Weight (air)	188 g

Model 102 Rectangular CT Sensor

Length	5.29 in (134.4 mm)
Width	1.16 in (29.5 mm)
Height	1.55 in (39.4 mm)
Typical Weight (air)	180 g

Model 103 Cylindrical CT Sensor

Diameter	3.00 in (76.2 mm)
Height	2.00 in (50.8 mm)
Assumed Hull Diameter	7.5 in (190.5 mm)
Typical Weight (air)	240 g

Electrical

Input Power	12 VDC +/- 10%
Power Consumption	Max 30 mA / 36 mW @12V

Communications and Sampling

Protocol	RS-232, 8-N-1
Speed	9600 to 19,200 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	0.01 mS/cm
Resolution	0.0001 mS/cm
Electrodes	99.95% pure platinum

Options

Modular Connectors	Impulse MKS(W)-307 SubConn MCIL6M, MCIL8M Others On Request

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3. Setup and Operation

Installation

The plastic CT cell with attached cable 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 cell. For best performance the forward end of the cell should point towards the dominant direction of platform motion.

The accompanying electronics board should be securely mounted in a dry area within the platform's pressure housing. The board requires clean DC power at 12 VDC +/- 10%. A DC/DC converter on the board generates the +/-5 VDC required by the board electronics. The conductivity cell is in electrical contact with seawater but is DC isolated from the system power supply to avoid interfering with the vehicle ground fault detection circuits.

Wiring diagrams detailing the required connections are provided in Section 6 of this document.

Basic Operation

1. Connect an RS-232 serial jumper to the data connector (J4) on the CT circuit board and connect to a serial port on the host computer. See Section 6 for details.

2. Connect the CT cell to the circuit board following the appropriate diagram in Section 6.

3. Configure the host computer to communicate at 9600 baud, no parity, 8 data bits, 1 stop bit.

4. Apply 12 VDC power to the 2 pin connector on the circuit board 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 modified using the '*d*' command as described below in Section 5. If the sensor has been configured to output data in engineering units ('*d3*' – see Section 5) then the following columnar data should be expected:

Column 1: Temperature (deg C)
Column 2: Conductivity (mS/cm)
Column 3: Salinity
Column 4: Elapsed time (tenths of seconds)

Example:

```
25.52289 52.61953 34.2721 40464
25.52289 52.62044 34.2728 40468
```

The ‘*d3*’ command may be further used to customize the content of this display. See Section 5 for details.

In raw data mode (‘*d1*’) the columnar output reflects the A/D counts associated with several internal CT Sensor 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: Full-scale reference resistance
Column 2: Half-scale reference resistance
Column 3: Zero-scale reference resistance
Column 4: Temperature
Column 5: Conductivity Current
Column 6: Conductivity Voltage
Column 7: Pressure (optional)
Column 8: Circuit Board Temperature
Column 9: Elapsed time (tenths of seconds)

Example:

```
15911676  8067752   223435 10698810 11782702  5839450   222823    0 40432
15911747  8067776   223423 10698811 11782611  5839420   222298    0 40434
15911810  8067740   223449 10698816 11782653  5839450   223247    0 40436
```

The default sampling / output rate is 5 Hz. The time between samples can be adjusted using the ‘*j*’ command (Section 5).

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

Please refer to the CT Sensor Care page at the front of this document for appropriate post-deployment cleaning.

4. Calibration

Temperature

The temperature sensor is calibrated in a high-stability temperature-controlled water bath. During calibration, the bath temperature is carefully 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 as calibration coefficients C0 – C4 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 CT 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. The calculated coefficients are entered into the CT board nonvolatile memory as calibration coefficients C5 and C6. The calibration is spot checked by comparing against a precision conductivity transfer standard.

5. CT Sensor Command Summary

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

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

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

All commands must be terminated by a <CR>. No spaces are permitted between the command letter and any subsequent numerical value.

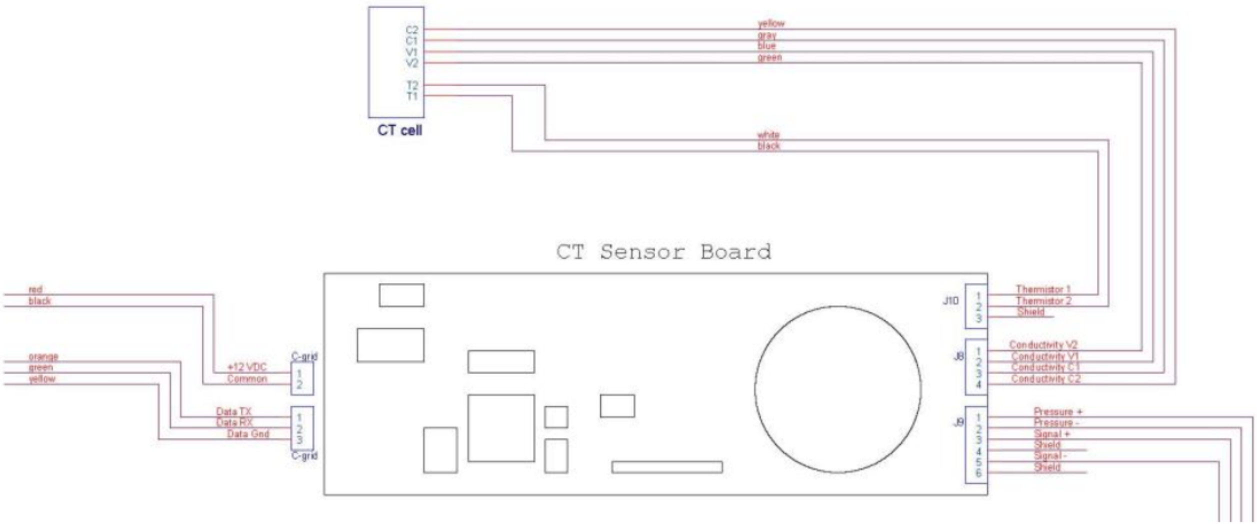
Examples:

1. To check the board firmware version: *v <CR>*
2. To change the baud rate to 38,400 baud: *b2 <CR>*
3. To change calibration constant 4 to a value of 1.23e-4: *C41.23e-4 <CR>*

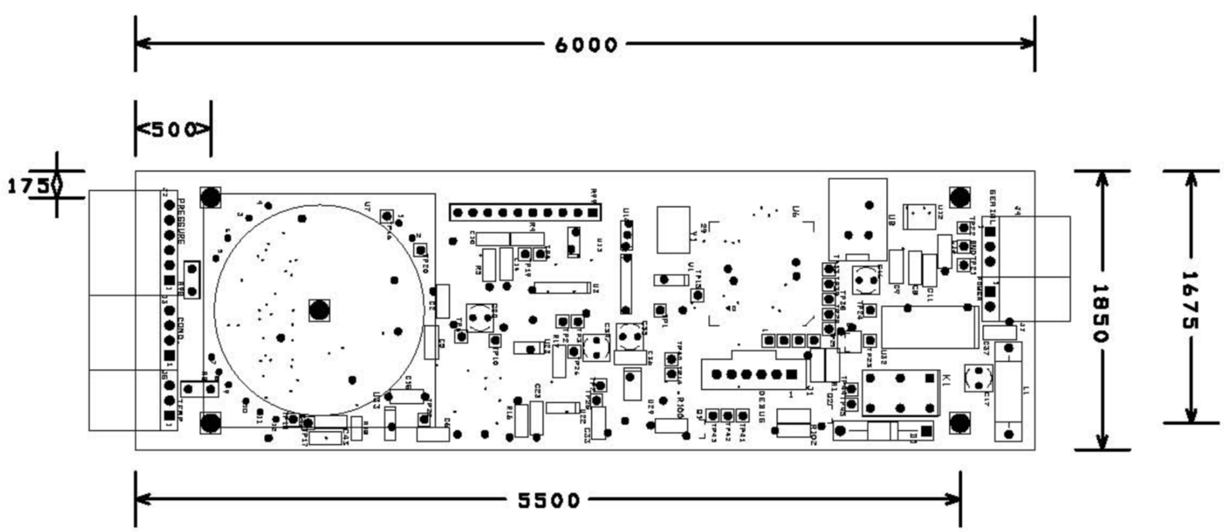
COMMAND	REPLY	FUNCTION	DEFAULT
b [br]	None	Set baud rate: 0=9600, 1=19.2k, 2=38.4k	0 (9600)
c	Calibration constants	Print list of all calibration constants	
c [n][k]	New c value	Change calibration constant n to value k	
d [mode][T]	If d3, print list of available data output columns	Set data output mode: 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>*	3
g	None	GO: Start continuous scan mode	
h	None	HALT: Stop continuous scan mode	
j [t]	None	Set time t (0.1 s) between samples.	2 (5 Hz)
n [sn]	Board S/N	Read/write board serial number	
T	Current Tick	Read the time tick counter	
v	Firmware Version	Read firmware version	
z	None	Reset time tick counter to zero	
?	Help	Display a summary of available commands. Note that some of the commands shown are intended for factory use only.	

6. Wiring Diagrams and Pinouts

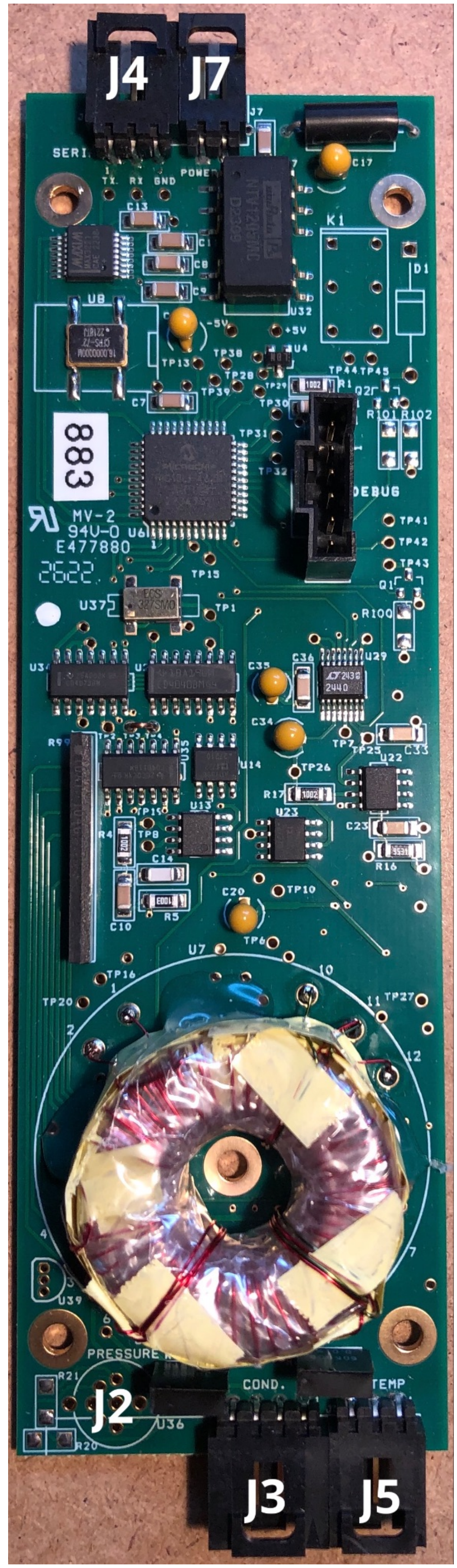
CT Sensor Board Schematic



CT Sensor Board Dimensions



CT Sensor Board Connections



J5 (Thermistor)

Pin	Function
1	Thermistor 1
2	Thermistor 2
3	Shield

J3 (Conductivity Electrodes)

Pin	Function
1	Conductivity Voltage 1
2	Conductivity Voltage 2
3	Conductivity Current 2
4	Conductivity Current 1

J2 (Optional Pressure Sensor)

Pin	Function
1	Pressure +
2	Pressure -
3	Signal +
4	Shield
5	Signal -
6	Shield

J4 (Data)

Pin	Function
1	TX
2	RX
3	Ground

J7 (Power)

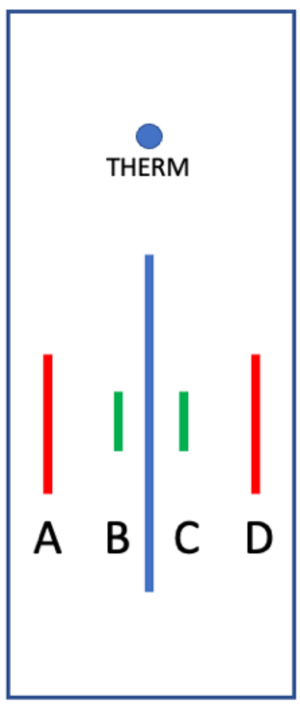
Pin	Function
1	Power +
2	Power -

CT Sensor Pinouts

Your CT sensor was custom configured with one of several connector options. Please be sure to correctly identify your connector before proceeding.

Where available, connector pinouts are provided with reference to the connector and/or the corresponding bulkhead connector. To avoid wiring errors please use the most appropriate drawing and always confirm connections by pin number before applying power.

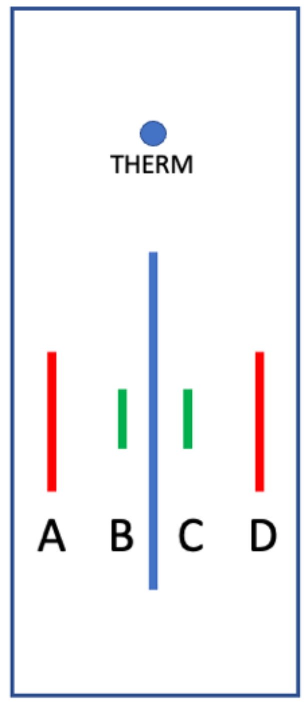
The arrangement of electrodes relative to the sensor body and the thermistor is shown in the rectangular diagram both below and accompanying the pinout charts which follow. While it is possible to confirm correct connections by testing continuity between the appropriate pins and electrodes, please take care to avoid scratching or otherwise damaging the electrodes with your test probe.



SubConn MCIL8M

(cable end view)

Pin	Board	Function	Electrode
1	J3 - 4	Conductivity C1	D
2	J3 - 3	Conductivity C2	A
3	J3 - 2	Conductivity V2	B
4	J3 - 1	Conductivity V1	C
5	J5 - 2	Thermistor 2	
6	J5 - 1	Thermistor 1	
7	NC		
8	NC		

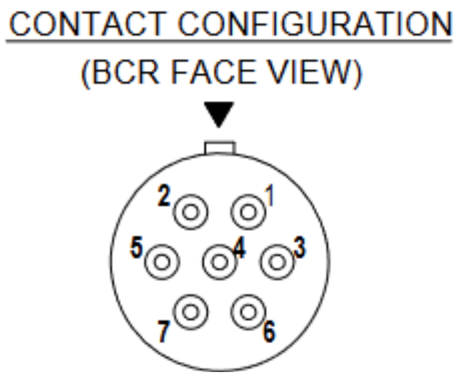


SubConn MCIL6M

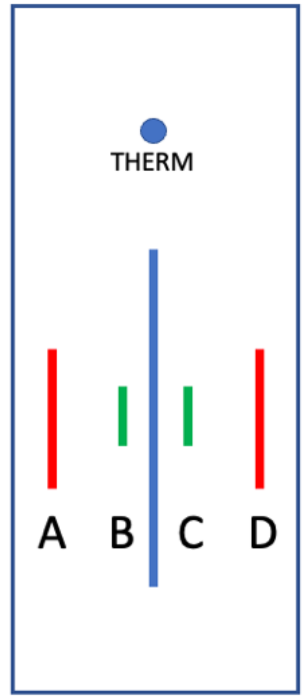
(cable end view)

Pin	Board	Function	Electrode
1	J5 - 1	Thermistor 1	
2	J5 - 2	Thermistor 2	
3	J3 - 1	Conductivity V1	B
4	J3 - 2	Conductivity V2	C
5	J3 - 3	Conductivity C2	D
6	J3 - 4	Conductivity C1	A

Impulse MKS(W)-307-CCP

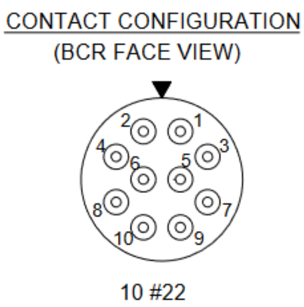


(bulkhead male pins)



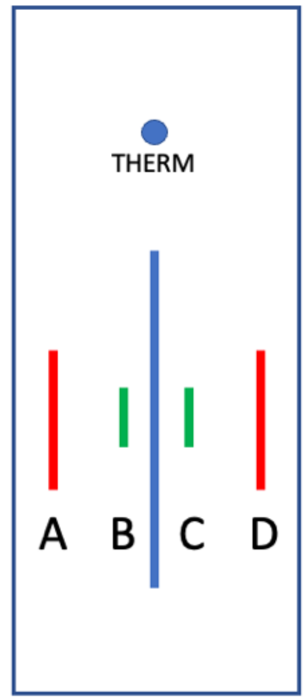
Pin	Board	Function	Electrode
1	J5 - 1	Thermistor 1	
2	J5 - 2	Thermistor 2	
3	J5 - 3	Shield	
4	J3 - 1	Conductivity V1	C
5	J3 - 2	Conductivity V2	B
6	J3 - 3	Conductivity C2	A
7	J3 - 4	Conductivity C1	D

Impulse MKA(W)-3L10-CCP



(Bulkhead male pins)

Pin	Board	Function	Electrode
1	NC	NC	
2	NC	NC	
3	NC	NC	
4	J5 - 1	Thermistor 1	
5	J5 - 2	Thermistor 2	
6	J3 - 1	Conductivity V1	C
7	J3 - 2	Conductivity V2	B
8	J3 - 3	Conductivity C2	A
9	J3 - 4	Conductivity C1	D
10	NC	NC	



7. Appendix A: SubConn Connector Care

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.

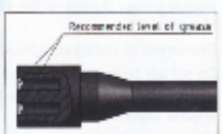
Handling

- 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

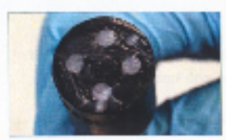
Greasing products

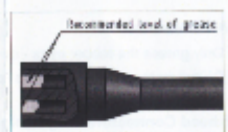
Greasing and mating above water (dry mate)



- 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

8. Revision History

REVISION	DATE	DESCRIPTION	APPROVED
3.0	01/2024	Initial rewrite with additional content, new wiring diagrams and updated formatting.	DF
3.1	02/2024	Expanded to include all current Series 100 CT Sensors	DF
3.2	03/2024	Updated Specifications section to match current brochure. Added SubConn connector care guidelines.	DF