NBOSI-CT Operation and Calibration Manual

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Introduction
The CT sensor board is designed to interface to a 4 electrode conductivity cell, and an ultrastable thermistor. By default, the serial port outputs data as Temperature and Conductivity at a 5 Hz sample rate and a baud rate of 9600-N-8-1. A "fin" style, internal field conductivity cell with integral pressure-protected thermistor is cabled to a 4-pin connector for conductivity and 3-pin connector for temperature. 12V DC power and bi-directional serial communication connectors are provided at the other end of the circuit board.

Setup and Operation
Connect an RS-232, serial port jumper to the comms connector on the CT circuit board and connect to a PC. Start a terminal emulation program on the PC with serial settings 9600 baud N-8-1. Apply 12 VDC power to the 2 contact connector. The data should start streaming in fixed field format with temperaure in the first column in units of degrees C, conductivity in the second column in units of mmhos/cm and pressure in the last column in units of tenths of seconds.

The data output mode can be modified using the 'd' command. In processed data mode, individual columns can be toggled on and off with the 'd3' command described below. The following is a sample of typical CT data in the default data mode:

20.46307 43.28130 14230
20.46329 43.28116 14232
20.46329 43.28129 14234
20.46310 43.28085 14236
20.46319 43.28131 14238
20.46310 43.28150 14240
20.46316 43.28198 14242

The columns above are:
Temperature, Conductivity, Elapsed time in 0.1 sec.

Any of the variable can be toggled off or on using the d3 command, in addition, salinity can be listed as well. That is, "d33 (return)" will toggle on the salinity listing, repeating that will toggle off the salinity. 'd34 (return)' will toggle off the time listing.

The output data mode can be changed to output raw data in counts using the 'd1' command. The following is a sample of raw data output.

```
data(0)   data(1) data(2) data(3) data(4) data(5)data(6)data(7)time
15778500 8003236  228843 9997376 8912291 5423793  229534 527 14060
15778458 8003259  228846 9997387 8912351 5423799  228848 527 14062
15778473 8003264  228840 9997380 8912304 5423896  229210 525 14064
15778544 8003234  228843 9997382 8912409 5423854  229216 525 14066
15778486 8003253  228868 9997403 8912336 5423784  228828 527 14068
15778476 8003292  228858 9997359 8912266 5423870  229410 525 14070
15778499 8003241  228848 9997385 8912295 5423786  229450 525 14072
```

The columns are:
Full-scale-/Half-scale-/Zero-scale-reference/Temperature/Conductivity current/Conductivity voltage/Pressure (NA)/Board Temp/Time (0.1 s)

Power Specifications

DC power at 12 VDC +/- 10% is supplied to the CT board. A DC/DC converter on the CTD board generates the +/-5VDC required by the board electronics. A fully populated board draws about 30 mA independent of sample rate. 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.

Calibration Procedure

The thermistor temperature sensor is calibrated in a high stability temperature-controlled bath. During calibration, the bath temperature is varied over 6 discrete points covering the range 0C – 25C. At each point a sample of CT raw data is collected and the temperature of the bath is measured with a precision temperature bridge. The temperature data is then fit to the sensor raw output using a Steinhart-Hart type cubic function. Several steps go into this procedure, including correction of any electronic drifts by scaling of the output with the reference measurement channels. The temperature is obtained using the equation

$$1/T_{Kelvin} = C0 + C1 \ln(R_T) + C2 \ln (R_T)^2 + C3 \ln (R_T)^{3} + C4 \ln (R_T)^4$$

Where R is the reference scaled output of the temperature channel and T_{Kelvin} is the absolute temperature on the Kelvin scale. Conversion to Celsius involves subtraction of 273.15 ($T_{Celsius}$ = T_{Kelvin} − 273.15). R_T is obtained by scaling the raw temperature output by the full scale and zero references (see data output discussion above), (R_T = (data(3) − data(2))/ (data(0) − data(2))), where data(0) refers to the first raw data channel (full sale reference), data(1) is the second raw data channel (½ scale reference) etc.

The results are plotted and residual errors are noted. The 5 Steinhart-Hart terms are then entered into the CTD board EEPROM memory as C0 – C4 and the calibration is spot checked by running a single point bath comparison against the temperature bridge.

The conductivity cell calibration is performed at 2 points typically at salinities of 35 psu and 20 psu in large, well-stirred salt water tanks. The cell should be linear with conductivity so 3 points (including fresh water) are sufficient for an accurate calibration. For each data point the sensor is lowered into the bath and allowed to equilibrate with the bath for a few minutes or longer until the data output is stable. Some CT raw data is collected, the water temperature is measured and a water sample is taken for processing with a laboratory salinometer. The conductivities calculated from the processed bath salinities are 2 point linear-fit to the CT output data. The calculated coefficients are entered into the CT board EEPROM memory as C5 and C6. The calibration is checked using both a freshwater and a seawater sample and comparing against a precision conductivity transfer standard. Since the Conductivity sensor will normally output near zero for fresh water, the C5 offset term should be close to zero.
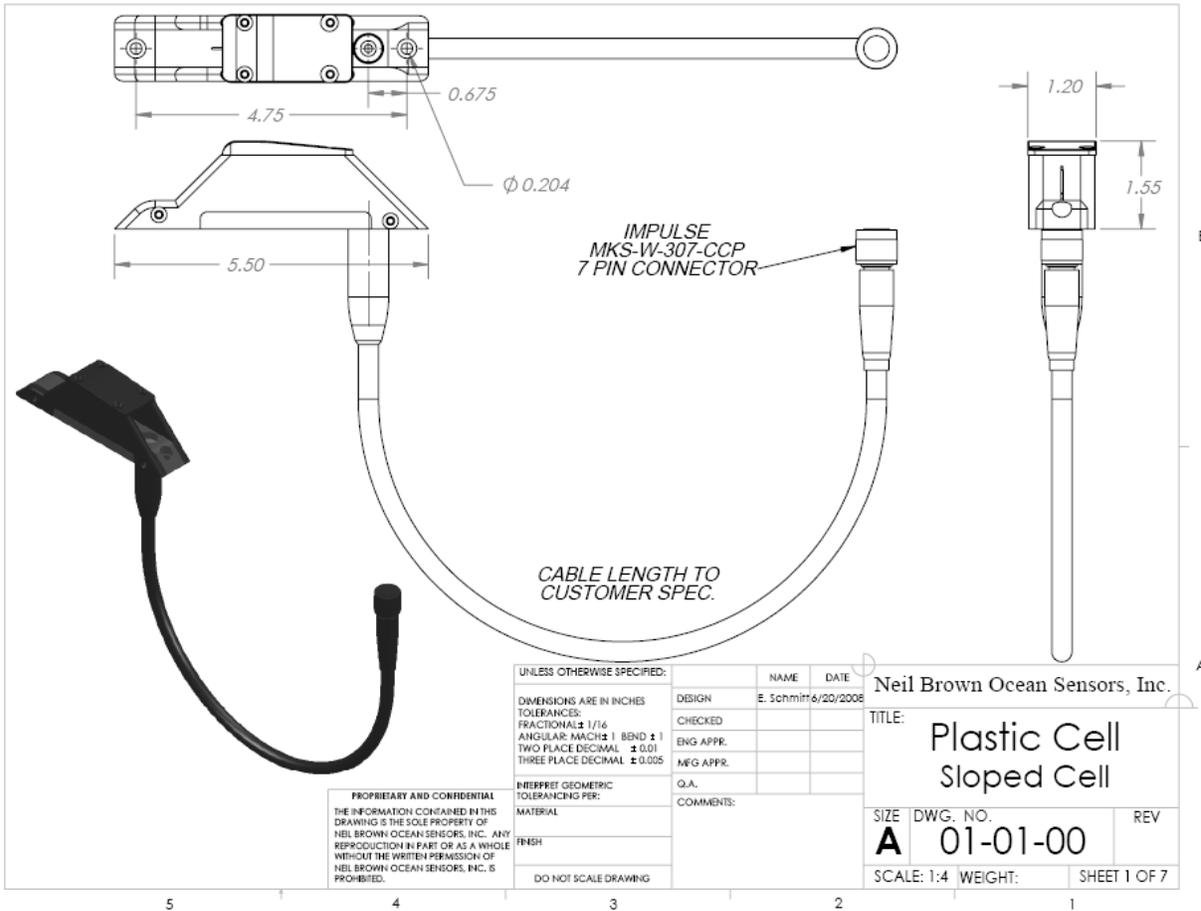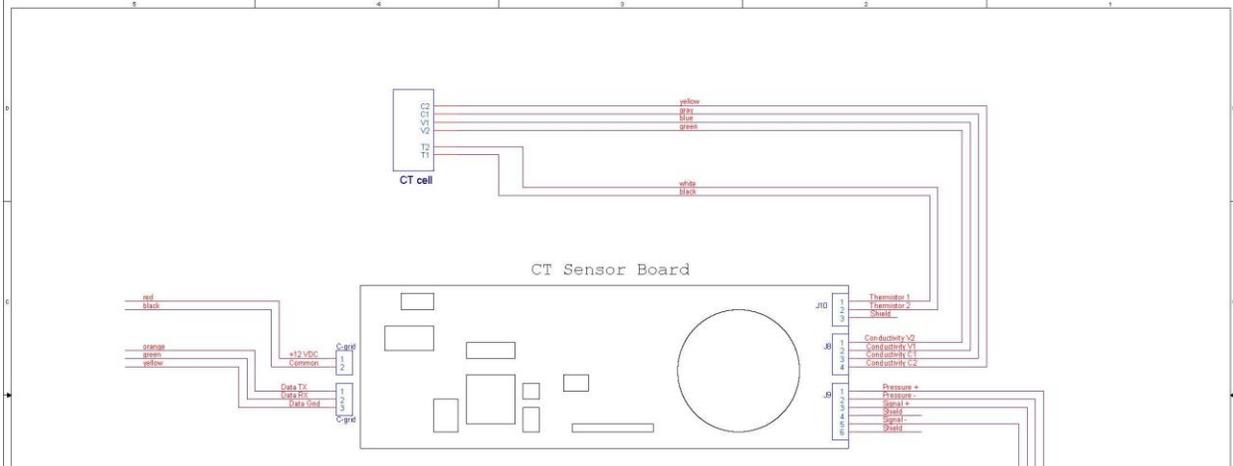
CT Command Protocol

The CT command protocol provides interactive control of the sensor board functions via serial communications. These operations allow control of baud rate, sample rate and data mode control. All commands must be terminated by a <CR>. Some commands generate replies as described below. Commands which are persistant through power cycles are shown in boldface. Most of the commands below are for engineering and are included for reference only.

CT Command Summary:

Command	Reply	Function
a [CR]	none	Read data from a/d converter
b [br] [CR]	none	Set baud rate - br = 0 (9600) *default*, br = 1 (19.2k), br = 2 (38.4k)
c [n][k][CR	New c value	Change calibration constant 'Cx' to value 'n', eg. 'c4 38.47[CR]' changes the C4 constant (conductivity cell constant) to 38.47. **Cal formulas:** $T_{Celsius} = T_{Kelvin} - 273.15$ $1/T_{Kelvin} = C0 + C1\ \ln(\ R_T\ ) + C2\ \ln(\ R_T\ )^2 + C3\ \ln(\ R_T\ )^3 + C4\ \ln(\ R_T\ )^4$ where $R_T = (data(3) - data(2))/\ (data(0) - data(2))$ $C = C5 + C6*\ C\_data$ where $C\_data = (data(4)-dat(2))/(data(5)-data(2))$

		Typical cal constants: Constant 0 is 2.939890e-03 Constant 1 is -6.236912e-04 Constant 2 is 1.505019e-04 Constant 3 is -1.174193e-05 Constant 4 is 3.521871e-07 Constant 5 is -8.400000e-02 Constant 6 is 2.550400e+01
d [md][CR]	none	Set data output mode: 1-raw, 2-resistance, 3-custom (T,C,S, Time)
g [CR]	none	Start continuous scan mode
h [CR]	"Output stopped"	Halt continuous scan mode
i [sample rate][CR]	none	Set a/d sample rate from 0 to 15. Default is "6" equivalent to 10 samples per second (do not change "i". Use "j" command.
j [tenths of a second][CR]	none	Set time between samples, eg. 'j 2[CR]' changes the sample rate to 5 Hz
n [s/n][CR]	Board S/N	Read/write board S/N
s FF [CR]	Switch state =	Set the switch state - Command syntax : [s][Hex switch state][CR]
t [CR]	Time tick=	Read the time tick counter
v [CR]	Version - date	Read the firmware version
w [0/1] [CR]	none	Start single channel dwell mode
z [CR]	none	reset tick counter to zero
? [CR]	*Command list*	print help message a [CR] - read data from a/d converter b [br][CR] - Set baud rate br = 0 (9600), br = 1 (19.2k), br = 2 (38.4k)

		c [n][k][CR] - change calibration constant 'n' to value 'k' d [md][CR] - data output mode: md=1-raw, 2-resistance, 3-custom (P,T,C) g [CR] - start continuous scan mode h [CR] - halt continuous scan mode i [sample rate][CR] - set a/d sample rate from 0 to 15 j [tenths of a second][CR] - set time between samples k [samples][CR] - set number of samples collected per period m [minutes][CR] - set number of minutes between sampling periods n [s/n][CR] - read/write Board S/N o [0/1][CR] - change cover position to OFF/ON p [0/1][CR] - motor mode OFF/ON s [FF][CR] - Set the switch state - Command syntax : [s][Hex switch state][CR] t [CR] - Read the time tick counter v [CR] - Read the firmware version w [0/1][CR] - start single channel dwell mode z [CR] - reset tick counter to zero ? [CR] - print help message

CT cell

yellow
gray
blue
green

white
black

CT Sensor Board

red
black

orange
green
yellow

+12 VDC
Common
C-gnd
1
2

Data TX
Data RX
Data Gnd
1
2
3
C-gnd

J10
1
2
3
Thermistor 1
Thermistor 2
Shield

J8
1
2
3
4
Conductivity V2
Conductivity V1
Conductivity C1
Conductivity C2

J9
1
2
3
4
5
Pressure +
Pressure -
Signal +
Shield
Signal -
Shield

4.75

0.675

⌀ 0.204

5.50

IMPULSE
MKS-W-307-CCP
7 PIN CONNECTOR

1.20

1.55

CABLE LENGTH TO
CUSTOMER SPEC.

UNLESS OTHERWISE SPECIFIED:		NAME	DATE	Neil Brown Ocean Sensors, Inc.		
DIMENSIONS ARE IN INCHES	DESIGN	E. Schmitt	6/20/2008	TITLE:		
TOLERANCES:	CHECKED			**Plastic Cell**		
FRACTIONAL ± 1/16				Sloped Cell		
ANGULAR: MACH ± 1 BEND ± 1	ENG APPR.					
TWO PLACE DECIMAL ± 0.01	MFG APPR.					
THREE PLACE DECIMAL ± 0.005						
INTERPRET GEOMETRIC	Q.A.					
TOLERANCING PER:	COMMENTS:			SIZE	DWG. NO.	REV
MATERIAL				**A**	01-01-00	
FINISH				SCALE: 1:4	WEIGHT:	SHEET 1 OF 7

DO NOT SCALE DRAWING

1675

1850

6000

5500

500

175

SERIAL

POWER

J4

J7

L1

C37

C17

TP27 GND TP23

U12

C11

C9

C7

U8

K1

U32

TP24

TP26

TP44 TP45

R1

R102

J1

DEBUG

U6

TP41

TP42

TP43

Y1

U1

TP15

P1

C33

U11

U29

R100

TP18 TP19

R99

U13

U2

TP25

U22

TP3 TP26

TP2

R17

U23

C23

R4

TP19

C34

R16

C30

R3

TP16

C36

TP20

C2

C5

C6

C16

U33

R18

C43

TP17

J2

PRESSURE

COND.

TEMP

U7