DATA PRODUCT SPECIFICATION FOR PRESSURE (DEPTH)

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Document Control Sheet

Version	Date	Description	Author
0-01	2011-10-04	Initial Release	M. Vardaro
0-02	2011-11-04	Changed from absolute pressure to sea pressure, included details for hex conversion and scaling for all make/models, and updated to match ATBD Template.	S. Webster
0-03	2011-11-14	Small updates to conform with other CTD L1 data products.	S. Webster
0-04	2011-11-28	Removed GPCTD because it will be processed internally on the glider and AUV.	S. Webster
0-05	2011-12-12	Renamed to Data Product Specification and updated to match Data Product Spec. Outline.	S. Webster
0-06	2012-01-03	Updated language as per comments from 5-Day Review.	S. Webster
1-00	2012-01-13	Initial Release.	E. Chapman
1-01	2012-07-26	Changed to OutputFormat 0 for SBE 16plusV2 as per ECR 1300-00273.	S. Webster, G. Proskurowski
1-02	2012-09-24	Formatting, copy edits	E. Griffin

Signature Page

This document has been reviewed and approved for release to Configuration Management.

OOI Senior Systems Engineer: ______________________________

Date:2012-01-13

This document has been reviewed and meets the needs of the OOI Cyberinfrastructure for the purpose of coding and implementation.

OOI CI Signing Authority:______________________________

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Table of Contents

1 Abstract

This document describes the computation used to calculate the OOI Level 1 Pressure (Depth) core data product, which is calculated using data from the Sea-Bird Electronics conductivity, temperature and depth (CTD) family of instruments. This document is intended to be used by OOI programmers to construct appropriate processes to create the L1 pressure product.

2 Introduction

2.1 Author Contact Information

Please contact Sarah Webster (swebster@oceanleadership.org) or the Data Product Specification lead (DPS@lists.oceanobservatories.org) for more information concerning this document..

2.2 Metadata Information

2.2.1 Data Product Name

The OOI Core Data Product Name for this data product is

- PRESWAT

The OOI Core Data Product Descriptive Name for this data product is

- Pressure (Depth)

2.2.2 Data Product Abstract (for Metadata)

The OOI Level 1 Pressure (Depth) core data product is computed by converting raw hexadecimal pressure data from the conductivity, temperature and depth (CTD) family of instruments into decibars.

2.2.3 Computation Name

Not required for data product algorithms.

2.2.4 Computation Abstract (for Metadata)

This algorithm computes the OOI Level 1 Pressure (Depth) core data product, which is computed by converting raw hexadecimal pressure data from the conductivity, temperature and depth (CTD) family of instruments into decibars.

2.2.5 Instrument-Specific Metadata

There are no instrument-specific metadata that need to be added for the algorithm.

2.2.6 Synonyms

Synonyms for this data product are

- Water pressure
- Sea pressure
- Relative pressure (if pressure is measured relative to 1 atm)

2.2.7 Similar Data Products

Similar products that this may be confused with are

- Gauge pressure
- Absolute pressure
- Relative pressure (if pressure is measured relative to pressure other than exactly 1 atm)

Additional information regarding the similar products can be found at the TEOS-10 website (http://www.teos-10.org) and references listed in Section 2.5.2.

2.3 Instruments

The CTD Processing Flow document (DCN 1342-00001) describes the instrument classes and make/models that produce the data from which the L1 pressure data product is calculated. This document also describes the flow of data from the CTDs through all of the relevant QC, calibration, and data product algorithms.

Note that the raw data from the GPCTD make/model—the CTDs on board the gliders and autonomous underwater vehicles (AUVs)—are processed onboard the vehicles with proprietary software from the vehicle vendors. These data are presented already in decimal format in appropriate units (°C, Siemens/meter, decibars), therefore processing raw hexadecimal data from the CTDGP is not included in the algorithm described in this document.

Please see the Instrument Application in the SAF for specifics on instrument locations and platforms.

2.4 Literature and Reference Documents

Sea-Bird (2009), SBE 16*plus* V2 SEACAT User's Manual. Manual Version #005.

Sea-Bird (2011), SBE 37-IM MicroCAT User's Manual. Manual Version #027.

2.5 Terminology

2.5.1 Definitions

The following terms are defined here for use throughout this document. Definitions of general OOI terminology are contained in the Level 2 Reference Module in the OOI requirements database (DOORS).

Sea pressure: absolute pressure less the pressure of one standard atmosphere

Absolute pressure: pressure as measured by the instrument in situ (includes the effect of atmospheric pressure on the surface of the water)

Gauge pressure: absolute pressure less the absolute pressure of the atmosphere at the time of the instrument's calibration

2.5.2 Acronyms, Abbreviations and Notations

General OOI acronyms, abbreviations and notations are contained in the Level 2 Reference Module in the OOI requirements database (DOORS).

There are no other acronyms, abbreviations, or notations for this document.

2.5.3 Variables and Symbols

The following variables and symbols are defined here for use throughout this document.

P_L1	L1 pressure data product
p_dec	instrument pressure data in decimal
p_hex	instrument pressure data in hexadecimal
t_dec	thermistor at pressure sensor data in decimal
t_v	thermistor at pressure sensor data in decimal volts
P_rng	pressure range of the instrument (factory-set calibration)

3 Theory

3.1 Description

Absolute pressure is one of the variables directly measured by CTD instruments and is calculated from the raw hexadecimal data provided by the instrument. The SBE 16plusV2 model will output “raw frequencies and voltages in hexadecimal" as it is referred to in the Sea-Bird manuals. The 37IM model will output “engineering units in Hex”. This requires that the L0 pressure data product, which is a hexadecimal string, be converted to decimal and scaled according to the CTD manual (different for each CTD make/model). Conversion and scaling (described herein) results in sea pressure in decibars (dbar). Note that the data product is named Pressure (Depth) because, though depth is not calculated, 1 dbar in pressure is approximately equal to one meter in depth.

It is worth noting that sea pressure is not exactly the same as the hydrostatic pressure of the water column. The CTD’s internal pressure sensor measures absolute pressure: the pressure of the water column (hydrostatic pressure) plus the current atmospheric pressure at the sea surface. Sea pressure is calculated by the CTD’s internal software by subtracting one standard atmosphere from the measured absolute pressure. Because the actual atmospheric pressure is not necessarily exactly one standard atmosphere, sea pressure is not necessarily identical to the hydrostatic pressure. Also, Sea-Bird uses a slightly different constant for one atmosphere: according to their manuals, the CTDs internal software converts absolute pressure to sea pressure by subtracting 14.7 psi * 0.689476 dbar/psi = 10.1352972 dbar. This is different from the TEOS-10 standard atmospheric pressure of 101325 Pa or 10.1325 dbar. Sea pressure is the pressure measurement that is provided by the CTD (in hex and with some scaling) when the output format is set to deliver the data in “engineering units”, as it is for the 37 IM CTDs. Therefore **to back calculate absolute pressure in psia from dbar for the 37 IM data**, use the Sea-Bird-specified conversion:

$$P_{37IM}\text{ (psia)} = [P_{37IM}\text{ (dbar)} / 0.689476] + 14.7$$

The conversion between psia and dbar for the 16plusV2 follows the TEOS-10 conventions using a “standard atmosphere”:

$$P_{16plusV2}\text{ (dbar)} = [0.689475729 * P_{16plusV2}\text{ (psia)}] - 10.1325$$

3.2 Mathematical Theory

The CTD is received by OOI calibrated from Sea-Bird before its initial deployment. Post-initial deployment calibration checks and/or recalibrations will be performed at Sea-Bird. The factory-calibrated pressure is scaled into efficient, memory-saving hexadecimal string aboard the CTD instrument. This hexadecimal string, after it is separated from the rest of the data stream by the CTD driver, is the L0 pressure data product. The parsing instructions for the instrument hexadecimal string can be found in Appendix A.

The L1 pressure data product algorithm takes the L0 pressure data product and converts it into decibars (dbar). L0 Pressure is a hexadecimal string. Once the hexadecimal string is converted to decimal, several simple calculations are necessary to produce the correct decimal representation of the data in decibar. The scaling function (and the conversion to decimal in one case) differs by CTD make/model as described in Section 4.3.

3.3 Known Theoretical Limitations

No known theoretical limitations.

3.4 Revision History

No revisions to date.

4 Implementation

4.1 Overview

The conversion from the L0 pressure data product to the L1 data product consists of a simple conversion from hex to decimal and a scaling operation. Existing code to perform these operations is not available, but modified examples from the CTD manuals are provided herein.

4.2 Inputs

Inputs

- L0 PRESWAT (p_hex) Pressure (Depth) as a hexadecimal string
  Additional inputs for SBE 16plus V2 only:
- L0 TEMPCTD (t_hex) thermistor output
- PTEMPA0, PTEMPA1, PTEMPA2, PTCA0, PTCA1, PTCA2, PTCB0, PTCB1, PTCB2, PA0, PA1, and PA2 calibration coefficients (originally from instrument calibration sheet, available from the metadata of the L0 PRESWAT data product)

Additional inputs for SBE 37IM only:

- Pressure range, a factory-set calibration coefficient, stored by the instrument in units of psia. This value is available from the metadata of the L0 PRESWAT data product.

Input Data Formats

The L0 pressure data products is a hexadecimal string, the number of digits (and order of bytes) varies by instrument make/model:

SBE 16plus V2 (Output Format 0) -- *applies to all 16plus V2, running either its native firmware or the 19plus V2 firmware*

6-character hexadecimal string for A/D strain-gauge pressure counts

4-character hexadecimal string for voltage of thermistor mounted at pressure sensor for temperature compensation

SBE 37IM (Output Format 0)

4-character (2 byte) hexadecimal string with bytes in reverse order

4.3 Processing Flow

The specific steps necessary to create all calibrated and quality controlled data products for the CTD are described in the CTD Processing Flow document (DCN 1342-00001). This processing flow document contains a flow diagram showing all of the specific algorithms (data product and QC) necessary to compute all data products from the CTD and the order in which the algorithms must be applied.

The processing flow for the pressure algorithm code is as follows:

SBE 16plus V2 Output Format 0 (running either its native firmware or the 19plus V2 firmware)

1) Standard conversion from hex to decimal
   a. 6-character pressure hex string (p_hex) to decimal (p_dec)
   b. 4-character thermistor hex string (t_hex) to decimal (t_dec)
2) Convert raw decimal to voltage: $t\_v = t\_dec/13{,}107$
3) Calculate t (thermistor temp): $t = PTEMPA0 + PTEMPA1*t\_v + PTEMPA2*t\_v^2$
4) Calculate x: $x = p\_dec - PTCA0 - PTCA1*t - PTCA2*t^2$
5) Calculate n: $n = x*PTCB0 / (PTCB0 + PTCB1*t + PTCB2 * t^2)$
6) Calculate p_abs (press in psia): $p\_abs = PA0 + PA1*n + PA2*n^2$
7) Calculate P_L1 by converting p_abs to dbar and subtracting one standard atmosphere:
   $P\_L1\ [dbar] = (p * 0.689475729) - 10.1325$

where PTEMPA0, PTEMPA1, PTEMPA2, PTCA0, PTCA1, PTCA2, PTCB0, PTCB1, PTCB2, PA0, PA1, and PA2 are calibration coefficients provided on individual instrument calibration sheets and stored as metadata.

SBE 37IM Output Format 0

1) Reverse the order of the bytes in the 4-character (2 byte) hex string before converting to decimal: p_hex = p1a p1b p2a p2b (raw data, bytes in reverse order)
   P_hex' =p2a p2b p1a p1b
2) Standard conversion from 4-character hex string (p_hex') to decimal (p_dec)
3) Scaling: P_L1 [dbar] = [p_dec * P_rng / (0.85 * 65536)] – (0.05*P_rng)

where P_rng is the pressure range in dbar of the instrument. The pressure range is a factory-set calibration coefficient, stored by the instrument in units of psia and is an input to the algorithm.

The final product P_L1 is the L1 pressure data product in dbar.

Examples taken from the CTD manuals are included in Appendix A.

4.4 Outputs

The outputs of the pressure algorithm are

- Sea pressure (P_L1) in dbar as a floating point number with three decimal places %.3f.

The metadata for the output data include

- there is no additional metadata that need to be included with this data product

See Appendix B for a discussion of the accuracy of the algorithm output.

4.5 Computational and Numerical Considerations

4.5.1 Numerical Programming Considerations

There are no numerical programming considerations for this algorithm. No special numerical methods are used.

4.5.2 Computational Requirements

Computation estimate not required for algorithms that are not computationally intensive.

4.6 Code Verification and Test Data Sets

The code will be verified using the test data set provided, which contains inputs and their associated correct outputs. CI will verify that the code is correct by checking that the output, generated using the test data inputs, is identical to the test data pressure output.

The test data sets below provide paired input and output data for both CTD models, which would be characteristic of a typical water column.

A spreadsheet (CTD16plusv2_outputformat0_v2.xls) that can be used to verify all calculations for the 16plusV2 data is included with references in the DPS Artifacts folder on Alfresco, along with a copy of the 16plusV2 calibration sheet (SVE+16plusV2+SEACAT+RS232+SN+16P66805-6943.pdf): Alfresco (https://alfresco.oceanobservatories.org)
REFERENCE > Data product Specification Artifacts > 1341-00020_PRESWAT

SBE 37IM Test Data	
Inputs	**Output**
raw pressure in hex	Sea Pressure [dbar]
0AEC	0.192440257
15CD	50.18741383
20AE	100.1823874
2B90	150.1953125
3671	200.1902861
4152	250.1852597
4C34	300.1981847
5715	350.1931583
61F6	400.1881319
6CD7	450.1831055
77B9	500.1960306
829A	550.1910041
pressure range = 1000 psia	

SBE 16plus V2 Test Data*

4.7 rawHex	L1_T (ITS-90 °C)	L1_C (S/m)	P (psi) interim calc.	L1_P (dbar)	thermistor T (°C)
0461FC0A609208064F591F	18.9288	0.005771	0.225	0.158	18.55
0461FD0A609208064F591F	18.9287	0.005771	0.225	0.158	18.55
0461FC0A609208064F591F	18.9288	0.005771	0.225	0.158	18.55
03CCC50A67860801B35E7B	22.4892	0.010898	-18.609	-12.828	23.76
03CADB0A67860801B35E82	22.5379	0.010898	-18.610	-12.828	23.79
03CA3D0A67830801B25E8B	22.5536	0.010890	-18.627	-12.840	23.82
03C8EC0A677E0801B35E9B	22.5872	0.010875	-18.613	-12.830	23.88
03C7F90A677C0801B25E91	22.6114	0.010869	-18.628	-12.841	23.84
03C63B0A677E0801B25E95	22.6559	0.010875	-18.628	-12.841	23.86
03BFBA199F150803D05EAD	22.8227	5.011614	-10.095	-6.957	23.95
03CA971987D70810225EEF	22.5447	4.969069	39.565	27.282	24.20
04E0FB1806AB08437C5D5E	16.2108	4.286307	246.51	169.965	22.68
0637351688F90883725798	9.9227	3.651432	504.146	347.599	17.07
0778CA156B7F08CED05130	4.9768	3.203659	807.345	556.648	10.83
07DF9415254B08F7984E66	3.5383	3.097099	971.188	669.613	8.11
08281415013E094EEE4B2C	2.5580	3.042976	1321.399	911.075	4.97

* This test data set applies for both SBE 16plus V2 running its native firmware and the 16plus V2 running the 19plus V2 firmware.

Note that the conductivity data were calculated using the temperature (in degrees C) and pressure (in dbar), both of which were calculated from the original rawHex. See the TEMPWAT DPS (DCN 1341-00010) and PRESWAT DPS (1341-00020) for more details.

Appendix A Example Data Processing

Following are three examples, one for each CTD make/model. These are examples modified from the examples given in the CTD manuals.

SBE 16plus V2 with internally mounted strain gauge pressure sensor
(OutputFormat = 0)

Hex scan = ttttttccccccppppppvvvvssssssss
= 0A53711BC7220C14C17D820EC4270B

- Temperature = tttttt = 0A5371 (676721 decimal);
  temperature A/D counts = 676721
- Conductivity = 1BC722 (1820450 decimal);
  conductivity frequency = 1820450 / 256 = 7111.133 Hz
- Internally mounted strain gauge pressure = pppppp = 0C14C1 (791745 decimal);
  Strain gauge pressure A/D counts = 791745
- Internally mounted strain gauge temperature compensation = vvvv = 7D82 (32,130 decimal);
  Strain gauge temperature = 32,130 / 13,107 = 2.4514 volts
- Time = ssssssss = 0EC4270B (247,736,075 decimal);
  seconds since January 1, 2000 = 247,736,075

SBE 37IM with internally mounted strain gauge pressure sensor
(OutputFormat = 0)

Hex scan = tttttccccccppppTTTTTTTT
= 531850c355e50a805F0C14

- Temperature: ttttt = 53185 hex = 340357 decimal
  temperature (°C) = (ttttt / 10000) – 10 = (340357 / 10000) – 10 = 24.0357 °C
- Conductivity: ccccc = 0c355 hex = 50005 decimal
  conductivity (S/m) = (ccccc / 100000) – 0.5 = (50005 / 100000) – 0.5 = 0.00005 S/m
- Pressure range: From file header (metadata for OOI), the pressure range is 1000 psia.
  P_range (dbar) = 0.6894757 * [P_range (psia) – 14.7] = 679.34040721
- Pressure: pppp = e50a in hex (bytes in reverse order) = 0ae5 in hex = 2789 decimal
  pressure (dbar) = [pressure number * P_range / (0.85 * 65536)] – (0.05 * P_range)
  = [2789 * 679.34040721 / (0.85 * 65536)] – (0.05 * 679.34040721)
  = 0.045 dbar
- Time: TTTTTTTT = 805F0C14 hex (bytes in reverse order) = 140C5F80 = 336355200 decimal
  seconds since January 1, 2000 = 336355200

Appendix B Output Accuracy

The algorithm output accuracy for the OOI L1 Pressure (Depth) core data product calculated by this algorithm is equivalent to the accuracy of the instrument:

SBE 16plus V2	0.1% of full scale range w/ stability of 0.1% of full scale range/year
SBE 37IM	0.1% of full scale range w/ stability of 0.05% of full scale range/year
SBE GPCTD	±0.1% of full scale depth

The accuracy requirement for Pressure (Depth) in the OOI requirements database (DOORS) for Mobile Assets and Profilers is ±0.1% of the full scale range (L2-SR-RQ-3480; L2-SR-RQ-3481; L4-CG-IP-RQ-174; L4-CG-IP-RQ-176; L4-RSN-IP-RQ-294).

The accuracy requirement for Pressure (Depth) in the OOI requirements database (DOORS) for Fixed Platforms is ±0.1% of the full scale range (L2-SR-RQ-3480; L4-CG-IP-RQ-174; L4-CG-IP-RQ-176; L4-RSN-IP-RQ-294).

Note that the accuracy requirements for the GPCTD, the CTD on the gliders and AUVs, are included here for completeness, but data from this make/model of instrument will be processed onboard the vehicles and presented already in decimal format in appropriate units (°C, Siemens/meter, decibars). Therefore processing “raw” data from the CTDGP is not included in the algorithm described in this document.

Appendix C Sensor Calibration Effects

None.