SBE 16plusV2-IM SEACAT

Conductivity and Temperature Recorder (Pressure optional) with Inductive Modem Interface



Serial Number: 16P55726-6405

User Manual, Version 003

Sea-Bird Electronics, Inc.
1808 136th Place NE
Bellevue, Washington 98005 USA
Tel: 425/643-9866
Fax:425/643-9954

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SBE 16plus CTD OPERATING AND REPAIR MANUAL

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SEA-BIRD ELECTRONICS, INC.
1808 136th Place NE
Bellevue, Washington 98005 USA
Phone: (425) 643 9866
Fax: (425) 643 9954
Email: seabird@seabird.com

Manual Generation Date: 14 September 2009

LIMITED LIABILITY STATEMENT

Extreme care should be exercised when using or servicing this equipment. It should be used or serviced only by personnel with knowledge of and training in the use and maintenance of oceanographic electronic equipment.

SEA-BIRD ELECTRONICS, INC. disclaims all product liability risks arising from the use or servicing of this system. SEA-BIRD ELECTRONICS, INC. has no way of controlling the use of this equipment or of choosing the personnel to operate it, and therefore cannot take steps to comply with laws pertaining to product liability, including laws which impose a duty to warn the user of any dangers involved in operating this equipment. Therefore, acceptance of this system by the customer shall be conclusively deemed to include a covenant by the customer to defend, indemnify, and hold SEA-BIRD ELECTRONICS, INC. harmless from all product liability claims arising from the use of servicing of this system.

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WARNING !!

**Do not submerge this instrument (S/N 16P55726-6405)
beyond the depth rating of the lowest rated component listed below!**

Main Housing (Plastic)	**600 meters**
Pressure Sensor (600 dBar) Druck	600 meters
DO Sensor (SBE 43)	600 meters
Pump (SBE 5P)	600 meters

SYSTEM CONFIGURATION 12 September 2009

Model SBE 16plusV2-IM	**S/N 16P55726-6405**
Instrument Type	**SBE 16plusV2 SeaCaT IM**
Firmware Version	**2.1a**
Communications	**Inductive Modem**
Inductive Modem ID#	**01**
Memory	**64MB**
Housing	**600 meter (Acetron plastic)**
0 Conductivity Raw Frequency	**2590.52 Hz**
Operating Mode	**Moored**
Pressure Sensor	**Strain Gauge: 600 db**

Number of Voltages Sampled:	**1**
Serial RS-232C Sensor	**None**

Data Format:

Count	**Temperature**
Frequency	**Conductivity**
Count	**Pressure, Strain Gauge**
Stored Voltage 0 (External Voltage 0)	**Oxygen, SBE 43**

Pump (SBE 5P)	**055414**
DO Sensor (SBE 43)	**431663**

Individual Voltage Delay Settings for Moored Mode Applications:

SBE 43	40 Seconds

Configured Overall Voltage Delay Setting: **40 Seconds**

Note: The 40 second voltage delay for the SBE 43 is based on the typical response time at 2 degrees Celsius for a 1.0-mil thick membrane to read within 1% of its final value. Please consult Application Note 64 under Summary of Response Times for Moored Applications for more information.

Note: Overall Voltage Delay Setting is based on the longest time delay listed above. To recalculate this value when adding or removing sensors, please refer to manual text.

IMPORTANT SOFTWARE & HARDWARE CONFIGURATION INFORMATION

Sea-Bird supplies two versions of our software package for communication, real-time data acquisition, and data analysis and display:

- SEASOFT-Win32 - Windows software for PC running Win 95/98/NT/2000/XP
- SEASOFT-DOS - DOS software for IBM-PC/AT/386/486 or compatible computer with a hard drive

Detailed information on the use of the **Windows** software follows:

SEASOFT-Win32

SEASOFT-Win32 software was supplied on a CD-ROM with your CTD. This software package is designed to run on a PC running Win 95/98/NT/2000/XP. The CD-ROM also contains software manuals that describe the appropriate applications for the various programs, the procedure for installing the software, and instructions on using the programs. There are three primary programs used with the CTD for setup, data collection and retrieval, data display, and data processing:

- SEATERM - terminal program for setup of the CTD and uploading of data from the CTD memory (**Note**: If using the CTD with the 90208 Auto Fire Module or SBE 17*plus* V2 SEARAM, use SeatermAF instead of SEATERM)
- SEASAVE - real-time data acquisition program
- SBE Data Processing - data processing program

Instructions for using the software are found in their Help files.

To communicate with the CTD to set it up or to upload data from the CTD memory to the computer hard drive, **SEATERM** must have information about the CTD hardware configuration (communication parameters, internal firmware, etc.) and about the computer. To communicate with the CTD, double click on Seaterm.exe:

1. In the Configure menu, select the CTD. The Configuration Options dialog box appears.
   A. On the COM Settings tab, select the firmware version (if applicable), baud rate, data bits, and parity to match the CTD's configuration sheet. If necessary, change the com port to match the computer you are using.
   B. On the Upload Settings tab, enter upload type (all as a single file, etc.) as desired.
   For the SBE 17 and 25 only: enter the serial number for the SBE 3 (temperature) and SBE 4 (conductivity) modular sensors, exactly as they appear in the configuration (.con) file.
   C. On the Header Information tab, change the settings as desired.
   Click OK when done. SEATERM saves the settings in a SEATERM.ini file.
2. On the Toolbar, click Connect to communicate with the CTD.
3. To set up the CTD prior to deployment:
   On the Toolbar, click Status. SEATERM sends the Status command and displays the response. Verify that the CTD setup matches your desired deployment. If not, send commands to modify the setup.
4. To upload data from the CTD:
   On the Toolbar, click Upload to upload data from the CTD memory to the computer.

Sea-Bird CTDs store and/or transmit data from their primary and auxiliary sensors in the form of binary or hexadecimal number equivalents of the sensors' frequency or voltage outputs. This is referred to as the *raw* data. The calculations required to convert from *raw* data to *engineering* units of the measured parameters (temperature, conductivity, pressure, dissolved oxygen, pH, etc.) are performed using the software, either in real time, or after the data has been stored in a file. SEASAVE creates the file in real time. As noted above, SEATERM uploads the recorded data and creates the file on the computer hard drive.

To successfully store data to a file on the computer and subsequently convert it to engineering units, the software must know the CTD type, CTD configuration, and calibration coefficients for the sensors installed on the CTD. This information is unique to each CTD, and is contained in a *configuration* file. The configuration file, which has a .con extension, was written onto a floppy disk and the CD-ROM shipped with the CTD. The .con file for a given CTD is named with the last four digits of the serial number for that CTD (e.g., 1234.con). The configuration file is created or modified (e.g., changing coefficients after recalibration, or adding another sensor) by using the Configure menu in **SEASAVE** or
SBE Data Processing. The configuration file is used by SEASAVE to convert raw data to engineering units when it acquires, stores, and displays real-time data. The configuration file is also used by some modules in SBE Data Processing (Data Conversion and Derive) that convert raw data to engineering units during data processing.

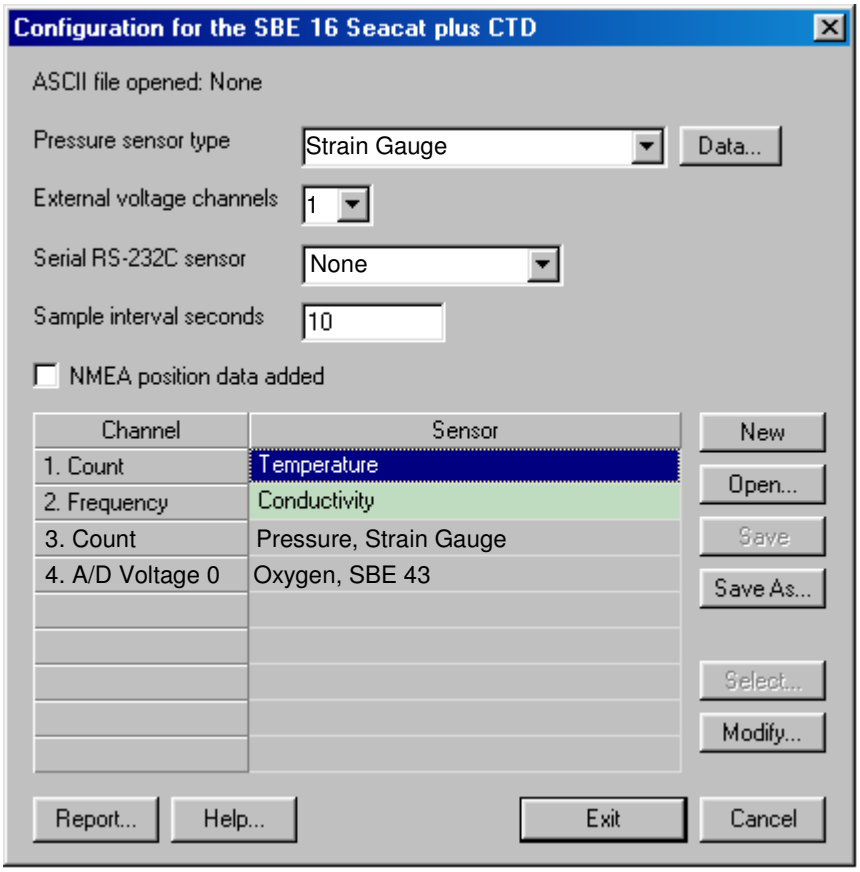
The instrument type and instrument configuration settings of the .con file and the required setup for the SEATERM.ini file for the CTD *as delivered* are documented below. The calibration coefficients for the CTD's sensors are contained in the calibration coefficient section of the CTD manual.

NOTE:

SEATERM will not upload data correctly without a properly configured SEATERM.ini file. SEASAVE and SBE Data Processing will not interpret the data correctly without the correct .con file.

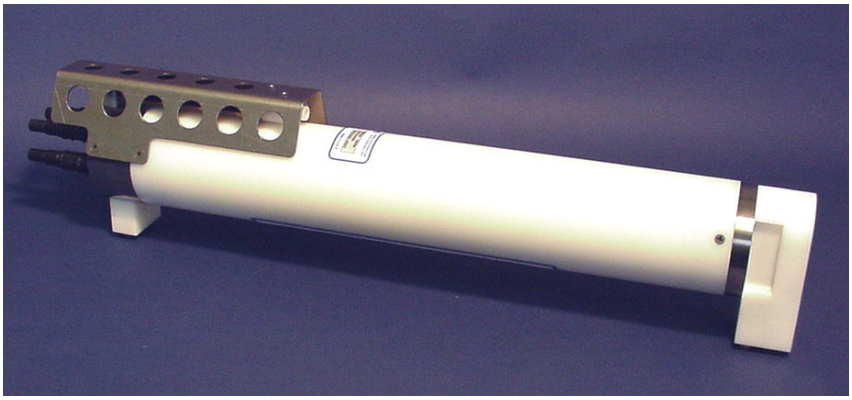
SEASOFT CONFIGURATION:

The correct instrument type for your instrument is SBE 16plus SEACAT Profiler. The correct settings for the configuration of your instrument as delivered are documented below:



SBE 16*plus*-IM V2 SEACAT

Conductivity and Temperature Recorder (pressure optional) with Inductive Modem Interface



User's Manual

Sea-Bird Electronics, Inc.
1808 136th Place NE
Bellevue, Washington 98005 USA
Telephone: 425/643-9866
Fax: 425/643-9954
E-mail: seabird@seabird.com
Website: www.seabird.com

Manual Version #003, 07/23/09
16*plus*-IM Digital Firmware Version 2.2 & later
16*plus*-IM Modem Firmware Version 1.1c & later
SIM Firmware Version 3.0a & later
IMM firmwre version 1.00 & later
SeatermV2 Version 1.00h and later
SBE Data Processing Version 7.19 & later

Limited Liability Statement

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Section 1: Introduction

This section includes a Quick Start procedure, and photos of a standard SBE 16*plus*-IM V2 shipment.

About this Manual

This manual is to be used with the SBE 16*plus*-IM V2 SEACAT Conductivity and Temperature (pressure optional) Recorder with Inductive Modem. It is organized to guide the user from installation through operation and data collection. We have included detailed specifications, command descriptions, maintenance and calibration information, and helpful notes throughout the manual.

Sea-Bird welcomes suggestions for new features and enhancements of our products and/or documentation. Please contact us with any comments or suggestions (seabird@seabird.com or 425-643-9866). Our business hours are Monday through Friday, 0800 to 1700 Pacific Standard Time (1600 to 0100 Universal Time) in winter and 0800 to 1700 Pacific Daylight Time (1500 to 0000 Universal Time) the rest of the year.

Quick Start

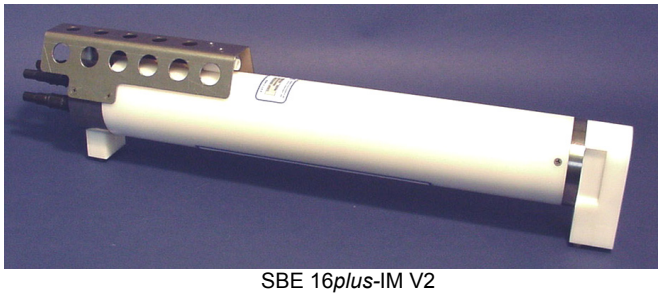
Follow these steps to get a Quick Start using the SBE 16*plus*-IM V2. The manual provides step-by-step details for performing each task:

1. Perform pre-check (*Section 3: Preparing for Deployment*):
   A. Test power and communications.
   B. Set 16*plus*-IM V2 ID.

2. Deploy (*Section 4: Deploying and Operating SBE 16plus-IM V2*):
   A. Install new batteries if necessary.
   B. Ensure all data has been uploaded, and then send **#iiInitLogging** to make entire memory available for recording if desired.
   C. Set date and time (**#iiDateTime=**) and establish setup and logging parameters.
   D. Check status (**#iiDS**) and calibration coefficients (**#iiDCal**) to verify setup.
   E. Set 16*plus*-IM V2 to start logging now (**#iiStartNow**) or in the future (**#iiStartDateTime=** and **#iiStartLater**).
   F. Remove protective plugs from anti-foulant device cups, and verify AF24173 Anti-Foulant Devices are installed. Leave protective plugs off for deployment.
   G. Install dummy plugs and/or cable connectors, and locking sleeves.
   H. Install 16*plus*-IM V2 on mooring cable.
   I. (optional) Install Inductive Cable Coupler on mooring cable.
   J. Wire system.

Unpacking SBE 16*plus*-IM V2

Shown below is a typical SBE 16*plus*-IM V2 shipment.



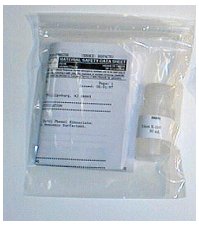
SBE 16*plus*-IM V2



Spare o-ring and hardare kit



Conductivity cell filling and storage kit



Conductivity cell cleaning solution (Triton-X)

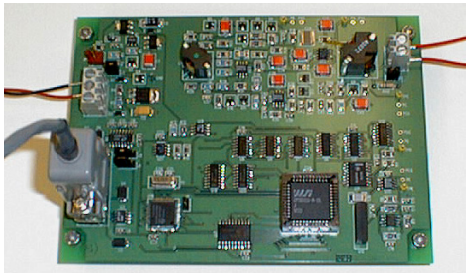


SBE 16*plus*-IM V2 manual

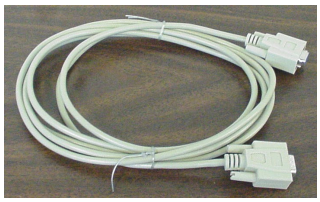


Software, and Electronic Copies of Software Manuals and User Manual

Note:
SBE 16*plus*-IM V2 can be used with SIM or with IMM; IMM not shown.



Surface Inductive Modem (SIM) PCB (one per mooring, optional)



I/O Cable (included with SIM)



Inductive Cable Coupler (ICC) (optional with SIM, one per mooring)

Section 2: Description of SBE 16*plus*-IM V2

This section describes the functions and features of the SBE 16*plus*-IM V2 SEACAT, including:

- system description
- specifications
- dimensions and end cap connectors
- data storage
- batteries and battery endurance
- configuration options and plumbing
- Surface Inductive Modem (SIM), Inductive Cable Coupler (ICC), and mooring requirements

System Description

Note:
For detailed information on inductive modem systems, see *Real-Time Oceanography with Inductive Moorings*, at www.seabird.com under Technical Papers.

The SBE 16*plus*-IM V2 SEACAT is designed to measure conductivity, temperature, and (optional) pressure in marine or fresh-water environments in moored applications. The 16*plus*-IM V2 has internal batteries and non-volatile memory. It uses an Inductive Modem (IM) to transmit data and receive commands over a plastic-jacketed steel mooring cable (or other insulated conductor), using differential-phase-shift-keyed (DPSK) telemetry. No electrical cables or connectors are required. The 16*plus*-IM V2's built-in inductive coupler (split toroid) and cable clamp provide easy and secure attachment to the mooring cable.

Note:
Half-duplex communication is **one-direction** at a time (i.e., you cannot send commands and receive data at the same time). For example, if the IMM or SIM commands a 16*plus*-IM V2 to upload data, nothing else can be done while the data is being sent – the data upload cannot be stopped, and commands cannot be sent to other 16*plus*-IM V2s on the line.

Communicating with one or more 16*plus*-IM V2s requires the use of a Sea-Bird Inductive Modem Module (IMM) or Surface Inductive Modem (SIM). These devices provide a standard serial interface between the user's computer or other controlling device and up to 100 16*plus*-IM V2s (or other IM-compatible sensors), coupled to a single cable. The user can communicate with these devices via full-duplex RS-232C or half-duplex RS-485. Commands and data are transmitted half-duplex between these devices and the 16*plus*-IM V2.

Commands sent to the 16*plus*-IM V2 provide status display, data acquisition setup, data retrieval, and diagnostic tests. User-selectable operating modes include:

- **Polled sampling** – On command, the 16*plus*-IM V2 takes one sample and transmits data.
- **Autonomous sampling** – At pre-programmed intervals, the 16*plus*-IM V2 wakes up, samples, stores data in its FLASH memory, and powers off.
- **Combo sampling** – Autonomous sampling is in progress, and the 16*plus*-IM V2 can be commanded to transmit the last stored data.

The 16*plus*-IM V2 features the proven Sea-Bird conductivity and temperature sensors. Nine D-size alkaline batteries provide power for approximately 290,000 samples (with no pressure sensor, pump, or auxiliary sensors), depending on the sampling and telemetry schedule. The 64 Mbyte FLASH RAM memory records 2 years of conductivity, temperature, and date/time data while sampling every 10 seconds (other configurations/setups vary). User-selectable output format is raw data or engineering units, in hexadecimal or decimal form; XML output is also available. Setup, diagnostics, and data extraction are performed without opening the housing. The 16*plus*-IM V2 can power external sensors and acquire their outputs.

A standard 16*plus*-IM V2 is supplied with:
- Plastic housing for depths to 600 meters (1950 feet)
- Bulkhead connectors (Impulse glass-reinforced epoxy):
  - one 2-pin pump connector;
  - three 6-pin connectors, for two differential auxiliary A/D inputs each;
  - one 4-pin connector, for RS-232 auxiliary sensor (SBE 38 secondary temperature sensor, SBE 50 pressure sensor, or up to two Pro-Oceanus Gas Tension Devices, or Aanderaa Oxygen Optode 4330 or 4835)
- 64 Mbyte FLASH RAM memory
- 9 D-size alkaline batteries (Duracell MN1300, LR20)
- Anti-foulant device attachments and expendable AF24173 Anti-Foulant Devices. These are attached to each end of the conductivity cell, so that any water that enters the cell is treated.

16*plus*-IM V2 options include:
- Titanium housing for use to 7000 or 10500 meters (22,900 or 34,440 feet)
- Internally mounted pressure sensor -
  - Strain gauge pressure sensor, or
  - Quartz pressure sensor
- Pump -
  - SBE 5M (available in plastic or titanium housing) for pumped conductivity, or
  - SBE 5P (plastic housing) or 5T (titanium housing) for pumped conductivity **and** pumped auxiliary sensors
- Sensors for dissolved oxygen, fluorescence, light (PAR), light transmission, and turbidity
- Wet-pluggable (MCBH) connectors in place of standard connectors
- Battery pack kit for lithium batteries for longer deployments (lithium batteries **not** supplied by Sea-Bird).

Data upload can be accomplished without opening the 16*plus*-IM V2 housing, using the inductive modem telemetry (baud rate between 16*plus*-IM V2 and SIM or IMM is always 1200 baud). Alternatively, by opening the 16*plus*-IM V2 electronics chamber to access the internal RS-232 serial connector, fast upload of large data sets can be performed at rates up to 115,200 baud, using the optional data I/O cable (PN 801880).

Future upgrades and enhancements to the SBE 16*plus*-IM V2 firmware can be easily installed in the field through a computer serial port and the internal RS-232 serial connector inside the 16*plus*-IM V2, without the need to return the 16*plus*-IM V2 to Sea-Bird, using the optional data I/O cable (PN 801880).

The 16*plus*-IM V2 is supplied with a powerful Win 2000/XP software package, SEASOFT V2, which includes:
- **Deployment Endurance Calculator** – program for determining deployment length based on user-input deployment scheme, instrument power requirements, and battery capacity.
- **SeatermV2** – terminal program for easy communication and data retrieval. SeatermV2 is a *launcher*. Depending on the instrument selected it launches **SeatermIM** (inductive modem instruments, such as this 16*plus*-IM V2), Seaterm232 (RS-232 instruments), or Seaterm485 (RS-485 instruments).
- **SBE Data Processing** - program for calculation and plotting of conductivity, temperature, pressure, auxiliary sensor data, and derived variables such as salinity and sound velocity.

Notes:
- Help files provide detailed information on the software.
- A separate software manual contains detailed information on SBE Data Processing.
- Sea-Bird supplies the current version of our software when you purchase an instrument. As software revisions occur, we post the revised software on our FTP site. See our website (www.seabird.com) for the latest software version number, a description of the software changes, and instructions for downloading the software from the FTP site.

Specifications

	Temperature (°C)	Conductivity (S/m)	Pressure (optional)
Measurement Range	-5 to +35	0 to 9	0 to full scale range: • *Strain gauge sensor:* 20 / 100 / 350 / 600 / 1000 / 2000 / 3500 / 7000 meters • *Quartz sensor:* 20 / 60 / 130 / 200 / 270 / 680 / 1400 / 2000 / 4200 / 7000 / 10500 meters
Initial Accuracy	0.005	0.0005	• *Strain gauge sensor:* 0.1% of full scale range • *Quartz sensor:* 0.02% of full scale range
Typical Stability	0.0002/month	0.0003/month	• *Strain gauge sensor:* 0.1% of full scale range/year • *Quartz sensor:* 0.025% of full scale range/year
Resolution	0.0001	• 0.00005 (most oceanic water; resolves 0.4 ppm in salinity). • 0.00007 (high salinity water; resolves 0.4 ppm in salinity). • 0.00001 (fresh water; resolves 0.1 ppm in salinity).	• *Strain gauge sensor:* 0.002% of full scale range • *Quartz sensor:* 0.0006% of full scale range for 1-second integration; depends on sample integration time (see notes below)
Sensor Calibration (measurement outside these ranges may be at slightly reduced accuracy due to extrapolation errors)	+1 to +32	0 to 9; physical calibration over the range 2.6 to 6 S/m, plus zero conductivity (air)	Ambient pressure to full scale range in 5 steps

***Notes on Internally Mounted Quartz Pressure Sensor Resolution:**
Pressure Sensor Resolution = Sensitivity * Counter Resolution

- Sensitivity = Δ pressure / Δ frequency
  where Δ pressure is change in pressure in desired units (psia, db, meters, etc.) = pressure sensor full scale range
  Δ frequency is change in frequency in Hz ≈ 3000 Hz over sensor's full scale range
- Counter Resolution = pressure sensor output frequency / (**#iiParosIntegration** * 1,843,200)
  where pressure sensor output frequency ≈ 35,000 Hz
  #iiParosIntegration = user-input integration time (seconds)
- To convert pressure units: db = psia / 1.45

Example:
What resolution can be obtained for a 7000 meter (10,000 psia) Quartz pressure sensor?

Sensitivity = Δ pressure / Δ frequency = 7000 m / 3000 Hz = 2.333 m / Hz

Counter Resolution = pressure sensor output frequency / (**#iiParosIntegration** * 1,843,200)
= 35,000 Hz / (**#iiParosIntegration** * 1,843,200)

Resolution = Sensitivity * Counter Resolution = 2.333 db/Hz * 35,000 Hz / (**#iiParosIntegration** * 1,843,200)
Looking at the resolution that can be obtained with a range of values for the integration time:

Integration time (#iiParosIntegration=)	Resolution
1 second	0.044 m (44 mm)
2.2 seconds	0.02 m (20 mm)
4.4 seconds	0.01 m (10 mm)
44 seconds	0.001 m (1 mm)

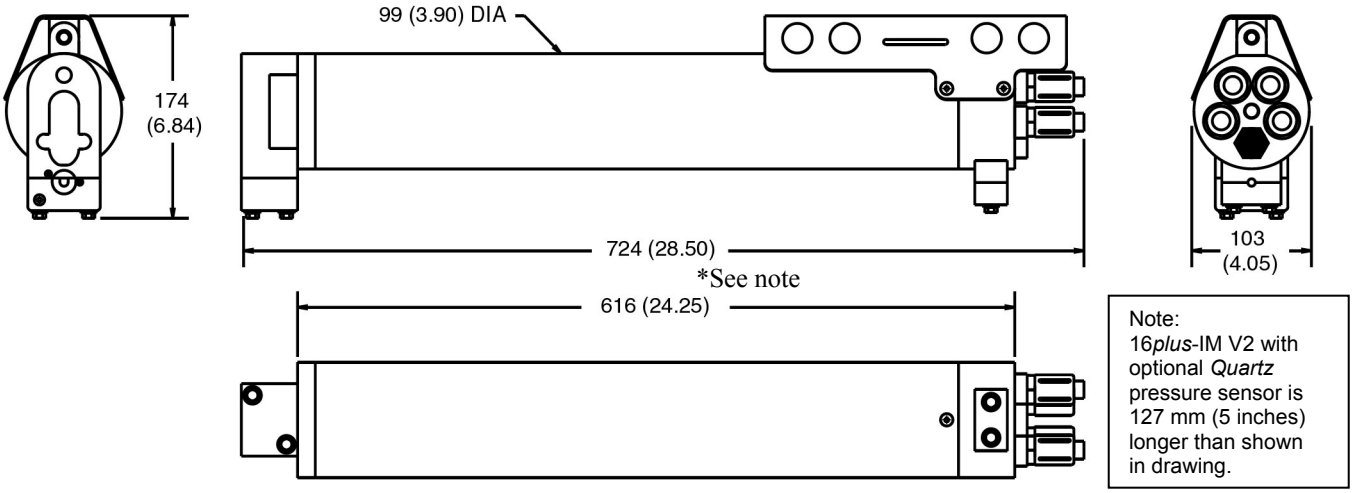
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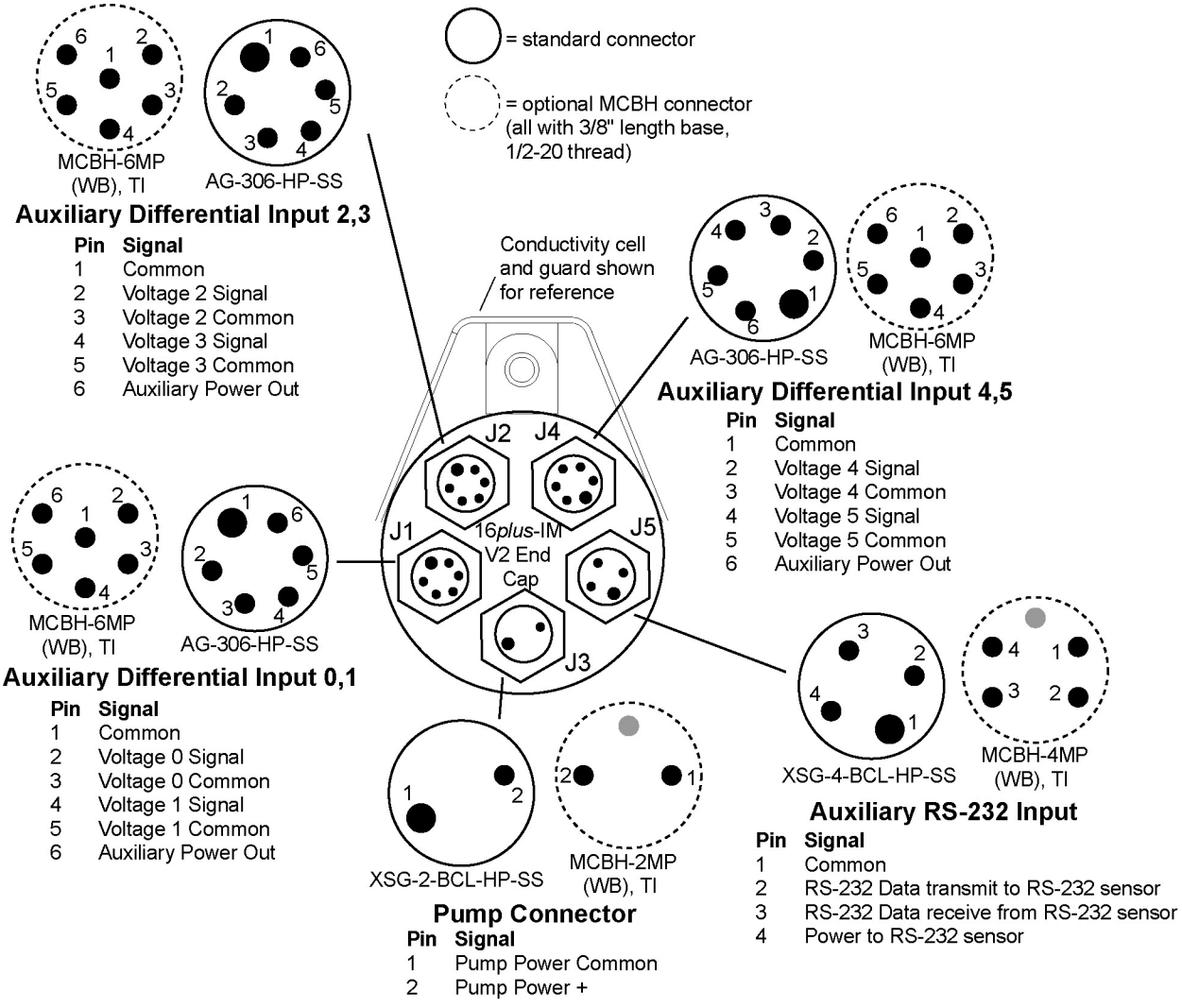
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Memory	64 Mbyte non-volatile FLASH memory
Data Storage	**Recorded Parameter** — **Bytes/sample** temperature + conductivity — 6 (3 each) internally mounted strain gauge or Quartz pressure — 5 each external voltage — 2 SBE 38 secondary temperature — 3 SBE 50 pressure — 3 Each Pro-Oceanus GTD — 4 (pressure) + 3 (temperature) Aanderaa Optode — 3 date and time — 4
Real-Time Clock	32,768 Hz TCXO accurate to ±1 minute/year.
Internal Batteries	Nine alkaline D-cells (Duracell MN 1300, LR20; nominal capacity 14 amp-hours).
Power Requirements	*Sampling*: no pressure sensor — 55 mA with internally mounted pressure sensor — 70 mA *Optional Pump:* SBE 5M — 100 mA SBE 5P or 5T — 150 mA *Communications:* — 4 mA *Quiescent:* — 140 μA Sampling time (see *Sample Timing* for example calculations): • Minimum 2.2 seconds/sample (no pump, no pressure sensor, 1 measurement/sample, and no delays). • Add 0.3 seconds with internally mounted strain gauge pressure sensor. • Add integration time with internally mounted Quartz pressure sensor (**#iiParosIntegration=**; minimum 1 second). • Add 0.25 seconds for each additional measurement/sample (**#iiNCycles ≥ 2**). • Add pump on-time (0.5 second) if pump running before taking sample (**#iiPumpMode=1**). • Add time for user-programmed delay before sampling (**#iiDelayBeforeSampling=**). Approximate Battery Endurance [1]: CT only: 290,000 samples CTD only: 200,000 samples CTD & 5M pump: 110,000 samples [1] With Duracell MN 1300 (LR20) cells. Dependent on sampling and telemetry scheme; see *Battery Endurance* for example calculations.
Auxiliary Voltage and RS-232 Sensors	*Auxiliary power out*: up to 500 mA at 10.5 - 11 VDC *Voltage sensor A/D resolution*: 14 bits *Voltage sensor Input range*: 0 - 5 VDC
Housing Depth Range and Materials	600 meter (1950 ft): acetal copolymer (plastic) 7000 meter (22,900 ft): 3AL-2.5V titanium 10,500 meter (34,400 ft): 6AL-4V titanium
Weight (without pump)	With plastic housing: *in air* - 9 kg (20 lbs) *in water* - 4 kg (9 lbs) With 3AL-2.5V titanium housing: *in air* - 17 kg (38 lbs) *in water* - 12 kg (27 lbs)

Dimensions and End Cap Connectors

Dimensions in millimeters (inches)





Data Storage

Note:
See *Battery Endurance* for power limitations.

The SBE 16*plus*-IM V2 has a 64 Mbyte FLASH memory. Shown below are examples of available data storage for several configurations. See *Specifications* for storage space required for each parameter.

Example 1: internally mounted strain gauge pressure and no auxiliary sensors
T & C = 6 bytes/sample
Strain gauge P = 5 bytes/sample
Date/Time = 4 bytes/sample
Storage space ≈ 64,000,000 / (6 + 5 + 4) ≈ 4,266,000 samples

Example 2: internally mounted Quartz pressure, 6 external voltages, and SBE 38 secondary temperature sensor
T & C = 6 bytes/sample
Quartz P = 5 bytes/sample
External voltages = 2 bytes/sample * 6 voltages = 12 bytes/sample
SBE 38 = 3 bytes/sample
Date/Time = 4 bytes/sample
Storage space ≈ 64,000,000 /(6 + 5 + 12 + 3 + 4) ≈ 2,133,000 samples

Sample Timing

Notes:
- See sampling times in *Specifications*.
- Sample timing information is approximate.
- See *Battery Endurance* for power limitations.

Sample timing is dependent on a number of factors, including whether the 16*plus*-IM V2 has an optional pressure sensor and the pressure sensor type – strain gauge or Quartz, setup for a Quartz pressure sensor (**#iiParosIntegration=**), setup for the optional pump (**#iiPumpMode=**), and user-programmable sampling parameters for number of samples per measurement (**#iiNCycles=**) and delay before sampling to allow time for auxiliary sensors to stabilize (**#iiDelayBeforeSampling=**).

For autonomous sampling (logging), the 16*plus*-IM V2 requires a minimum of 5 seconds from the end of one sample to the beginning of the next sample. After it takes each sample, it checks the time for the start of the next sample, based on the user-programmable sampling interval (**#iiSampleInterval=**). If there is less than 5 seconds remaining until the programmed start of the next sample, the 16*plus*-IM V2 provides a message:

```
Error - - > alarm time not far enough in the future,
resetting alarm to 5 sec from now
```

The 16*plus*-IM V2 takes the next sample in 5 seconds. The 16*plus*-IM V2 performs this check after each sample; because of small variations in sampling time, this can cause samples to be taken at uneven intervals. Therefore, best practice is to check the sample timing before you set up the instrument, to ensure that the sample interval is long enough.

Examples are shown below:

Example 1 - pump on for 0.5 sec before each sample (**#iiPumpMode=1**), no internally mounted pressure sensor, 1 measurement/sample (**#iiNCycles=1**)*:*

Sampling time = 0.5 sec (pump before sampling) + 2.2 sec (basic sampling time) = 2.7 sec
Minimum sample interval (**#iiSampleInterval=**) = 2.7 sec + 5 (sec between samples) = 7.7 sec < 10 sec minimum, so **minimum #iiSampleInterval=10**.

Example 2 - pump on during sample (**#iiPumpMode=2**), 15 sec delay before sampling (**#iiDelayBeforeSampling=15**), internally mounted Quartz pressure sensor integrating for 3 sec/sample (**#iiParosIntegration=3**), and 4 measurements/sample (**#iiNCycles=4**):

Sampling time = 15 (delay before sampling) + 2.2 (basic sampling time) + 3 (Quartz integration) + (4 – 1) * 0.25 (additional measurements/sample for **#iiNCycles**) = 20.95 sec
Minimum sample interval (**#iiSampleInterval=**) = 20.95 sec + 5 (sec between samples) = 25.95 sec, so **minimum #iiSampleInterval=28** (round up by a few seconds, to account for any small differences in sample timing).

Batteries

For the main battery, the SBE 16*plus*-IM V2 uses nine D-cell alkaline batteries (Duracell MN 1300, LR20). If necessary, lithium, carbon-zinc, or mercury cells can also be used.

On-board lithium batteries (non-hazardous units which are unrestricted for shipping purposes) are provided to back-up the buffer and the real-time clock in the event of main battery failure or exhaustion. The main batteries may be replaced without affecting either the real-time clock or memory.

Battery Endurance

Notes:
- If the 16*plus*-IM V2 is logging data and the battery voltage is less than 7.5 volts, the 16*plus*-IM V2 halts logging and displays a low battery indication in the data.
- See *Data Storage* and *Specifications* for data storage limitations.

The standard alkaline battery pack has a nominal capacity of 14 amp-hours. For planning purposes, Sea-Bird recommends using a conservative value of:
- 12.2 amp-hours for a 16*plus*-IM V2 with no pump or auxiliary sensors
- 10.5 amp-hours for a 16*plus*-IM V2 drawing more current because of optional pump and/or auxiliary sensors

Current consumption and sampling times vary greatly, depending on the instrument configuration (inclusion of pressure sensor, pump, and/or auxiliary sensors) as well as user-programmed sampling parameters (pump operating mode, number of measurements per sample, delay before sampling). Examples are shown below for several sampling schemes. **You can use the Deployment Endurance Calculator** to determine the maximum deployment length, instead of performing the calculations by hand.
- Assuming the fastest practical interrogation scheme (wake all 16*plus*-IM V2s on mooring, send **GData**, send **Dataii** or **!iiData** to each 16*plus*-IM V2, and power off all 16*plus*-IM V2s), the communications current is drawn for approximately 0.5 seconds **per 16*plus*-IM V2 on the mooring**. Each 16*plus*-IM V2 on the mooring draws this current while any 16*plus*-IM V2 is being queried to transmit data. Other interrogation schemes require more time.

Ten 16*plus*-IM V2s with standard alkaline batteries are set up to sample autonomously every 10 minutes (6 samples/hour), and the last data sample will be requested by the computer every hour. How long can the instruments be deployed?

Example 1 – no pump, pressure sensor, or auxiliary sensors; 1 measurement/sample (**#iiNCycles=1**):

Sampling current = 55 mA * 2.2 sec = 0.12 amp-sec/sample
In 1 hour, sampling current = 6 samples * 0.12 amp-sec/sample = 0.72 amp-sec/hour
Quiescent current = 140 microamps = 0.140 mA In 1 hour, quiescent current ≈ 0.140 mA * 3600 sec/hour = 0.50 amp-sec/hour
Communication current / query = 4 mA * 0.5 sec / 16*plus*-IM V2 to be queried * 10 instruments = 0.02 amp-sec/hour

Current consumption / hour = 0.72 + 0.50 + 0.02 = 1.24 amp-sec/hour
Capacity = (12.2 amp-hours * 3600 sec/hr) / (1.24 amp-sec/hour) = 35,419 hours = 1475 days = 4.0 years
However, Sea-Bird recommends that batteries should not be expected to last longer than 2 years in the field.

Example 2 - with 5M pump on for 0.5 sec/sample (**#iiPumpMode=1**), no pressure sensor or auxiliary sensors, 1 measurement/sample (**#iiNCycles=1**):

Sampling current = 55 mA * (2.2 sec + 0.5 sec) = 0.148 amp-sec/sample
In 1 hour, sampling current = 6 * 0.135 amp-sec/sample = 0.89 amp-sec/hour
Pump current = 100 mA * 0.5 sec = 0.05 amp-seconds/sample
In 1 hour, pump current = 6 * 0.05 amp-sec/sample = 0.3 amp-sec/hour
Quiescent current = 140 microamps = 0.140 mA In 1 hour, quiescent current ≈ 0.140 mA * 3600 sec/hour = 0.50 amp-sec/hour
Communication current / query = 4 mA * 0.5 sec / 16*plus*-IM V2 to be queried * 10 instruments = 0.02 amp-sec/hour

Current consumption / hour = 0.89 + 0.3 + 0.50 + 0.02 = 1.71 amp-sec/hour
Capacity = (10.5 amp-hours * 3600 seconds/hr) / (1.71 amp-seconds/hour) = 22,105 hours = 921 days = 2.5 years
However, Sea-Bird recommends that batteries should not be expected to last longer than 2 years in the field.

Example 3 – with 5T pump on during sample (**#iiPumpMode=2**), internally mounted Quartz pressure sensor integrating for 3 sec/sample (**#iiParosIntegration=3**), 15 sec delay before sampling (**#iiDelayBeforeSampling=15**), auxiliary sensors drawing 100 mA, 4 measurements/sample (**#iiNCycles=4**):

On-time = 2.2 + 3 (Quartz integration) + 15 (delay before sampling) + (4 – 1) * 0.25 (additional measurements/sample) = 20.95 sec
Sampling current = 70 mA * 20.95 sec = 1.47 amp-sec/sample
In 1 hour, sampling current = 6 * 1.47 amp-sec/sample = 8.8 amp-sec/hour
5T Pump current = 150 mA * 20.95 sec = 3.14 amp-sec/sample
In 1 hour, pump current = 6 * 3.14 amp-sec/sample = 18.9 amp-sec/hour
Auxiliary sensor current = 100 mA * 20.95 sec = 2.10 amp-sec/sample
In 1 hour, auxiliary sensor current = 6 * 2.10 amp-sec/sample = 12.6 amp-sec/hour
Quiescent current = 140 microamps = 0.140 mA In 1 hour, quiescent current ≈ 0.140 mA * 3600 sec/hour = 0.50 amp-sec/hour
Communication current / query = 4 mA * 0.5 sec / 16*plus*-IM V2 to be queried * 10 instruments = 0.02 amp-sec/hour

Current consumption / hour = 8.8 + 18.9 + 12.6 + 0.50 + 0.02 = 40.8 amp-sec/hour
Capacity = (10.5 amp-hours * 3600 sec/hr) / (40.8 amp-sec/hour) = 926 hours = 38 days = 0.1 years

Configuration Options and Plumbing

The SBE 16*plus*-IM V2 is available with an optional, externally mounted, submersible pump. The pump is required for a 16*plus*-IM V2 configured with an optional dissolved oxygen sensor or pumped fluorometer, but also provides the following benefits for conductivity data:

- Improved conductivity response - The pump flushes the previously sampled water from the conductivity cell and brings a new water sample quickly into the cell.
- Improved anti-foulant protection - Water does not freely flow through the conductivity cell between samples, allowing the anti-foulant concentration inside the cell to build up.

Several pump models are available:

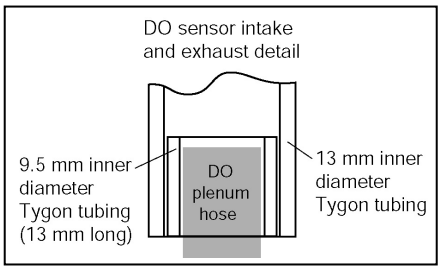
- SBE 5M miniature pump (available in plastic or titanium) - for pumped conductivity
- SBE 5P (plastic) or 5T (titanium) pump - a more powerful pump for use if the 16*plus*-IM V2 is configured with a dissolved oxygen sensor and/or pumped fluorometer

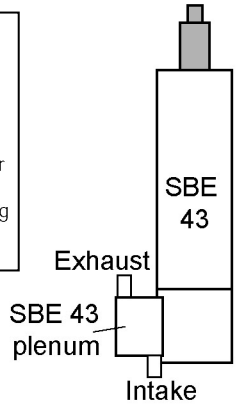
In all cases, the pump is powered via a cable connected to the standard 2-pin Pump bulkhead connector on the sensor end cap.

The 16*plus*-IM V2 can be configured with a wide range of auxiliary sensors. Three standard 6-pin bulkhead connectors on the sensor end cap serve as the input ports for the auxiliary sensor signal voltages and provide power to the sensors. Additionally, a standard 4-pin bulkhead connector on the sensor end cap is provided for an RS-232 sensor, such as SBE 38 secondary temperature sensor, SBE 50 secondary strain-gauge pressure sensor, Pro-Oceanus Gas Tension Devices (up to two GTDs can be integrated with the 16*plus*-IM V2), or Aanderaa Optode 4330 or 4835.

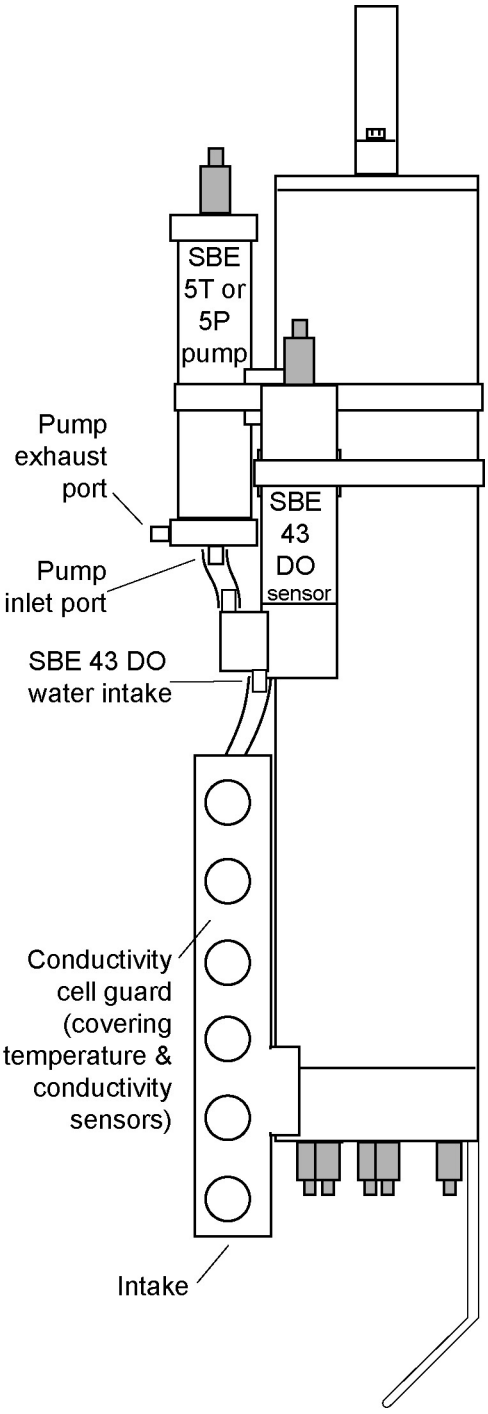
Shown below is the plumbing arrangement of an SBE 16*plus*-IM V2 equipped with a pump and the optional SBE 43 Dissolved Oxygen sensor.
See *Section 4: Deploying and Operating SBE 16plus-IM V2* for pump setup and operation details.

- Main plumbing is 13 mm ID x 19 mm OD (1/2 inch x 3/4 inch) Tygon tubing.
- A 13 mm (0.5 inch) long piece of 9.5 mm ID x 13 mm OD (3/8 inch x 1/2 inch) Tygon tubing to fit to the main plumbing is installed:
  - on the conductivity cell exhaust, and
  - on the SBE 43 intake and exhaust





Place DO sensor with plenum intake closer than exhaust to SBE 43 housing, as shown.
Note: SBE 43 housing orientation (connector end up or down) does not affect operation. Plenum can be reversed on housing by removing and replacing 2 screws.



Inductive Modem Module (IMM) or Surface Inductive Modem (SIM)

An Inductive Modem Module or Surface Inductive Modem is required for communication with the SBE 16*plus*-IM V2. These devices impress (*modulate*) the mooring cable with a DPSK signal that is encoded with commands received from the computer/controller. The encoded signals are *demodulated* by inductive modem instruments coupled to the cable. Replies from inductive modem instruments are similarly coupled to the cable and *demodulated* by these devices.

Inductive Modem Module (IMM)

The IMM must be supplied with 7 to 24 volts DC power. The maximum operating current is approximately 15 milliamps.

The user's computer or buoy controller is interfaced via RS-232 (optional RS-485) serial port to the IMM. The standard interface protocol between the computer/controller and IMM is 1200, 2400, 4800, 9600, 19200, or 38400 baud (user-selectable); 8 data bits; no parity; RS-232C.

The DPSK communication link between the IMM and IM instrument(s) is half-duplex, so talking and listening is sequential only. Although the data link between the IMM and the user's computer/controller is established at 1200, 2400, 4800, 9600, 19200, or 38400, the DPSK modem communication between IMM and IM instruments always operates at 1200 baud.

See the IMM Manual for details.

Surface Inductive Modem (SIM)

The SIM must be supplied with 7 to 25 volts DC power. The operating current is approximately 30 milliamps.

The user's computer or buoy controller is interfaced via RS-232 (optional RS-485) serial port to the SIM. The standard interface protocol between the computer/controller and SIM is 1200, 2400, 4800, or 9600 baud (user-selectable); 8 data bits; no parity; RS-232C; with echoing of characters.

The DPSK communication link between the SIM and IM instrument(s) is half-duplex, so talking and listening is sequential only. Although the data link between the SIM and the user's computer/controller is established at 1200, 2400, 4800, or 9600 baud, the DPSK modem communication between SIM and IM instruments always operates at 1200 baud.

Mooring Cable and Wiring Requirements

Note:
For wiring, see applicable document:
- IMM manual. **OR**
- *Appendix IV: SIM Hookup and Configuration*.

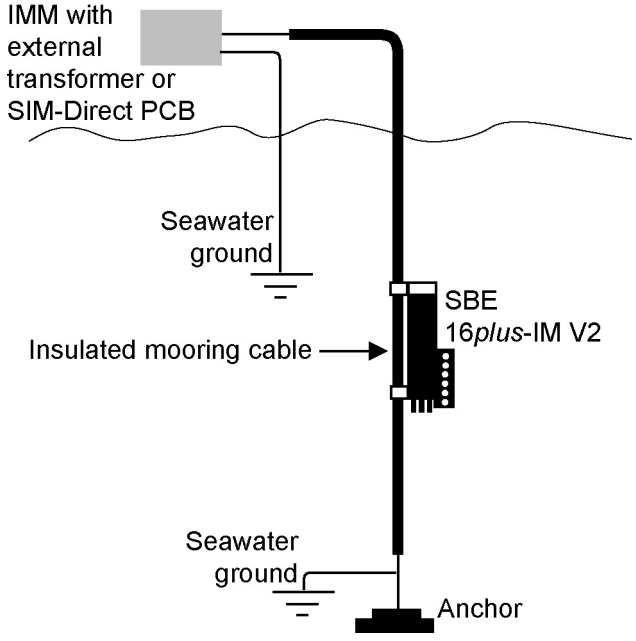
The SBE 16*plus*-IM V2 can mechanically accommodate mooring cables up to 16 mm (0.63 inches) in diameter. Clamps for specific cable diameters are available, or can be supplied on a custom basis. Suitable mooring cables use steel wire rope with a polypropylene or polyethylene-insulating jacket. The SIM operates without data errors using up to 8000 meters (26,200 feet) of 3 mm (0.12 inches) or larger cable.

The mooring cable must provide for connection to seawater ground below the deepest IM instrument. Terminating the wire with a metallic eye or clevis readily provides this connection.

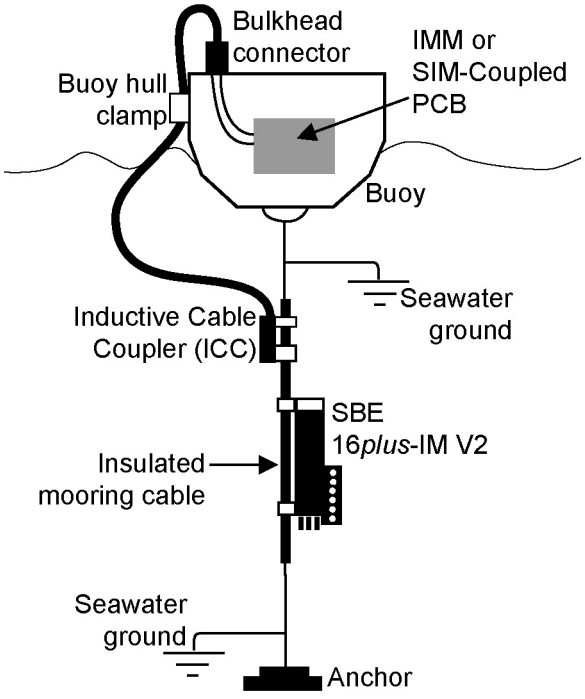
The mooring cable must also provide for connection to the IMM or SIM.

- In a direct connection (typical cable-to-shore applications), the bottom end of the wire is grounded to seawater, and the top end remains insulated to the connection to the IMM or SIM. A second wire from the IMM or SIM connects to seawater ground, completing the circuit.

- In typical surface buoys it is often preferable to connect the jacketed mooring wire to the buoy with a length of chain, grounding the jacketed wire to seawater at each end. An Inductive Cable Coupler (ICC) connects the IMM or SIM to the jacketed wire above the uppermost IM instrument and below the point where the wire is grounded.



Direct Connection



Connection with Inductive Cable Coupler (ICC)

Section 3: Preparing for Deployment

This section describes:

- Installation and use of SeatermV2 terminal program
- Power and communications test to verify that the system works prior to deployment
- Setting SBE 16*plus*-IM V2 ID - each 16*plus*-IM V2 on a mooring must have a unique ID for communicating with the SIM and computer/controller

Software Installation

Notes:
- Help files provide detailed information on the software. A separate software manual on the CD-ROM contains detailed information on SBE Data Processing.
- It is possible to use the 16*plus*-IM V2 without the SeatermV2 terminal program by sending direct commands from a dumb terminal or terminal emulator, such as Windows HyperTerminal.
- Sea-Bird supplies the current version of our software when you purchase an instrument. As software revisions occur, we post the revised software on our FTP site. See our website (www.seabird.com) for the latest software version number, a description of the software changes, and instructions for downloading the software from the FTP site.

Sea-Bird recommends the following minimum system requirements for SEASOFT V2 software: Windows 2000 or later, 500 MHz processor, 256 MB RAM, and 90 MB free disk space for installation. Although SEASOFT V2 was designed to work with a PC running Win 2000/XP; extensive testing has not shown any compatibility problems when using the software with a PC running Windows Vista.

If not already installed, install Sea-Bird software programs on your computer using the supplied software CD:

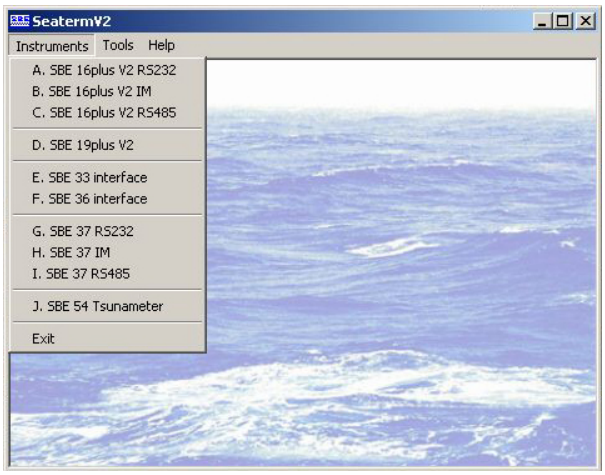
1. Insert the CD in your CD drive.
2. Install software: Double click on **SeasoftV2_*date*.exe** (*date* is the date that version of the software was created). Follow the dialog box directions to install the software. The installation program allows you to install the desired components. Install all the components, or just install Deployment Endurance Calculator (battery endurance calculator), SeatermV2 (terminal program *launcher* for the 16*plus*-IM V2), and SBE Data Processing (data processing).

The default location for the software is c:\Program Files\Sea-Bird. Within that folder is a sub-directory for each program.

SeatermV2 Use

Note:
See SeatermV2's Help files.

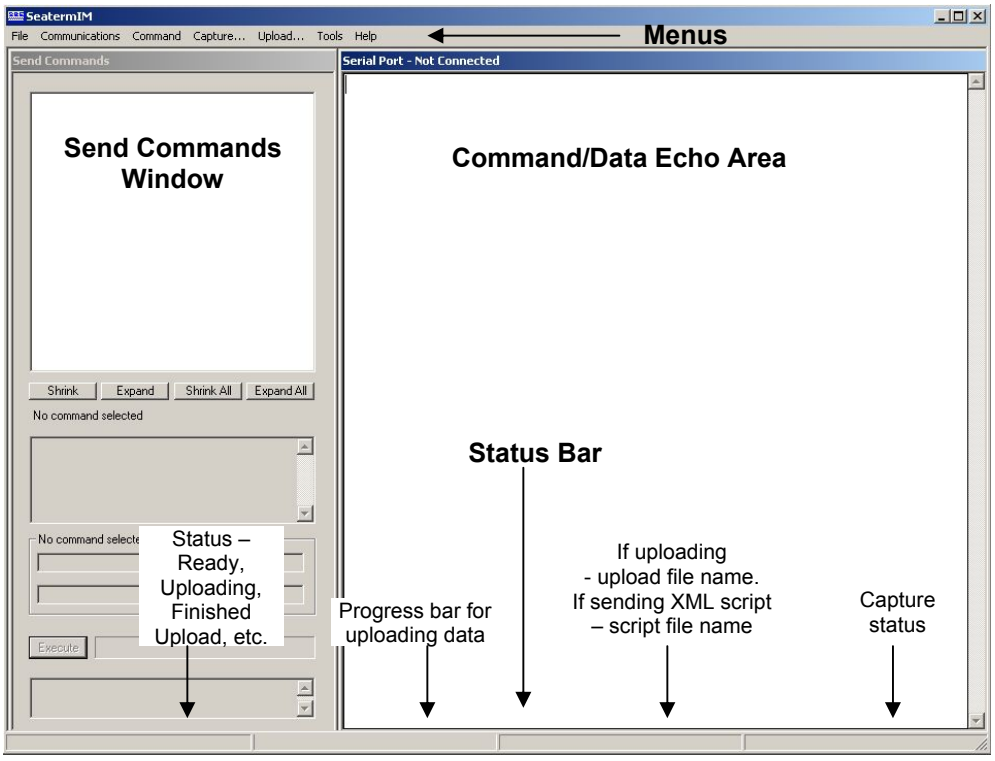
1. Double click on **SeatermV2.exe**. The main screen looks like this:



SeatermV2 is a *launcher*. Depending on the instrument selected, it launches SeatermIM (inductive modem instruments), Seaterm232 (RS-232 instruments), or Seaterm485 (RS-485 instruments).

Notes:
- See SeatermIM's Help files.
- If using the 16*plus*-IM V2 internal RS-232 connector to set up and/or upload data: select *SBE 16plus V2 RS232* instead of *SBE 16plus V2 IM*. This launches Seaterm232 instead of SeatermIM. Seaterm232 is similar to SeatermIM, but is optimized for RS-232 communications.

2. In the Instruments menu, select *SBE 16plus V2 IM*. **SeatermIM** opens; the main screen looks like this:



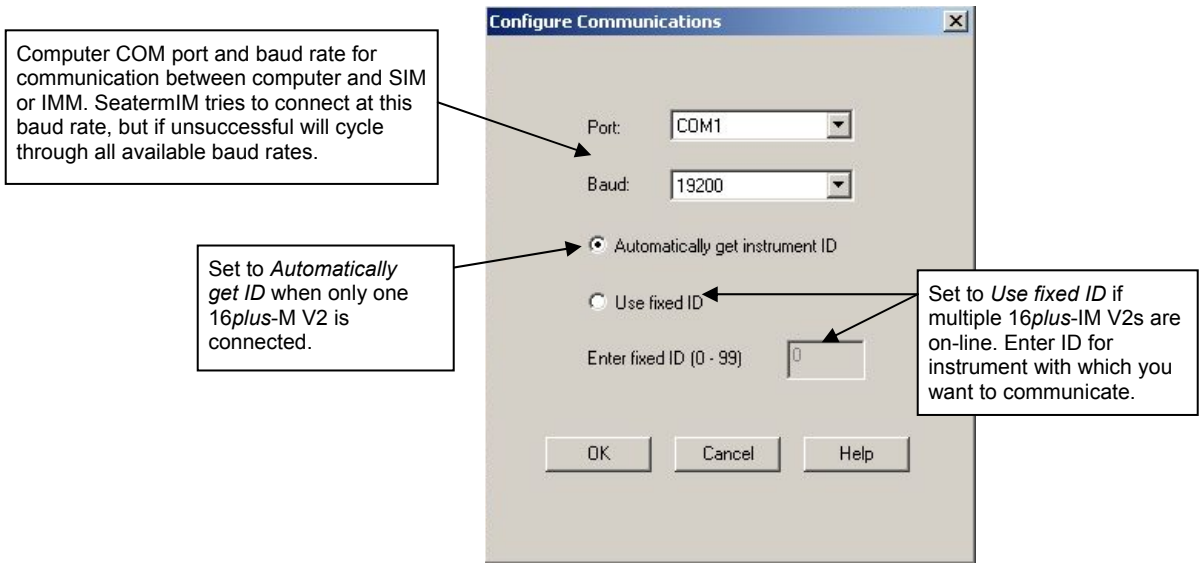
- Menus – For tasks and frequently executed instrument commands.
- Send Commands window – Contains commands applicable to your 16*plus*-IM V2. The list appears after you connect to the 16*plus*-IM V2.
- Command/Data Echo Area – Title bar of this window shows SeatermIM's current comm port and baud rate. Commands and the 16*plus*-IM V2 responses are echoed here. Additionally, a command can be manually typed or pasted (ctrl + V) here. Note that the 16*plus*-IM V2 must be *connected* and *awake* for it to respond to a command.
- Status bar – Provides connection, upload, script, and capture status information.

Following is a description of the menus:

Menu	Description	Equivalent Command*
File	• Load command file – opens selected .XML command file, and fills Send Commands window with commands. • Unload command file – closes command file, and removes commands from Send Commands window. • Exit - Exit program.	-
Communications	• Configure – Establish communication parameters (comm port, baud rate, ID). • Connect – connect to comm port. Re-establish communications by sending wakeup tone to **all** IM instruments on line. Inductive modem instruments *go to sleep* after 2 minutes without communication from computer have elapsed. • Disconnect – disconnect from comm port • Disconnect and reconnect – may be useful if instrument has stopped responding.	• **PwrOn**
Command	• Abort – interrupt and stop 16*plus*-IM V2's attempt to connect or to upload data, or sending of a script. • Send stop command – to stop logging. • Set local time– Set date and time to time sent by timekeeping software on your computer; accuracy ± 25 msec of time provided by computer. • Set UTC Time (Greenwich Mean Time) – Set date and time to time sent by timekeeping software on your computer; accuracy ± 25 msec of time provided by computer.	• (press Esc key several times for Abort) • **#iiStop** • **#iiDateTime=** • **#iiDateTime=**
Capture	Capture instrument responses on screen to file, to save real-time data or use for diagnostics. File has .cap extension. Click Capture menu again to turn off capture. Capture status displays in Status bar.	—
Upload	Upload data stored in memory, in a format that Sea-Bird's data processing software can use (raw hex). Uploaded data has .xml extension, and is then automatically converted to a file with .hex extension. Before using Upload: **stop logging** by sending **#iiStop**.	Several status commands and appropriate data upload command as applicable to user selection of range of data to upload (use Upload menu if you will be processing data with SBE Data Processing or viewing archived data with Seasave)
Tools	• Diagnostics log - Keep a diagnostics log. • Convert .XML data file – Using Upload menu automatically does this conversion; tool is available if there was a problem with the automatic conversion. • Send script – Send XML script to 16*plus*-IM V2. May be useful if you have a number of 16plus-IM V2s to program with same setup.	-

*See *Command Descriptions* in *Section 4: Deploying and Operating SBE 16plus-IM V2*.

3. If this is the first time SeatermIM is being used, the configuration dialog box displays:



Make the desired selections, and click OK.

4. SeatermIM tries to automatically connect to the 16*plus*-IM V2. It first sends commands to determine if it is connected to a SIM or an IMM, and sends the appropriate command to wake up all IM instruments on the line. The remaining connection attempt varies, depending on the configuration setting the last time SeatermIM was used:
   - If SeatermIM was set to *Automatically get instrument ID* the last time it was used – SeatermIM sends **id?** and waits for a response from the 16*plus*-IM V2. Once the ID response is received, SeatermIM sends **!iiDS** and #**iiGetHD**, using the ID provided by the 16*plus*-IM V2.
   - If SeatermIM was set to *Use fixed ID* the last time it was used – SeatermIM sends **!iiDS** and **#iiGetHD**, using the fixed ID that was entered the last time the software was used.

Note:
!iiDS and **#iiGetHD** provide factory-set data such as instrument type, serial number, and firmware version for the 16*plus*-IM V2 's communication microcontroller and acquisition microcontroller.

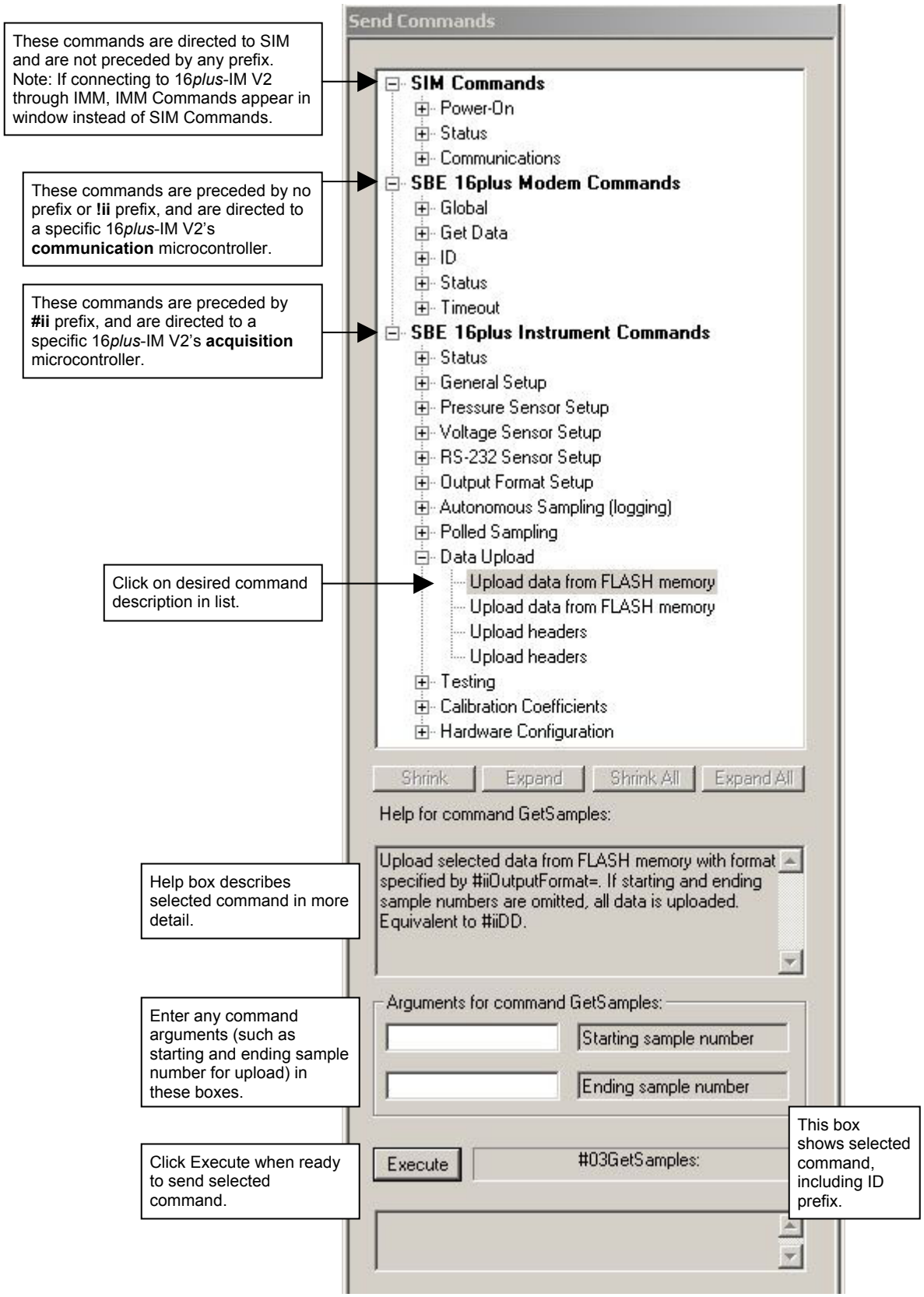
SeatermIM then fills the Send Commands window with the correct list of commands for your 16*plus*-IM V2.

Notes:
- SeatermIM's baud rate must be the same as the IMM or SIM baud rate, as applicable. For both the SIM and the IMM, baud is factory-set to 9600, but can be changed by the user.
- Set to *Use fixed ID* to designate the appropriate 16*plus*-IM V2 if there are multiple 16*plus*-IM V2s on the IM line. If desired, use *Automatically get instrument ID* if there is only one 16*plus*-IM V2 on the IM line. Note that the ID is stored in the 16*plus*-IM V2's EEPROM and can be changed so that multiple 16*plus*-IM V2s on a single IM line each have a unique ID. See the Configuration Sheet for the factory-set ID.

If there is no communication (no response to **id?** and/or no response to **!iiDS** and/or **#iiGetHD):**

A. In the Communications menu, select *Configure*. The Configure Communications dialog box appears. Select the Comm port and baud rate for communication. Note that the factory-set baud rate is documented on the Configuration Sheet. If using a fixed ID, verify that the designated ID is correct for the 16*plus*-IM V2 with which you want to communicate. Click OK.
B. In the Communications menu, select *Connect* (if *Connect* is grayed out, select *Disconnect and reconnect*). SeatermIM will attempt to connect at the baud specified in Step A, but if unsuccessful will then cycle through all other available baud rates.
C. If there is still no communication, check cabling between the computer, SIM or IMM, and 16*plus*-IM V2, and try to connect again.
D. If there is still no communication, repeat Step A with a different comm port and/or different fixed ID, and try to connect again.

Taking a look at the Send Commands window:



You can use the Send Commands window to send commands, or simply type the commands in the Command/Data Echo area if desired.

Power and Communications Test and Setting SBE 16*plus*-IM V2 IDs – Using Surface Inductive Modem (SIM)

The power and communications test will verify that the system works, prior to deployment.

Test Setup with SIM

Note:
For testing and setup, an ICC is not required, even if using SIM-Coupled.

Note:
Important! For Normal Deployed operation, reinstall the jumper across J5.

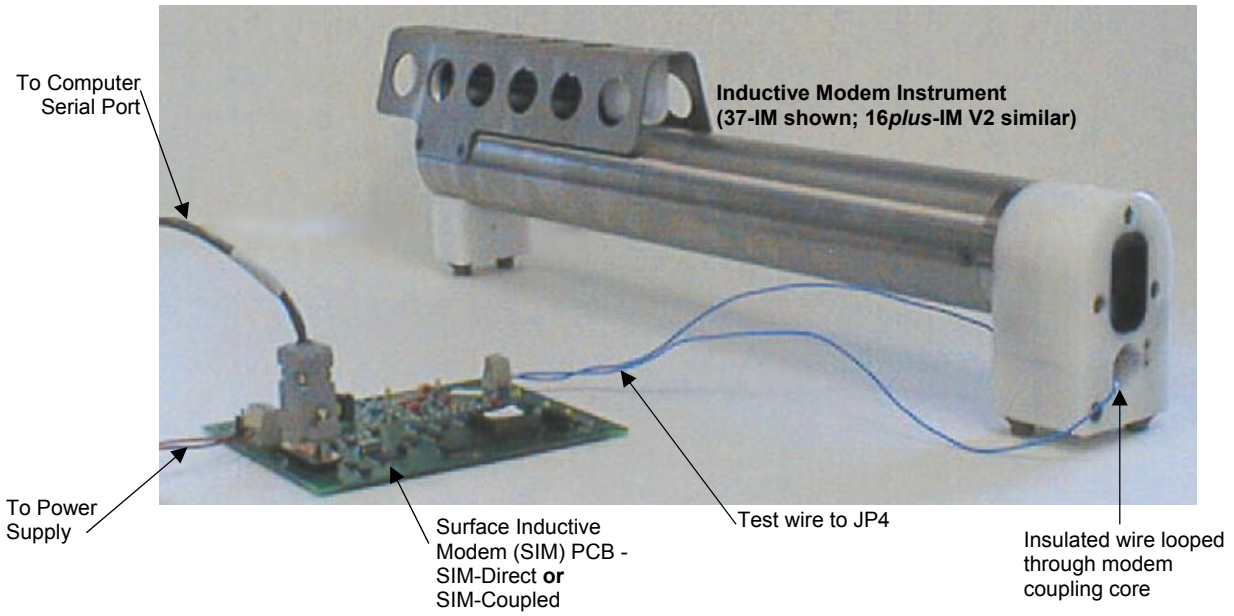
1. Loop insulated wire through the 16*plus*-IM V2 modem coupling core to simulate a mooring cable. Connect the test wire ends to the SIM's mooring cable terminals (JP4). (See *Appendix IV: SIM Hookup and Configuration* for detailed information.)

2. On the SIM, remove the jumper on J5 (see *Appendix IV*). This inserts a 1K resistor in series with the inductive loop and reduces signal amplitude, preventing 16*plus*-IM V2s that are near but not attached to the inductive loop from responding to commands (especially important when sending the ***ID=** command).

3. Sea-Bird recommends a minimum of 20 ohms impedance to reduce noise during testing.

4. Connect the SIM to a 7-25 VDC power supply. A minimum of 30 milliamps are required. **Do not turn on the power supply yet**.

5. Connect the SIM to your computer's serial port using the 9-pin to 9-pin cable supplied with the SIM.

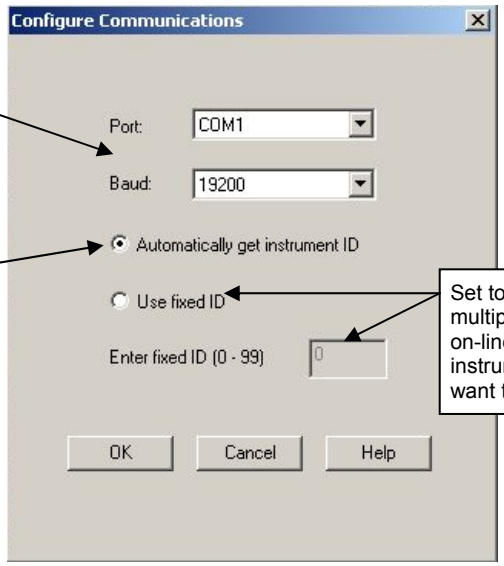


Test and Set SBE 16*plus*-IM V2 ID Using SIM

Note:
See SeatermV2 and SeatermIM Help files.

1. Double click on **SeatermV2.exe**. In the Instruments menu, select *SBE 16plus V2 IM*. **SeatermIM** opens.

2. If this is the first time SeatermIM is being used, the configuration dialog box displays:



Computer COM port and baud rate for communication between computer and SIM or IMM. SeatermIM tries to connect at this baud rate, but if unsuccessful will cycle through all available baud rates.

Set to *Automatically get ID* when only one 16*plus*-M V2 is connected.

Set to *Use fixed ID* if multiple 16*plus*-IM V2s are on-line. Enter ID for instrument with which you want to communicate.

Make the desired selections, and click OK.

3. SeatermIM tries to automatically connect to the 16*plus*-IM V2. It sends **DS** to get SIM status information, and **PwrOn** to wake up all IM instruments on the line. The remaining connection attempt varies, depending on the configuration setting the last time SeatermIM was used:
   - If SeatermIM was set to *Automatically get instrument ID* the last time it was used – SeatermIM sends **id?** and waits for a response from the 16*plus*-IM V2. Once the ID response is received, SeatermIM sends **!iiDS** and #**iiGetHD**, using the ID provided by the 16*plus*-IM V2.
   - If SeatermIM was set to *Use fixed ID* the last time it was used – SeatermIM sends **!iiDS** and **#iiGetHD**, using the fixed ID that was entered the last time the software was used.

Note:
!iiDS and **#iiGetHD** provide factory-set data such as instrument type, serial number, and firmware version for the 16*plus*-IM V2's communication microcontroller and acquisition microcontroller.

SeatermIM then fills the Send Commands window with the correct list of commands for your 16*plus*-IM V2.

Notes:
- SeatermIM's baud rate must be the same as the IMM or SIM baud rate, as applicable. For both the SIM and the IMM, baud is factory-set to 9600, but can be changed by the user.
- Set to *Use fixed ID* to designate the appropriate 16*plus*-IM V2 if there are multiple 16*plus*-IM V2s on the IM line. If desired, use *Automatically get instrument ID* if there is only one 16*plus*-IM V2 on the IM line. Note that the ID is stored in the 16*plus*-IM V2's EEPROM and can be changed so that multiple 16*plus*-IM V2s on a single IM line each have a unique ID. See the Configuration Sheet for the factory-set ID.

If there is no communication (no response to id? and/or no response to !iiDS and #iiGetHD):

A. In the Communications menu, select *Configure*. The Configure Communications dialog box appears. Select the Comm port and baud rate for communication. Note that the factory-set baud rate is documented on the Configuration Sheet. If using a fixed ID, verify that the designated ID is correct for the 16*plus*-IM V2 with which you want to communicate. Click OK.
B. In the Communications menu, select *Connect* (if *Connect* is grayed out, select *Disconnect and reconnect*). SeatermIM will attempt to connect at the baud specified in Step A, but if unsuccessful will then cycle through all other available baud rates.
C. If there is still no communication, check cabling between the computer, SIM or IMM, and 16*plus*-IM V2, and try to connect again.
D. If there is still no communication, repeat Step A with a different comm port and/or different fixed ID, and try to connect again.

Note:
Sending the status command causes the optional pump to turn on for a moment, so that the 16*plus*-IM V2 can measure and output the pump current. Because the pump is designed to be water lubricated, you may hear a noise when the impeller spins in air. Running the pump *dry* for **short** periods (for example, when sending the status command) will not harm the pump.

4. Display 16*plus*-IM V2 status information by typing **#iiDS** (ii = 16*plus*-IM V2 ID) and pressing the Enter key. The display looks like this:

```
SBE 16plus-IM V 2.2  SERIAL NO. 0001    01 Oct 2009  14:02:13
vbatt = 10.3, vlith = 8.5, ioper = 62.5 ma, ipump = 21.6 ma,
iext01 = 76.2
status = not logging
samples = 0, free = 3870479
sample interval = 15 seconds, number of measurements per sample = 1
run pump for 0.5 sec, delay before sampling = 0.0 seconds
battery cutoff = 7.5 volts
pressure sensor = strain gauge, range = 1000.0
SBE 38=no, SBE 50 = no, OPTODE = no, Gas Tension Device = no
Ext Volt 0 = yes, Ext Volt 1 =no,
Ext Volt 2 = no, Ext Volt 3 = no,
Ext Volt 4 = no, Ext Volt 5 = no
output format = converted decimal
output salinity = no, output sound velocity = no, output sample number
= yes
```

Note:
The SIM and 16*plus*-IM V2 have timeout algorithms designed to:
- restore control to the computer if an illegal command is sent
- conserve battery energy if too much time elapses between commands

If the system does not appear to respond, see *Timeout Descriptions* in *Section 4: Deploying and Operating SBE 16plus-IM V2*.

5. Command the 16*plus*-IM V2 to take a sample by typing **#iiTS** (ii = 16*plus*-IM V2 ID) and pressing the Enter key. The display looks like this (if 16*plus*-IM V2 includes optional internally mounted pressure sensor, and is set up for converted decimal output format, output sample number, no output salinity or sound velocity, and auxiliary voltage sensor on channel 0):

   ```
   4000, 23.7658,0.00019, 0.062, 0.5632, 01 Oct 2009, 14:10:10, 5
   ```

   where 0001 = 16*plus*-IM V2 serial number 4000 (16pxxxxx-0001)
   23.7658 = temperature in degrees Celsius
   0.00019 = conductivity in S/m
   0.062 = pressure in db
   0.5632 = voltage for auxiliary sensor channel 0
   01 Oct 2009 = date
   14:10:10 = time
   5 = sample number in memory

   These numbers should be reasonable; i.e., room temperature, zero conductivity, barometric pressure (gauge pressure), current date and time (set at factory to Pacific Daylight or Standard Time), expected number of samples in memory.

Note:
If more than one 16*plus*-IM V2 is on-line when you set the ID, all 16*plus*-IM V2s will be set to the same ID.

6. Each 16*plus*-IM V2 on a mooring must have a unique ID for communicating with the SIM and computer. Set the ID as described below, first verifying that only one 16*plus*-IM V2 is on-line before you set the ID:
   A. Set the 16*plus*-IM V2 ID by typing ***ID=ii** (ii= user-assigned ID number) and pressing the Enter key.
   B. The computer responds by requesting verification, requiring you to again type ***ID=ii** and press the Enter key.
   C. Record the ID for future reference.
   D. In the Communications menu, select *Configure*. Set to *Use fixed ID*, enter the new ID, and click OK. This provides SeatermIM with the correct ID information for sending commands listed in the Send Commands window.

7. Command the 16*plus*-IM V2 to go to sleep (quiescent state) by typing **PwrOff** and pressing the Enter key.

The SBE 16*plus*-IM V2 is ready for programming and deployment.

Important! When testing and ID setting is complete for all 16*plus*-IM V2s, reinstall the J5 jumper on the SIM PCB. The jumper must be installed for Normal Deployed operation.

Power and Communications Test and Setting SBE 16*plus*-IM V2 IDs – Using Inductive Modem Module (IMM)

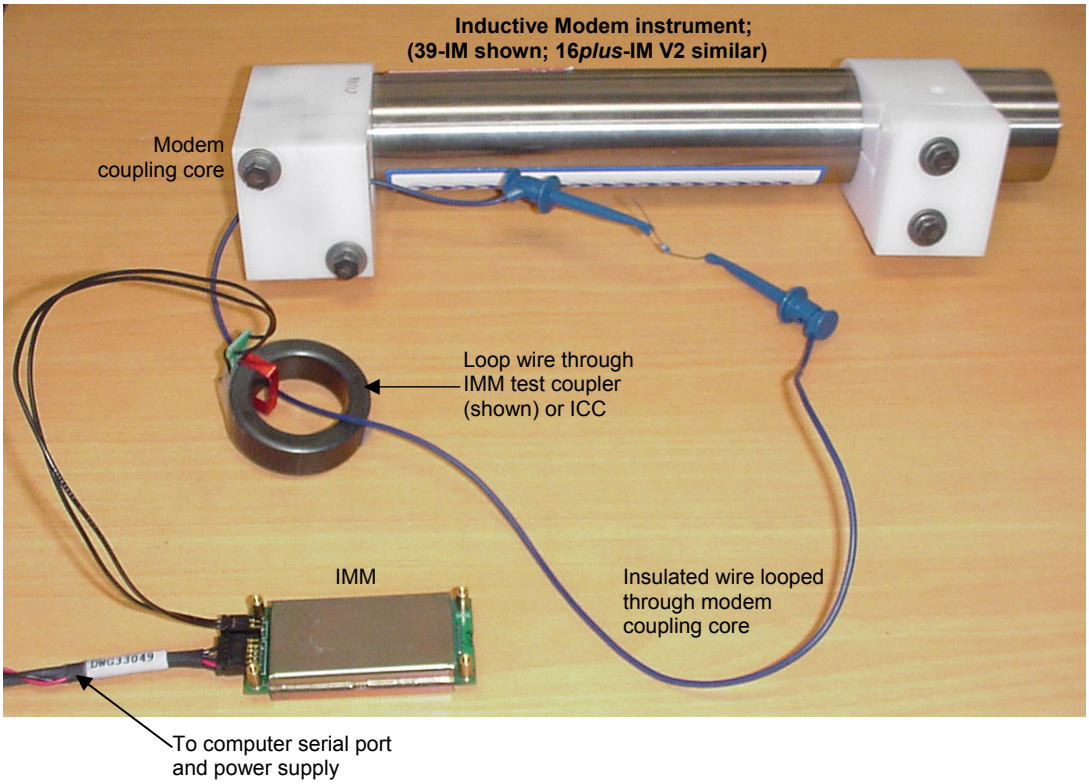
The power and communications test will verify that the system works, prior to deployment.

Test Setup with IMM

1. Loop insulated wire through the 16*plus*-IM V2's modem coupling core to simulate a mooring cable. Place the other end of the loop through the IMM test coupler (supplied with the IMM) or the ICC. Connect the wire ends from the IMM test coupler or ICC to the IMM's mooring cable terminals (J1) (see IMM Manual).

2. Sea-Bird recommends a minimum of 20 ohms impedance to reduce noise during testing.

3. Connect the IMM to your computer's serial port and to a 7 – 24 VDC power supply using the cable supplied with the IMM. A maximum of 15 mA is required.



Setup of IMM for use with 16*plus*-IM V2

Note:
See the IMM manual for complete details on the use and setup of the IMM.

Sea-Bird recommends **one** of the following setups of the IMM for use with the SBE 16*plus*-IM V2:

To make full use of IMM capabilities:

***Init**
***Init** (Resets IMM to factory default state [must be sent twice])
SetConfigType=2
SetEnableAutoIMFlag=0
SetEnableBackSpace=1
SetEnableBinaryData=0
SetEnableEcho=1
SetEnableHostFlagConfirm=0
SetEnableHostFlagTerm=0
SetEnableHostFlagWakeup=0
SetEnableHostPromptConfirm=0
SetEnableHostServeOnPwrUp=1
SetEnablePrompt=1
SetEnableHostWakeupCR=0
SetEnableSignalDetector=0
SetTermFromHost=36
SetTermToHost=13

To have the IMM emulate the SIM:

***Init**
***Init** (Resets IMM to factory default state [must be sent twice])
SetConfigType=1
SetEnableBinaryData=0

Verify that the IMM is set up as described by sending the **GetCD** command before proceeding with the 16*plus*-IM V2 setup.

A script including one of the above setups should be included in the buoy controller, to allow the IMM to be reset to the appropriate state if it becomes corrupted.

Test and Set SBE 16*plus*-IM V2 ID Using IMM

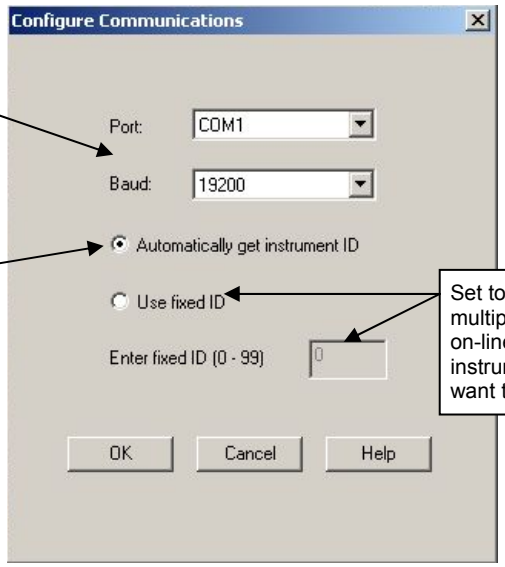
Note:
See SeatermV2 and SeatermIM Help files.

1. Double click on **SeatermV2.exe**. In the Instruments menu, select *SBE 37 IM*. **SeatermIM** opens:

2. If this is the first time SeatermIM is being used, the configuration dialog box displays:

Computer COM port and baud rate for communication between computer and IMM. SeatermIM tries to connect at this baud rate, but if unsuccessful will cycle through all available baud rates.

Set to *Automatically get ID* when only one 16*plus*-IM V2 is connected.



Set to *Use fixed ID* if multiple 16*plus*-IM V2s are on-line. Enter ID for instrument with which you want to communicate.

Make the desired selections, and click OK.

3. SeatermIM tries to automatically connect to the 16*plus*-IM V2. It sends **DS** to determine if it is communicating with a SIM. If there is no response to **DS**, it assumes it is communicating with an IMM and proceeds as follows.
   A. It sends **GetHD** to get IMM status information.
   B. If **ConfigType=1**, it sends **PwrOn** to wake up all IM instruments on the line. If **ConfigType=2**, it sends **ForceCaptureLine** to reserve the IM line by transmitting a carrier signal, and **SendWakeupTone** to wake up all IM instruments on the line.
   C. The remaining connection attempt varies, depending on the configuration setting the last time SeatermIM was used:
      - If SeatermIM was set to *Automatically get instrument ID* – It sends **id?** and waits for a response from the 16*plus*-IM V2. It then sends **!iiDS** and #**iiGetHD**, using the ID provided by the 16*plus*-IM V2.
      - If SeatermIM was set to *Use fixed ID* – It sends **!iiDS** and **#iiGetHD**, using the fixed ID that was entered the last time SeatermIM was used.

   SeatermIM then fills the Send Commands window with the correct list of commands for your 16*plus*-IM V2.

Note:
!iiDS and **#iiGetHD** provide factory-set data such as instrument type, serial number, and firmware version for the 16*plus*-IM V2's communication microcontroller and acquisition microcontroller.

Notes:
- SeatermIM's baud rate must be the same as the IMM baud rate. Baud is factory-set to 9600, but can be changed by the user.
- Set to *Use fixed ID* to designate the appropriate 16*plus*-IM V2 if there are multiple 16*plus*-IM V2s on the IM line. If desired, use *Automatically get instrument ID* if there is only 1 16*plus*-IM V2 on the IM line. Note that the ID is stored in the 16*plus*-IM V2's EEPROM and can be changed so that multiple 16*plus*-IM V2s on a single IM line each have a unique ID. See the Configuration Sheet for the factory-set ID.

4. **If there is no communication** (no response to **id?** and/or no response to **!iiDS** and/or **#iiGetHD**):
   A. In the Communications menu, select *Configure*. The Configure Communications dialog box appears. Select the Comm port and baud rate for communication. Note that the factory-set baud rate is documented on the Configuration Sheet. If using a fixed ID, verify that the designated ID is correct for the 16*plus*-IM V2 with which you want to communicate. Click OK.
   B. In the Communications menu, select *Connect* (if *Connect* is grayed out, select *Disconnect and reconnect*). SeatermIM will attempt to connect at the baud specified in Step A, but if unsuccessful will then cycle through all other available baud rates.
   C. If there is still no communication, check cabling between the computer, IMM, and 16*plus*-IM V2, and try to connect again.
   D. If there is still no communication, repeat Step A with a different comm port and/or different fixed ID, and try to connect again.

Note:
The IMM and 16*plus*-IM V2 have timeout algorithms designed to:
- restore control to the computer if an illegal command is sent
- conserve battery energy if too much time elapses between commands

If the system does not appear to respond:
- If **ConfigType=1**: send **PwrOn**.
- If **ConfigType=2**: wait at least 1 second, send **ForceCaptureLine**, and send **SendWakeupTone**.

See *Timeout Descriptions* in *Section 4: Deploying and Operating 16plus-IM V2* and the IMM manual.

Note:
Sending the status command causes the optional pump to turn on for a moment, so that the 16*plus*-IM V2 can measure and output the pump current. Because the pump is designed to be water lubricated, you may hear a noise when the impeller spins in air. Running the pump *dry* for **short** periods (for example, when sending the status command) will not harm the pump.

5. Display 16*plus*-IM V2 status information by typing **#iiDS** (ii = 16*plus*-IM V2 ID) and pressing the Enter key. The display looks like this:

```
SBE 16plus-IM V 2.2  SERIAL NO. 0001    01 Oct 2009  14:02:13
vbatt = 10.3, vlith = 8.5, ioper = 62.5 ma, ipump = 21.6 ma,
iext01 = 76.2
status = not logging
sample interval = 15 seconds, number of measurements per sample = 1
samples = 0, free = 3870479
run pump for 0.5 sec, delay before sampling = 0.0 seconds
battery cutoff = 7.5 volts
pressure sensor = strain gauge, range = 1000.0
SBE 38=no, SBE 50 = no, OPTODE = no, Gas Tension Device = no
Ext Volt 0 = yes, Ext Volt 1 =no,
Ext Volt 2 = no, Ext Volt 3 = no,
Ext Volt 4 = no, Ext Volt 5 = no
output format = converted decimal
output salinity = no, output sound velocity = no, output sample number
= yes
```

Note:
The IMM and 16*plus*-IM V2 have timeout algorithms designed to:
- restore control to the computer if an illegal command is sent
- conserve battery energy if too much time elapses between commands

If the system does not appear to respond, see:
- *Timeout Descriptions* in *Section 4: Deploying and Operating SBE 16plus-IM V2* in this manual, and
- IMM manual.

6. Command the 16*plus*-IM V2 to take a sample by typing **#iiTS** (ii = 16*plus*-IM V2 ID) and pressing the Enter key. The display looks like this (if 16*plus*-IM V2 includes optional internally mounted pressure sensor, and is set up for converted decimal output format, output sample number, no output salinity or sound velocity, and auxiliary voltage sensor on channel 0):

```
4000, 23.7658,0.00019, 0.062, 0.5632, 01 Oct 2009, 14:10:10, 5
```

where 0001 = 16*plus*-IM V2 serial number 4000 (16pxxxxx-0001)
23.7658 = temperature in degrees Celsius
0.00019 = conductivity in S/m
0.062 = pressure in db
0.5632 = voltage for auxiliary sensor channel 0
01 Oct 2009 = date
14:10:10 = time
5 = sample number in memory

These numbers should be reasonable; i.e., room temperature, zero conductivity, barometric pressure (gauge pressure), current date and time (set at factory to Pacific Daylight or Standard Time), expected number of samples in memory.

Note:
If more than one 16*plus*-IM V2 is on-line when you set the ID, all 16*plus*-IM V2s will be set to the same ID.

7. Each 16*plus*-IM V2 on a mooring must have a unique ID for communicating with the IMM and computer. Set the ID as described below, first verifying that only one 16*plus*-IM V2 is on-line before you set the ID:
   A. Set the 16*plus*-IM V2 ID by typing ***ID=ii** (ii= user-assigned ID number) and pressing the Enter key.
   B. The computer responds by requesting verification, requiring you to again type ***ID=ii** and press the Enter key.
   C. Record the ID for future reference.
   D. In the Communications menu, select *Configure*. Set to *Use fixed ID*, enter the new ID, and click OK. This provides SeatermIM with the correct ID information for sending commands listed in the Send Commands window.

8. Send additional commands, as desired.

9. Command the 16*plus*-IM V2 to go to sleep (quiescent state) by typing **PwrOff** and pressing the Enter key.

The SBE 16*plus*-IM V2 is ready for programming and deployment.

Section 4: Deploying and Operating SBE 16*plus*-IM V2

Note:
Separate software manuals and Help files contain detailed information on installation, setup, and use of Sea-Bird's software.

This section provides instructions for deploying the SBE 16*plus*-IM V2. It includes discussions of:

- System operation and timeout descriptions
- Sampling modes with example sets of commands
- Pump operation
- Command descriptions
- Data formats
- Deployment
- System installation and wiring
- Recovery - physical handling and uploading data
- Processing data with SBE Data Processing
- Editing a raw data file

Operation Description

The SBE 16*plus*-IM V2 internal functions are supervised by two internal microcontrollers. The acquisition microcontroller supervises measurement acquisition, and setup and sampling functions. The communication microcontroller supervises communication between the 16*plus*-IM V2 and IMM/SIM. These two microcontrollers allows for independent control of power usage by the communication and acquisition circuits. Acquisition consumes more power, but for shorter duration. Communication protocols take proportionately more time, but can be controlled separately and operate at lower power, thus maximizing battery life. This also prevents communication protocols from interfering with measurement acquisition timing.

Commands can be directed to the IMM or SIM (typically at the surface), the 16*plus*-IM V2 communication microcontroller (with a ! prefix), or the 16*plus*-IM V2 acquisition microcontroller (with a # prefix).

- An ID command prefix (**#ii** or **!ii**) is used to direct commands to a 16*plus*-IM V2 with the same ID.
- A Group command prefix (**#Gn:** or **!Gn:**) is used to direct commands to all instruments in a Group. **All 16*plus*-IM V2s have been factory assigned to Group 0 and Group 9.**
- Global commands do not require a prefix and are recognized by all 16*plus*-IM V2s attached to the same inductive cable.

Surface Inductive Modem (SIM)
- Power on/Power off
- SIM status
- Set baud (SIM to computer)
- Set timeouts
- Set echo parameter

OR

Inductive Modem Module (IMM)
See IMM manual for details.

↔

16*plus*-IM V2 Communication Microcontroller
- Get data
- Get and set 16*plus*-IM V2 ID
- Display status
- Set timeout
- Global commands to get data and set clock

↔

16*plus*-IM V2 Acquisition Microcontroller
- Display status
- Setup
- Autonomous sampling (logging)
- Data upload
- Polled sampling
- Testing
- Calibration coefficients
- Hardware configuration

Timeout Descriptions

For **IMM timeouts**, see the IMM manual.

SIM timeouts restore control to the computer if no reply is received from the 16*plus*-IM V2 (for example, upon sending an illegal command) within a specified length of time. This allows new commands to be sent. There are two user-programmable SIM timeouts:

- **DataNNMax** – timeout for **!iiData** and **Dataii** only. Default 1000 milliseconds.
- **RelayMax** – timeout for all other commands. Default 20 seconds.

When using RS-232 between the SIM and computer, control of the SIM can be re-established sooner than the timeout by pressing the Esc key and then the Enter key. When the `S>` prompt is displayed, new commands can be sent.

The **16*plus*-IM V2 timeout** powers down the 16*plus*-IM V2 communication circuits if the 16*plus*-IM V2 does not receive a command for 2 minutes, to prevent exhaustion of its batteries. **To re-establish control:**

- Select *Connect* in SeatermIM's Communications menu. or
- (if using the SIM) Send **PwrOn**. or
- (if using the IMM) Wait at least 1 second, send **ForceCaptureLine**, and then send **SendWakupTone**.

The 16*plus*-IM V2 also has a user-programmable timeout (**!iiWait=**) that provides the maximum amount of time for the communication microcontroller to wait for a response from the acquisition microcontroller.

Sampling Modes

Note:
The 16*plus*-IM V2 communications microcontroller automatically enters quiescent state after 2 minutes without receiving a command.

The SBE 16*plus*-IM V2 has three basic sampling modes for obtaining data:
- Polled Sampling
- Autonomous Sampling (logging)
- Combo Sampling

Sampling commands can be used in various combinations to provide a high degree of operating flexibility. Review the operation of the three basic sampling modes and the commands described in *Command Descriptions* before setting up your system.

Descriptions and examples of the sampling modes follow for a system with three 16*plus*-IM V2s (IDs 01, 02, and 03) on a mooring cable. Note that the 16*plus*-IM V2 response to each command is not shown in the examples.

Polled Sampling

On command, the SBE 16*plus*-IM V2 takes one sample of data and sends the data to the SIM or IMM. Storing of data in the 16*plus*-IM V2 FLASH memory is dependent on the particular command used. Note that it is not possible to synchronize the data samples from each 16*plus*-IM V2 in polled sampling.

Example: ***Polled Sampling*** (user input in bold)
Send wakeup tone to all IM instruments. Globally set date and time to September 1, 2009 at 9:05 am.
Set up each 16*plus*-IM V2 with 1 voltage sensor, no pump, take and average 4 measurements for each sample, and output data in converted decimal format. After all parameters are entered, verify setup. Send power-off command to all 16*plus*-IM V2s.

(Select *Connect* in SeatermIM's Communications menu to connect and wake up all 16*plus*-IM V2s.)
DATETIME=09012009090500
#01VOLT0=Y
#01PUMPMODE=0
#01NCYCLES=4
#01OUTPUTFORMAT=3
#01GETCD (to verify setup)
(Repeat **#iiPTYPE=** through **#iiGETCD** for 16*plus*-IM V2s 02 and 03.)
PWROFF

Send wakeup tone to all 16*plus*-IM V2s. Command each 16*plus*-IM V2 to take a sample, and send data to SIM/IMM. Send power-off command to all 16*plus*-IM V2s.

(Select *Connect* in SeatermIM's Communications menu to connect and wake up all 16*plus*-IM V2s.)
#01TS (16*plus*-IM V2 with ID=01 takes and transmits a sample.)
#02TS (16*plus*-IM V2 with ID=02 takes and transmits a sample.)
#03TS (16*plus*-IM V2 with ID=03 takes and transmits a sample.)
PWROFF

Autonomous Sampling (logging)

At pre-programmed intervals, the SBE 16*plus*-IM V2 wakes up, samples data, stores the data in its FLASH memory, and enters quiescent (sleep) state. The 16*plus*-IM V2 goes to sleep for a minimum of 5 seconds between each sample. The 16*plus*-IM V2 does not transmit data to the SIM or IMM. Autonomous sampling is started with **#iiStartNow** or **#iiStartLater**, and is stopped with **#iiStop**.

To synchronize the data samples for each 16*plus*-IM V2 in Autonomous Sampling (see *Specifications* in *Section 2: Description of SBE 16plus-IM V2* for the real-time clock specifications):

- Send a global command to set the date and time for all 16*plus*-IM V2s.
- Set the sampling interval for each 16*plus*-IM V2 to the same value.
- Set the start sampling date and time for each 16*plus*-IM V2 to the same value, and then send **#iiStartLater**.

The 16*plus*-IM V2 has a *lockout* feature to prevent unintended interference with sampling. If the 16*plus*-IM V2 is sampling or is waiting to start sampling (**#iiStartLater** has been sent, but logging hasn't started yet), only the following commands will be accepted:

- All SIM or IMM commands,
- These 16*plus*-IM V2 Communication Microcontroller commands: **GData** (send **SendGData** if using IMM), **Dataii**, **!iiData**, **ID?**, and **!iiDS**
- These 16*plus*-IM V2 Acquisition Microcontroller commands: **#iiGetCD**, **#iiGetSD**, **#iiGetCC**, **#iiGetEC**, **#iiResetEC**, **#iiGetHD**, **#iiDS**, **#iiDCal**, **#iiTS**, **#iiSL**, **#iiSLT**, and **#iiStop**.

Note:
Use **#iiStop** to:
- stop autonomous sampling
- stop waiting to start autonomous sampling (after **#iiStartLater** has been sent)

Once **#iiStop** is sent, the 16*plus*-IM V2 accepts all commands again.

Example: ***Autonomous Sampling*** (user input in bold)
Send wakeup tone to all 16*plus*-IM V2*s*. Globally set date and time to September 1, 2009 at 9:05 am. For each 16*plus*-IM V2: initialize logging to overwrite previous data in memory, set up with 1 voltage sensor, take a sample every 120 seconds, take and average 4 measurements for each sample, and output data in raw hex format. Set up pump to run for 0.5 seconds before each sample. Set up to start logging on 15 September 2009 at 12:00:00. Send command to start logging at designated date and time. After all parameters are entered, verify setup. Send power-off command to all 16*plus*-IM V2s.

(Select *Connect* in SeatermIM's Communications menu to connect and wake up all 16*plus*-IM V2s.)

```
DATETIME=09012009090500
#01INITLOGGING
#01VOLT0=Y
#01SAMPLEINTERVAL=120
#01NCYCLES=4
#01OUTPUTFORMAT=0
#01PUMPMODE=1
#01STARTDATETIME=09152009120000
#01STARTLATER
#01GETCD        (to verify setup)
```

(Repeat **#iiINITLOGGING** through **#iiGETCD** for 16*plus*-IM V2s 02 and 03.)

```
PWROFF
```

Deploy 16*plus*-IM V2. Logging starts automatically at designated date and time.
When ready to upload all data to computer, wake up all 16*plus*-IM V2s, stop sampling, and upload data:

(Select *Connect* in SeatermIM's Communications menu to connect and wake up all 16*plus*-IM V2s.)

```
#01STOP
```

(Click Upload menu – SeatermIM leads you through screens to define data to be uploaded and where to store it.)
(Repeat **#iiSTOP** through Upload for 16*plus*-IM V2s 02 and 03.)

```
PWROFF
```

Combo Sampling

Combo Sampling combines Autonomous Sampling with the ability to retrieve the last data sample from each SBE 16*plus*-IM V2, to look at data without stopping the sampling. As in Autonomous Sampling, the 16*plus*-IM V2 wakes up, samples data at pre-programmed intervals, stores the data in its FLASH memory, and powers-off (enters quiescent state).

When desired, the user can request the last stored data sample from a particular 16*plus*-IM V2. There are two ways to get the last stored sample:

- From a specific 16*plus*-IM V2 - use **#iiSL**.
- From all 16*plus*-IM V2s - use **GData** (send **SendGData** if using IMM), which is a global command to each 16*plus*-IM V2 to hold the last data sample in its buffer. Then, send **!iiData** to each 16*plus*-IM V2 to transmit the last data sample from its buffer.

Example: ***Combo Sampling*** (user input in bold)
Set up all 16*plus*-IM V2s as shown above for Autonomous Sampling.

After logging begins, look at data from last sample to check results:

(Select *Connect* in SeatermIM's Communications menu to connect and wake up all 16*plus*-IM V2s.)

```
#01SL
#02SL
#03SL
PWROFF
```

OR

If using the **IMM** and want to retrieve data from all IM instruments on line:
(send **FCL** to reserve the IM line by transmitting a carrier signal, and send **SWT** to send a wake-up tone to all instruments on line.)

```
SENDGDATA
!01DATA
!02DATA
!03DATA
PWROFF
```

OR

If using the **SIM** and want to retrieve data from all IM instruments on line:
(Select *Connect* in SeatermIM's Communications menu to connect and wake up all 16*plus*-IM V2s.)

```
GDATA
!01DATA
!02DATA
!03DATA
PWROFF
```

Upload all data as shown above for Autonomous Sampling.

Pump Operation

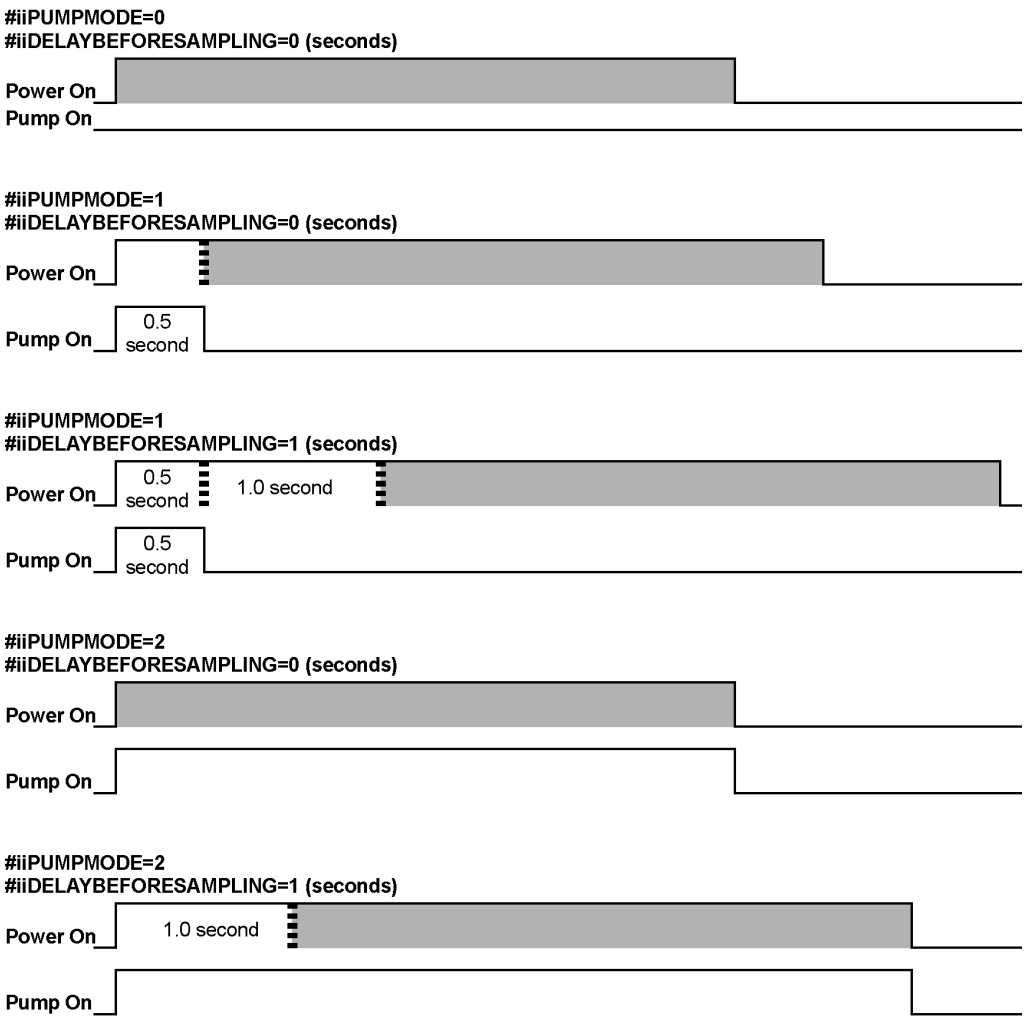
Do not run the pump dry. The pump is water lubricated; running it without water will damage it. If briefly testing your system in dry conditions, fill the inside of the pump head with water via the pump exhaust port. This will provide enough lubrication to prevent pump damage during brief testing.

Pump operation is governed by two user-programmable parameters:

- **#iiPumpMode=0**, **1**, or **2**
  The 16*plus*-IM V2 can be set up to operate with no pump (0), with the pump running for 0.5 seconds before each sample (1), or with the pump running during each sample (2).
- **#iiDelayBeforeSampling=**
  The 16*plus*-IM V2 can be set up to delay sampling after turning on external voltage sensors. Some instruments require time to equilibrate or stabilize after power is applied, to provide good quality data.

Note:
For the SIM: Set **RelayMax=** greater than **#iiDelayBeforeSampling=** to prevent the SIM from timing out during polled sampling.

#iiPumpMode= and **#iiDelayBeforeSampling=** interact in the operation of the pump, as shown below. Recommendations for settings are provided on the next page.



Note:
Sampling time includes time for instrument to warm up as well as time to actually measure parameters.
The 2.2 second sampling time is for 16*plus*-IM V2 with no pressure sensor, and 1 measurement / sample (**#iiNCycles=1**).
See *Specifications* in *Section 2: Description of SBE 16plus-IM V2* for sampling times for other setups.

Pump Setting Recommendations

Sea-Bird provides the following recommendations for pump settings.
Note that longer pump times increase power usage, reducing battery endurance. See *Battery Endurance* in *Section 2: Description of SBE 16plus-IM V2* for sample battery endurance calculations.

Pump through Conductivity Cell Only (SBE 5M, 5P, or 5T pump)

For most deployments, set **#iiPumpMode=1** and **#iiDelayBeforeSampling=0**. The pump operates for 0.5 seconds before the conductivity measurement is made, providing enough time to ventilate the cell and bring in a new sample of water.

If the 16*plus*-IM V2 is moored in an area with large thermal gradients, it may be necessary to pump for a longer period of time, to eliminate any cell thermal mass effects on the measurement. In this case, set **#iiPumpMode=2** and set **#iiDelayBeforeSampling=** to a non-zero value, providing additional ventilation time (allowing the conductivity cell temperature to equilibrate to the water temperature) before taking the measurement.

Pump through Conductivity Cell and SBE 43 Dissolved Oxygen Sensor (requires SBE 5P or 5T pump)

Set **#iiPumpMode=2**.

As the pump brings new water into the SBE 43 plenum, some time is required for the sensor to equilibrate to the new oxygen level. The time required is dependent on the sensor's membrane thickness, and on the water temperature. Prior to 2007, all SBE 43s were sold with a 0.5 mil thick membrane. Beginning in 2007, Sea-Bird began offering two membrane thicknesses –
0.5 mil (faster response, typically for profiling applications) and
1.0 mil (slower response but more durable, typically for moored applications).

- For a **0.5 mil thick** membrane – Recommended **#iiDelayBeforeSampling=** varies in a non-linear fashion, from 15 seconds at 15 °C to 30 seconds at 0 °C.
- For a **1.0 mil thick** membrane – Recommended **#iiDelayBeforeSampling=** varies in a non-linear fashion, from 25 seconds at 15 °C to 40 seconds at 0 °C.

Note:
See *Application Note 64: SBE 43 Dissolved Oxygen Sensor – Background Information, Deployment Recommendations, and Cleaning and Storage* for the response time curves.

Pump through Conductivity Cell and Beckman- or YSI-type Dissolved Oxygen Sensor (requires SBE 5P or 5T pump)

Set **#iiPumpMode=2**. Set **#iiDelayBeforeSampling=** to 120 to 180 seconds, allowing time for the oxygen sensor to polarize before taking the measurement.

Command Descriptions

Notes:
- If using the 16*plus*-IM V2 with an **Inductive Modem Module (IMM)**, see the IMM manual for details on IMM commands.
- If using the 16*plus*-IM V2 with a **Surface Inductive Modem (SIM)**, the SIM commands are included in this manual.

This section describes commands and provides sample outputs.
See *Appendix III: Command Summary* for a summarized command list.

When entering commands:

- Input commands in upper or lower case letters and register commands by pressing the Enter key.
- The 16*plus*-IM V2 sends an error message if an invalid command is entered.
- (If **#iiOutputExecutedTag=N**) If the system does not return an `S>` prompt after executing a command, press the Enter key to get the `S>` prompt.
- Commands to enable a parameter or output (such as enabling a voltage channel) can be entered with the *argument* as Y or 1 for yes, and N or 0 for no (for example, **#iiVolt0=y** and **#iiVolt0=1** are equivalent; both enable voltage channel 0).
- If a new command is not received within 2 minutes after completion of a command, the 16*plus*-IM V2 communications microcontroller returns to the quiescent (sleep) state.
- If in quiescent state, re-establish communications by selecting *Connect* in SeatermIM's Communications menu, or
  - (if using SIM) entering **PwrOn**.
  - (if using IMM set to **ConfigType=1**) sending **PwrOn**.
  - (if using IMM set to **ConfigType=2**) waiting at least 1 second, sending **ForceCaptureLine**, and sending **Send WakeupTone**.
- The 16*plus*-IM V2 cannot have samples with different scan lengths (more or fewer data fields per sample) in memory. If the scan length is changed by commanding it to add or subtract a data field (such as an external voltage), the 16*plus*-IM V2 must initialize logging. Initializing logging sets the sample number and header number to 0, so the entire memory is available for recording data with the new scan length. **Initializing logging should only be performed after all previous data has been uploaded**. Therefore, do not send the following commands, which change the scan length, unless all previous data has been uploaded: **#iiPType=**, **#iiVolt0=**, **#iiVolt1=**, **#iiVolt2=**, **#iiVolt3=**, **#iiVolt4=**, **#iiVolt5=**, **#iiSBE38=**, **#iiSBE50=**, **#iiGTD=**, **#iiDualGTD=**, **#iiOptode=**.
- When sampling autonomously, the 16*plus*-IM V2 responds only to commands that do not change its setup or interfere with sampling (see *Autonomous Sampling* for command list). If you wake it while sampling (for example, to send **#iiDS** to check sampling progress), it temporarily stops sampling. Sampling resumes when it goes back to sleep again (after 2-minute timeout).
- While *waiting to start autonomous sampling* (if you sent **#iiStartLater** but sampling has not started yet), the 16*plus*-IM V2 responds only to commands that do not change its setup or interfere with sampling (see *Autonomous Sampling* for a list of commands). To send any other commands, send **#iiStop**, send the desired commands to modify the setup, and then send **#iiStartLater** again.

Note:
All 16*plus*-IM V2s are factory assigned to Group 0 and Group 9.

- When you send a group command (**#Gn:** or **!Gn:**), the IMM or SIM connected to the controller will not get a response from the instruments, because only 1 instrument can communicate at a time (IM telemetry is half-duplex). The IMM and SIM have been programmed to not wait for a response from a group command.

- If desired, you can upload data from the 16*plus*-IM V2 using the internal RS-232 connector (see *Appendix II: Electronics Disassembly/Reassembly* to access the connector) and the optional data I/O cable (PN 801880). If used in this way, omit the **#ii** prefix in the Acquisition Microcontroller commands, and use Seaterm232 instead of SeatermIM (select *SBE 16plus V2 IM RS232* in SeatermV2's Instrument menu).

Entries made with the commands are permanently stored in the SBE 16*plus*-IM V2 and remain in effect until you change them.

- The only exception occurs if the electronics are removed from the housing and disconnected from the battery Molex connector (see *Appendix II: Electronics Disassembly/Reassembly*). Upon reassembly, reset date and time (**DateTime=** or **#iiDateTime=**) and initialize logging (**#iiInitLogging**).

SIM Commands

SIM commands are directed to the Surface Inductive Modem, to set it up for operation with the 16*plus*-IM V2.

Power-On Commands

PwrOn — Send wakeup tone to **all** IM instruments on-line.

PwrOff — Send power-off command to **all** IM instruments on-line. Main power turned off and IM instruments placed in quiescent (sleep) state. Autonomous sampling and memory retention not affected.

AutoPwrOn=x

x=Y (default): Automatically send **PwrOn** to all IM instruments on-line when power applied to SIM. This wakes up all IM instruments on-line.

x=N: Do not send **PwrOn** when power applied to SIM.

Note:
AutoPwrOn=N is not typically used with the 16*plus*-IM V2.

Status Command

DS — Display SIM firmware version and setup. Example includes commands used to modify parameters [in parentheses].

Note:
The **DS** response shows `SBE 37` because the SIM was originally developed for the SBE 37-IM MicroCAT.

Example (user input in bold)

```
DS
SBE 37 SURFACE MODEM V 3.0a
wait time for dataNN response = 1000 msec              [DataNNMax=]
wait time for relay command response = 20 seconds      [RelayMax=]
binary relay character timeout = 1000 msec  [not applicable to 16plus-IM V2]
echo = yes                                             [EchoOn or EchoOff]
execute pwron command on powerup = yes                 [AutoPwrOn=]
```

Communications Commands

Note:
The SIM's baud rate (set with **Baud=**) must be the same as SeatermIM's baud rate (set in *Configure* in the Communications menu). After you send **Baud=**, you must disconnect and reconnect (in the Communications menu, select *Disconnect and reconnect*) to communicate at the new baud rate.

Baud=x

x= baud rate between SIM and computer/controller (1200, 2400, 4800, or 9600). Default 9600.

Note:
If outputting data in XML format (**#iiOutputFormat=5**), Sea-Bird recommends setting **DataNNmax=** to 4000 milliseconds.

DataNNMax=x

x= timeout (0 – 32767 milliseconds; SIM rounds down to nearest 50 milliseconds) that applies to **!iiData** or **Dataii** only. If no reply is received within **DataNNMax**, control is returned to computer and other commands can be sent. Default 1000 milliseconds.

Note:
Set **RelayMax=** greater than **#iiDelayBeforeSampling=**. See *Pump Operation*.

RelayMax=x

x= timeout (0-3276 seconds) that applies to all commands other than **Dataii** or **!iiData**. If no reply is received within **RelayMax**, control is returned to computer and other commands can be sent. Default 20 seconds.

EchoOn

Echo characters received from computer (default) - computer monitor will show entered commands as you type.

EchoOff

Do not echo characters.

16*plus*-IM V2 Communication Microcontroller Commands

Note:
All 16*plus*-IM V2s are factory assigned to Group 0 and Group 9.

The following Communication Microcontroller commands can be sent as group commands: **GData**, **DateTime=**, **DS**, and **Wait=**. For example, **!G9:GData** sends **GData** to all instruments on-line that are in Group **9**.

Global Commands

Note:
If the 16*plus*-IM V2 batteries have been removed, the date and time must be reset.

DateTime=mmddyyyyhhmmss — Set real-time clock month, day, year, hour, minute, second for **all** 16*plus*-IM V2s.

When using IMM with either ConfigType: Use **#iiDateTime=** to set clock in each individual 16*plus*-IM V2. **DateTime=** does not work.

Note:
The 16*plus*-IM V2 has a buffer that stores the most recent data sample. Unlike data in the FLASH memory, data in the buffer is erased upon removal or failure of power.

GData — Command **all** communication microcontrollers to get last data sample from acquisition microcontrollers. Communication microcontrollers hold data in a buffer until receiving **!iiData** or **Dataii**.

When using IMM with ConfigType=2: Use **SendGData** instead; this results in IMM sending **GData** to all IM instruments online.

Get Data Command

!iiData or **Dataii** — Get data obtained with **GData** from 16*plus*-IM V2 with ID = ii (ii = 0-99).

When using IMM with either ConfigType: Use **!iiData**. **Dataii** does not work.

16*plus*-IM V2 ID Command

Only one IM instrument can be on line when sending these commands.

ID? — Display ID (ID = ii, where ii= 0-99).

***ID=ii** — Set 16*plus*-IM V2 ID to ii (ii= 0-99). Must be sent twice, because verification requested. **If more than one IM instrument on-line, all IM instruments will be set to same ID**.

16*plus*-IM V2 Communication Microcontroller Status Command

!iiDS — Display communication microcontroller firmware version and timeout parameter for 16*plus*-IM V2 with ID=ii.

Example (user input in bold, command used to modify parameter in parentheses)

```
!01DS
SCplus IM V2 1.1c
Response wait time 10 seconds                    [!iiWait=]
```

16*plus*-IM V2 Communication Microcontroller Timeout Command

!iiWait=x — **x=** maximum time (seconds) for communication microcontroller to wait for response from acquisition microcontroller. Range 2 – 600 seconds.

Note:
Set **!iiWait=** longer than (10 sec + **#iiDelayBeforeSampling=**).

16*plus*-IM V2 Acquisition Microcontroller Commands

Notes:
- All 16*plus*-IM V2s are factory assigned to Group 0 and Group 9.
- If using the 16*plus*-IM V2's internal RS-232 connector to upload data: n SeatermV2's Instruments menu, select *SBE 16plus V2 RS232* instead of *SBE 16plus V2 IM*. This launches Seaterm232 instead of SeatermIM. Seaterm232 is similar to SeatermIM, but is optimized for RS-232 communications.

- When using inductive modem telemetry, all 16*plus*-IM V2 Acquisition Microcontroller commands are preceded by **#ii** (ii= 16*plus*-IM V2 ID), as shown in the command listings below.
  All Acquisition Microcontroller commands can also be sent as group commands (substitute **#Gn:** for **#ii** in the command). For example, **#G9:StartNow** sends **StartNow** to all instruments on-line that are in Group **9**.

- When using RS-232 telemetry (connecting directly to the 16*plus*-IM V2's internal RS-232 serial connector), omit the **#ii** prefix shown in the command listings.

Status Commands

#iiGetCD

Get and display configuration data, which includes all parameters related to setup of 16*plus*-IM V2, including communication settings and sampling settings. Most of these parameters can be user-input/modified. List below includes, where applicable, command used to modify parameter:
- Device type, Serial number
- Sample interval [**#iiSampleInterval=**]
- Number of measurements to take and average per sample [**#iiNCycles=**]
- Integration time for Quartz pressure sensor [**#iiParosIntegration=**]
  (only appears if **#iiPType=3**)
- Reference pressure to use if no internally mounted pressure sensor [**#iiRefPress=**]
  (only appears if **#iiPType=0**)
- Pump turn-on parameter [**#iiPumpMode=**]?
- Pump turn-on delay [**#iiDelayBeforeSampling=**]
- Sample external voltages 0, 1, 2, 3, 4, and 5 [**#iiVolt0=** through **#iiVolt5=**]?
- Sample SBE 38 secondary temperature sensor [**#iiSBE38=**]?
- Sample SBE 50 secondary pressure sensor [**#iiSBE50=**]?
- Sample Optode [**#iiOptode=**]?
- Sample Gas Tension Device [**#iiGTD=**], or dual Gas Tension Devices [**#iiDualGTD=**]?
- Output Executing and Executed tags [**#iiOutputExecutedTag=**]?
- Output format [**#iiOutputFormat=**]
- Output salinity [**#iiOutputSal=**]?
  (only if output format = converted decimal or converted XML UVIC)
- Output sound velocity [**#iiOutputSV=**]?
  (only if output format = converted decimal or converted XML UVIC)
- Output sigma-t, voltage, and current with each sample [**#iiOutputUCSD=**]?
  (only if output format = converted decimal or converted XML UVIC)
- Output sample number with each sample [**#iiOutputSampleNumber=**]?

Notes:
- **#iiGetCD** output does not include calibration coefficients. To display calibration coefficients, use the **#iiGetCC** command.
- The **#iiDS** response contains similar information as the combined responses from **#iiGetSD** and **#iiGetCD**, but in a different format.

Status Commands (*continued*)

Example: 16*plus*-IM V2 with ID=01 (user input in bold, command used to modify parameter in parentheses)

#01getcd

```
<ConfigurationData DeviceType='SBE16plus-IM' SerialNumber='01606001'>
   <SamplingParameters>
      <SampleInterval>15</SampleInterval>                                  [#iiSampleInterval=]
      <MeasurementsPerSample>1</MeasurementsPerSample>                     [#iiNCycles=]
      <Pump>run pump during sample</Pump>                                  [#iiPumpMode=]
      <DelayBeforeSampling>0.0</DelayBeforeSampling>                       [#iiDelayBeforeSampling=]
   </SamplingParameters>
   <DataChannels>
      <ExtVolt0>yes</ExtVolt0>                                             [#iiVolt0=]
      <ExtVolt1>no</ExtVolt1>                                              [#iiVolt1=]
      <ExtVolt2>no</ExtVolt2>                                              [#iiVolt2=]
      <ExtVolt3>yes</ExtVolt3>                                             [#iiVolt3=]
      <ExtVolt4>no</ExtVolt4>                                              [#iiVolt4=]
      <ExtVolt5>no</ExtVolt5>                                              [#iiVolt5=]
      <SBE38>no</SBE38>                                                    [#iiSBE38=]
      <SBE50>no</SBE50>                                                    [#iiSBE50=]
      <OPTODE>no</OPTODE>                                                  [#iiOptode=]
      <GTD>no</GTD>                                                        [#iiGTD= or #iiDualGTD=]
   </DataChannels>
   <OutputExecutedTag>no</OutputExecutedTag>                               [#iiOutputExecutedTag=]
   <OutputFormat>converted decimal</OutputFormat>                          [#iiOutputFormat=]
   <OutputSalinity>no</OutputSalinity>                                     [#iiOutputSal=]
   <OutputSoundVelocity>no</OutputSoundVelocity>                           [#iiOutputSV=]
   <OutputSigmaT-V>no</OutputSigmaT-V>                                     [#iiOutputUCSD=]
   <OutputSampleNumber>no</OutputSampleNumber>                             [#iiOutputSampleNumber=]
</ConfigurationData>
```

Notes:
- The **#iDS** response contains similar information as the combined responses from **#iiGetSD** and **#iiGetCD**, but in a different format.
- If configured with a pump, sending **#iiGetSD** causes the pump to turn on for a moment, so that the 16*plus* –IM V2 can measure and output the pump current. Because the pump is designed to be water lubricated, you will hear a noise when the impeller spins in air. Running the pump *dry* for such a **short** time will not harm the pump.
- In the example below, only voltage channel 0 is enabled, so external voltage current iext2345= (for channels 2, 3, 4, and 5) is not shown.
- In the example below, no RS-232 sensor is enabled, so RS-232 sensor current iserial= is not shown.
- If the 16*plus*-IM V2 is set up with a WET Labs ECO-FL fluorometer with Bio-Wiper (**#iiBiowiper=Y**) and if **#iiOutputExecutedTag=**, the **#iiGetSD** response shows: `<Executing/>` to allow time for the Bio-Wiper to close before it measures the enabled external voltage currents.

Status Commands (*continued*)

#iiGetSD

Get and display status data, which contains data that changes while deployed.
List below includes, where applicable, command used to modify parameter:
- Device type, Serial number
- Date and time [**#iiDateTime=**] in ISO8601-2000 extended format (yyyy – mm-ddThh:mm:ss)
- Logging status (not logging, logging, waiting to start at . . ., or unknown status)
- Number of recorded events in event counter [reset with **#iiResetEC**]
- Voltages and currents -
  - Main battery voltage
  - Back-up lithium battery voltage
  - Operating current
  - Pump current
  - External voltage sensor current (channels 0 and 1) – displays only if 1 or more channels enabled
  - External voltage sensor current (channels 2, 3, 4, and 5) – displays only if 1 or more channels enabled
  - RS-232 sensor current – displays only if channel enabled
- Memory - [reset with **#iiInitLogging**]
  - Number of bytes in memory
  - Number of samples in memory
  - Number of additional samples that can be placed in memory
  - Length (number of bytes) of each sample
  - Number of headers in memory

Example: 16*plus*-IM V2 with ID=01 (user input in bold, command used to modify parameter in parentheses)

```
#01getsd
<StatusData DeviceType = 'SBE16plus-IM' SerialNumber = '01606001'>
   <DateTime>2009-07-24T10:53:03</DateTime>                          [#iiDateTime=]
   <LoggingState>not logging</LoggingState>
   <EventSummary numEvents = '0'/>                                   [can clear with #iiResetEC]
   <Power>
      <vMain>10.1</vMain>
      <vLith>8.9</vLith>
      <iMain>61.9</iMain>
      <iPump>20.6</iPump>
      <iExt01>67.2</iExt01>
   </Power>
   <MemorySummary>
      <Bytes>0</Bytes>                                               [can clear with #iiInitLogging]
      <Samples>0</Samples>                                           [can clear with #iiInitLogging]
      <SamplesFree> 3870479</SamplesFree>                            [can clear with #iiInitLogging]
      <SampleLength>17</SampleLength>
      <Headers>0</Headers>                                           [can clear with InitLogging]
   </MemorySummary>
</StatusData>
```

Notes:
- **#iiDCal** and **#iiGetCC** responses contain similar information, but in different formats.
- Dates shown are when calibrations were performed.

Status Commands (*continued*)

#iiGetCC — Get and display calibration coefficients, which are initially factor-set and should agree with Calibration Certificates shipped with 16*plus*-IM V2.

Example: 16*plus*-IM V2 with ID=01, strain gauge pressure sensor (user input in bold, command used to modify coefficient in parentheses)

```
#01getcc
<CalibrationCoefficients DeviceType = 'SBE16plus-IM' SerialNumber = '01606001'>
   <Calibration format = 'TEMP1' id = 'Main Temperature'>
      <SerialNum>01600001</SerialNum>
      <CalDate>19-Jul-09</CalDate>                                          [#iiTCalDate=]
      <TA0>1.155787e-03</TA0>                                                  [#iiTA0=]
      <TA1>2.725208e-04</TA1>                                                  [#iiTA1=]
      <TA2>-7.526811e-07</TA2>                                                 [#iiTA2=]
      <TA3>1.716270e-07</TA3>                                                  [#iiTA3=]
      <TOFFSET>0.000000e+00</TOFFSET>                                       [#iiTOffset=]
   </Calibration>
   <Calibration format = 'WBCOND0' id = 'Main Conductivity'>
      <SerialNum>01600001</SerialNum>
      <CalDate>19-Jul-09</CalDate>                                          [#iiCCalDate=]
      <G>-1.006192e+00</G>                                                     [#iiCG=]
      <H>1.310565e-01</H>                                                      [#iiCH=]
      <I>-2.437852e-04</I>                                                     [#iiCI=]
      <J>3.490353e-05</J>                                                      [#iiCJ=]
      <CPCOR>-9.570000e-08</CPCOR>                                          [#iiCPCor=]
      <CTCOR>3.250000e-06</CTCOR>                                           [#iiCTCor=]
      <CSLOPE>1.000000e+00</CSLOPE>                                         [#iiCSlope=]
   </Calibration>
   <Calibration format = 'STRAIN0' id = 'Main Pressure'>
      <SerialNum>01600001</SerialNum>
      <CalDate>27-Jul-09</CalDate>                                          [#iiPCalDate=]
      <PA0>-5.137085e-02</PA0>                                                 [#iiPA0=]
      <PA1>1.550601e-03</PA1>                                                  [#iiPA1=]
      <PA2>7.210415e-12</PA2>                                                  [#iiPA2=]
      <PTCA0>5.154159e+05</PTCA0>                                           [#iiPTCA0=]
      <PTCA1>2.560262e-01</PTCA1>                                           [#iiPTCA1=]
      <PTCA2>-8.533080e-02</PTCA2>                                          [#iiPTCA2=]
      <PTCB0>2.426612e+01</PTCB0>                                           [#iiPTCB0=]
      <PTCB1>-7.750000e-04</PTCB1>                                          [#iiPTCB1=]
      <PTCB2>0.000000e+00</PTCB2>                                           [#iiPTCB2=]
      <PTEMPA0>-7.667877e+01</PTEMPA0>                                      [#iiPTempA0=]
      <PTEMPA1>4.880376e+01</PTEMPA1>                                       [#iiPTempA1=]
      <PTEMPA2>-4.555938e-01</PTEMPA2>                                      [#iiPTempA2=]
      <POFFSET>0.000000e+00</POFFSET>                                    [#iiPOffset= (decibars)]
      <PRANGE>1.000000e+03</PRANGE>                                      [#iiPRange= (psia)]
   </Calibration>
   <Calibration format = 'VOLT0' id = 'Volt 0'>
      <OFFSET>0.000000e+00</OFFSET>                                         [#iiVOffset0=]
      <SLOPE>1.260977e+00</SLOPE>                                           [#iiVSlope0=]
   </Calibration>
   <Calibration format = 'VOLT0' id = 'Volt 1'>
      <OFFSET>-4.728750e-02</OFFSET>                                        [#iiVoffset1=]
      <SLOPE>1.259474e+00</SLOPE>                                           [#IiVSlope1=]
   </Calibration>
   <Calibration format = 'VOLT0' id = 'Volt 2'>
      <OFFSET>-4.715313e-02</OFFSET>                                        [#iiVoffset2=]
      <SLOPE>1.259946e+00</SLOPE>                                           [#iiVSlope2=]
   </Calibration>
   <Calibration format = 'VOLT0' id = 'Volt 3'>
      <OFFSET>-4.772396e-02</OFFSET>                                        [#iiVoffset3=]
      <SLOPE>1.260486e+00</SLOPE>                                           [#iiVSlope3=]
   </Calibration>
   <Calibration format = 'VOLT0' id = 'Volt 4'>
      <OFFSET>-4.765417e-02</OFFSET>                                        [#iiVoffset4=]
      <SLOPE>1.260014e+00</SLOPE>                                           [#iiVSlope4=]
   </Calibration>
   <Calibration format = 'VOLT0' id = 'Volt 5'>
      <OFFSET>-4.744167e-02</OFFSET>                                        [#iiVoffset5=]
      <SLOPE>1.260255e+00</SLOPE>                                           [#iiVSlope5=]
   </Calibration>
   <Calibration format = 'FREQ0' id = 'external frequency channel'>
      <EXTFREQSF>1.000000e+00</EXTFREQSF>                                   [#iiExtFreqSF=]
   </Calibration>
</CalibrationCoefficients>
```

Status Commands (*continued*)

#iiGetEC

Get and display event counter data, which can help to identify root cause of a malfunction. Event counter records number of occurrences of common timeouts, power-on resets, etc. Can be cleared with **#iiResetEC**. Possible events that may be logged include:

- Power fail – main batteries and/or external voltage below voltage cutoff
- EEPROM read or EEPROM write – all power removed (main batteries removed, and back-up lithium batteries are dead)
- Alarm short – woke up 16*plus*-IM V2 to send a command while logging
- Alarm long –sent **#iiStartLater**, but **#iiStartDateTime=** is more than 1 month in future
- AD7730 timeout – response from temperature and pressure A/D converter delayed; typically if woke up to send a command while logging
- AD7714 timeout – response from voltage channel A/D converter delayed; typically if woke up to send a command while logging
- FLASH out of memory – all available memory space is used; autonomous sampling continues, but no additional data written to FLASH (does not overwrite)
- FLASH correctable error – single bit error in a page, corrects itself, does not affect data
- FLASH ECC error – does not affect data
- FLASH timeout – problem with FLASH
- FLASH ready – problem with FLASH; timeout error
- FLASH erase failed – problem with FLASH
- FLASH write failed – problem with FLASH
- FLASH uncorrectable – problem with FLASH; 2 or more bits of errors in a page
- FLASH block overrun – problem with FLASH
- New bad block – problem with FLASH; FLASH write or erase failed, or a FLASH uncorrectable error

Example 16*plus*-IM V2 with ID=01 (user input in bold, command used to modify parameter in parentheses)

```
#01getec
<EventCounters DeviceType = 'SBE16plus-IM' SerialNumber = '01606001'>
   <EventSummary numEvents = '1'/>                          [can clear with #iiResetEC]
   <Event type='alarm short' count='1'/>
</EventCounters>
```

#iiResetEC

Delete all events in event counter (number of events displays in **#iiGetSD** response, and event details display in **#iiGetEC** response).

Status Commands (*continued*)

#iiGetHD

Get and display hardware data, which is fixed data describing 16*plus*-IM V2:

- Device type, Serial number
- Manufacturer
- Firmware version
- Firmware date
- Command set version
- PCB serial number and assembly number
- Manufacture date
- Internal sensor types and serial numbers
- External sensor types (for example, dissolved oxygen, fluorometer, etc.) and serial numbers

Note:
External sensor types and serial numbers can be changed in the field, to accommodate changes in auxiliary sensors cabled to the 16*plus*-IM V2. Other hardware data is typically not changed by the user.

Example: 16*plus*-IM V2 with ID=01 (user input in bold, command used to modify parameter in parentheses)

```
#01gethd
<HardwareData DeviceType = 'SBE16plus-IM' SerialNumber = '01600003'>
   <Manufacturer>Sea-Bird Electronics, Inc.</Manufacturer>
   <FirmwareVersion>2.2</FirmwareVersion>
   <FirmwareDate>07 July 2009 16:25</FirmwareDate>
   <CommandSetVersion>2.0</CommandSetVersion>
   <PCBAssembly PCBSerialNum = 'not assigned' Version = '41054F'/>     [#iiSetPcbSerialNum1=, #iiSetPCBAssembly1=]
   <PCBAssembly PCBSerialNum = 'not assigned' Version = '41580'/>      [#iiSetPcbSerialNum2=, #iiSetPCBAssembly2=]
   <PCBAssembly PCBSerialNum = 'not assigned' Version = '41056E'/>     [#iiSetPcbSerialNum3=, #iiSetPCBAssembly3=]
   <PCBAssembly PCBSerialNum = 'not assigned' Version = '41059D '/>    [#iiSetPcbSerialNum4=, #iiSetPCBAssembly4=]
   <MfgDate>03 september 2009</MfgDate>                                                    [#iiSetMfgDate=]
   <InternalSensors>
      <Sensor id = 'Main Temperature'>
         <type>temperature0</type>
         <SerialNumber>01606003</SerialNumber>
      </Sensor>
      <Sensor id = 'Main Conductivity'>
         <type>conductivity-0</type>
         <SerialNumber>01606003</SerialNumber>
      </Sensor>
      <Sensor id = 'Main Pressure'>
         <type>strain-0</type>                                                             [#iiPType=]
         <SerialNumber>2580011</SerialNumber>
      </Sensor>
   </InternalSensors>
   <ExternalSensors>
      <Sensor id = 'volt 0'>
         <type>not assigned</type>                                                  [#iiSetVoltType0=]
         <SerialNumber>not assigned</SerialNumber>                                  [#iiSetVoltSN0=]
      </Sensor>
      <Sensor id = 'volt 1'>
         <type>not assigned</type>                                                  [#iiSetVoltType1=]
         <SerialNumber>not assigned</SerialNumber>                                  [#iiSetVoltSN1=]
      </Sensor>
      <Sensor id = 'volt 2'>
         <type>not assigned</type>                                                  [#iiSetVoltType2=]
         <SerialNumber>not assigned</SerialNumber>                                  [#iiSetVoltSN2=]
      </Sensor>
      <Sensor id = 'volt 3'>
         <type>not assigned</type>                                                  [#iiSetVoltType3=]
         <SerialNumber>not assigned</SerialNumber>                                  [#iiSetVoltSN3=]
      </Sensor>
      <Sensor id = 'volt 4'>
         <type>not assigned</type>                                                  [#iiSetVoltType4=]
         <SerialNumber>not assigned</SerialNumber>                                  [#iiSetVoltSN4=]
      </Sensor>
      <Sensor id = 'volt 5'>
         <type>not assigned</type>                                                  [#iiSetVoltType5=]
         <SerialNumber>hi there</SerialNumber>                                      [#iiSetVoltSN5=]
      </Sensor>
   </ExternalSensors>
</HardwareData>
```

Status Commands (*continued*)

Notes:
- The **#iiDS** response contains similar information as the combined responses from **#iiGetSD** and **#iiGetCD**, but in a different format.
- If configured with a pump, sending **#iiDS** causes the pump to turn on for a moment, so that the 16*plus*-IM V2 can measure and output the pump current. Because the pump is designed to be water lubricated, you will hear a noise when the impeller spins in air. Running the pump *dry* for such a **short** time will not harm the pump.
- In the example below, only voltage channel 0 is enabled, so external voltage current iext2345= (for channels 2, 3, 4, and 5) is not shown.
- In the example below, no RS-232 sensor is enabled, so RS-232 sensor current iserial= is not shown.
- If the 16*plus*-IM V2 is set up for dual GTDs, the **#iiDS** shows: `Dual Gas Tension Device = Yes`
- If the 16*plus*-IM V2 is set up with a WET Labs ECO-FL fluorometer with Bio-Wiper (**#iiBiowiper=Y**), the **#iiDS** reply shows: `wait 4 seconds for biowiper to close` before it measures the enabled external voltage currents.

#iiDS

Display operating status and setup parameters.

List below includes, where applicable, command used to modify parameter.

- Firmware version, serial number, date and time [**DateTime=** or **#iiDateTime=**]
- Voltages and currents (main and back-up lithium battery voltages; currents – operating, pump, external voltage sensors, RS-232 sensor)
- Logging status (not logging, logging, waiting to start at . . ., or unknown status)
- Number of samples and available sample space in memory
- Sample interval [**#iiSampleInterval=**] and number of measurements to take and average per sample [**#iiNCycles=**]
- Integration time [**#iiParosIntegration=**] (only appears if pressure sensor = quartz with temp comp)
- Pump turn-on parameter [**#iiPumpMode=**], and turn-on delay [**#iiDelayBeforeSampling=**]
- Battery cut-off voltage
- Internally mounted pressure sensor type [**#iiPType=**] and range [**#iiPRange=**]
- Sample RS-232 sensor - SBE 38 secondary temperature sensor [**#iiSBE38=**], SBE 50 pressure sensor [**#iiSBE50=**], Optode [**#iiOptode=**], Gas Tension Device or Dual Gas Tension Devices [**#iiGTD=** or **#iiDualGTD=**]?
- Sample external voltages 0, 1, 2, 3, 4, and 5? [**#iiVolt0=** through **#iiVolt5=**]
- Output format [**#iiOutputFormat=**]
- Output salinity [**#iiOutputSal=**], sound velocity [**#iiOutputSV=**], and sample number [**#iiOutputSampleNumber=**] with each sample? (only if output format = converted decimal or converted XML UVIC)
- Output sigma-t, voltage, and current with each sample [**#iiOutputUCSD=**]? (only if output format = converted decimal or converted XML UVIC; and if set to Y)

Example: 16*plus*-IM V2 with ID=01 (user input in bold, command used to modify parameter in parentheses)

```
#01DS
SBE 16plus-IM V 2.2  SERIAL NO. 0001    01 Jul 2009  14:02:13                    [#iiDateTime=]
vbatt = 9.6, vlith = 8.5, ioper = 61.2 ma, ipump = 25.5 ma
iext01 = 78.4 ma
status = not logging
samples = 0, free = 3870479
sample interval = 15 seconds, number of measurements per sample = 1   [#iiSampleInterval=, #iiNCycles=]
run pump during sample, delay before sampling = 2.0 seconds   [#iiPumpMode=, #iiDelayBeforeSampling=]
battery cutoff =  7.5 volts
pressure sensor = strain gauge, range = 1000.0                          [#iiPType=, #iiPRange=]
SBE 38=no, SBE 50=no, OPTODE=no, Gas Tension Device=no   [#iiSBE38=, #iiSBE50=, #iiOptode=, #iiGTD=, #iiDualGTD=]
Ext Volt 0=yes, Ext Volt 1=no,                                  [#iiVolt0= and #iiVolt1=]
Ext Volt 2=no, Ext Volt 3=no,                                   [#iiVolt2= and #iiVolt3=]
Ext Volt 4 = no, Ext Volt 5 = no                                [#iiVolt4= and #iiVolt5=]
output format = raw HEX                                              [#iiOutputFormat=]
```

Notes:
- The **#iiDCal** and **#iiGetCC** responses contain the same information, but in different formats.
- Dates shown are when calibrations were performed.

Status Commands (*continued*)

#iiDCal — Display calibration coefficients, which are initially factory-set and should agree with Calibration Certificates shipped with 16*plus*-IM V2.

Example: 16*plus*-IM V2 with ID=01 with internally mounted strain gauge pressure sensor (user input in bold, command used to modify coefficient in parentheses).

```
#01dcal
SBE 16plus-IM V 2.2  SERIAL NO. 0001  24 Jul 2009  14:46:05          [#iiDateTime=]
temperature:  20-jul-09                                               [#iiTCalDate=]
    TA0 = -3.178124e-06                                                  [#iiTA0=]
    TA1 = 2.751603e-04                                                   [#iiTA1=]
    TA2 = -2.215606e-06                                                  [#iiTA2=]
    TA3 = 1.549719e-07                                                   [#iiTA3=]
    TOFFSET = 0.000000e+00                                            [#iiTOffset=]
conductivity:  20-jul-09                                              [#iiCCalDate=]
    G = -9.855242e-01                                                    [#iiCG=]
    H = 1.458421e-01                                                     [#iiCH=]
    I = -3.290801e-04                                                    [#iiCI=]
    J = 4.784952e-05                                                     [#iiCJ=]
    CPCOR = -9.570000e-08                                             [#iiCPCor=]
    CTCOR = 3.250000e-06                                              [#iiCTCor=]
    CSLOPE = 1.000000e+00                                             [#iiCSlope=]
pressure S/N 2580011, range = 2000 psia:  14-jul-09     [#iiPRange= (psia), #iiPCalDate=]
    PA0 = 0.000000e+00                                                   [#iiPA0=]
    PA1 = 0.000000e+00                                                   [#iiPA1=]
    PA2 = 0.000000e+00                                                   [#iiPA2=]
    PTEMPA0 = 0.000000e+00                                            [#iiPTempA0=]
    PTEMPA1 = 0.000000e+00                                            [#iiPTempA1=]
    PTEMPA2 = 0.000000e+00                                            [#iiPTempA2=]
    PTCA0 = 0.000000e+00                                                 [#iiPTCA0=]
    PTCA1 = 0.000000e+00                                                 [#iiPTCA1=]
    PTCA2 = 0.000000e+00                                                 [#iiPTCA2=]
    PTCB0 = 0.000000e+00                                                 [#iiPTCB0=]
    PTCB1 = 0.000000e+00                                                 [#iiPTCB1=]
    PTCB2 = 0.000000e+00                                                 [#iiPTCB2=]
POFFSET = 0.000000e+00                                  [#iiPOffset= (decibars)]
volt 0: offset = 0.000000e+00, slope = 1.000000e+00     [#iiVOffset0=, #iiVSlope0=]
volt 1: offset = 0.000000e+00, slope = 1.000000e+00     [#iiVoffset1=, #iiVSlope1=]
volt 2: offset = 0.000000e+00, slope = 1.000000e+00     [#iiVoffset2=, #iiVSlope2=]
volt 3: offset = 0.000000e+00, slope = 1.000000e+00     [#iiVoffset3=, #iiVSlope3=]
volt 4: offset = 0.000000e+00, slope = 1.000000e+00     [#iiVoffset4=, #iiVSlope4=]
volt 5: offset = 0.000000e+00, slope = 1.000000e+00     [#iiVoffset5=, #iiVSlope5=]
    EXTFREQSF = 1.000000e+00                                          [#iiExtFreqSF=]
```

General Setup Commands

#iiDateTime=
mmddyyyyhhmmss

Set real-time clock month, day, year, hour, minute, second.

Example: Set current date and time for 16*plus*-IM V2 with ID=01 to 05 October 2009 12:05:00 (user input in bold).

#01DATETIME=10052009120500

#iiOutputExecutedTag=x

x=Y: Display XML Executing and Executed tags (***default***). Executed tag displays at end of each command response; Executing tag displays one or more times if 16*plus*-IM V2 response to command requires additional time.

x=N: Do not.

Example: Set 16*plus*-IM V2 with ID=01 to output Executed and Executing tags (user input in bold).

#01outputexecutedtag=y
<Executed/>**#01getcd**
. . . (**#iiGetCD** response)
<Executed/>

#iiPumpMode=x

x=0: No pump.

x=1: Run pump for 0.5 seconds before each sample (typical for pumping through conductivity cell only, with no auxiliary sensors connected to plumbing).

x=2: Run pump during each sample (typical for pumping through conductivity cell and in-line auxiliary sensor).

Notes:
- Pump operation is affected by both **#iiPumpMode=** and **#iiDelayBeforeSampling=**. See *Pump Operation*.
- **#iiPumpMode=**, **#iiNCycles=**, **#iiParosIntegration=**, and **#iiDelayBeforeSampling=** affect the time required to sample. If the time required to sample is too high, the 16*plus*-IM V2 is unable to take the required number of measurements and do the calculations within **#iiSampleInterval=**. See *Sample Timing* in *Section 2: Description of SBE 16plus-IM V2*.

#iiNCycles=x

x= number of measurements to take and average for each sample. Range 1 – 100; ***default 1***. 16*plus*-IM V2 takes and averages **#iiNCycles=** measurements (each 0.25 seconds apart). For autonomous sampling; averaged data is stored in FLASH memory.

General Setup Commands (*continued*)

Notes:
- When **#iiInitLogging** or **#iiSampleNumber=**, the 16*plus*-IM V2 responds that it is initializing logging.
- **#iiInitLogging** and **#iiSampleNumber=0** have identical effects. Use either command to initialize logging.
- **Do not initialize logging until all data has been uploaded.** These commands do not delete data; they reset the data pointer. **If you accidentally initialize logging before uploading**, recover data as follows:
  1. Set **#iiSampleNumber=a** and **#iiHeaderNumber=b**, where **a** and **b** are your estimate of number of samples and headers in memory.
  2. Upload data. If **a** is more than actual number of samples or **b** is more than actual number of headers in memory, data for non-existent samples/headers will be bad, random data. Review uploaded data file carefully and delete any bad data.
  3. If desired, increase **a** and/or **b** and upload data again, to see if there is additional valid data in memory.

#iiInitLogging

Initialize logging - after all previous data has been uploaded, initialize logging before starting to log again to make entire memory available for recording. **#iiInitLogging** sets sample number (**#iiSampleNumber=**) and header number (**#iiHeaderNumber=**) to 0 (sampling will start with sample 1 and header 1). If not set to 0, data will be stored after last recorded sample. **Do not send #iiInitLogging until all existing data has been uploaded.**

#iiSampleNumber=x

x= sample number for last sample in memory. **#iiSampleNumber=0** is equivalent to **#iiInitLogging**.
Do not send #iiSampleNumber=0 until all existing data has been uploaded.

#iiHeaderNumber=x

x= header number for last header in memory. Typically only used to recover data if you accidentally initialize logging (using **#iiInitLogging** or **#iiSampleNumber=0**) before uploading all existing data.
16*plus*-IM V2 can have a maximum of 1000 stored headers. Note that 16*plus*-IM V2 writes a new header each time autonomous sampling is started and after every 2000 samples are stored in memory.

Pressure Sensor Setup Commands

Notes:
- **Do not send #iiPType= unless all previous data has been uploaded from memory**. When **#iiPType=** is sent, the 16*plus*-IM V2 responds that it is initializing logging.
- The 16*plus*-IM V2 configuration (.con) file must match the **#iiPType=** selection of internally mounted pressure sensor when processing uploaded data. View and edit the .con file in SBE Data Processing. **#iiPType=** is factory-set to match the ordered configuration.

#iiPType=x

Internally mounted pressure sensor type (set at factory):

x=0: No internally mounted pressure sensor.

x=1: Strain gauge.

x=3: Quartz with temperature compensation.

#iiRefPress=x

x= reference pressure (gauge) in decibars to use if 16*plus*-IM V2 does not include internally mounted pressure sensor; 16*plus*-IM V2 uses reference pressure in conductivity, salinity, and sound velocity calculation. Value entered for **#iiRefPress=** is displayed in **#iiGetCD** and **#iiDS** responses if 16*plus*-IM V2 does not include internally mounted pressure sensor.
Entry ignored if 16*plus*-IM V2 includes internally mounted pressure sensor.
If 16*plus*-IM V2 interfaces with an SBE 50 pressure sensor, it does **not** use SBE 50 data in conductivity, salinity, and sound velocity calculation.

Notes:
- The 16*plus*-IM V2 does the integration for the Quartz pressure sensor *after* **#iiNCycles=** measurements have been taken.
- **#iiPumpMode=**, **#iiNCycles=**, **#iiParosIntegration=**, and **#iiDelayBeforeSampling=** affect the time required to sample. If the time required to sample is too high, the 16*plus*-IM V2 is unable to take the required number of measurements and do the calculations within **#iiSampleInterval=**. See *Sample Timing* in *Section 2: Description of SBE 16plus-IM V2*.

#iiParosIntegration=x

x= integration time for optional internally mounted Quartz pressure sensor (not applicable for strain gauge pressure sensor). Range 1 – 600 seconds; default 1 second. Increasing integration time increases resolution.
See *Specifications* in *Section 2: Description of SBE 16plus-IM V2* to determine resolution for Quartz pressure sensor.

Notes:
- **Do not send #iiVolt0 = through #iiVolt5= unless all previous data has been uploaded from memory.** When one of these commands is sent, the 16*plus*-IM V2 responds that it is initializing logging
- The 16*plus*-IM V2 configuration (.con) file must match this selection of number of external voltages when viewing real-time data or processing uploaded data. View and edit the .con file in SBE Data Processing. Note that these parameters are factory-set to match the ordered instrument configuration.
- External voltage numbers 0, 1, 2, 3, 4, and 5 correspond to wiring of sensors to a voltage channel on the 16*plus*-IM V2 end cap (see *Dimensions and End Cap Connectors* in *Section 2: Description of 16plus-IM V2*). However, in the .con file, voltage 0 is the first external voltage in the data stream, voltage 1 is the second, etc.

Notes:
- Set **RelayMax=** (time SIM waits for reply from 16*plus*-IM V2 before it times out) longer than **#iiDelayBeforeSampling=**.
- Set **!iiWait=** longer than (10 sec + **#iiDelayBeforeSampling=**).
- **#iiPumpMode=**, **#iiNCycles=**, **#iiParosIntegration=**, and **#iiDelayBeforeSampling=** affect the time required to sample. If the time required to sample is too high, the 16*plus*-IM V2 is unable to take the required number of measurements and do the calculations within **#iiSampleInterval=**. See *Sample Timing* in *Section 2: Description of SBE 16plus-IM V2*.
- Pump operation is affected by both **#iiPumpMode=** and **#iiDelayBeforeSampling=**. See *Pump Operation*.

Note:
If an ECO-FL with Bio-Wiper is installed and **#iiBiowiper=N**, sending **#iiGetSD** or **#iiDS** will open the Bio-Wiper, but not provide enough powered time to close it again. If you then deploy the instrument with the Bio-Wiper open and with a delayed start time, the ECO-FL may become fouled because the Bio-Wiper will remain open until the first sample is completed.

Voltage Sensor Setup Commands

#iiVolt0=x
x=Y: Enable external voltage 0.
x=N: Do not enable external voltage 0.

#iiVolt1=x
x=Y: Enable external voltage 1.
x=N: Do not enable external voltage 1.

#iiVolt2=x
x=Y: Enable external voltage 2.
x=N: Do not enable external voltage 2.

#iiVolt3=x
x=Y: Enable external voltage 3.
x=N: Do not enable external voltage 3.

#iiVolt4=x
x=Y: Enable external voltage 4.
x=N: Do not enable external voltage 4.

#iiVolt5=x
x=Y: Enable external voltage 5.
x=N: Do not enable external voltage 5.

Example: Enable voltage sensors wired to channels 0 and 3 on end cap; ID=01 (user input in bold).

```
#01VOLT0=Y
#01VOLT1=N
#01VOLT2=N
#01VOLT3=Y
#01VOLT4=Y
#01VOLT5=Y
```

There will be 2 external sensor voltages in data stream. In .con file (in SBE Data Processing), indicate *2* external voltage channels. Voltage 0 corresponds to sensor wired to external voltage channel 0; voltage 1 corresponds to sensor wired to external voltage channel 3.

#iiDelayBeforeSampling=x
x= time (seconds) to wait after switching on external voltage before sampling (0-600 seconds). ***Default 0 seconds.*** Typical value if using:

- SBE 43 oxygen sensor – time is dependent on membrane thickness and water temperature (see *Pump Operation*). Use with **#iiPumpMode=2**.

- Beckman- or YSI-type oxygen sensor – 120 to 180 seconds required to provide time for sensor to polarize. Use with **#iiPumpMode=2**.

- Sea Tech fluorometer - 15 seconds required to provide time for sensor to stabilize.

#iiBiowiper=x
x=Y: Configuration includes WET Labs ECO-FL fluorometer with Bio-Wiper. With this setup, 16*plus*-IM V2 is powered longer for **#iiGetSD** and **#iiDS**, providing sufficient time for Bio-Wiper to open and then shut again if Bio-Wiper is set up to take 1 measurement for each sample (see *Application Note 72* for details).

x=N (default): No ECO-FL with Bio-Wiper.

Notes:
- **Do not send #iiSBE38=, #iiSBE50=, #iiGTD=, #iiDualGTD=, or #iiOptode= unless all previous data has been uploaded from memory.** When one of these commands is sent, the 16*plus*-IM V2 responds that it is initializing logging.
- The 16*plus*-IM V2 configuration (.con) file must match this selection of RS-232 sensor when processing uploaded data. View and edit the .con file in SBE Data Processing. Note that these parameters are factory-set to match the ordered instrument configuration.
- See the SBE 38, SBE 50, Pro-Oceanus GTD, or Aanderaa Optode 4330 or 4835 manual for command details for these instruments.

RS-232 Sensor Setup Commands

The 16*plus*-IM V2 can interface the following RS-232 instruments (connected to the 4-pin *Auxiliary RS-232 Input* bulkhead connector on the 16*plus*-IM V2 end cap): SBE 38 secondary temperature sensor, SBE 50 pressure sensor, up to 2 Pro-Oceanus Gas Tension Devices (GTDs), or Aanderaa Oxygen Optode 4330 or 4835.

Setup for SBE 38:

Set up SBE 38 to interface with SBE 16*plus*-IM V2, **before** you connect it to 16*plus*-IM V2. Connect SBE 38 directly to computer, power with an external power supply, and (using SEATERM or Seaterm232) set:
- **Baud rate** to 1200 (**Baud=1200**)
- **Interface** to RS-232 (**Interface=232**)
- **Sampling** to begin when power applied (**AutoRun=Y**)
- **Output** to converted data (**Format=C**)

Connect SBE 38 to SBE 16*plus*-IM V2 *Auxiliary RS-232 Input* connector, using provided cable. In the 16*plus*-IM V2, set **#iiSBE38=Y** to enable interface.

#iiSBE38=x

x=Y: Enable SBE 38 secondary temperature sensor.

x=N: Do not enable SBE 38.

Setup for SBE 50:

Set up SBE 50 to interface with SBE 16*plus*-IM V2, **before** you connect it to 16*plus*-IM V2. Connect SBE 50 directly to computer, power with an external power supply, and (using SEATERM or Seaterm232) set:
- **Baud rate** to 1200 (**Baud=1200**).
- **Output** to converted data in psia, decibars, meters, or feet (**OutputFormat= 1**, **2**, **3**, **4**, **5**, or **6**).
  Note: **If you will be using SBE Data Processing**, you **must** set the SBE 50 format to psia (**OutputFormat=1**)

Connect SBE 50 to SBE 16*plus*-IM V2 *Auxiliary RS-232 Input* connector, using provided cable. In the 16*plus*-IM V2, set **#iiSBE50=Y** to enable interface.

#iiSBE50=x

x=Y: Enable SBE 50 pressure sensor.

x=N: Do not enable SBE 50.

RS-232 Sensor Setup Commands (*continued*)

Note:
The 16*plus*-IM V2 sample interval (**#iiSampleInterval=**) must be greater than or equal to the sum of the times required to sample. Total time is affected by the following:
- **Programmable pressure integration time for GTD**.
- **Programmable temperature integration time for GTD**.
- Minimum time required for 16*plus*-IM V2 to take a sample (≈ 2.5 sec).
- Time required for integration of optional Quartz pressure sensor (**#iiParosIntegration=**).
- Time required for 16*plus*-IM V2 to take and average **#iiNCycles=** samples; samples are taken 0.25 sec apart.
- Delay after providing power to external voltage sensors before sampling (**#iiDelayBeforeSampling=**).
- Time required to run pump before sampling (0.5 sec if **#iiPumpMode=1**).

Setup for GTD:

Set up GTD to interface with SBE 16*plus*-IM V2, **before** you connect it to 16*plus*-IM V2. Connect GTD directly to computer, power with an external power supply, and (using software provided by Pro-Oceanus) set:
- **Baud rate** to 1200.
- **Output** to millibars.
- Sum of **pressure integration time** and **temperature integration time** so that the GTD responds to a *take pressure reading* command in 40 seconds or less (required so that 16*plus*-IM V2 does not *time out* while waiting for reply).

Connect GTD to SBE 16*plus*-IM V2 *Auxiliary RS-232 Input* connector, using provided cable (end labeled *Pro-Oceanus* to GTD and end labeled *Sea-Bird* to 16*plus*-IM V2). In the 16*plus*-IM V2, set:
- **#iiGTD=Y** or **#iiDualGTD=Y** to enable interface.
- **#iiSendGTD=** to change IDs if necessary.

Each time a sample is to be taken, SBE 16*plus*-IM V2 sends following commands to GTD (ID= 01, 02, etc.):
- ***ID00VR** <CR><LF> - get GTD firmware version; wait up to 3 seconds for reply.
- ***ID00SN** <CR><LF> - get GTD serial number; wait up to 5 seconds for reply.
- ***9900P5** <CR><LF> - command all GTDs to sample pressure; hold data in GTD.
- ***ID00DB** <CR.<LF> - get held pressure; wait up to 90 seconds for reply.
- ***9900Q5 <**CR><LF> - command all GTDs to sample temperature; hold data in GTD.
- ***ID00DB** <CR.<LF> - get held temperature; wait up to 90 seconds for reply.

Notes:
- A 16*plus*-IM V2 with dual GTDs is shipped with a Y-cable installed for the GTDs. The GTD ends are labeled GTD #1 and #2, and Sea-Bird set the GTD IDs to match.
- If **#iiDualGTD=Y**, setting for **#iiGTD=** has no effect.

#iiGTD=x
x=Y: Enable GTD.
x=N: Do not enable GTD.

#iiDualGTD=x
x=Y: Enable dual (2) GTDs.
x=N: Do not enable dual GTDs.

#iiTGTD
Measure GTD(s), output 1 sample of data from each GTD (firmware version, serial number, pressure, and temperature).

Example: Output GTD data for 16*plus*-IM V2 (ID=01) with dual GTDs (user input in bold):

```
#01TGTD
GTD#1 VR reply = *0001VR=s2.03    (GTD firmware version)
GTD#2 VR reply = *0002VR=s2.03    (GTD firmware version)
GTD#1 SN reply = *0001SN = 75524    (GTD serial number)
GTD#2 SN reply = *0002SN = 81440    (GTD serial number)
GTD#1 pressure reply = *00011010.04661, p = 101004661  (millibars x 10^5)
GTD#2 pressure reply = *00021010.01580, p = 101001580  (millibars x 10^5)
GTD#1 temperature reply = *000123.49548, t = 23.4955    (°C)
GTD#2 temperature reply = *000223.0357038, t = 23.0357  (°C)
```

#iiSendGTD=command
Command 16*plus*-IM V2 to send **command** to GTD and receive response; **command** can be any command recognized by GTD (see GTD manual).

Examples: (user input in bold)

Send firmware version command from 16*plus*-IM V2 (ID=01) to GTD #1:

```
#01SENDGTD=*0100vr
Sending GTD: **0100vr
GTD RX = *0001VR=s2.03
```

Send serial number command from 16*plus*-IM V2 (ID=01) to GTD #2:

```
#01SENDGTD=*0200sn
Sending GTD: **0200sn
GTD RX = *0002SN=81440
```

Setup for Aanderaa Optode:

Note:
When setting up the configuration (.con) file In Seasave and/or SBE Data Processing, select *Oxygen, Optode* for the Serial RS-232C sensor. Enter the serial number, calibration date, and information required for salinity and depth corrections. The *internal salinity* must match the value you programmed into the Optode (the value is ignored if you do not enable the *Salinity correction*). If you enable *Salinity correction*, our software corrects the oxygen output from the Optode based on the actual salinity (calculated from the CTD data). If you enable *Depth correction*, our software corrects the oxygen output from the Optode based on the depth (calculated from the CTD data).

Set up Optode to interface with 16*plus*-IM V2, **before** you connect it to 16*plus*-IM V2. Connect Optode directly to computer, power with an external power supply, and (following directions provided by Aanderaa) set:

- **Communication** to RS-232.
- **Sample interval** to 5.
- **Output** to model number, serial number, and oxygen concentration (micromoles/liter) in decimal format. Disable all other output (air saturation, temperature, raw data, and text).

Connect Optode to SBE 16*plus*-IM V2 *Auxiliary RS-232 Input* connector. In 16*plus*-IM V2, set **#iiOptode=Y** to enable interface.

#iiOptode=x	**x=Y**: Enable RS-232 Optode.
	x=N: Do not enable Optode.

Output Format Setup Commands

See *Data Format* after the command descriptions for complete details on all formats.

Note:
Output format does not affect how data is stored in FLASH memory. Sea-Bird's data processing software (SBE Data Processing) requires data in raw hexadecimal (**#iiOutputFormat=0**).

Typical use of the output format command is:
- Before beginning logging, set the output format to converted decimal (**#iiOutputFormat=3**) for ease in viewing data in SeatermIM (if you will be transmitting occasional data samples while logging).
- After stopping sampling, use SeatermIM's Upload menu to upload data from memory. This automatically uploads the data in raw hex (regardless of the **#iiOutputFormat=** setting), so the data is compatible with SBE Data Processing for processing and with Seasave for viewing archived data.

#iiOutputFormat=x

x=0: Output raw frequencies and voltages in hexadecimal; required for data that will be processed with Sea-Bird software. When using SeatermIM's Upload menu, SeatermIM sends **#iiOutputFormat=0**, causing 16*plus*-IM V2 to upload data in memory in raw hex, regardless of user-programmed **#iiOutputFormat=**.

x=1: Output converted (engineering units) data in hexadecimal.

x=2: Output raw frequencies and voltages in decimal.

x=3: Output converted (engineering units) data in decimal; required to output salinity, sound velocity, or serial number and sample number.

x=4: Not a valid output format.

x=5: Output converted (engineering units) data in decimal, in XML.

#iiOutputSal=x

x=Y: Calculate and output salinity (psu). Only applies if **#iiOutputFormat=3** or **5**.

x=N: Do not.

#iiOutputSV=x

x=Y: Calculate and output sound velocity (m/sec), using Chen and Millero formula (UNESCO Technical Papers in Marine Science #44). Only applies if **#iiOutputFormat=3** or **5**.

x=N: Do not.

#iiOutputUCSD=x

x=Y: Calculate and output density sigma-t (kg/m^3), battery voltage, and operating current (mA) with data polled while logging. Voltage and current measured after delay before sampling, but before sampling. Only applies if **#iiOutputFormat=3** or **5**.

x=N: Do not.

Note:
#iiOutputSampleNumber=Y could be used to verify that logging is occurring at the correct rate. For example, while logging:
1. Send **#iiSL**.
2. After some interval, send **#iiSL** again. Compare change in output sample numbers to expected change based on **#iiSampleInterval=**.

#iiOutputSampleNumber=x

x=Y: Output 6-character sample number (number of samples in memory at time sample was taken) with data from **Dataii**, **!iiData**, **#iiSL**, **#iiSLT**, **#iiTS**, and #**iiTSS**. Only applies if **#iiOutputFormat=3** or **5**.

x=N: Do not.

Notes:
- In SeatermIM, to save data to a file (if you will be transmitting occasional data samples while logging), click the Capture menu before beginning logging.
- If the FLASH memory is filled to capacity, data sampling continues, but excess data is not saved in memory. **The 16*plus*-IM V2 will not overwrite data stored in memory.**
- If the maximum number of headers is reached but there is still room for samples in FLASH memory, the 16*plus*-IM V2 continues to sample and store sample data in FLASH memory without writing additional headers.
- If the 16*plus*-IM V2 is sampling and the voltage is less than the cut-off voltage (7.5 volts), the 16*plus*-IM V2 halts logging and displays `WARNING: LOW BATTERY VOLTAGE`.

Note:
#iiPumpMode=, **#iiNCycles=**, **#iiParosIntegration=**, and **#iiDelayBeforeSampling=** affect the time required to sample. If the time required to sample is too high, the 16*plus*-IM V2 is unable to take the required number of measurements and do the calculations within **#iiSampleInterval=**. See *Sample Timing* in *Section 2: Description of SBE 16plus-IM V2*.

Notes:
- After receiving **#iiStartLater**, the 16*plus*-IM V2 displays `waiting to start at ...` in reply to **#iiGetSD** or **#iiDS**. Once logging has started, the reply displays `logging`.
- If the delayed start time has already passed when **#iiStartLater** is received, the 16*plus*-IM V2 executes **#iiStartNow**.
- If the delayed start date and time is more than 90 days in the future when **#iiStartLater** is received, the 16*plus*-IM V2 assumes that the user made an error in setting the delayed start date and time, and it executes **#iiStartNow**.

Notes:
- You may need to send **#iiStop** several times to get the 16*plus*-IM V2 to respond.
- You must stop logging before uploading data.

Autonomous Sampling (logging) Commands

Autonomous sampling commands direct the 16*plus*-IM V2 to sample at a pre-programmed interval. When commanded to start sampling with **#iiStartNow** or **#iiStartLater**, the 16*plus*-IM V2 takes samples, stores the data in its FLASH memory, and enters quiescent (sleep) state between samples.

To start sampling, use **#iiStartNow**; sampling starts **#iiSampleInterval=** seconds after receipt of **#iiStartNow**. Alternatively, use **#iiStartDateTime=** and **#iiStartLater** to start sampling at a designated date and time.
The first time sampling starts after receipt of the initialize logging command (**#iiInitLogging**), data recording starts at the beginning of memory and any previously recorded data is written over. When **#iiStop** is sent, recording stops. Each time **#iiStartNow** or **#iiStartLater** is sent again, recording continues, with new data stored after the previously recorded data. A new header is written each time logging starts and every 2000 samples thereafter. A maximum of 1000 headers can be written.

The 16*plus*-IM V2 responds only to **#iiGetCD**, **#iiGetSD**, **#iiGetCC**, **#iiGetEC**, **#iiResetEC**, **#iiGetHD**, **#iiDS**, **#iiDCal**, **#iiTS**, **#iiSL**, **#iiSLT**, **#iiGetLastSamples:x**, and **#iiStop** while logging or waiting to start logging. If you wake the 16*plus*-IM V2 (for example, to send **#iiDS** to check logging progress), it temporarily stops sampling. Sampling resumes when the Acquisition microcontroller goes back to sleep (as soon as it finishes processing the command).

#iiSampleInterval=x — **x**= interval (seconds) between samples (10 – 14,400 seconds).

Example: If **#iiSampleInterval=10** and **#iiNCycles=4**, every 10 seconds 16*plus*-IM V2 takes 4 samples (each 0.25 seconds apart), averages data from 4 samples, and stores averaged data in FLASH memory.

#iiStartNow — Start autonomous sampling now.

#iiStartDateTime= mmddyyyyhhmmss — Set delayed start month, day, year, hour, minute, second.

#iiStartLater — Start autonomous sampling at time set with **#iiStartDateTime=**. If you need to change 16*plus*-IM V2 setup after **#iiStartLater** has been sent (but before logging has started), send **#iiStop**, change setup as desired, and then send **#iiStartLater** again.

Example: Program 16*plus*-IM V2 with ID=01 to start logging on 20 January 2009 12:00:00 (user input in bold).

#01STARTDATETIME=01202009120000
#01STARTLATER

#iiStop — Stop autonomous sampling or stop waiting to start autonomous sampling (if **#iiStartLater** was sent but sampling has not begun yet). Connect to 16*plus*-IM V2 (*Connect* in SeatermIM's Communications menu) before sending **#iiStop**.

Note:
The 16*plus*-IM V2 has a buffer that stores the most recent data sample. Unlike data in the FLASH memory, data in the buffer is erased upon removal or failure of power.

Polled Sampling Commands

These commands request a single sample (with the exception of **#iiGetLastSamples:x**). The 16*plus*-IM V2 always stores data for the most recent sample in its buffer. Some Sampling commands also store data in FLASH memory - the 16*plus*-IM V2 will not execute the *store data in FLASH memory* portion of those commands while sampling autonomously.

#iiSL	Output last sample from buffer (sample obtained with polled sampling command, or latest sample from logging).
#iiSLT	Output last sample from buffer, then take new sample and store data in buffer. **Data is not stored in FLASH memory**.
#iiTS	Take new sample, store data in buffer, and output data. **Data is not stored in FLASH memory**.
#iiTSS	Take new sample, store data in buffer and **FLASH memory**, and output data.
#iiGetLastSamples:x	Output last **x** samples from FLASH memory. If **x** is greater than the number of samples in memory, 16*plus*-IM V2 outputs all samples in memory. If **x** is omitted, 16*plus*-IM V2 outputs just the last sample.

Data Upload Commands

Stop sampling autonomously (send **#iiStop**) before uploading data.
If manually sending a data upload command, data is uploaded in the format defined by **#iiOutputFormat=**.

Notes:
- The uploaded data format is the same, regardless of the choice of upload telemetry (IM or RS-232).
- **Use SeatermIM's or Seaterm232's Upload menu to upload data that will be processed by SBE Data Processing**. Manually entering a data upload command does not produce data with the required header information for processing by our software. These commands are included here for reference for users who are writing their own software.
- **If not using the Upload menu** - To save data to a file, click the Capture menu before entering a data upload command.
- See *Data Format* after these *Command Descriptions*.

Upload data using one of these telemetry methods:
- **RS-232 (serial mode)** - Much faster upload (up to 115,200 baud) is available in serial mode; however, you must open the 16*plus*-IM V2 housing to access the internal RS-232 serial connector. When using RS-232 telemetry, select *SBE 16lus V2 RS232* in SeatermV2's Instrument menu; this launches **Seaterm232**.
  Note: When uploading in Seaterm232, the Upload Data dialog box allows you to select *Text* or *Binary* as the Upload format. However, ***Binary is not compatible*** with the 16*plus*-IM V2.
- **Inductive modem** – Data can be uploaded while the 16*plus*-IM V2 is deployed, or is wired in the lab as shown in *Test Setup with SIM* or *Test Setup with IMM* in *Section 3: Preparing 16plus-IM V2 for Deployment*. Upload speed is limited by the baud rate between the 16*plus*-IM V2 and IMM/SIM, which is 1200 baud.

#iiGetSamples:b,e or **#iiDDb,e** Upload data from sample **b** to sample **e**. If **b** and **e** are omitted, all data is uploaded. First sample is number 1.

Examples: 16*plus*-IM V2 with ID=01, upload samples 1-1000 to a file (user input in bold): (Click Capture menu and enter desired filename in dialog box.)
#01GETSAMPLES:1,1000
or
#01DD1,1000

#iiGetHeaders:b,e or **#iiDHb,e** Upload header **b** to header **e** (a maximum of 500 headers can be uploaded at one time). If **b** and **e** are omitted, the first 500 headers are uploaded. First header number is 1. Header includes:
- header number
- month, day, hour, minute, and second when header was written
- first and last sample for header
- interval between samples (**#iiSampleInterval=**)
- reason logging was halted (batfail = battery voltage too low; stop cmd = received **#iiStop** or Home or Ctrl Z character; timeout = error condition; unknown = error condition; ?????? = error condition)

Example: 16*plus*-IM V2 with ID=01, upload second header to a file (user input in bold): (Click Capture menu and enter desired filename in dialog box.)
#01GETHEADERS:2,2
or
#01DH2,2
16*plus*-IM V2 responds:
```
hdr 2 30 Aug 2009 12:30:33 samples 35 to 87, int=60, stop=stop cmd
```

Note:
If your 16plus-IM V2 includes an optional pump:
Testing commands do not automatically turn the pump on. Thus, for instruments plumbed with the pump, they report data from essentially the same sample of water for all 30 measurements, because the pump does not run but the pump and associated plumbing prevent water from freely flowing through the conductivity cell and other plumbed sensors (for example, dissolved oxygen sensor). To get data from fresh samples, send **#iiPumpOn** before sending a testing command, and then send **#iiPumpOff** when the test is complete.

Testing Commands

The 16*plus*-IM V2 takes and outputs **30 samples** for each test (except as noted); data is **not** stored in FLASH memory.

#iiTC — Measure conductivity, output converted data.

#iiTCR — Measure conductivity, output raw data.

#iiTT — Measure temperature, output converted data.

#iiTTR — Measure temperature, output raw data.

#iiTP — Measure internally mounted pressure (strain gauge or Quartz), output converted data.

#iiTPR — Measure internally mounted pressure (strain gauge or Quartz), output raw data.

#iiTV — Measure 6 external voltage channels, output converted data.

#iiTVR — Measure voltages read by A/D converter, output raw data:

Column	Output
1 – 6	External voltages
7	Main battery voltage / 11
8	Back-up lithium battery voltage / 3.741
9	External current / 333.33
10	Pressure temperature voltage

#iiTF — Measure frequency (internally mounted Quartz pressure sensor), output converted data.

#iiTFR — Measure frequency (internally mounted Quartz pressure sensor), output raw data.

#iiT38 — Measure SBE 38 (secondary temperature), output converted data.

#iiT50 — Measure SBE 50 pressure, output converted data.

#iiTOptode — Measure Aanderaa Optode, output product number, serial number, and dissolved oxygen (micromoles/liter).

#iiPumpOn — Turn pump on for testing purposes.
Use this command:
- Before sending testing command to obtain pumped data from sensors plumbed with the pump, or
- To test pump.

#iiPumpOff — Turn pump off for testing purposes.

Calibration Coefficients Commands

Calibration coefficients are initially factory-set and should agree with Calibration Certificates shipped with the 16*plus*-IM V2.

Notes:
- F = floating point number
  S = string with no spaces
- If using an SBE 38 secondary temperature sensor or SBE 50 pressure sensor, its calibration coefficients are not stored in the 16*plus*-IM V2 EEPROM. View and/or modify the instrument's calibration coefficients by connecting the instrument to the computer directly and using SEATERM or Seaterm232.

Temperature

#iiTCalDate=S	**S**=calibration date
#iiTA0=F	**F**=A0
#iiTA1=F	**F**=A1
#iiTA2=F	**F**=A2
#iiTA3=F	**F**=A3
#iiTOffset=F	**F**=offset correction

Conductivity

#iiCCalDate=S	**S**=calibration date
#iiCG=F	**F**=G
#iiCH=F	**F**=H
#iiCI=F	**F**=I
#iiCJ=F	**F**=J
#iiCPCor=F	**F**=pcor
#iiCTCor=F	**F**=tcor
#iiCSlope=F	**F**=slope correction

Internally Mounted Pressure - General

#iiPCalDate=S	**S**=calibration date
#iiPRange=F	**F**=sensor full scale range (**psia**)
#iiPOffset=F	**F**=offset correction (**decibars**)

Internally Mounted Strain Gauge Pressure

#iiPA0=F	**F**=A0
#iiPA1=F	**F**=A1
#iiPA2=F	**F**=A2
#iiPTempA0=F	**F**=pressure temperature A0
#iiPTempA1=F	**F**=pressure temperature A1
#iiPTempA2=F	**F**=pressure temperature A2
#iiPTCA0=F	**F**=pressure temperature compensation ptca0
#iiPTCA1=F	**F**=pressure temperature compensation ptca1
#iiPTCA2=F	**F**=pressure temperature compensation ptca2
#iiPTCB0=F	**F**=pressure temperature compensation ptcb0
#iiPTCB1=F	**F**=pressure temperature compensation ptcb1
#iiPTCB2=F	**F**=pressure temperature compensation ptcb2

Internally Mounted Quartz Pressure

#iiPC1=F	**F**=C1
#iiPC2=F	**F**=C2
#iiPC3=F	**F**=C3
#iiPD1=F	**F**=D1
#iiPD2=F	**F**=D2
#iiPT1=F	**F**=T1
#iiPT2=F	**F**=T2
#iiPT3=F	**F**=T3
#iiPT4=F	**F**=T4
#iiPSlope=F	**F**=slope correction

External Frequency

#iiExtFreqSF=F	**F**=external frequency scale factor (applies to Quartz pressure sensor)

Note:
If using auxiliary A/D sensors (**#iiVolt0=** through **#iiVolt5=**), their calibration coefficients are not stored in the 16*plus*-IM V2 EEPROM, but are stored in the 16*plus*-IM V2 configuration (.con) file. View and/or modify the calibration coefficients using the Configure menu in SBE Data Processing.

Voltage Channels

The following commands set voltage channel offsets and slopes **at the factory**. These are properties of the 16*plus*-IM V2's electronics, and are not calibration coefficients for the auxiliary sensors. These commands are included here for completeness, **but should never be used by the customer**.

#iiVOffset0=	**#iiVSlope0=**
#iiVOffset1=	**#iiVSlope1=**
#iiVOffset2=	**#iiVSlope2=**
#iiVOffset3=	**#iiVSlope3=**
#iiVOffset4=	**#iiVSlope4=**
#iiVOffset5=	**#iiVSlope5=**

Hardware Configuration Commands

The following commands are used to set manufacturing date, PCB serial numbers, PCB assembly numbers, and auxiliary channel sensor types (description such as *oxygen*, *fluorometer*, etc.) and serial number.

Factory Settings – do not modify in the field
#iiSetMfgDate=
#iiSetPcbSerialNum1=
#iiSetPcbSerialNum2=
#iiSetPcbSerialNum3=
#iiSetPcbSerialNum4=
#iiSetPcbAssembly1=
#iiSetPcbAssembly2=
#iiSetPcbAssembly3=
#iiSetPcbAssembly4=

Auxiliary Sensor Settings – can be modified in the field to accommodate changes in auxiliary sensors cabled to the 16plus-IM V2
#iiSetVoltType0=
#iiSetVoltSN0=
#iiSetVoltType1=
#iiSetVoltSN1=
#iiSetVoltType2=
#iiSetVoltSN2=
#iiSetVoltType3=
#iiSetVoltSN3=
#iiSetVoltType4=
#iiSetVoltSN4=
#iiSetVoltType5=
#iiSetVoltSN5=

Data Format

Note:
For the date and time output with the data, time is the time at the **start** of the sample, after:
- a small amount of time (1 to 2 seconds) for the 16*plus*-IM V2 to wake up and prepare to sample, and
- any programmed **#iiDelayBeforeSampling=**.

For example, if the 16*plus*-IM V2 is programmed to wake up and sample at 12:00:00, and **#iiDelayBeforeSampling=20**, the output time for the first sample will be 12:00:21 or 12:00:22.

The SBE 16*plus*-IM V2 stores data in a compact machine code. Data is converted and output in the user-selected format without affecting data in memory. Because memory data remains intact until deliberately overwritten, you can upload in one format, then choose another format and upload again.

Output format is dependent on **#iiOutputFormat= (0, 1, 2, 3, or 5)** and on the command used to retrieve the data, as detailed below. The inclusion of some data is dependent on system configuration - if the system does not include the specified sensor, the corresponding data is not included, shortening the data string.

#iiOutputFormat=0 (raw frequencies and voltages in Hex)

Data is output in the order listed, with no spaces or commas between parameters. Shown with each parameter is the number of digits, and how to calculate the parameter from the data (use the decimal equivalent of the hex data in the equations).

Uploaded Data (from #iiGetSamples:b,e, #iiDDb,e, or Upload menu) or Polled Data (from #iiSL, #iiSLT, #iiTS, or #iiTSS):

1. Temperature
   A/D counts = ttttt
2. Conductivity
   conductivity frequency (Hz) = cccccc / 256
3. Strain gauge pressure sensor pressure (if **#iiPType=1**)
   A/D counts = pppppp
4. Strain gauge pressure sensor pressure temperature compensation (if **#iiPType=1**)
   pressure temperature compensation voltage = vvvv / 13,107
5. Quartz pressure sensor pressure (if **#iiPType=3**)
   Quartz pressure frequency (Hz) = pppppp / 256
6. Quartz pressure sensor temperature compensation (if **#iiPType=3**)
   Quartz temperature compensation voltage = vvvv / 13,107
7. External voltage 0 (if **#iiVolt0=Y**)
   external voltage 0= vvvv / 13,107
8. External voltage 1 (if **#iiVolt1=Y**)
   external voltage 1 = vvvv / 13,107
9. External voltage 2 (if **#iiVolt2=Y**)
   external voltage 2 = vvvv / 13,107
10. External voltage 3 (if **#iiVolt3=Y**)
    external voltage 3 = vvvv / 13,107
11. External voltage 4 (if **#iiVolt4=Y**)
    external voltage 4 = vvvv / 13,107
12. External voltage 5 (if **#iiVolt5=Y**)
    external voltage 5 = vvvv / 13,107
13. SBE 38 secondary temperature (if **#iiSBE38=Y**)
    SBE 38 temperature (°C, ITS-90) = (ttttt / 100,000) – 10
14. SBE 50 strain gauge pressure (if **#iiSBE50=Y**)
    SBE 50 pressure (decibars, psia, meters, or feet) = (pppppp / 10,000) – 100
15. GTD #1 pressure (if **#iiGTD=Y** or **#iiDualGTD=Y**)
    GTD #1 pressure (millibars) = pppppppp / 100,000
16. GTD #1 temperature (if **#iiGTD=Y** or **#iiDualGTD=Y**)
    GTD #1 temperature (°C, ITS-90) = (ttttt / 100,000) – 10
17. GTD #2 pressure (if **#iiDualGTD=Y**)
    GTD #2 pressure (millibars) = pppppppp / 100,000
18. GTD #2 temperature (if **#iiDualGTD=Y**)
    GTD #2 temperature (°C, ITS-90) = (ttttt / 100,000) – 10
19. Optode oxygen (if **#iiOptode=Y**)
    Optode oxygen (micromoles/liter) = (oooooo / 10,000) – 10
20. Time
    seconds since January 1, 2000 = ssssssss

Notes:

- When using SeatermIM's Upload menu, SeatermIM sends **#iiOutputFormat=0**. This causes the 16*plus*-IM V2 to upload data in memory in raw hex, regardless of the user-programmed format, providing the data in a format that SBE Data Processing can use.
- Our software uses the equations shown to perform these calculations; alternatively, you can use the equations to develop your own processing software.
- The pressure sensor is an absolute sensor, so its **raw** output includes the effect of atmospheric pressure (14.7 psi). As shown on the Calibration Sheet, Sea-Bird's calibration (and resulting calibration coefficients) is in terms of psia. However, when outputting pressure in **engineering units**, the 16*plus*-IM V2 outputs pressure relative to the ocean surface (i.e., at the surface the output pressure is 0 decibars). The 16*plus*-IM V2 uses the following equation to convert psia to decibars:
  pressure (db) =
  [pressure (psia) - 14.7] * 0.689476
- Although **#iiOutputFormat=0** outputs *raw* data for temperature, conductivity, etc., it outputs engineering units for SBE 38, SBE 50, GTD, and Optode data. SBE 50 units are dependent on **OutputFormat=** programmed into the SBE 50; if you will be using SBE Data Processing, you must set the SBE 50 format to psia (**OutputFormat=1**).

Example: 16*plus*-IM V2 with strain gauge pressure sensor and 2 external voltages sampled, example scan = ttttttccccccppppppvvvvvvvvvvvvssssssss
= 0A53711BC7220C14C17D82030505940EC4270B

- Temperature = ttttt = 0A5371 (676721 decimal);
  temperature A/D counts = 676721
- Conductivity = 1BC722 (1820450 decimal);
  conductivity frequency = 1820450 / 256 = 7111.133 Hz
- Strain gauge pressure = pppppp = 0C14C1 (791745 decimal);
  Strain gauge pressure A/D counts = 791745
- Strain gauge temperature compensation =
  vvvv = 7D82 (32,130 decimal);
  Strain gauge temperature = 32,130 / 13,107 = 2.4514 volts
- First external voltage = vvvv = 0305 (773 decimal);
  voltage = 773 / 13,107 = 0.0590 volts
- Second external voltage = vvvv = 0594 (1428 decimal);
  voltage = 1428 / 13,107 = 0.1089 volts
- Time = ssssssss = 0EC4270B (247,736,075 decimal)
  seconds since January 1, 2000 = 247,736,075

Polled Data from Dataii or !iiData:

Data is preceded by the 16*plus*-IM V2 two-character decimal ID and a comma. The rest of the data stream is as described above.

Example: 16*plus*-IM V2 with strain gauge pressure sensor and 2 external voltages sampled.

DATA01

01, 0A53711BC7220C14C17D82030505940EC4270B

Same as example above, but hex data stream is preceded by 16*plus*-IM V2 ID (01).

#iiOutputFormat=1 (engineering units in Hex)

Data is output in the order listed, with no spaces or commas between the parameters. Shown with each parameter is the number of digits, and how to calculate the parameter from the data (use the decimal equivalent of the hex data in the equations).

Uploaded Data (from #iiGetSamples:b,e or #iiDDb,e) or Polled Data (from #iiSL, #iiSLT, #iiTS, or #iiTSS):

1. Temperature
   temperature (°C, ITS-90) = (ttttt / 100,000) - 10
2. Conductivity
   Conductivity (S/m) = (cccccc / 1,000,000) - 1
3. Pressure (Quartz or strain gauge - **#iiPType=1** or **3**)
   pressure (decibars) = (pppppp / 1,000) - 100
4. External voltage 0 (if **#iiVolt0=Y**)
   external voltage 0= vvvv / 13,107
5. External voltage 1 (if **#iiVolt1=Y**)
   external voltage 1 = vvvv / 13,107
6. External voltage 2 (if **#iiVolt2=Y**)
   external voltage 2 = vvvv / 13,107
7. External voltage 3 (if **#iiVolt3=Y**)
   external voltage 3 = vvvv / 13,107
8. External voltage 4 (if **#iiVolt4=Y**)
   external voltage 4 = vvvv / 13,107
9. External voltage 5 (if **#iiVolt5=Y**)
   external voltage 5 = vvvv / 13,107
10. SBE 38 secondary temperature (if **#iiSBE38=Y**)
    SBE 38 temperature (°C, ITS-90) = (ttttt / 100,000) – 10
11. SBE 50 strain gauge pressure (if **#iiSBE50=Y**)
    SBE 50 pressure (decibars, psia, meters, or feet) = (pppppp / 10,000) – 100
12. GTD #1 pressure (if **#iiGTD=Y** or **#iiDualGTD=Y**)
    GTD #1 pressure (millibars) = pppppppp / 100,000
13. GTD #1 temperature (if **#iiGTD=Y** or **#iiDualGTD=Y**)
    GTD #1 temperature (°C, ITS-90) = (ttttt / 100,000) – 10
14. GTD #2 pressure (if **#iiDualGTD=Y**)
    GTD #2 pressure (millibars) = pppppppp / 100,000
15. GTD #2 temperature (if **#iiDualGTD=Y**)
    GTD #2 temperature (°C, ITS-90) = (ttttt / 100,000) – 10
16. Optode oxygen (if **#iiOptode=Y**)
    Optode oxygen (micromoles/liter) = (oooooo / 10,000) – 10
17. Time
    seconds since January 1, 2000 = ssssssss

Note:
SBE 50 units are dependent on **OutputFormat=** programmed into the SBE 50.

Example: 16*plus*-IM V2 with strain gauge pressure sensor and 2 external voltages sampled,
example scan = ttttttccccccppppppvvvvvvvvssssssss = 3385C40F42FE0186DE030505940EC4270B

- Temperature = ttttt = 3385C4 (3376580 decimal); temperature (°C, ITS-90) = (3376580 / 100,000) - 10 = 23.7658
- Conductivity = cccccc = 0F42FE (1000190 decimal); conductivity (S/m) = (1000190 / 1,000,000) - 1 = 0.00019
- Pressure = pppppp = 0186DE (100062 decimal); pressure (decibars) = (100062 / 1,000) - 100 = 0.062
- First external voltage = vvvv = 0305 (773 decimal); voltage = 773 / 13,107 = 0.0590 volts
- Second external voltage = vvvv = 0594 (1428 decimal); voltage = 1428 / 13,107 = 0.1089 volts
- Time = ssssssss = 0EC4270B (247,736,075 decimal); seconds since January 1, 2000 = 247,736,075

Polled Data from Dataii or !iiData:
Data is preceded by the 16*plus*-IM V2 two-character decimal ID and a comma. The rest of the data stream is as described above.

Example: 16*plus*-IM V2 with strain gauge pressure sensor and 2 external voltages sampled.

DATA01

01, 3385C40F42FE0186DE0305059425980600

Same as example above, but hex data stream is preceded by 16*plus*-IM V2 ID (01).

#iiOutputFormat=2 (raw frequencies and voltages in decimal)

Data is output in the order listed, with a comma followed by a space between each parameter. Shown with each parameter are the number of digits and the placement of the decimal point. Leading zeros are suppressed, except for one zero to the left of the decimal point.

Uploaded Data (from #iiGetSamples:b,e or #iiDDb,e) or Polled Data (from #iiSL, #iiSLT, #iiTS, or #iiTSS):

1. Temperature
   A/D counts = ttttt
2. Conductivity
   conductivity frequency (Hz) = cccc.ccc
3. Strain gauge pressure sensor pressure (if **#iiPType=1**)
   A/D counts = pppppp
4. Strain gauge pressure sensor pressure temperature compensation (if **#iiPType=1**)
   pressure temperature compensation voltage = v.vvvv
5. Quartz pressure sensor pressure (if **#iiPType=3**)
   Quartz pressure frequency (Hz) = ppppp.ppp
6. Quartz pressure sensor temperature compensation (if **#iiPType=3**)
   Quartz temperature compensation voltage = v.vvvv
7. External voltage 0 (if **#iiVolt0=Y**)
   external voltage 0= v.vvvv
8. External voltage 1 (if **#iiVolt1=Y**)
   external voltage 1 = v.vvvv
9. External voltage 2 (if **#iiVolt2=Y**)
   external voltage 2 = v.vvvv
10. External voltage 3 (if **#iiVolt3=Y**)
    external voltage 3 = v.vvvv
11. External voltage 4 (if **#iiVolt4=Y**)
    external voltage 4 = v.vvvv
12. External voltage 5 (if **#iiVolt5=Y**)
    external voltage 5 = v.vvvv
13. SBE 38 secondary temperature (if **#iiSBE38=Y**)
    SBE 38 temperature (°C, ITS-90) = ttt.tttt
14. SBE 50 strain gauge pressure (if **#iiSBE50=Y**)
    SBE 50 pressure (decibars, psia, meters, or feet) = pppp.ppp
15. GTD #1 pressure (if **#iiGTD=Y** or **#iiDualGTD=Y**)
    GTD #1 pressure (millibars) = pppppppppp / 100,000
16. GTD #1 temperature (if **#iiGTD=Y** or **#iiDualGTD=Y**)
    GTD #1 temperature (°C, ITS-90) = tt.ttt
17. GTD #2 pressure (if **#iiDualGTD=Y**)
    GTD #2 pressure (millibars) = pppppppppp / 100,000
18. GTD #2 temperature (if **#iiDualGTD=Y**)
    GTD #2 temperature (°C, ITS-90) = tt.ttt
19. Optode oxygen (if **#iiOptode=Y**)
    Optode oxygen (micromoles/liter) = oooo.ooo
20. Time
    date, time = dd Mmm yyyy, hh:mm:ss (day month year hour:minute:second)

Notes:
- Although **#iiOutputFormat=2** outputs *raw* data for temperature, conductivity, etc., it outputs engineering units for SBE 38, SBE 50, GTD, and Optode data.
- SBE 50 units are dependent on **OutputFormat=** programmed into the SBE 50.

Example: 16*plus*-IM V2 with strain gauge pressure sensor and 2 external voltages sampled,
example scan = tttttt, cccc.ccc, pppppp, v.vvvv, v.vvvv, v.vvvv, dd mmm yyyy, hh:mm:ss
= 676721, 7111.133, 791745, 2.4514, 0.0590, 0.1089, 7 Nov 2007, 07:34:35

- Temperature = tttttt = 676721; temperature A/D counts = 676721
- Conductivity = cccc.ccc = 7111.133; conductivity frequency = 7111.133 Hz
- Strain gauge pressure = pppppp = 791745; Strain gauge pressure A/D counts = 791745
- Strain gauge temperature compensation = v.vvvv = 2.4514; Strain gauge temperature = 2.4514 volts
- First external voltage = v.vvvv = 0.0590; voltage = 0.0590 volts
- Second external voltage = v.vvvv = 0.1089; voltage = 0.1089 volts
- Date, time = dd Mmm yyyy, hh:mm:ss = 7 Nov 2007, 07:34:35; Date, time = 7 November 2007, 07:34:35

Polled Data from Dataii or !iiData:
Data is preceded by the 16*plus*-IM V2 two-character decimal ID and a comma. The rest of the data stream is as described above.

Example: 16*plus*-IM V2 with strain gauge pressure sensor and 2 external voltages sampled.

DATA01

01, 676721, 7111.133, 791745, 2.4514, 0.0590, 0.1089, 7 Nov 2007, 07:34:35

Same as example above, but data stream is preceded by 16*plus*-IM V2 ID (01).

#iiOutputFormat=3 (engineering units in decimal)

Data is output in the order listed, with a comma followed by a space between each parameter. Shown with each parameter are the number of digits and the placement of the decimal point. Leading zeros are suppressed, except for one zero to the left of the decimal point.

Uploaded Data (from #iiGetSamples:b,e or #iiDDb,e):

1. Temperature
   temperature (°C, ITS-90) = ttt.tttt
2. Conductivity
   Conductivity (S/m) = cc.ccccc
3. Pressure (Quartz or strain gauge - **#iiPType=1** or **3**)
   pressure (decibars) = pppp.ppp
4. External voltage 0 (if **#iiVolt0=Y**)
   external voltage 0= v.vvvv
5. External voltage 1 (if **#iiVolt1=Y**)
   external voltage 1 = v.vvvv
6. External voltage 2 (if **#iiVolt2=Y**)
   external voltage 2 = v.vvvv
7. External voltage 3 (if **#iiVolt3=Y**)
   external voltage 3 = v.vvvv
8. External voltage 4 (if **#iiVolt4=Y**)
   external voltage 4 = v.vvvv
9. External voltage 5 (if **#iiVolt5=Y**)
   external voltage 5 = v.vvvv
10. SBE 38 secondary temperature (if **#iiSBE38=Y**)
    SBE 38 temperature (°C, ITS-90) = ttt.tttt
11. SBE 50 strain gauge pressure (if **#iiSBE50=Y**)
    SBE 50 pressure (decibars, psia, meters, or feet) = pppp.ppp
12. GTD #1 pressure (if **#iiGTD=Y** or #ii**DualGTD=Y**)
    GTD #1 pressure (millibars) = pppppppp / 100,000
13. GTD #1 temperature (if **#iiGTD=Y** or **#iiDualGTD=Y**)
    GTD #1 temperature (°C, ITS-90) = tt.ttt
14. GTD #2 pressure (if **#iiDualGTD=Y**)
    GTD #2 pressure (millibars) = pppppppp / 100,000
15. GTD #2 temperature (if **#iiDualGTD=Y**)
    GTD #2 temperature (°C, ITS-90) = tt.ttt
16. Optode oxygen (if **#iiOptode=Y**)
    Optode oxygen (micromoles/liter) = oooo.ooo
17. Salinity (if **#iiOutputSal=Y**)
    salinity (psu) = sss.ssss
18. Sound velocity (if **#iiOutputSV=Y**)
    sound velocity (meters/second) = vvvv.vvv
19. Time
    date, time = dd mmm yyyy, hh:mm:ss (day month year hour:minute:second)

Note:
SBE 50 units are dependent on **OutputFormat=** programmed into the SBE 50.

Example: 16*plus*-IM V2 with strain gauge pressure sensor and 2 external voltages sampled, example scan = ttt.tttt, cc.ccccc, pppp.ppp, v.vvvv, v.vvvv, dd mmm yyyy, hh:mm:ss
= 23.7658, 0.00019, 0.062, 0.0590, 0.1089, 7 Nov 2007, 07:34:35

- Temperature = ttt.tttt = 23.7658; temperature (°C, ITS-90) = 23.7658
- Conductivity = cc.ccccc = 0.00019; conductivity (S/m) = 0.00019
- Pressure = pppp.ppp = 0.062; pressure (decibars) = 0.062
- First external voltage = v.vvvv = 0.0590; voltage = 0.0590 volts
- Second external voltage = v.vvvv = 0.1089; voltage = 0.1089 volts
- Date, time = dd mmm yyyy, hh:mm:ss = 7 Nov 2007, 07:34:35
  Date, time = 7 November 2007, 07:34:35

Polled Data from #iiSL, #iiSLT, #iiTS, or #iiTSS:

- If **#iiOutputUCSD=Y** and the 16*plus*-IM V2 is logging (autonomous sampling is in progress), data is followed by density sigma-t in kg/m^3 (ddd.dddd), battery voltage (vv.v), and operating current in mA (ccc.c), each separated by a comma and a space. The rest of the data stream is as described above for uploaded data.
  Note: 16*plus*-IM V2 does not respond to **#iiTSS** while logging.

- If **#iiOutputSampleNumber=N**, data is preceded by the 16*plus*-IM V2 four-character serial number and a comma. The rest of the data stream is as described above for uploaded data.

- If **#iiOutputSampleNumber=Y**, data is preceded by the 16*plus*-IM V2 four-character serial number and a comma, and is followed at the very end (after **#iiOutputUCSD** data if applicable) by the six-character sample number (number of samples in memory at the time the sample was taken). The rest of the data stream is as described above for uploaded data.

Example: Serial number 4000 16*plus*-IM V2 with pressure sensor and 2 external voltages sampled, and with **#iiOutputSampleNumber=Y**. Command instrument to send output from last sample taken, which was sample 11.

#01SL

4000, 23.7658, 0.00019, 0.062, 0.0590, 0.1089, 7 Nov 2007, 07:34:35, 11
(same as example above for uploaded data, but data stream is preceded by serial number and followed by sample number)

Polled Data from Dataii or !iiData:

- If **#iiOutputUCSD=Y**, data is followed by density sigma-t in kg/m^3 (ddd.dddd), battery voltage (vv.v), and operating current in mA (ccc.c), each separated by a comma and a space. The rest of the data stream is as described above for uploaded data.

- If **#iiOutputSampleNumber=N**, data is preceded by the 16*plus*-IM V2 two-character ID and a comma and four-character serial number and a comma. The rest of the data stream is as described above for uploaded data.

- If **#iiOutputSampleNumber=Y**, data is preceded by the 16*plus*-IM V2 two-character ID and a comma and four-character serial number and a comma, and is followed at the very end (after **#iiOutputUCSD** data if applicable) by the six-character sample number (number of samples in memory at the time the sample was taken). The rest of the data stream is as described above for uploaded data.

Example: Serial number 4000 16*plus*-IM V2 with pressure sensor and 2 external voltages sampled, and with **#iiOutputSampleNumber=Y**. Command instrument to send output from last sample taken, which was sample 11.

DATA01

01, 4000, 23.7658, 0.00019, 0.062, 0.0590, 0.1089, 7 Nov 2007, 07:34:35, 11
(same as example above for uploaded data, but data stream is preceded by ID and serial number and followed by sample number)

#iiOutputFormat=5 (engineering units in decimal, in XML)

Note:
#iiOutputFormat=5 is listed in the **#iiGetCD** and **#iiDS** response as `converted XML UVIC`.

Data is output in the order listed, with **no** carriage return or line feed between each parameter (however, there is a carriage return and line feed at the end of the data stream, after the </datapacket> closing tag). Shown with each parameter are the number of digits and the placement of the decimal point. Leading zeroes are suppressed, except for one zero to the left of the decimal point.

Uploaded Data (from #iiGetSamples:b,e or #iiDDb,e):

Note:
For ease in reading, the data structure is shown with each XML tag on a separate line. However, there are no carriage returns or line feeds between tags (see example below).

```
<?xml?>
<datapacket>
<hdr>
<mfg>Sea-Bird</mfg>
<model>16plus</model>
<sn>nnnn</sn>
</hdr>
<data>
<t1>ttt.tttt</t1>
<c1>cc.ccccc</c1>
<p1>pppp.ppp </p1>                                  (if #iiPType=1 or 3)
<v0>v.vvvv</v0>                                    (if #iiVolt0=Y)
<v1>v.vvvv</v1>                                    (if #iiVolt1=Y)
<v2>v.vvvv</v2>                                    (if #iiVolt2=Y)
<v3>v.vvvv</v3>                                    (if #iiVolt3=Y)
<v4>v.vvvv</v4>                                    (if #iiVolt4=Y)
<v5>v.vvvv</v5>                                    (if #iiVolt5=Y)
<ser1>
<type>sbe38, sbe50, gtd, or optode</type>          (indicates type of RS-232 sensor)
<t38>ttt.tttt</t38>                                (if #iiSBE38=Y)
<p2>pppp.ppp</p2>                                  (if #iiSBE50=Y)
<p1>ppppppppp</p1>                                 (if #iiGTD=Y or #iiDualGTD=Y)
<t1>tt.ttt</t1>                                    (if #iiGTD=Y or #iiDualGTD=Y)
<p2>ppppppppp</p2>                                 (if #iiDualGTD=Y)
<t2>tt.ttt</t2>                                    (if #iiDualGTD=Y)
<oox>oooo.ooo</oox>                                (if #iiOptode=Y)
</ser1>
<sal>sss.ssss</sal>                                (if #iiOutputSal=Y)
<sv>vvvv.vvv</sv>                                  (if #iiOutputSV=Y)
<dt>yyyy-mm-ddThh:mm:ss</dt>
<smpl>xxxxxxx</smpl>                               (if #iiOutputSampleNumber=Y)
</data>
</datapacket>
```

where

Serial number = nnnn
Temperature (°C, ITS-90) = ttt.tttt
Conductivity (S/m) = cc.ccccc
Internally mounted pressure (decibars) = pppp.ppp
External voltage = v.vvvv (for voltage 0, 1, 2, 3, 4, and 5)
SBE 38 temperature (°C, ITS-90) = ttt.tttt
SBE 50 pressure (decibars, psia, meters, or feet) = pppp.ppp
GTD pressure (millibars) = pppppppppp / 100,000 (for GTD #1 and #2)
GTD temperature (°C, ITS-90) = tt.ttt (for GTD #1 and #2)
Optode oxygen (micromoles/liter) = oooo.ooo
Salinity (psu) = sss.ssss
Sound velocity (meters/second) = vvvv.vvv
Date, time = year month day T hour:minute:second (yyyy-mm-ddThh:mm:ss)
Sample number = xxxxxxx

Note:
SBE 50 units are dependent on **OutputFormat=** programmed into the SBE 50.

Example: 16*plus*-IM V2 with internally mounted strain gauge pressure sensor and 2 external voltages sampled, example scan =

<?xml?><datapacket><hdr><mfg>Sea-Bird</mfg><model>16plus</model><sn>1234</sn></hdr><data><t1>23.7658</t1><c1>0.00019</c1><p1>0.062</p1><v0>0.0590</v0><v1>0.1089</v1><dt>2007-11-07T07:34:35</dt></data></datapacket>CRLF

Serial number = 1234, Temperature (°C, ITS-90) = 23.7658, Conductivity (S/m) = 0.00019, Internally mounted pressure (decibars) = 0.062, First external voltage = 0.0590 volts, Second external voltage = 0.1089 volts, and Date, time = November 7, 2007, 07:34:35

Polled Data from #iiSL, #iiSLT, #iiTS, or #iiTSS:
If **#iiOutputUCSD=Y** and the 16*plus*-IM V2 is logging (autonomous sampling is in progress), data is followed by:
<dens>ddd.dddd</dens><vb>vv.v</vb>ccc.c

where
density sigma-t (kg/m^3) = ddd.dddd
battery voltage = vv.v
operating current (mA) = ccc.c

The rest of the data stream is as described above for uploaded data.

Setup for Deployment

1. Install new batteries (see *Replacing Alkaline Batteries* in *Section 5: Routine Maintenance and Calibration*) or ensure the existing batteries have enough capacity to cover the intended deployment.

2. Program the 16*plus*-IM V2 for the intended deployment using SeatermIM (see *Section 3: Preparing for Deployment* for connection information; see this section for setup/configuration, sampling modes, pump operation, and commands):

   A. Ensure all data has been uploaded, and then send **#iiInitLogging** to make the entire memory available for recording. If **#iiInitLogging** is not sent, data will be stored after the last recorded sample.

   B. Set the date and time. Date and time can be set globally for all 16*plus*-IM V2s online (**DateTime=**) or individually for each 16*plus*-IM V2 (**#iiDateTime=**) To synchronize autonomous sampling for a system with multiple 16*plus*-IM V2s on a mooring cable, set the date and time globally, with all the 16*plus*-IM V2s online (see *Autonomous Sampling* for synchronization details).

   C. Establish setup and logging parameters.

   D. If the system will have multiple 16*plus*-IM V2s (or other IM instruments) on the mooring cable, verify that SeatermIM is set to *Use fixed ID* to allow use of SeatermIM's Send Commands window:
      1) In the Communications menu, select *Configure*.
      2) Click on *Use fixed ID*. Enter the 16*plus*-IM V2's ID.
      3) Click OK.

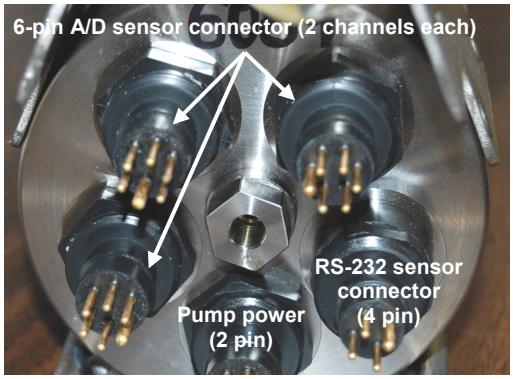
   E. Send **#iiGetCD** or **#DS** to verify the setup.

   F. Use **one** of the following sequences to initiate logging:
      - **#iiStartNow** to start logging now.
      - **#iiStartDateTime=** and **#iiStartLater** to start logging at the specified date and time.

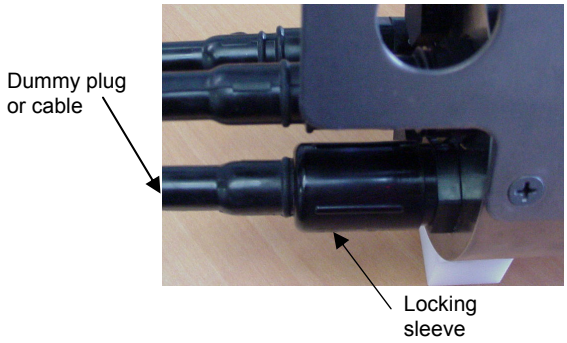
3. If you will be using SeatermIM to view occasional data samples while logging, click the Capture menu to save the data to a file. Note that this file **cannot be processed by SBE Data Processing, as it does not have the required headers and format for Sea-Bird's processing software**.

Deployment

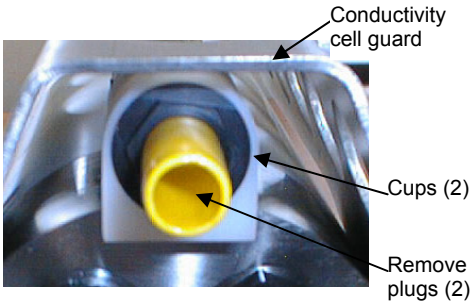
CAUTION:
Do not use WD-40 or other petroleum-based lubricants, as they will damage the connectors.



1. Install a cable or dummy plug for each connector on the 16*plus*-IM V2 sensor end cap:
   A. Lightly lubricate the inside of the dummy plug/cable connector with silicone grease (DC-4 or equivalent).
   B. **Standard Connector** - Install the plug/cable connector, aligning the raised bump on the side of the plug/cable connector with the large pin (pin 1 - ground) on the 16*plus*-IM V2. Remove any trapped air by *burping* or gently squeezing the plug/connector near the top and moving your fingers toward the end cap. **OR**
   MCBH Connector – Install the plug/cable connector, aligning the pins.
   C. Place the locking sleeve over the plug/cable connector. Tighten the locking sleeve finger tight only. **Do not overtighten the locking sleeve and do not use a wrench or pliers.**



2. Connect the other end of the cables installed in Step 1 to the appropriate sensors.



3. As applicable, remove the plug(s) from the anti-foulant device cap(s), or remove the Tygon tubing (and associated barbed anti-foulant device caps) that is looped end-to-end around the conductivity cell (see *Conductivity Cell Maintenance* in *Section 5: Routine Maintenance and Calibration*). Verify that the two plastic cups contain AF24173 Anti-Foulant Devices (see *Section 5: Routine Maintenance and Calibration* for Anti-Foulant Device replacement). If using the 16*plus*-IM V2 with a pump, verify that the system plumbing is correctly installed (see *Configuration Options and Plumbing* in *Section 2: Description of SBE 16plus-IM V2*).

Mounting clamp, with opening sized to specified cable diameter – cable **clamped** by this bracket. Note: Installing clamp on larger cable than specified may cause damage to cable and/or modem and prevent IM communications.

For both mounting brackets – loosen hardware to separate bracket halves and mount on mooring cable

Mounting guide / inductive modem coupler – contains modem coupling toroid core. Cable goes through here but is **not clamped**, to avoid putting through tension on end cap (which could pull off end cap).

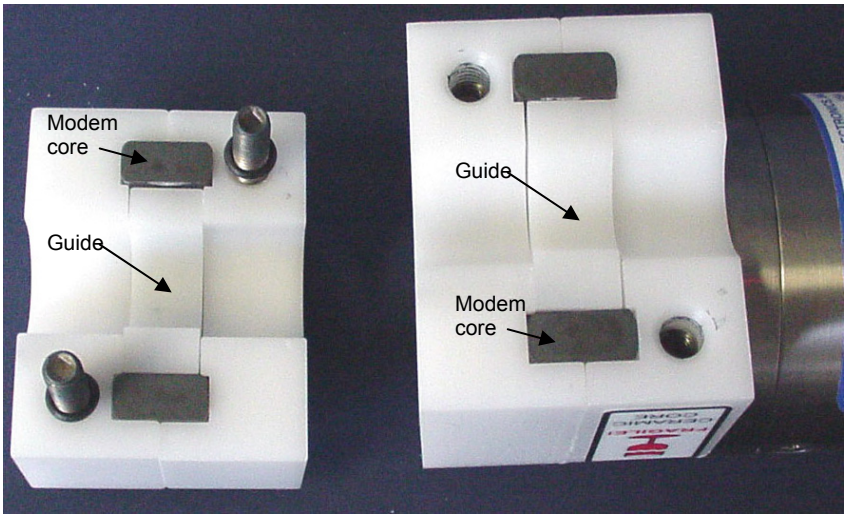


For proper communications, 2 halves of modem coupling toroid core must mate, with no gaps

4. Attach the mounting brackets to the insulated mooring cable:
   A. Open each mounting bracket by unthreading the two large titanium hex bolts.
   B. Place the insulated mooring cable inside the brackets' grooves.
   C. Reinstall each bracket half with the hex bolts.
   D. Verify that the two halves of the modem coupling toroid have come together evenly, and that the mounting clamp is secure.

5. Verify that the hardware and external fittings are secure.

Mounting guide / Inductive Modem Coupler Detail
(Note: Photo is 37-IMP; detail similar for 16*plus*-IM V2)
Guide is sized ***slightly*** bigger than specified cable diameter, to allow cable to pass through freely but limit vibration of 16*plus*-IM V2 on cable



The SBE 16*plus*-IM V2 is ready to go into the water.

System Installation and Wiring

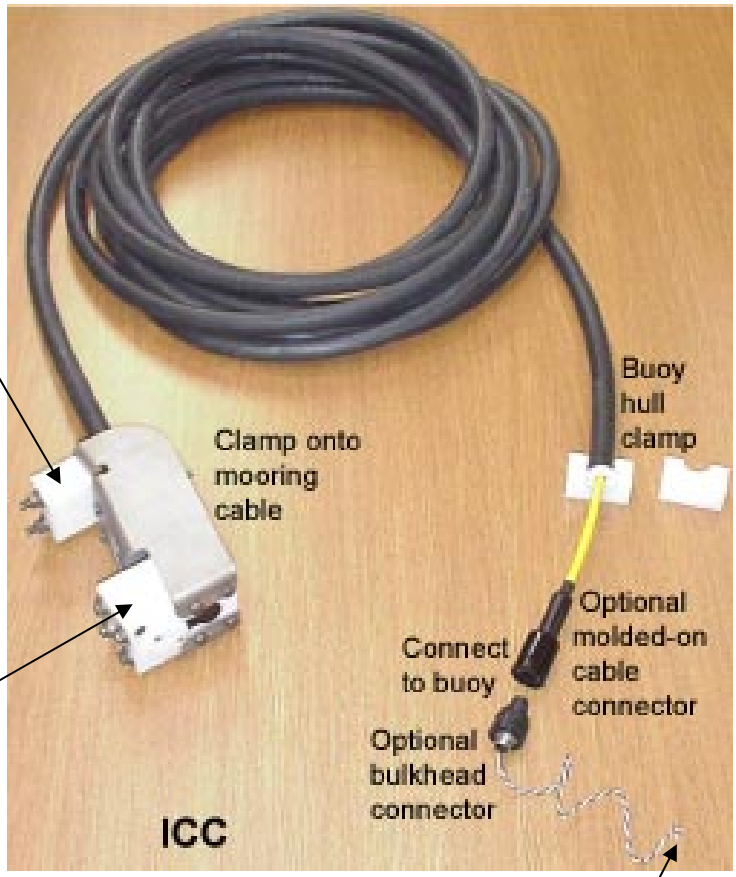
For system installation and wiring details, refer to:

- *Mooring Cable and Wiring Requirements* in *Section 2: Description of SBE 16plus-IM V2*
- *Appendix IV: SIM Hookup and Configuration* or *IMM Manual*.

Installing Optional Inductive Cable Coupler (ICC)

1. Loosen the titanium hex head bolts connecting the two halves of each of the ICC brackets. Pull the halves apart.
2. Place the insulated mooring cable inside the brackets' grooves.
3. Reinstall each bracket half with the hex bolts.
4. Verify that the two halves of the modem coupling toroid have come together evenly, and that the mounting clamp is secure.

Note:
See *Application Note 85: Handling of Ferrite Core on Instruments with Inductive Modem Telemetry* for more detailed information on handling and installation.



Mounting clamp, with opening sized to specified cable diameter – cable **clamped** by this bracket. Note: Installing clamp on larger cable than specified may cause damage to cable and/or modem and prevent IM communications.

Mounting guide / inductive modem coupler – contains modem coupling toroid. Cable goes through here but is **not clamped**, to avoid putting through tension on end cap (which could pull off end cap). **Detail of guide and core is similar to shown above for the 16*plus*-IM V2 guide and core.**

Recovery

WARNING!
If the 16*plus*-IM V2 stops working while underwater, is unresponsive to commands, or shows other signs of flooding or damage, carefully secure it away from people until you have determined that abnormal internal pressure does not exist or has been relieved. Pressure housings may flood under pressure due to dirty or damaged o-rings, or other failed seals. When a sealed pressure housing floods at great depths and is subsequently raised to the surface, water may be trapped at the pressure at which it entered the housing, presenting a danger if the housing is opened before relieving the internal pressure. Instances of such flooding are rare. However, a housing that floods at 5000 meters depth holds an internal pressure of more than 7000 psia, and has the potential to eject the end cap with lethal force. A housing that floods at 50 meters holds an internal pressure of more than 85 psia; this force could still cause injury.
If you suspect the 16*plus*-IM V2 is flooded, point the 16*plus*-IM V2 in a safe direction away from people, and loosen 1 end cap bulkhead connector very slowly, at least 1 turn. This opens an o-ring seal under the connector. Look for signs of internal pressure (hissing or water leak). If internal pressure is detected, let it bleed off slowly past the connector o-ring. Then, you can safely remove the end cap.

1. Rinse the instrument and conductivity cell with fresh water. (See *Section 5: Routine Maintenance and Calibration* for cell cleaning and storage.)

2. Reinsert the protective plugs in the anti-foulant device cups.

3. If the batteries are exhausted, new batteries must be installed before the data can be extracted. Stored data will not be lost as a result of exhaustion or removal of batteries. See *Section 5: Routine Maintenance and Calibration* for replacement of batteries.

4. If immediate redeployment is not required, it is best to leave the 16*plus*-IM V2 with batteries in place and in a quiescent (sleep) state (**PwrOff**). Because the quiescent current required is only 140 microamps, the batteries can be left in place without significant loss of capacity. If the 16*plus*-IM V2 is to be stored for a long time, **replace the batteries yearly to prevent battery leakage** (which could damage the 16*plus*-IM V2).

Uploading Data

Notes:
- The uploaded data format is the same, regardless of the choice of upload telemetry (IM or RS-232).
- In Seaterm232 (used to upload data in Serial Mode), the Upload Data dialog box allows you to select *Text* or *Binary* upload. **However, binary upload is not a valid selection for the 16*plus*-IM V2**.

Upload data using one of these telemetry methods:

- **Inductive modem** – Data can be uploaded while the SBE 16*plus*-IM V2 is deployed, or is wired in the lab as shown in *Test Setup with SIM* or *Test Setup with IMM* in *Section 3: Preparing for Deployment*. Upload speed is limited by the baud rate between the 16*plus*-IM V2 and IMM/SIM, which is 1200 baud.

- **RS-232 (Serial Mode)** – Much faster upload (up to 115,200 baud) is available in serial mode; however, you must open the 16*plus*-IM V2 housing and access the internal RS-232 serial connector on the electronics. When using RS-232 telemetry, select *SBE 16 V2 RS232* in SeatermV2's Instrument menu; this launches **Seaterm232**.

Each upload method is detailed separately below.

Upload Using Inductive Modem Telemetry

Note:
Data may be uploaded during deployment or after recovery. If uploading after recovery. Wire the 16*plus*-IM V2 and SIM or IMM as described in *Section 3: Preparing for Deployment*.

1. Double click on **SeatermV2.exe**. The main screen appears.

2. In the Instruments menu, select *SBE 16plus V2 IM*. **SeatermIM** opens.

3. SeatermIM first sends commands to determine if it is connected to a SIM or an IMM, and sends the appropriate command to wake up all IM instruments on the line. The remaining connection attempt varies, depending on the configuration setting the last time SeatermIM was used:
   - If SeatermIM was set to *Automatically get instrument ID* the last time it was used – SeatermIM sends **id?** and waits for a response from the 16*plus*-IM V2. Once the ID response is received, SeatermIM sends **!iiDS** and #**iiGetHD**, using the ID provided by the 16*plus*-IM V2.
   - If SeatermIM was set to *Use fixed ID* the last time it was used – SeatermIM sends **!iiDS** and **#iiGetHD**, using the fixed ID that was entered the last time the software was used.

   SeatermIM then fills the Send Commands window with the correct list of commands for your 16*plus*-IM V2.

Notes:
- SeatermIM's baud rate must be the same as the IMM or SIM baud rate, as applicable. For both the SIM and the IMM, baud is factory-set to 9600, but can be changed by the user.
- Set to *Use fixed ID* to designate the appropriate 16*plus*-IM V2 if there are multiple 16*plus*-IM V2s on the IM line. If desired, use *Automatically get instrument ID* if there is only one 16*plus*-IM V2 on the IM line. Note that the ID is stored in the 16*plus*-IM V2's EEPROM and can be changed so that multiple 16*plus*-IM V2s on a single IM line each have a unique ID. See the Configuration Sheet for the factory-set ID.

   If there is no communication (no response to **id?** and/or no response to **!iiDS** and/or **#iiGetHD**):
   A. In the Communications menu, select *Configure*. The Configure Communications dialog box appears. Select the Comm port and baud rate for communication. Note that the factory-set baud rate is documented on the Configuration Sheet. If using a fixed ID, verify that the designated ID is correct for the 16*plus*-IM V2 with which you want to communicate. Click OK.
   B. In the Communications menu, select *Connect* (if *Connect* is grayed out, select *Disconnect and reconnect*). SeatermIM will attempt to connect at the baud specified in Step A, but if unsuccessful will then cycle through all other available baud rates.
   C. If there is still no communication, check cabling between the computer, SIM or IMM, and 16*plus*-IM V2, and try to connect again.
   D. If there is still no communication, repeat Step A with a different comm port and/or different fixed ID, and try to connect again.

Note:
You may need to send **#iiStop** several times to get the 16plus-IM V2 to respond.

4. If you have not already done so, command the 16*plus*-IM V2 to stop autonomous sampling by typing **#iiStop** (ii= 16plus-IM V2 ID) and pressing the Enter key.

5. Display 16*plus*-IM V2 status information by typing **#iiDS** (ii = 16*plus*-IM V2 ID) and pressing the Enter key. The display looks like this:

```
SBE 16plus-IM V 2.2 SERIAL NO. 0001 01 Aug 2009 14:11:48
vbatt = 10.3, vlith = 8.5, ioper = 62.5 ma, ipump = 21.6 ma,
iext01 = 76.2 ma
status = not logging
samples = 162, free = 3870317
sample interval = 15 seconds, number of measurements per sample = 2
run pump during sample, delay before sampling = 2.0 seconds
battery cutoff = 7.5 volts
pressure sensor = strain gauge, range = 1000.0
SBE 38 = no, SBE 50 = no, OPTODE = no, Gas Tension Device = no
Ext Volt 0 = yes, Ext Volt 1 = no,
Ext Volt 2 = no, Ext Volt 3 = no,
Ext Volt 4 = no, Ext Volt 5 = no
output format = raw HEX
```

   Verify that the status shows **`status = not logging`**.

6. Click the Upload menu to upload stored data in a form that Sea-Bird's data processing software can use. SeatermIM responds as follows:

   A. SeatermIM sends a wake-up tone.

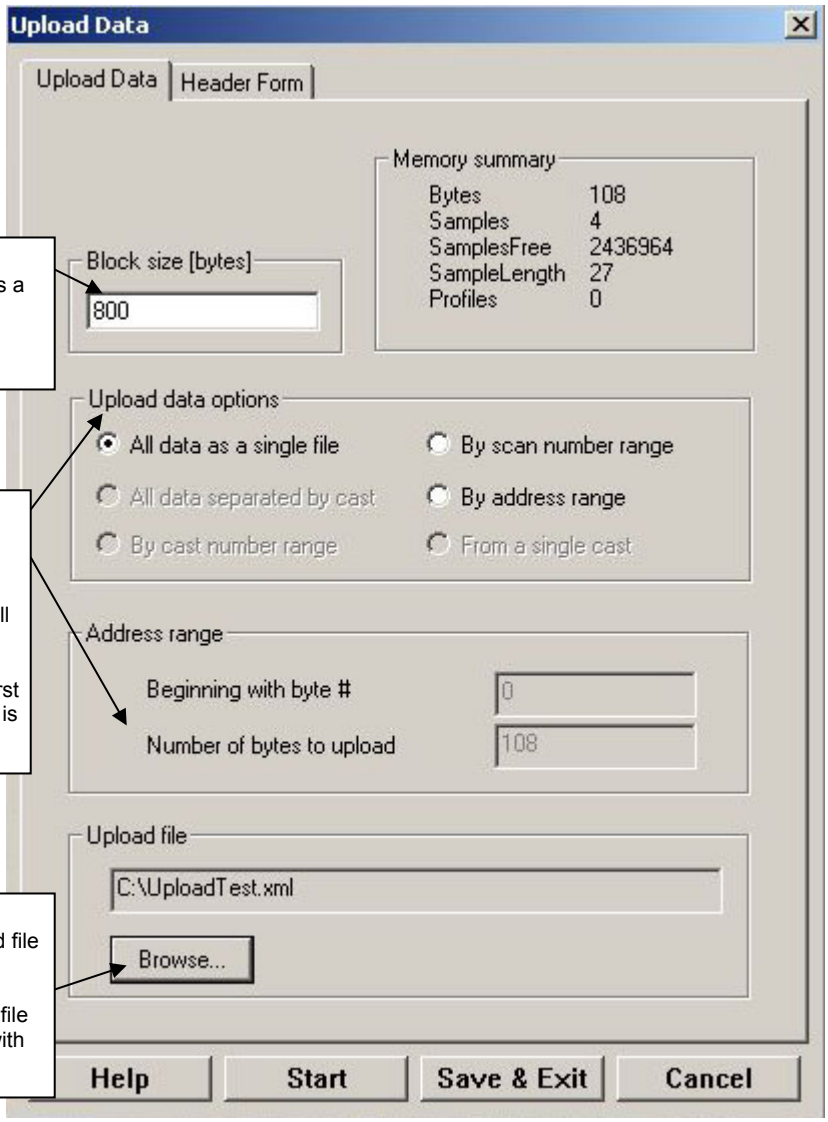
   B. SeatermIM sends **#iiOutputExecutedTag=Y**, which is necessary for the upload process.

   C. SeatermIM sends **#iiGetSD** and displays the response. **#iiGetSD** provides information on the instrument status, and the number of samples in memory.

   D. In the Save As dialog box, enter the desired upload file name and click OK. The upload file has a .XML extension.

   E. An Upload data dialog box appears.

Note:
SeatermIM sends a wake-up tone several times during the upload process, to ensure communications if the 16*plus*-IM V2 has gone to sleep.



Select number of bytes uploaded in each block. SeatermIM uploads data in blocks, and calculates a checksum at end of each block. If block fails checksum verification, SeatermIM tries to upload block of data again, cutting block size in half.

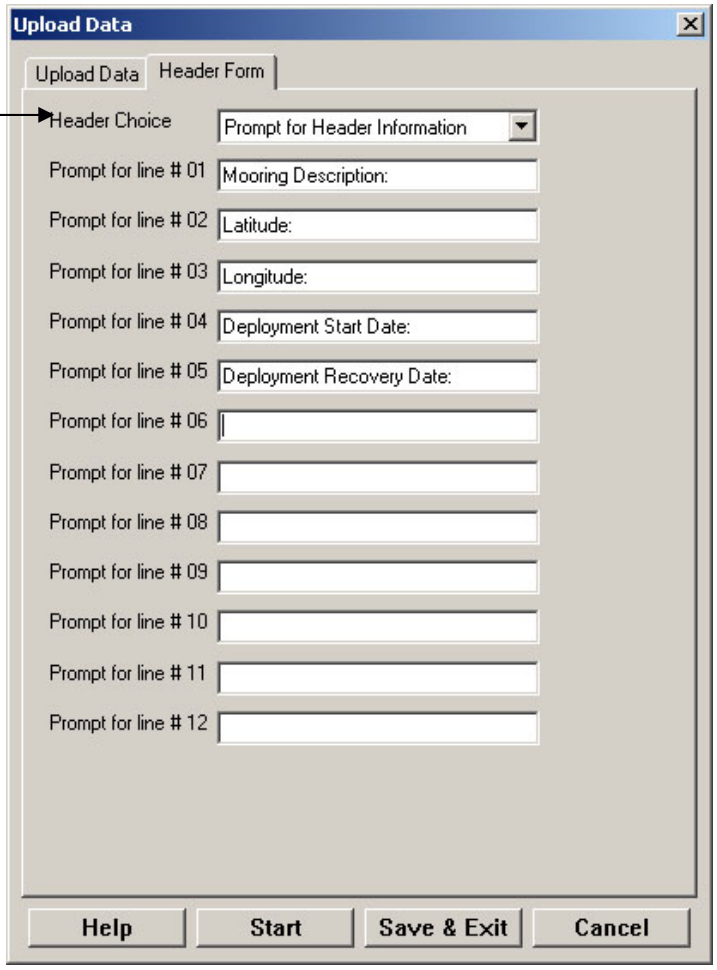
Defines data upload type and range:
- All data as a single file – All data is uploaded into 1 file.
- By scan number range – Enter beginning scan (sample) number and total number of scans. All data within range is uploaded into 1 file.
- By address range – Enter beginning byte number and total number of bytes. Note that first byte in memory is byte 0. All data within range is uploaded into 1 file.

To change upload file name selected in Step D above, click Browse to navigate to desired upload file path and name. Upload file has a .xml extension. After Seaterm232 uploads data into .xml file, it automatically converts .xml file to .hex file (same file name, different extension), which is compatible with Seasave and SBE Data Processing.

Make the desired selections.

7. Click the Header Form tab to customize the header:

Defines header information included with uploaded data:
- Prompt for header information – As data is uploaded, user is prompted to fill out user-defined header form.
- Include default header form in upload file – User-defined default header form included in upload file. User is not prompted to add any information when data is uploaded.
- Don't include default header form in upload file – Header information not included in upload file.



The entries are free form, 0 to 12 lines long. This dialog box establishes:
- the header prompts that appear for the user to fill in when uploading data, if *Prompt for header information* was selected
- the header included with the uploaded data, if *Include default header form in upload file* was selected

Enter the desired header/header prompts.

8. Click Start; the Status bar at the bottom of the window displays the upload progress.

   A. SeatermIM sends a wake-up tone. It then sends **#iiGetHD** (get hardware data), **#iiGetSD** (get status data), **#iiGetCD** (get configuration data), **#iiGetCC** (get calibration coefficients), **#iiGetEC** (get event counter), and **#iiGetHeaders:b,e**, and writes the responses to the upload file. These commands provide information regarding the number of samples in memory, calibration coefficients, etc.

   B. **If you selected *Prompt for header information* in the Upload Data dialog box** – a dialog box with the header form appears. Enter the desired header information, and click OK. SeatermIM writes the header information to the upload file.

   C. SeatermIM sends the data upload command, based on your selection of upload range in the Upload Data dialog box, writes the data to the upload .xml file, and then creates the .hex file from the .xml file. The .hex file contains the data in raw hexadecimal, for compatibility with SBE Data Processing and Seasave.

Note:
To prepare the 16*plus*-IM V2 for re-deployment:
1. After all data has been uploaded, send **#iiInitLogging**. If this command is not sent and logging is started, new data will be stored after the last recorded sample, preventing use of the entire memory capacity.
2. Send **PwrOff** to put the 16*plus*-IM V2 in quiescent (sleep) state until ready to redeploy. The quiescent current is only 140 microamps, so the batteries can be left in place without significant loss of capacity.

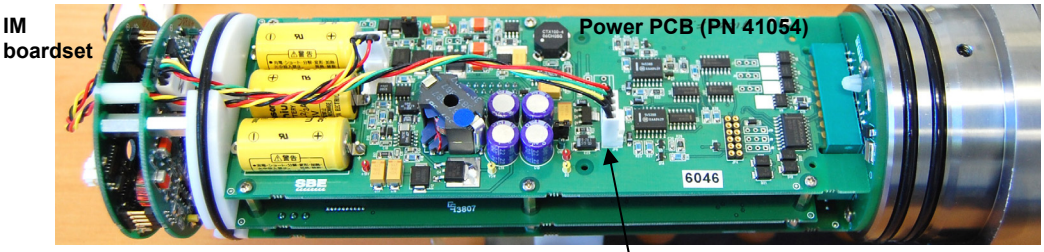
9. Ensure all data has been uploaded by reviewing and processing the data.

   A. Use **Seasave** to display and plot the *raw* hexadecimal data in engineering units (see *Verifying Contents of Configuration (.con) File* and Seasave manual / Help files).

   B. Use **SBE Data Processing** to process and plot the data (see *Processing Data Using SBE Data Processing* and SBE Data Processing manual / Help files).

Upload Using RS-232 (Serial Mode) at Higher Baud Rates

1. Remove the sensor end cap and electronics from the housing (see *Appendix II: Electronics Disassembly/Reassembly* for details).
2. Unplug the IM boardset from JP6 on the PN 41054 PCB. Attach the RS-232 cable (supplied by Sea-Bird) to JP6 on the PN 41054 PCB and to the computer, using the optional data I/O cable (PN 801880).



JP6 internal RS-232 connector, for firmware update and/or fast upload. Unplug IM boardset, and connect JP6 to computer with optional data I/O cable (PN 801880).

3. Double click on **SeatermV2.exe**. The main screen appears.
4. In the Instruments menu, select *SBE 16plus V2* ***RS232*** (**not** *SBE 16plus V2 IM*). **Seaterm232** opens.
5. Seaterm232 will try to automatically connect to the 16*plus*-IM V2. In the Command menu, select *Abort* to interrupt the communication attempt.
6. In the Communications menu, select *Configure*. The Serial Port Configuration dialog box appears.
   A. Select the Comm port, and select **1200** as the baud rate.
   B. Click OK.
7. In the Communications menu, select *Connect* (if *Connect* is grayed out, select *Disconnect and reconnect*). Seaterm232 sends **GetHD** and displays the response. Seaterm232 also fills the Send Commands window with the correct list of commands for your 16*plus*-IM V2.
8. Command the 16*plus*-IM V2 to stop logging by pressing the Enter key, typing **Stop**, and pressing the Enter key again.
9. Type **Baud=38400** or **Baud=115200**, and press Enter.
   The 16*plus*-IM V2 should respond:
   `Switching to <38400 or 115200> for 5 minutes.`
10. In the Communications menu, select *Configure*. The Serial Port Configuration dialog box appears.
    A. Select the Comm port, and select 38400 or 115200 as the baud rate (match the baud rate entered in Step 9).
    B. Click OK.
11. SeatermV2 begins communicating at the new baud. Display status by typing **DS** and pressing the Enter key. The display looks like this:

```
SBE 16plus-IM V 2.2 SERIAL NO. 0001 01 Aug 2009 14:11:48
vbatt = 10.3, vlith = 8.5, ioper = 62.5 ma, ipump = 21.6 ma,
iext01 = 76.2 ma
status = not logging
samples = 162, free = 3870317
sample interval = 15 seconds, number of measurements per sample = 2
run pump during sample, delay before sampling = 2.0 seconds
battery cutoff = 7.5 volts
pressure sensor = strain gauge, range = 1000.0
SBE 38 = no, SBE 50 = no, OPTODE = no, Gas Tension Device = no
Ext Volt 0 = yes, Ext Volt 1 = no,
Ext Volt 2 = no, Ext Volt 3 = no,
Ext Volt 4 = no, Ext Volt 5 = no
output format = raw HEX
```

Verify that the status shows **`status = not logging`**.

Notes:
- The 16*plus*-IM V2 uses 1200 baud for IM telemetry; you must initially connect at 1200 baud using RS-232 telemetry. You can increase the baud rate once you are connected.
- You may need to send **Stop** several times to get the 16*plus*-IM V2 to respond.
- Check your computer's capabilities before resetting the baud. The 16*plus*-IM V2 will remain at the specified higher baud rate (38400 or 115200) while communicating (i.e., if you are sending commands to it, or it is responding). **After 5 minutes with no communication, the 16*plus*-IM V2 automatically switches back to 1200 baud.**

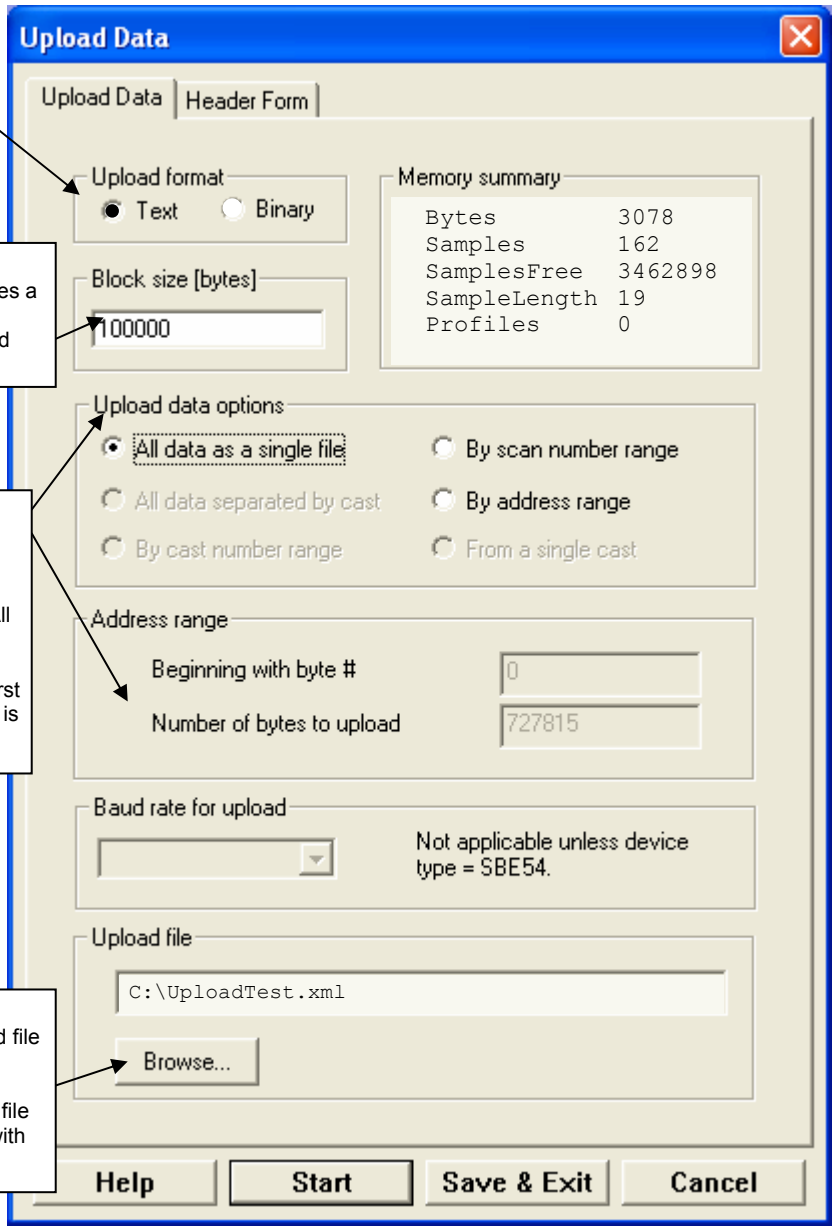
12. Click Upload to upload stored data. Seaterm232 responds as follows:
    A. Seaterm232 sends **GetSD** and displays the response. **GetSD** provides information on the instrument status, and number of samples in memory.
    B. Seaterm232 sends **DH** and displays the response. **DH** provides information on the headers in memory.
    C. In the Save As dialog box, enter the desired upload file name and click OK. The upload file has a .XML extension.
    D. An Upload Data dialog box appears:

Select to enable ASCII text. **Binary is not compatible with the 16*plus*-IM V2**.

Select number of bytes uploaded in each block. Seaterm232 uploads data in blocks, and calculates a checksum at end of each block. If block fails checksum verification, Seaterm232 tries to upload block of data again, cutting block size in half.

Defines data upload type and range:
- All data as a single file – All data is uploaded into 1 file.
- By scan number range – Enter beginning scan (sample) number and total number of scans. All data within range is uploaded into 1 file.
- By address range – Enter beginning byte number and total number of bytes. Note that first byte in memory is byte 0. All data within range is uploaded into 1 file.

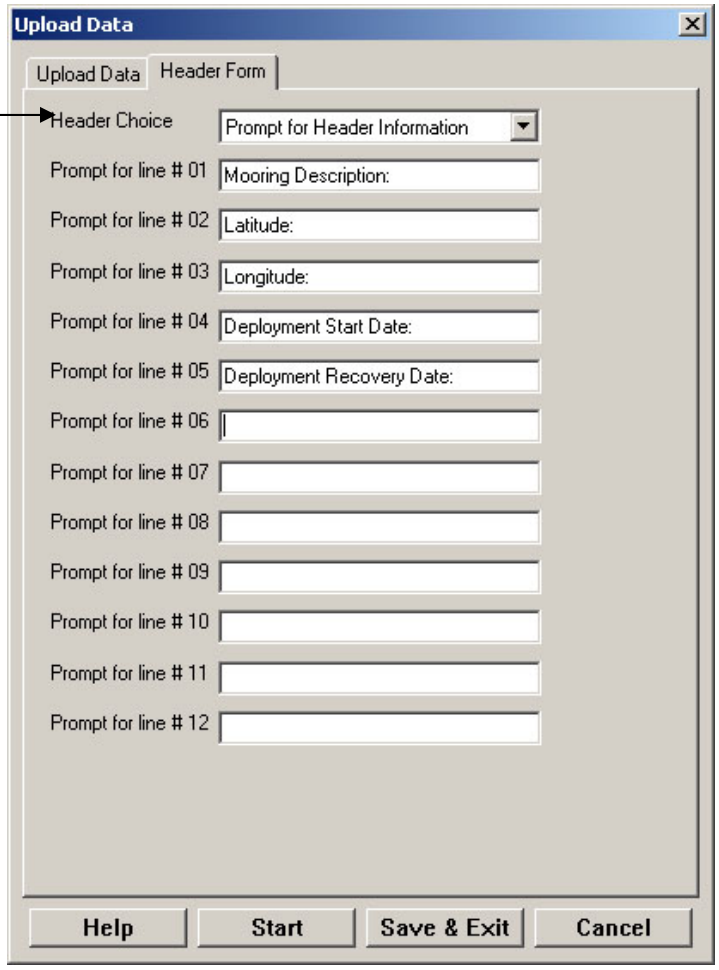
To change upload file name selected in Step C above, click Browse to navigate to desired upload file path and name. Upload file has a .xml extension. After Seaterm232 uploads data into .xml file, it automatically converts .xml file to .hex file (same file name, different extension), which is compatible with Seasave and SBE Data Processing.



Make the desired selections.

13. Click the Header Form tab to customize the header:

Defines header information included with uploaded data:
- Prompt for header information – As data is uploaded, user is prompted to fill out user-defined header form.
- Include default header form in upload file – User-defined default header form included in upload file. User is not prompted to add any information when data is uploaded.
- Don't include default header form in upload file – Header information not included in upload file.



The entries are free form, 0 to 12 lines long. This dialog box establishes:
- the header prompts that appear for the user to fill in when uploading data, if *Prompt for header information* was selected
- the header included with the uploaded data, if *Include default header form in upload file* was selected

Enter the desired header/header prompts.

14. Click Start; the Status bar at the bottom of the window displays the upload progress:
    A. Seaterm232 sends **GetHD** (get hardware data), **GetSD** (get status data), **GetCD** (get configuration data), **GetCC** (get calibration coefficients), and **GetEC** (get event counter), and writes the responses to the upload file. These commands provide information regarding the number of samples in memory, header numbers, calibration coefficients, etc.
    B. **If you selected *Prompt for header information* in the Upload Data dialog box** – a dialog box with the header form appears. Enter the desired header information, and click OK. Seaterm232 writes the header information to the upload file.
    C. Seaterm232 sends the data upload command, based on your selection of upload range in the Upload Data dialog box, writes the data to the upload .xml file, and then creates the .hex file from the .xml file. The .hex file contains the data in raw hexadecimal, for compatibility with Seasave and SBE Data Processing.
    D. When the data has been uploaded, Seaterm232 shows the `S>` prompt (if **OutputExecutedTag=N**).

15. Ensure all data has been uploaded by reviewing and processing the data:
    A. Use **Seasave** to display and plot the *raw* hexadecimal data in engineering units (see *Verifying Contents of .con File* and Seasave manual / Help files).
    B. Use **SBE Data Processing** to process and plot the data (see *Processing Data Using SBE Data Processing* and SBE Data Processing manual / Help files).

16. Remove the PN 801880 data I/O cable from JP6 on the PN 41054 PCB. Plug the IM boardset into JP6.

17. Reinstall the electronics and sensor end cap (see *Appendix II: Electronics Disassembly/Reassembly* for details).

Note:
To prepare for re-deployment (using IM telemetry):
1. After all data has been uploaded, send **#iiInitLogging**. If this command is not sent and sampling is started, new data will be stored after the last recorded sample, preventing use of the entire memory capacity.
2. Send **PwrOff** to put the 16*plus*-IM V2 in quiescent (sleep) state until ready to redeploy. The quiescent current is only 140 microamps, so the batteries can be left in place without significant loss of capacity.

Processing Data Using SBE Data Processing

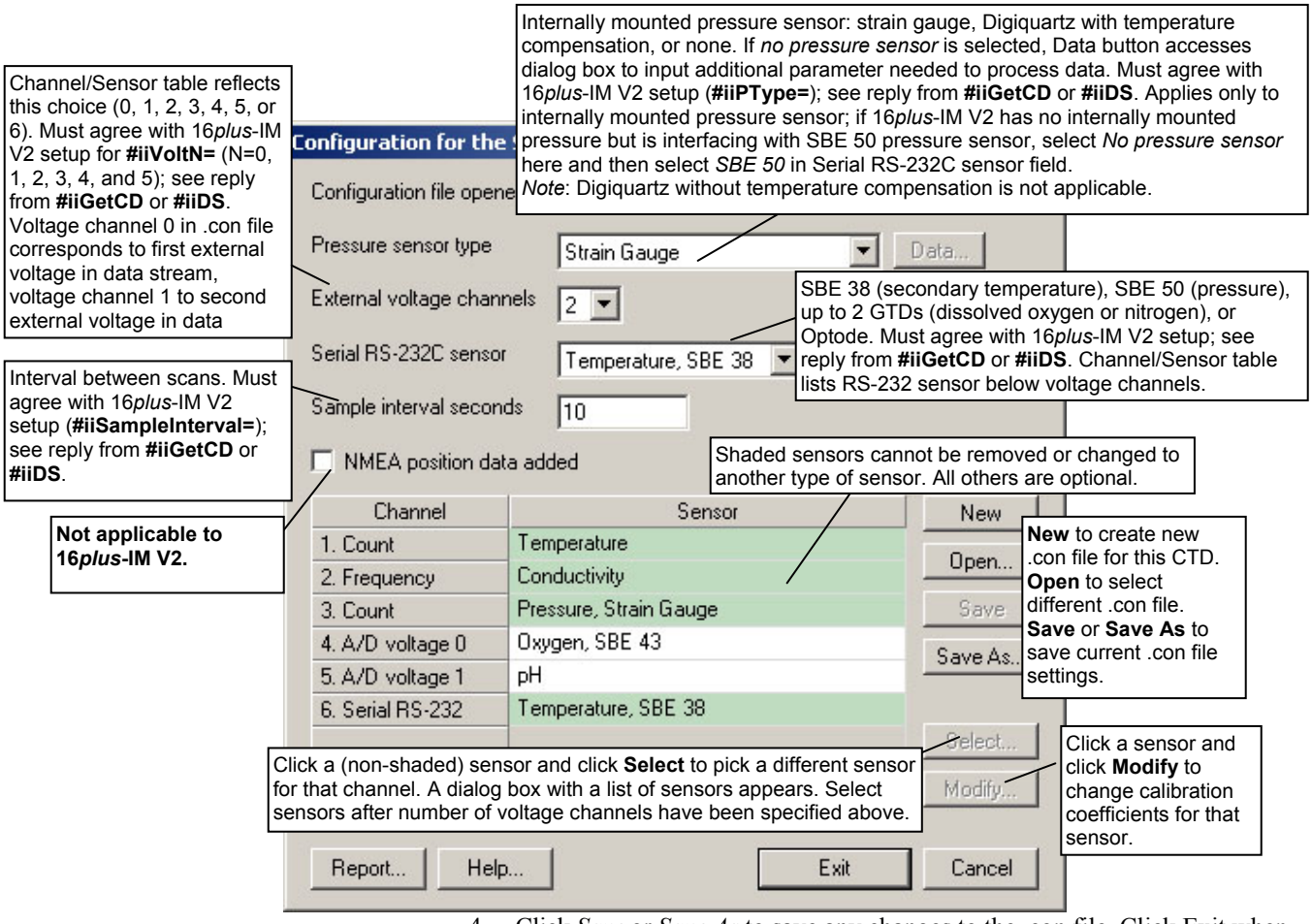
Notes:
- See the SBE Data Processing manual and/or Help files.
- When we ship a new instrument, we include a .con file that reflects the current instrument configuration *as we know it*. The .con file is named with the instrument serial number, followed with the .con extension. For example, for an instrument with serial number 2375, Sea-Bird names the .con file *2375.con*. You may rename the .con file if desired; this will not affect the results.
- In the 16*plus*-IM V2 setup commands, external voltage numbers 0, 1, 2, 3, 4, and 5 correspond to wiring of sensors to a voltage channel on the end cap (see *Dimensions and End Cap Connectors* in *Section 2: Description of SBE 16plus-IM V2*). However, in the .con file, voltage 0 is the first external voltage in the data stream, voltage 1 is the second, etc.

1. Convert the .hex (raw data) file (uploaded from 16*plus*-IM V2 memory) to a .cnv (engineering units) file in SBE Data Processing's Data Conversion module.
2. Once the data is converted: perform further processing (remove bad data, etc.), calculate derived variables, and plot data using SBE Data Processing's other modules.

Verifying Contents of Configuration (.con) File

To convert the .hex (raw data) file, you need a .con file, which defines the instrument – integrated sensors, and channels, serial numbers, and calibration dates and coefficients for all sensors (conductivity, temperature, and pressure as well as auxiliary sensors). SBE Data Processing uses the .con file information to interpret and process the raw data. **If the .con file does not match the actual instrument configuration, the software will be unable to interpret and process the data correctly.**

To view or modify the .con file:
1. Double click on SBEDataProc.exe.
2. In the Configure menu, select *SBE 16plus **V2** Seacat CTD*. The configuration dialog box appears. In the configuration dialog box, click Open.
3. In the Open dialog box, select the appropriate .con file and click Open. Verify that the sensors match those on your 16*plus*-IM V2, and that auxiliary sensors are assigned to the correct voltage channels. Verify that calibration coefficients for all sensors are up-to-date.



4. Click *Save* or *Save As* to save any changes to the .con file. Click Exit when done reviewing / modifying the .con file

Editing Raw Data File

Sometimes users want to edit the raw .hex data file before beginning processing, to remove data at the beginning of the file corresponding to instrument *soak* time, to remove blocks of bad data, to edit the header, or to add explanatory notes about the cast. **Editing the raw .hex file can corrupt the data, making it impossible to perform further processing using Sea-Bird software.** We strongly recommend that you first convert the data to a .cnv file (using Data Conversion in SBE Data Processing), and then use other SBE Data Processing modules to edit the .cnv file as desired.

Note:
Although we provide this technique for editing a raw .hex file, **Sea-Bird's strong recommendation, as described above, is to always convert the raw data file and then edit the converted file.**

The procedure for editing a .hex data file described below has been found to work correctly on computers running Windows 98, 2000, and NT. **If the editing is not performed using this technique, SBE Data Processing may reject the edited data file and give you an error message.**

1. **Make a back-up copy of your .hex data file before you begin.**
2. Run **WordPad**.
3. In the File menu, select Open. The Open dialog box appears. For *Files of type*, select *All Documents (*.*)*. Browse to the desired .hex data file and click Open.
4. Edit the file as desired, **inserting any new header lines after the System Upload Time line**. Note that all header lines must begin with an asterisk (*), and *END* indicates the end of the header. An example is shown below (for an SBE 21), with the added lines in bold:

```
* Sea-Bird SBE 21 Data File:
* FileName = C:\Odis\SAT2-ODIS\oct14-19\oc15_99.hex
* Software Version Seasave Win32 v1.10
* Temperature SN = 2366
* Conductivity SN = 2366
* System UpLoad Time = Oct 15 1999  10:57:19
* Testing adding header lines
* Must start with an asterisk
* Place anywhere between System Upload Time & END of header
* NMEA Latitude = 30 59.70 N
* NMEA Longitude = 081 37.93 W
* NMEA UTC (Time) = Oct 15 1999  10:57:19
* Store Lat/Lon Data = Append to Every Scan and Append to .NAV
File When <Ctrl F7> is Pressed
** Ship:       Sea-Bird
** Cruise:     Sea-Bird Header Test
** Station:
** Latitude:
** Longitude:
*END*
```

5. In the File menu, select Save (**not** Save As). If you are running Windows 2000, the following message displays:

```
You are about to save the document in a Text-Only format,
which will remove all formatting. Are you sure you want to do
this?
```

   Ignore the message and click *Yes*.
6. In the File menu, select Exit.

Section 5: Routine Maintenance and Calibration

This section reviews:
- corrosion precautions
- connector mating and maintenance
- battery replacement
- conductivity cell storage and cleaning
- pressure sensor maintenance
- pump maintenance
- AF24173 Anti-Foulant Device replacement
- sensor calibration

The accuracy of the SBE 16*plus*-IM V2 is sustained by the care and calibration of the sensors and by establishing proper handling practices.

Corrosion Precautions

Rinse the SBE 16*plus*-IM V2 with fresh water after use and prior to storage.

For both the plastic and titanium housing, all exposed metal is titanium (the plastic housing has a titanium end cap). No corrosion precautions are required, but direct electrical connection of the titanium to dissimilar metal hardware should be avoided.

Connector Mating and Maintenance

Note:
See *Application Note 57: Connector Care and Cable Installation*.

CAUTION:
Do not use WD-40 or other petroleum-based lubricants, as they will damage the connectors.

Clean and inspect connectors, cables, and dummy plugs before every deployment and as part of your yearly equipment maintenance. Inspect connectors that are unmated for signs of corrosion product around the pins, and for cuts, nicks or other flaws that may compromise the seal.

1. Lightly lubricate the inside of the dummy plug/cable connector with silicone grease (DC-4 or equivalent).
2. **Standard Connector** - Install the plug/cable connector, aligning the raised bump on the side of the plug/cable connector with the large pin (pin 1 - ground) on the 16*plus*-IM V2. Remove any trapped air by *burping* or gently squeezing the plug/connector near the top and moving your fingers toward the end cap. **OR**
   MCBH Connector – Install the plug/cable connector, aligning the pins.
3. Place the locking sleeve over the plug/cable connector. Tighten the locking sleeve finger tight only. **Do not overtighten the locking sleeve and do not use a wrench or pliers.**

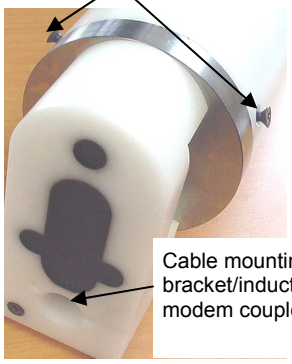
Verify that a cable or dummy plug is installed for each connector on the system before deployment.

Replacing Alkaline Batteries

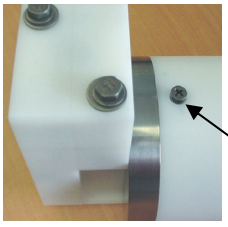
Alkaline D-cell (MN1300, LR20)



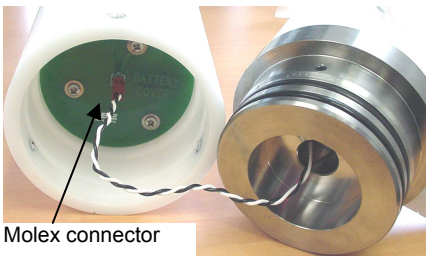
Screws securing end cap (shown partially removed)



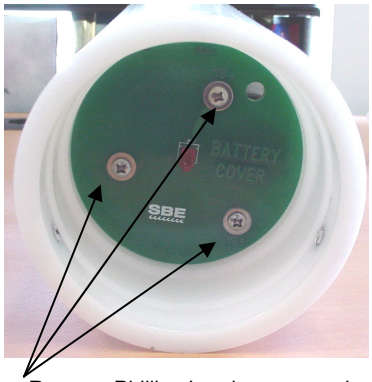
Cable mounting bracket/inductive modem coupler



Screw securing end cap (shown partially removed)



Molex connector



Remove Phillips-head screws and washers from battery cover plate

The SBE 16*plus*-IM V2 uses alkaline D-cells (Duracell MN1300, LR20), dropped into the battery compartment.

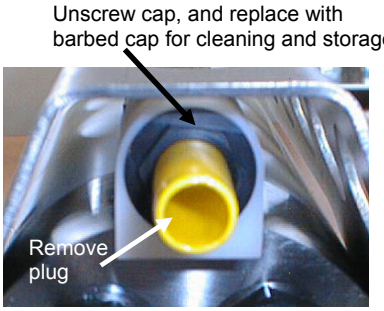
Leave the batteries in place when storing the SBE 16*plus*-IM V2 to prevent depletion of the back-up lithium batteries by the real-time clock. Even *exhausted* main batteries will power the clock almost indefinitely. If the 16*plus*-IM V2 is to be stored for long periods, **replace the batteries yearly to prevent battery leakage** (which could damage the 16*plus*-IM V2).

1. Remove the modem end cap (end cap without connectors):
   A. Wipe the outside of the end cap and housing dry, being careful to remove any water at the seam between them.
   B. Remove the three flat Phillips-head screws. Do not remove any other screws from the housing.
   C. Remove the end cap by pulling firmly and steadily on the plastic cable mounting bracket/inductive modem coupler. It may be necessary to twist or rock the end cap back and forth or use a non-marring tool on the edge of the cap to loosen it.
   D. The end cap is electrically connected to the electronics with a 2-pin Molex connector. Holding the wire cluster near the connector, pull gently to detach the female end of the connector from the pins.
   E. Remove any water from the O-ring mating surfaces inside the housing with a lint-free cloth or tissue.
   F. Put the end cap aside, being careful to protect the O-rings from damage or contamination.
2. Remove the battery cover plate from the housing:
   A. Remove the three Phillips-head screws and washers from the battery cover plate inside the housing.
   B. The battery cover plate will pop out. Put it aside.
3. Turn the 16*plus*-IM V2 over and remove the batteries.
4. Install the new batteries, with the + terminals against the flat battery contacts and the - terminals against the spring contacts.
5. Reinstall the battery cover plate in the housing:
   A. Align the battery cover plate with the housing. The posts inside the housing are not placed symmetrically, so the cover plate fits into the housing only one way. Looking at the cover plate, note that one screw hole is closer to the edge than the others, corresponding to the post that is closest to the housing.
   B. Reinstall the three Phillips-head screws and washers, while pushing hard on the battery cover plate to depress the spring contacts at the bottom of the battery compartment. **The screws must be fully tightened, or battery power to the circuitry will be intermittent**.
6. Check the battery voltage at BAT + and BAT - on the battery cover plate. It should be approximately 13.5 volts.
7. Reinstall the end cap:
   A. Remove any water from the O-rings and mating surfaces with a lint-free cloth or tissue. Inspect the O-rings and mating surfaces for dirt, nicks, and cuts. Clean or replace as necessary. Apply a light coat of o-ring lubricant (Parker Super O Lube) to O-rings and mating surfaces.
   B. Plug the female end of the 2-pin Molex connector onto the pins. Verify the connector is properly aligned - a backward connection will prevent communication with the computer.
   C. Carefully fit the end cap into the housing until the O-rings are fully seated.
   D. Reinstall the three flat Phillips-head screws to secure the end cap.

Conductivity Cell Maintenance

CAUTIONS:

- **Do not put a brush or any object inside the conductivity cell to dry it or clean it.** Touching and bending the electrodes can change the calibration. Large bends and movement of the electrodes can damage the cell.
- **Do not store the 16*plus*-IM V2 with water in the conductivity cell.** Freezing temperatures (for example, in Arctic environments or during air shipment) can break the cell if it is full of water.





The SBE 16*plus*-IM V2's conductivity cell is shipped dry to prevent freezing in shipping. **Refer to *Application Note 2D: Instructions for Care and Cleaning of Conductivity Cells* for conductivity cell cleaning procedures and cleaning materials.**

- The Active Use (after each cast) section of the application note is not applicable to the 16*plus*-IM V2, which is intended for use as a moored instrument.

The 16*plus*-IM V2 is shipped with a kit for cell filling and storage. The kit includes a syringe and tubing assembly, and two anti-foulant device caps with hose barbs. The tubing cannot attach to an anti-foulant device cap that is not barbed.

- If your 16*plus*-IM V2 does not include a pump - the installed anti-foulant device caps at both ends of the conductivity cell are not barbed.
- If your 16*plus*-IM V2 includes a pump - the installed anti-foulant device cap at the pump end of the cell is barbed; the installed anti-foulant device cap at the intake end of the cell is not barbed.

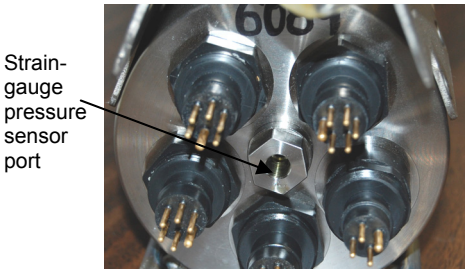
Cleaning and storage instructions below require use of the syringe and tubing assembly at the intake end of the cell (requiring one barbed cap), and looping Tygon tubing from end to end of the cell (requiring two barbed caps). Remove the installed anti-foulant device cap(s) and replace them with the anti-foulant device cap(s) with hose barbs **for cleaning and storage only**. Remember to reinstall the original anti-foulant device cap(s) before deployment. **Deploying an SBE 16*plus*-IM V2 with barbed anti-foulant device cap(s) in place of the installed caps is likely to produce undesirable results in your data.** See *Replacing Anti-Foulant Devices* for safety precautions when handling the AF24173 Anti-Foulant Devices.

Internally Mounted Pressure Sensor (optional) Maintenance

CAUTION:
Do not put a brush or any object in the pressure port. Doing so may damage or break the pressure sensor.

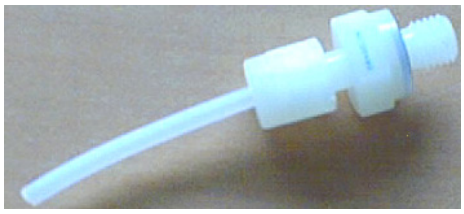
Pressure sensor maintenance varies, depending on the type of pressure sensor in your SBE 16*plus*-IM V2.

Strain Gauge Pressure Sensor



Periodically (approximately once a year) inspect the pressure port for particles and debris. Rinse the pressure port with warm, de-ionized water to remove any particles, debris, etc.

Quartz Pressure Sensor



Nylon pressure capillary fitting for 16*plus*-IM V2 with Quartz pressure sensor

At the factory, the pressure sensor and pressure port were filled with a silicon oil, and a nylon pressure capillary fitting – which includes a pressure port fitting and an external capillary tube – were used to retain the oil. The oil transmits hydrostatic pressure via internal, stainless steel, capillary tubing to the pressure sensor inside the instrument, and prevents corrosion that might occur if the sensor diaphragm was exposed to water. The internal tubing and nylon capillary fitting are vacuum back-filled at the factory.

Because of the viscosity of the silicone oil and capillary action, the silicone oil does not run out of the external capillary tube. However, due to temperature and pressure cycling over long periods, it is normal for some oil to slowly leak out of the external capillary tube. **When the oil is not visible or is receding inside the translucent tube, or if the fitting has been damaged, refill the oil** using the supplied pressure sensor oil refill kit. See *Application Note 12-1: Pressure Port Oil Refill Procedure & Nylon Capillary Fitting Replacement*.

Pump (optional) Maintenance

See *Application Note 75: Maintenance of SBE 5T, 5P, and 5M Pumps*.

Replacing Anti-Foulant Devices (SBE 16*plus*, SBE 19*plus*)



AF24173
Anti-Foulant
Device

The SBE 16*plus* and 19*plus* (moored option) have an anti-foulant device cup and cap on each end of the conductivity cell. A new SBE 16*plus* (or moored option 19*plus*) is shipped with an Anti-Foulant Device and a protective plug pre-installed in each cup.

Wearing rubber or latex gloves, follow this procedure to replace each Anti-Foulant Device (two):

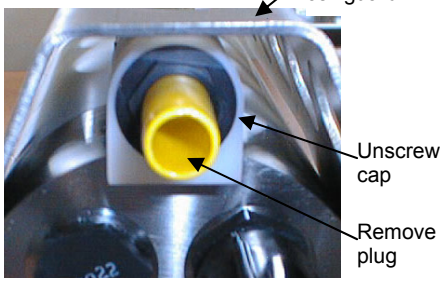
1. Remove the protective plug;
2. Unscrew the cap with a 5/8-inch socket wrench;
3. Remove the old Anti-Foulant Device. If the old Anti-Foulant Device is difficult to remove:
   - Use needle-nose pliers and carefully break up material;
   - If necessary, remove the conductivity cell guard to provide easier access;
4. Place the new Anti-Foulant Device in the cup;
5. Rethread the cap onto the cup. Do not over tighten;
6. Replace the protective plug if not ready to redeploy.

WARNING!

AF24173 Anti-Foulant Devices contain bis(tributyltin) oxide. Handle the devices only with rubber or latex gloves. Wear eye protection. Wash with soap and water after handling.

Read precautionary information on product label (see Appendix V) before proceeding.

It is a violation of US Federal Law to use this product in a manner inconsistent with its labeling.



CAUTION:

One of the anti-foulant device cups is attached to the guard and connected to the conductivity cell. **Removing the guard without disconnecting the cup from the guard will break the cell.** If the guard must be removed:

1. Remove the two screws connecting the anti-foulant device cup to the guard;
2. Remove the four Phillips-head screws connecting the guard to the housing and sensor end cap;
3. Gently lift the guard away.

Sensor Calibration

Note
After recalibration, Sea-Bird enters the new calibration coefficients in the 16*plus*-IM V2 EEPROM, and ships the instrument back to the user with Calibration Certificates showing the new coefficients. The user must enter the coefficients in the instrument configuration (.con) file in SBE Data Processing's Configure menu.

Sea-Bird sensors are calibrated by subjecting them to known physical conditions and measuring the sensor responses. Coefficients are then computed, which may be used with appropriate algorithms to obtain engineering units. The conductivity, temperature, and (optional) pressure sensors on the SBE 16*plus*-IM V2 are supplied fully calibrated, with coefficients stored in EEPROM in the 16*plus*-IM V2 and printed on their respective Calibration Certificates.

We recommend that the 16*plus*-IM V2 be returned to Sea-Bird for calibration.

Conductivity Sensor

The conductivity sensor incorporates a fixed precision resistor in parallel with the cell. When the cell is dry and in air, the sensor's electrical circuitry outputs a frequency representative of the fixed resistor. This frequency is recorded on the Calibration Certificate and should remain stable (within 1 Hz) over time.

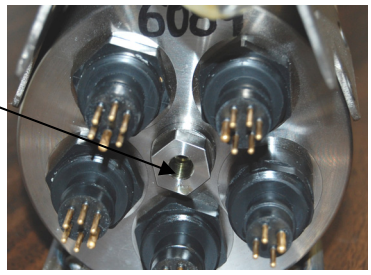
The primary mechanism for calibration drift in conductivity sensors is the fouling of the cell by chemical or biological deposits. Fouling changes the cell geometry, resulting in a shift in cell constant.

Accordingly, the most important determinant of long-term sensor accuracy is the cleanliness of the cell. We recommend that the conductivity sensors be calibrated before and after deployment, but particularly when the cell has been exposed to contamination by oil slicks or biological material.

Temperature Sensor

The primary source of temperature sensor calibration drift is the aging of the thermistor element. Sensor drift will usually be a few thousandths of a degree during the first year, and less in subsequent intervals. Sensor drift is not substantially dependent upon the environmental conditions of use, and — unlike platinum or copper elements — the thermistor is insensitive to shock.

Internally Mounted Pressure Sensor



The SBE 16*plus*-IM V2 is available with an internally mounted strain-gauge or Quartz pressure sensor. These sensors are capable of meeting the 16*plus*-IM V2 error specification with some allowance for aging and ambient-temperature induced drift.

Pressure sensors show most of their error as a linear offset from zero. A technique is provided below for making small corrections to the pressure sensor calibration using the *offset* (**#iiPOffset=**) calibration coefficient term by comparing 16*plus*-IM V2 pressure output to readings from a barometer.

Allow the 16*plus*-IM V2 to equilibrate in a reasonably constant temperature environment for at least 5 hours before starting. Pressure sensors exhibit a transient change in their output in response to changes in their environmental temperature. Sea-Bird instruments are constructed to minimize this by thermally decoupling the sensor from the body of the instrument. However, there is still some residual effect; allowing the 16*plus*-IM V2 to equilibrate before starting will provide the most accurate calibration correction.

Note:
The pressure sensor is an absolute sensor, so its **raw** output includes the effect of atmospheric pressure (14.7 psi). As shown on the Calibration Sheet, Sea-Bird's calibration (and resulting calibration coefficients) is in terms of psia. However, when outputting pressure in **engineering units**, the 16*plus*-IM V2 outputs pressure relative to the ocean surface (i.e., at the surface the output pressure is 0 decibars). The 16*plus*-IM V2 uses the following equation to convert psia to decibars:
pressure (db) =
[pressure (psia) - 14.7] * 0.689476

1. Place the 16*plus*-IM V2 in the orientation it will have when deployed.

2. In SeatermIM:
   A. Set the pressure offset to 0.0 (**#iiPOffset=0**).
   B. Send **#iiTP** to measure the 16*plus*-IM V2 pressure 30 times and transmit converted data in engineering units (decibars).

3. Compare the 16*plus*-IM V2 output to the reading from a good barometer at the same elevation as the 16*plus*-IM V2 pressure sensor.
   Calculate *offset* = barometer reading – 16*plus*-IM V2 reading

4. Enter the calculated offset (positive or negative) in two places:
   - In the 16*plus*-IM V2 EEPROM, using **#iiPOffset=** in SeatermIM, **and**
   - In the configuration (.con) file, using SBE Data Processing or Seasave.

Offset Correction Example
Absolute pressure measured by a barometer is 1010.50 mbar. Pressure displayed from 16*plus*-IM V2 is -2.5 dbars.
Convert barometer reading to dbars using the relationship: mbar * 0.01 = dbar
Barometer reading = 1010.50 mbar * 0.01 = 10.1050 dbar
The 16*plus*-IM V2's internal calculations and our processing software output gage pressure, using an assumed value of 14.7 psi for atmospheric pressure. Convert 16*plus*-IM V2 reading from gage to absolute by adding 14.7 psia to the 16*plus*-IM V2 output:
-2.5 dbars + (14.7 psi * 0.689476 dbar/psia) = -2.5 + 10.13 = 7.635 dbars
Offset = 10.1050 – 7.635 = + 2.47 dbars
Enter offset in 16*plus*-IM V2 and in .con file.

For demanding applications, or where the sensor's air ambient pressure response has changed significantly, calibration using a dead-weight generator is recommended. The end cap's $^{7}/_{16}$-20 straight thread permits mechanical connection to the pressure source. Use a fitting that has an O-ring tapered seal, such as Swagelok-200-1-4ST, which conforms to MS16142 boss.

Section 6: Troubleshooting

This section reviews common problems in operating the SBE 16*plus*-IM V2, and provides the most common causes and solutions.

Problem 1: Unable to Communicate with SBE 16*plus*-IM V2

The S> prompt indicates that communications between the 16*plus*-IM V2 and computer have been established. Before proceeding with troubleshooting, attempt to establish communications again by selecting *Connect* in the Communications menu in SeatermIM, or pressing the Enter key several times.

Cause/Solution 1: The I/O cable connection may be loose. Check the cabling between the SIM or IMM and computer for a loose connection.

Cause/Solution 2: The instrument communication settings may not have been entered correctly in SeatermIM. Verify the settings in the Configure Communications dialog box (Communications menu -> *Configure*). The settings should match those on the instrument Configuration Sheet.

Cause/Solution 3: The I/O cable between the SIM or IMM and computer may not be the correct one. The I/O cable supplied with the SIM or IMM permits connection to standard 9-pin RS-232 interfaces.

Cause/Solution 4: The modem core in the 16*plus*-IM V2 (and/or the ICC, if applicable) may have a gap, be misaligned, or be damaged. See *Application Note 85: Handling of Ferrite Core in Instruments with Inductive Modem Telemetry* for details on inspecting the modem core and proper installation of the 16*plus*-IM V2 and the ICC (if applicable) on the cable.

Problem 2: No Data Recorded

Cause/Solution 1: The memory may be full; once the memory is full, no further data will be recorded. Verify that the memory is not full using **#iiGetSD** or **#iiDS** (*free = 0* or *1* if memory is full). Sea-Bird recommends that you upload all previous data before beginning another deployment. Once the data is uploaded, send **#iiInitLogging** to reset the memory. After the memory is reset, **#iiGetSD** or **#iiDS** will show *samples = 0*.

Problem 3: Nonsense or Unreasonable Data

The symptom of this problem is an uploaded file that contains nonsense values (for example, 9999.999) or unreasonable values (for example, values that are outside the expected range of the data).

Cause/Solution 1: An uploaded data file with nonsense values may be caused by incorrect instrument configuration:

- Bad data may be caused by incorrect configuration in the 16*plus*-IM V2. Send **#iiGetCD** or **#iiDS** to verify the setup of the 16*plus*-IM V2 matches the instrument Configuration Sheet (correct pressure sensor, voltage sensors assigned to correct channels, etc).
- Bad data may be caused by incorrect configuration in the instrument .con file. Verify the settings in the instrument .con file match the instrument Configuration Sheet.

Note:
Each 16*plus*-IM V2 is shipped with a configuration (.con) file that matches the configuration of the instrument (number and type of auxiliary sensors, etc.) and includes the instrument calibration coefficients.

Cause/Solution 2: An uploaded data file with unreasonable (i.e., out of the expected range) values for temperature, conductivity, etc. may be caused by incorrect calibration coefficients:

- If you manually uploaded data in engineering units (**#iiOutputFormat=1**, **3**, or **5**) – Bad data may be caused by incorrect calibration coefficients in the 16*plus*-IM V2. Send **#iiGetCC** or **#iiDCal** to verify the calibration coefficients in the 16*plus*-IM V2 match the instrument Calibration Certificates. Note that calibration coefficients do not affect the raw data stored in 16*plus*-IM V2 memory. If you have not yet overwritten the memory with new data, you can correct the coefficients and then upload the data again.
- If you manually uploaded data in raw hexadecimal (**#iiOutputFormat=0**), or used SeatermIM's Upload menu to upload data and are processing the data in SBE Data Processing or viewing it in Seasave - Bad data may be caused by incorrect calibration coefficients in the instrument .con file. Verify the calibration coefficients in the .con file match the instrument Calibration Certificates.
- For RS-232 sensors interfacing to the 16*plus*-IM V2: Bad data may be caused by incorrect calibration coefficients programmed into the RS-232 sensor. Connect the sensor directly to the computer and use Seaterm232 or SEATERM to verify the calibration coefficients match the instrument Calibration Certificate.

Problem 4: Program Corrupted

Cause/Solution 1: In rare cases, a severe static shock or other problem can corrupt the program that controls the SBE 16*plus*-IM V2 microprocessor. This program can be initialized by using the reset switch. Proceed as follows to initialize:

1. Open the battery end cap and remove the batteries (see *Replacing Alkaline Batteries* in *Section 5: Routine Maintenance and Calibration*).
2. There is a small, pushbutton switch on the battery compartment bulkhead, which is visible after the batteries are removed. The switch is used to disconnect the internal back-up lithium batteries from the electronics. Push the switch in for 1 second.
3. Reinstall or replace the batteries, and close the battery end cap.
4. Establish communications with the 16*plus*-IM V2 (see *Section 3: Preparing for Deployment*). Send **#iiGetSD** or **#iiDS** to verify that the date and time and sample number are correct.

Note:
Using the reset switch does not affect the 16*plus*-IM V2 memory - data in memory and user-programmable parameter values are unaffected.

Glossary

Batteries – Nine alkaline D-cells (Duracell MN1300, LR20) standard.

Deployment Endurance Calculator – Sea-Bird's Windows 2000/XP software used to calculate deployment length for moored instruments, based on user-input deployment scheme, instrument power requirements, and battery capacity.

Fouling – Biological growth in the conductivity cell during deployment.

ICC – Inductive Cable Coupler, which clamps to the insulated mooring cable and transfers the inductive signal on wire to the SIM PCB installed inside the buoy or elsewhere.

IMM – Inductive Modem Module PCB, used to interface between the computer serial port and 16*plus*-IM V2s or other compatible IM instruments. Either an IMM or SIM is required to interface with the 16*plus*-IM V2.

PCB – Printed Circuit Board.

SBE Data Processing – Sea-Bird's 2000/XP data processing software, which calculates and plots temperature, conductivity, and optional pressure, data from auxiliary sensors, and derives variables such as salinity and sound velocity.

Scan – One data sample containing temperature, conductivity, optional pressure, date and time, and optional auxiliary inputs.

SEACAT – High-accuracy conductivity, temperature, and pressure recorder. The SEACAT is available as the SBE 16*plus* (moored applications), and SBE 19*plus* (moored or profiling applications).
The 16*plus* is available in three versions:

- 16*plus* with **RS-232** interface (standard)
- 16*plus* with **RS-485** interface
- 16*plus*-IM with **inductive modem** interface (**this manual**)

Version 2 (V2) of each of these instruments became available in late 2007 / early 2008, and have 2 additional A/D channels (for a total of 6), a standard channel for an RS-232 sensor, and larger memory (64 MB).
A *plus* version of the SBE 21 SEACAT (thermosalinograph) is under development.

Seasave V7 – Sea-Bird's Win 2000/XP software used to acquire, convert, and display real-time or archived raw data. **Seasave cannot be used to acquire data from the 16*plus*-IM V2, but can be used to display in engineering units the raw hexadecimal data uploaded from the 16*plus*-IM V2.**

SEASOFT V2 – Sea-Bird's complete Win 2000/XP software package, which includes software for communication, real-time data acquisition, and data analysis and display. SEASOFT V2 includes ***Deployment Endurance Calculator, SeatermV2***, ***SBE Data Processing***, ***Seasave V7***.

SeatermV2 – Win 2000/XP terminal program *launcher*.
Depending on the instrument selected, it launches SeatermIM (inductive modem instruments), Seaterm232 (RS-232 instruments), or Seaterm485 (RS-485 instruments).

SeatermIM – Win 2000/XP terminal program used with Sea-Bird instruments that communicate via an Inductive Modem (IM) interface, and that were developed or redesigned in 2006 and later. The common feature of these instruments is the ability to output data in XML. Instruments currently supported by SeatermIM include: SBE 16*plus*-IM V2 (IM interface, version 2 or later digital firmware) and 37-IM/-IMP (IM interface, version 3 or later digital firmware).

SIM – Surface Inductive Modem PCB, used to interface between computer serial port and SBE 16*plus*-IM V2 or other compatible IM instruments. Either an IMM or SIM is required to interface with the 16*plus*-IM V2.

Super O-Lube – Silicone lubricant used to lubricate O-rings and O-ring mating surfaces. Super O-Lube can be ordered from Sea-Bird, but should also be available locally from distributors. Super O-Lube is manufactured by Parker Hannifin (http://www.parker.com/ead/cm2.asp?cmid=3956)

TCXO – Temperature Compensated Crystal Oscillator.

Triton X-100 – Reagent grade non-ionic surfactant (detergent), used for cleaning the conductivity cell. Triton can be ordered from Sea-Bird, but should also be available locally from chemical supply or laboratory products companies. Triton is manufactured by Mallinckrodt Baker (http://www.mallbaker.com/changecountry.asp?back=/Default.asp)

Appendix I: Functional Description and Circuitry

Sensors

The SBE16*plus*-IM V2 embodies the same sensor elements (3-electrode, 2-terminal, borosilicate glass cell, and pressure-protected thermistor) previously employed in Sea-Bird's modular SBE 3 and SBE 4 sensors and in the original SEACAT design. The SBE 16*plus*-IM V2 differs from the SBE 16 in that it uses three independent channels to digitize temperature, conductivity, and pressure concurrently. Multiplexing is not used for these channels.

The optional internally mounted pressure sensor is a Druck strain-gauge sensor or Quartz sensor.

Sensor Interface

Temperature is acquired by applying an AC excitation to a bridge circuit containing an ultra-stable aged thermistor with a drift rate of less than 0.002 ºC per year. The other elements in the bridge are VISHAY precision resistors. A 24-bit A/D converter digitizes the output of the bridge. AC excitation and ratiometric comparison avoids errors caused by parasitic thermocouples, offset voltages, leakage currents, and reference errors.

Conductivity is acquired using an ultra-precision Wein-Bridge oscillator to generate a frequency output in response to changes in conductivity.

Strain-gauge pressure is acquired by applying an AC excitation to the pressure bridge. A 24-bit A/D converter digitizes the output of the bridge. AC excitation and ratiometric comparison avoids errors caused by parasitic thermocouples, offset voltages, leakage currents, and reference errors. A silicon diode embedded in the pressure bridge is used to measure the temperature of the pressure bridge. This temperature is used to perform offset and span corrections on the measured pressure signal.

The six external 0 to 5 volt DC voltage channels are processed by differential amplifiers with an input resistance of 50K ohms and are digitized with a 14-bit A/D converter.

Real-Time Clock

To minimize power and improve clock accuracy, a temperature-compensated crystal oscillator (TCXO) is used as the real-time-clock frequency source. The TCXO is accurate to ± 1 minute per year (0 ºC to 40 ºC).

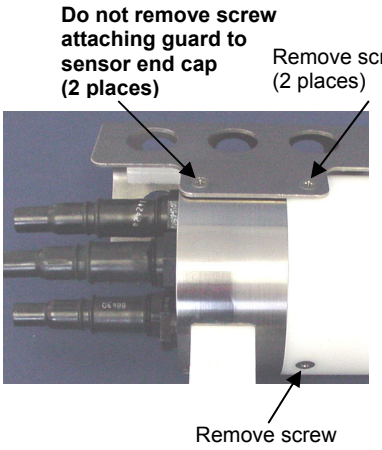
Battery Wiring

SBE 16*plus*-IM V2 main battery is a series connection of D-cells that drop into the battery compartment as a cluster of end-to-end stacks, three batteries each (standard 9-cell battery pack has three stacks). The positive battery connections are contact areas on double-thick printed circuit disks that form the internal bulkhead and battery retainer plates. Battery negative contacts are heavy beryllium-copper springs. The three cell stacks are aligned by plastic insulated aluminum spacers which also serve as electrical interconnects. The battery-to-circuit card connection is made by means of a Molex-type 3-pin pc board connector (JP3 on the power PCB).

The Power PCB contains three series-connected Panasonic BR-2/3A lithium cells (non-hazardous) which are diode OR'd with the main battery. The back-up lithium supply is capable of maintaining the buffer and the real-time clock if the main batteries are removed. If the back-up lithium battery voltage (*Vlith* in the **#iiGetSD** or **#iiDS** response) falls below 7 volts, replace the back-up batteries.

Appendix II: Electronics Disassembly/Reassembly

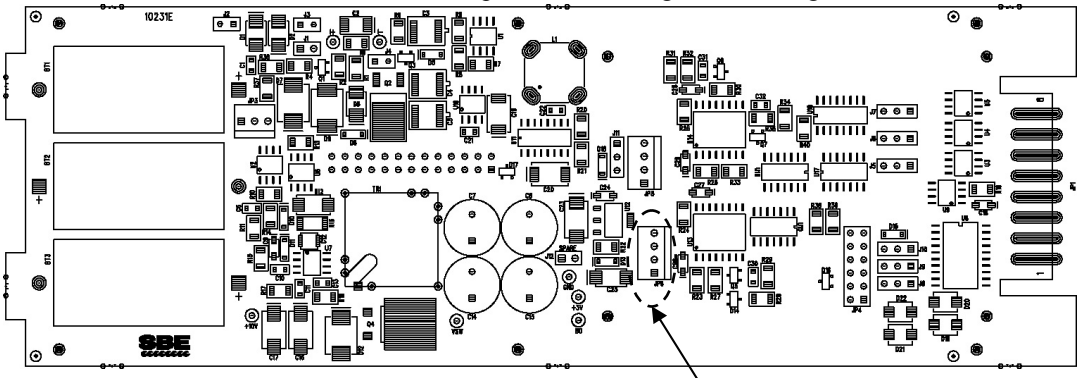
CAUTION:
Use caution during disassembly and reassembly to avoid breaking the conductivity cell.



Disassembly:

1. **As a precaution, upload any data in memory before beginning.**
2. Remove the two Phillips-head screws holding the conductivity cell guard to the housing. **Do not remove the two screws holding the conductivity cell guard to the sensor end cap.**
3. Remove the Phillips-head screw holding the sensor end cap to the housing on the side opposite the conductivity cell guard.
4. Remove the sensor end cap (with attached conductivity cell and cell guard) and electronics:
   A. Wipe the outside of the sensor end cap and housing dry, being careful to remove any water at the seam between them.
   B. Slide the end cap and attached electronics out of the housing.
   C. The electronics are electrically connected to the battery compartment bulkhead with a Molex connector. Disconnect the Molex connector.
   D. Remove any water from the O-rings and mating surfaces inside the housing with a lint-free cloth or tissue.
   E. Be careful to protect the O-rings from damage or contamination.

Power PCB (PN 41054)



JP6 internal RS-232 connector, for firmware update and/or fast upload. Unplug IM boardset, and connect JP6 to computer with optional data I/O cable (PN 801880).

Reassembly:

Note:
Before delivery, a desiccant package is placed in the electronics chamber, and the electronics chamber is filled with dry Argon gas. These measures help prevent condensation.
If the electronics are exposed to the atmosphere, dry gas backfill with Argon and replace the desiccant package.
See *Application Note 71: Desiccant Use and Regeneration (drying)* for desiccant information.
Battery replacement does not affect desiccation of the electronics, as no significant gas exchange is possible unless the electronics PCBs are actually removed from the housing.

1. Reinstall the sensor end cap, conductivity cell and guard, and electronics:
   A. Remove any water from the O-rings and mating surfaces in the housing with a lint-free cloth or tissue. Inspect the O-rings and mating surfaces for dirt, nicks, and cuts. Clean or replace as necessary. Apply a light coat of O-ring lubricant (Parker Super O Lube) to the O-rings and mating surfaces.
   B. Plug the Molex connector onto the pins on the battery compartment bulkhead. Verify the connector holes and pins are properly aligned.
   C. Carefully fit the end cap and electronics into the housing until the O-rings are fully seated.
2. Reinstall the three screws to secure the end cap.
3. Reset the date and time (**#iiDateTime=**) and initialize logging (**#iiInitLogging**) before redeploying. No other parameters should have been affected by the electronics disassembly (send **#iiGetCD** or **#iiDS** to verify).

Appendix III: Command Summary

Note:
See *Command Descriptions* in *Section 4: Deploying and Operating SBE 16plus-IM V2* for detailed information and examples.

FUNCTION	CATEGORY	COMMAND	DESCRIPTION
IMM Commands	-	See the IMM manual for a complete list of IMM commands.	
SIM Commands	**Power-On**	**PwrOn**	Send wakeup tone to **all** 16*plus*-IM V2s.
		PwrOff	Send power off command to **all** 16*plus*-IM V2s. SBE 16*plus*-IM V2s enter quiescent (sleep) state. Main power turned off, but data logging and memory retention unaffected.
		AutoPwrOn=x	**x=Y** (default): Send **PwrOn** to 16*plus*-IM V2s when power applied to SIM. This wakes up all 16*plus*-IM V2s on line. **x=N**: Do not send **PwrOn** when power applied to SIM.
	Status	**DS**	Display SIM firmware version and setup parameters.
	Communications	**Baud=x**	**x=** baud rate between SIM and computer/controller (1200, 2400, 4800, or 9600). Default 9600.
		DataNNMax=x	**x**= timeout (milliseconds) that applies to **!iiData** or **Dataii** only. If no reply received within **x** (0-32767), control returned to computer and other commands can be sent. Default 1000 milliseconds.
		RelayMax=x	**x**= timeout (seconds) that applies to all other commands. If no reply received within **x** (0-3276), control returned to computer and other commands can be sent. Default 20 seconds.
		EchoOn	Echo characters received from computer (default).
		EchoOff	Do not echo characters.
16*plus*-IM V2 Communication Microcontroller Commands	**Global**	**DateTime= mmddyyyyhhmmss**	Set real-time clock month, day, year, hour, minute, second for **all** 16*plus*-IM V2s.
		GData	Command **all** *16plus*-IM V2 communication microcontrollers to get last data sample from acquisition units. 16*plus*-IM V2 communication microcontrollers hold data in a buffer until receiving **!iiData** or **Dataii**.
	Get Data	**!iiData** or **Dataii**	Get data obtained with **GData** from 16*plus*-IM V2 with ID=ii.
	16*plus*-IM V2 ID Only 1 16*plus*-IM V2 can be on line when sending these commands.	**ID?**	Display 16*plus*-IM V2 ID (ID=ii, where ii=0 to 99)
		***ID=ii** (If more than 1 16*plus*-IM V2 on line when setting ID, all will have same ID)	Set 16*plus*-IM V2 ID to ii (ii=0 to 99). Command must be sent twice, because verification requested.
	16*plus*-IM V2 communication microcontroller status	**!iiDS**	Display firmware version and timeout parameter.
	16*plus*-IM V2 communication microcontroller timeout	**!iiWait=x**	**x**= maximum time (seconds) for communication microcontroller to wait for response from acquisition microcontroller. Range 2 – 600 seconds.

FUNCTION	CATEGORY	COMMAND	DESCRIPTION
16*plus*-IM V2 Acquisition Microcontroller Commands (ii = 16*plus*-IM V2 ID)	**Status**	**#iiGetCD**	Get and display configuration data (setup parameters).
		#iiGetSD	Get and display status data.
		#iiGetCC	Get and display calibration coefficients.
		#iiGetEC	Get and display event counter data.
		#iiResetEC	Delete all events in event counter
		#iiGetHD	Get and display hardware data.
		#iiDS	Get and display configuration data (setup parameters) and status data.
		#iiDCal	Get and display calibration coefficients.
	General Setup	**#iiDateTime= mmddyyyyhhmmss**	Set real-time clock month, day, year, hour, minute, second.
		#iiOutputExecutedTag=x	**x=Y**: Display XML Executing and Executed tags. **x=N**: Do not.
		#iiPumpMode =x	**x=0**: No pump. **x=1**: Run pump for 0.5 seconds before each sample. **x=2**: Run pump during each sample.
		#iiNCycles=x	**x=** number of measurements to take and average for each sample. Default 1.
		#iiInitLogging	After all previous data has been uploaded, send this before starting to sample to make entire memory available for recording. If not sent, data stored after last sample. Equivalent to **#iiSampleNumber=0**.
		#iiSampleNumber=x	**x=** sample number for last sample in memory. **#iiSampleNumber=0** is equivalent to **#iiInitLogging**.
		#iiHeaderNumber=x	**x=** header number for last header in memory.
	Pressure Sensor Setup	**#iiPType=x**	**Internally mounted pressure sensor type - x=0**: No internally mounted pressure sensor. **x=1**: Strain gauge. **x=3**: Quartz with temperature compensation.
		#iiRefPress=x	**x=** reference pressure (gauge) in db to use if 16*plus*-IM V2 does not include internally mounted pressure sensor.
		#iiParosIntegration=x	**x=** integration time (seconds) for optional internally mounted Quartz pressure sensor (1 - 600 seconds; default 1 second).
	Voltage Sensor Setup	**#iiVolt0=x**	**x=Y**: Enable external voltage 0. **x=N**: Do not.
		#iiVolt1=x	**x=Y**: Enable external voltage 1. **x=N**: Do not.
		#iiVolt2=x	**x=Y**: Enable external voltage 2. **x=N**: Do not.
		#iiVolt3=x	**x=Y**: Enable external voltage 3. **x=N**: Do not.
		#iiVolt4=x	**x=Y**: Enable external voltage 4. **x=N**: Do not.
		#iiVolt5=x	**x=Y**: Enable external voltage 5. **x=N**: Do not.
		#iiDelayBeforeSampling =x	**x=** time (seconds) to wait after switching on external voltage before sampling (0-600 seconds). Default 0 seconds.
		#iiBiowiper=x	**x=Y**: Configuration includes ECO-FL fluorometer with Bio-Wiper. **x=N** (default): Does not.

FUNCTION	CATEGORY	COMMAND	DESCRIPTION
16*plus*-IM V2 Acquisition Microcontroller Commands (ii = 16*plus*-IM V2 ID) (*continued*)	**RS-232 Sensor Setup**	**#iiSBE38=x**	**x=Y**: Enable SBE 38. **x=N**: Do not.
		#iiSBE50=x	**x=Y**: Enable SBE 50. **x=N**: Do not.
		#iiGTD=x	**x=Y**: Enable GTD. **x=N**: Do not.
		#iiDualGTD=x	**x=Y**: Enable dual (2) GTDs. **x=N**: Do not.
		#iiTGTD	Measure GTD(s), output 1 converted data sample for each GTD.
		#iiSendGTD=command	Command 16*plus*-IM V2 to send **command** to GTD and receive response (**command** can be any command recognized by GTD).
		#iiOptode=x	**x=Y**: Enable Aanderaa Optode. **x=N**: Do not.
	Output Format Setup	**#iiOutputFormat=x**	**x=0**: output raw frequencies and voltages in Hex (required if using SBE Data Processing or Seasave). **x=1**: output converted data in Hex. **x=2**: output raw frequencies and voltages in decimal. **x=3**: output converted data in decimal. **x=5**: output converted data in decimal XML.
		#iiOutputSal=x	**x=Y**: Calculate and output salinity (psu) if **#iiOutputFormat=3** or **5**. **x=N**: Do not.
		#iiOutputSV=x	**x=Y**: Calculate and output sound velocity (m/sec) if **#iiOutputFormat=3** or **5**. **x=N**: Do not.
		#iiOutputUCSD=x	**x=Y**: Calculate and output sigma-t (kg/m^3), battery voltage, and operating current (mA) with data polled while logging. Only applies if **#iiOutputFormat=3** or **5**. **x=N**: Do not.
		#iiOutputSampleNumber=x	**x=Y**: Output sample number with data from **Dataii**, **!iiData**, **#iiSL**, **#iiSLT**, **#iiTS**, and #**iiTSS** if **#iiOutputFormat=3** or **5**. **x=N**: Do not.
	Autonomous Sampling	**#iiSampleInterval=x**	**x=** interval (seconds) between samples (10 – 14,400).
		#iiStartNow	Start autonomous sampling now.
		#iiStartDateTime =mmddyyyyhhmmss	Delayed start: month, day, year, hour, minute, second.
		#iiStartLater	Start autonomous sampling at delayed start date and time.
		#iiStop	Stop autonomous sampling or stop waiting to start autonomous sampling. Must stop sampling before uploading data.
	Polled Sampling	**#iiSL**	Output last sample from buffer.
		#iiSLT	Output last sample from buffer, then take new sample and store in buffer.
		#iiTS	Take sample, store in buffer, output data.
		#iiTSS	Take sample, **store in buffer and FLASH memory**, output data.
		#iiGetLastSamples:x	Output last **x** samples from FLASH memory.
	Data Upload	**GetSamples:b,e** or **#iiDDb,e**	Upload data from scan **b** to scan **e**. Stop autonomous sampling before sending.
		GetHeaders:b,e or **#iiDHb,e**	Upload header **b** to header **e**.

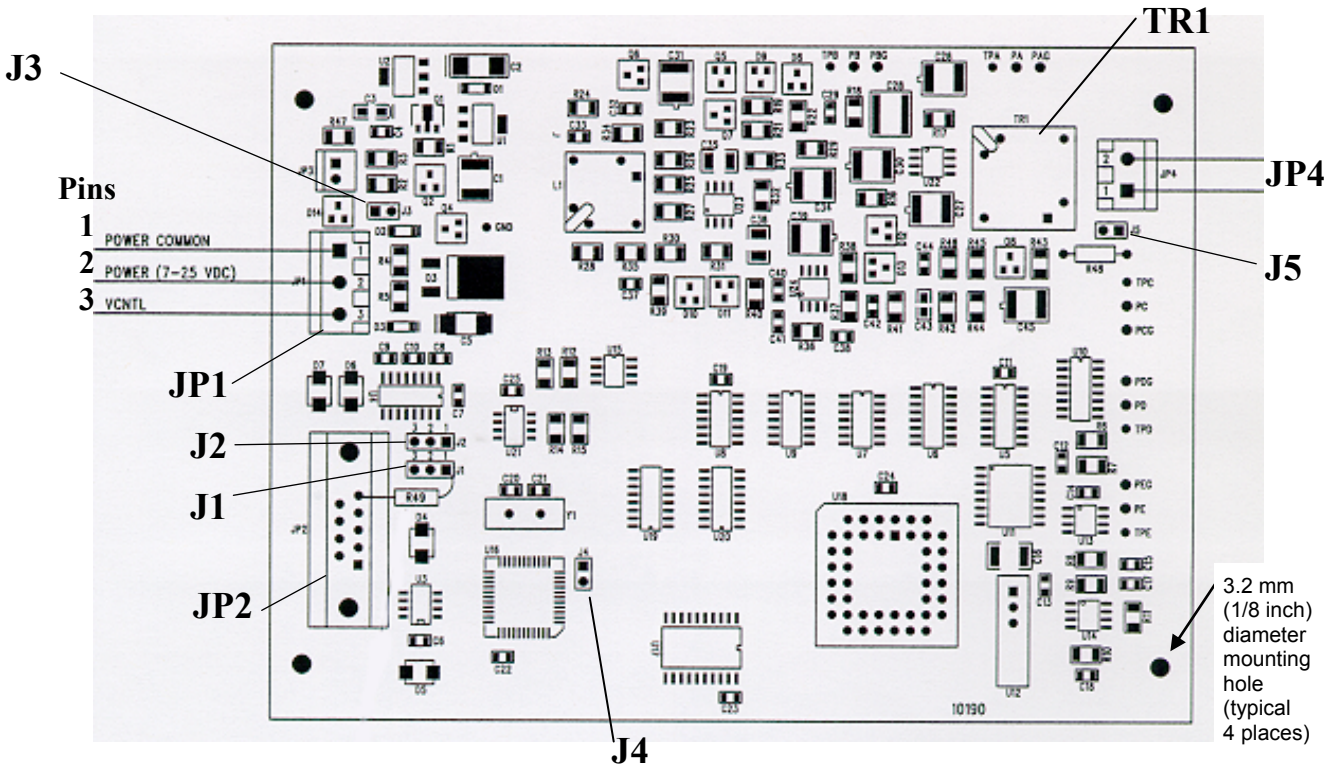
Note:
Use SeatermIM's Upload menu to upload data that will be processed by SBE Data Processing. Manually entering the data upload command does not produce data with the required header information for processing by SBE Data Processing.

FUNCTION	CATEGORY	COMMAND	DESCRIPTION
	Testing Takes and outputs 30 samples for each test.	**#iiTC**	Measure conductivity, output converted data.
		#iiTCR	Measure conductivity, output raw data.
		#iiTT	Measure temperature, output converted data.
		#iiTTR	Measure temperature, output raw data
		#iiTP	Measure pressure, output converted data.
		#iiTPR	Measure pressure, output raw data.
		#iiTV	Measure 6 external voltage channels, output converted data.
		#iiTVR	Measure 6 external voltage channels, main battery voltage, lithium battery voltage, external current, pressure temperature, output raw data.
		#iiTF	Measure frequency (Quartz pressure sensor), output converted data.
		#iiTFR	Measure frequency (Quartz pressure sensor), output raw data.
		#iiT38	Measure SBE 38, output converted data.
		#iiT50	Measure SBE 50, output converted data.
		#iiTOptode	Measure Aanderaa Optode, output converted data.
		#iiPumpOn	Turn pump on for testing purposes.
		#iiPumpOff	Turn pump off for testing purposes.

FUNCTION	CATEGORY	COMMAND	DESCRIPTION
16*plus*-IM V2 Acquisition Microcontroller Commands (ii = 16*plus*-IM V2 ID) (continued)	**Coefficients** (F=floating point number; S=string with no spaces) Dates shown are when calibrations were performed. Calibration coefficients are initially factory-set and should agree with Calibration Certificates shipped with 16*plus*-IM V2. View all coefficients with **#iiGetCC** or **#iiDCal**.	**#iiTCalDate=S**	**S=**Temperature calibration date.
		#iiTAO=F	**F=**Temperature A0.
		#iiTA1=F	**F=**Temperature A1.
		#iiTA2=F	**F=**Temperature A2.
		#iiTA3=F	**F=**Temperature A3.
		#iiTOffset=F	**F=**Temperature offset correction.
		#iiCCalDate=S	**S=**Conductivity calibration date.
		#iiCG=F	**F=**Conductivity G.
		#iiCH=F	**F=**Conductivity H.
		#iiCI=F	**F=**Conductivity I.
		#iiCJ=F	**F=**Conductivity J.
		#iiCPCor=F	**F=**Conductivity pcor.
		#iiCTCor=F	**F=**Conductivity tcor.
		#iiCSlope=F	**F=**Conductivity slope correction.
		#iiPCalDate=S	**S=**Pressure calibration date.
		#iiPRange=F	**F=**Pressure sensor full scale range (psia).
		#iiPOffset=F	**F=**Pressure offset correction (decibars).
		#iiPA0=F	**F=**Strain gauge pressure A0.
		#iiPA1=F	**F=**Strain gauge pressure A1.
		#iiPA2=F	**F=**Strain gauge pressure A2.
		#iiPTempA0=F	**F=**Strain gauge pressure temperature A0.
		#iiPTempA1=F	**F=**Strain gauge pressure temperature A1.
		#iiPTempA2=F	**F=**Strain gauge pressure temperature A2.
		#iiPTCA0=F	**F=**Strain gauge pressure temperature compensation ptca0.
		#iiPTCA1=F	**F=**Strain gauge pressure temperature compensation ptca1.
		#iiPTCA2=F	**F=**Strain gauge pressure temperature compensation ptca2.
		#iiPTCB0=F	**F=**Strain gauge pressure temperature compensation ptcb0.
		#iiPTCB1=F	**F=**Strain gauge pressure temperature compensation ptcb1.
		#iiPTCB2=F	**F=**Strain gauge pressure temperature compensation ptcb2.
		#iiPC1=F	**F=**Quartz pressure C1.
		#iiPC2=F	**F=**Quartz pressure C2.
		#iiPC3=F	**F=**Quartz pressure C3.
		#iiPD1=F	**F=**Quartz pressure D1.
		#iiPD2=F	**F=**Quartz pressure D2.
		#iiPT1=F	**F=**Quartz pressure T1.
		#iiPT2=F	**F=**Quartz pressure T2.
		#iiPT3=F	**F=**Quartz pressure T3.
		#iiPT4=F	**F=**Quartz pressure T4.
		#iiPSlope=F	**F=**Pressure slope correction.
		#iiExtFreqSF=F	**F=**External frequency (Quartz pressure sensor) scale factor.
		#iiVOffset0=, **#iiVSlope0=**, . . . **#iiVSlope5=**, **#iiVOffset5=**	Voltage channel offsets and slopes are all factory set, and should never be modified by customer. These are properties of 16*plus*-IM V2 electronics, and are not calibration coefficients for auxiliary sensors. Enter calibration coefficients for auxiliary sensors in .con file in SBE Data Processing.

FUNCTION	CATEGORY	COMMAND
	Hardware Configuration	*Factory Settings – do not modify in the field* **#iiSetMfgDate=** **#iiSetPcbSerialNum1=, #iiSetPcbSerialNum2=,** **#iiSetPcbSerialNum3=, #iiSetPcbSerialNum4=** **#iiSetPcbAssembly1=, #iiSetPcbAssembly2=,** **#iiSetPcbAssembly3=, #iiSetPcbAssembly4=** *Auxiliary Sensor Settings – can be modified in the field to accommodate changes in auxiliary sensors cabled to 16plus-IM V2* **#iiSetVoltType0=, #iiSetVoltSN0=** **#iiSetVoltType1=, #iiSetVoltSN1=** **#iiSetVoltType2=, #iiSetVoltSN2=** **#iiSetVoltType3=, #iiSetVoltSN3=** **#iiSetVoltType4=, #iiSetVoltSN4=** **#iiSetVoltType5=, #iiSetVoltSN5=**

Appendix IV:
SIM Hookup and Configuration



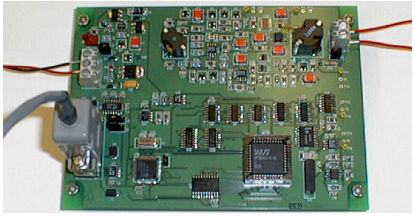


Photo shows SIM-Direct for use without Inductive Cable Coupler. SIM-Coupled for use with Inductive Cable Coupler is similar, but does not include TR1.

Dimensions:
PCB: 109 mm x 147.5 mm (4 1/4 x 5 3/4 inches)
Mounting holes: 90.5 mm x 138.1 mm (3 9/16 x 5 7/16 inches)

Power Connection

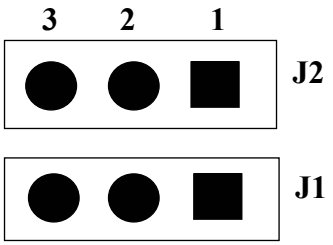
The SIM can be configured to power up in either of the following two modes:

- **Normal Power Switching (factory setting)** – The SIM runs when power is applied. Set up the SIM as follows:
  1. Connect Power Common to JP1 pin 1.
  2. Connect 7-25 VDC to JP1 pin 2.
  3. Verify there is no connection to JP1 pin 3.
  4. Verify jumper is across J3.

- **Logic Level Controlled Power Switching** – Power is always applied to JP1, pins 1 and 2. Voltage applied to JP1 pin 3 (VCNTL) switches power to the SIM. Set up the SIM as follows:
  1. Connect Power Common to JP1 pin 1.
  2. Connect 7-25 VDC to JP1 pin 2.
  3. Remove jumper on J3.

Note:
If VCNTL < 1 volt, SIM is Off (consuming < 100 microamps).
If VCNTL > 2 volts, SIM is On.

Interface Option Connection (J1, J2, and J4)

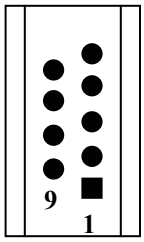


The SIM can be configured to accept RS-232 or RS-485:

- **RS-232 (factory setting)**
  1. Verify jumper is on J1 pins 2 and 3.
  2. Verify jumper is on J2 pins 2 and 3.
  3. Remove jumper on J4.

- **RS-485**
  1. Install jumper on J1 pins 1 and 2.
  2. Install jumper on J2 pins 1 and 2.
  3. Install jumper on J4.

I/O Connector Wiring (JP2)



Connect wires to JP2 as follows:

- **RS-232**
  1. **Pin 2** - RS-232 transmit from SIM to computer
  2. **Pin 3** - RS-232 transmit from computer to SIM
  3. **Pin 5** – Power Common

- **RS-485**
  1. **Pin 4** - RS-485 ‘A’
  2. **Pin 5** - Power Common
  3. **Pin 6** - RS-485 ‘B’

Inductive Mooring Cable Connection (JP4)

Note:
ICC version 4 may have 3 wires in the cable. If you ordered the ICC with a pigtail termination, solder the white and white/black wires together and attach to 1 terminal of JP4. Attach the white/red wire to the other terminal.

- **SBE 16*plus*-IM V2 installed with Inductive Cable Coupler (ICC)** - Connect wires from the ICC to JP4 on SIM-Coupled.

- **SBE 16*plus*-IM V2 installed without Inductive Cable Coupler (ICC)** - Connect wires from the mooring cable and seawater ground to JP4 on SIM-Direct.

Normal Deployed Operation (J5)

- **Normal Deployed Operation** - Ensure jumper on J5 is installed.

- **Instrument Setup and Lab Testing** - Remove jumper on J5. Removing this jumper inserts a 1K resistor in series with the inductive loop, reducing the signal amplitude. This prevents the SBE 16*plus*-IM V2s in close proximity from responding to commands, which is especially important when sending the ***ID=** command.

Appendix V: AF24173 Anti-Foulant Device

AF24173 Anti-Foulant Devices supplied for user replacement are supplied in polyethylene bags displaying the following label:

AF24173 ANTI-FOULANT DEVICE

FOR USE ONLY IN SEA-BIRD ELECTRONICS' CONDUCTIVITY SENSORS TO CONTROL THE GROWTH OF AQUATIC ORGANISMS WITHIN ELECTRONIC CONDUCTIVITY SENSORS.

ACTIVE INGREDIENT:

Bis(tributyltin) oxide…….……....	53.0%
OTHER INGREDIENTS: …….....	47.0%
Total…….....	100.0%

DANGER

See the complete label within the Conductivity Instrument Manual for Additional Precautionary Statements and Information on the Handling, Storage, and Disposal of this Product.

Net Contents: Two anti-foulant devices

Sea-Bird Electronics, Inc.
1808 - 136th Place Northeast
Bellevue, WA 98005

EPA Registration No. 74489-1
EPA Establishment No. 74489-WA-1

AF24173 Anti-Foulant Device

FOR USE ONLY IN SEA-BIRD ELECTRONICS' CONDUCTIVITY SENSORS TO CONTROL THE GROWTH OF AQUATIC ORGANISMS WITHIN ELECTRONIC CONDUCTIVITY SENSORS.

ACTIVE INGREDIENT:
Bis(tributyltin) oxide……..……..... 53.0%
OTHER INGREDIENTS: ……..... 47.0%
Total……..... 100.0%

DANGER
See Precautionary Statements for additional information.

FIRST AID	
If on skin or clothing	• Take off contaminated clothing. • Rinse skin immediately with plenty of water for15-20 minutes. • Call a poison control center or doctor for treatment advice.
If swallowed	• Call poison control center or doctor immediately for treatment advice. • Have person drink several glasses of water. • Do not induce vomiting. • Do not give anything by mouth to an unconscious person.
If in eyes	• Hold eye open and rinse slowly and gently with water for 15-20 minutes. • Remove contact lenses, if present, after the first 5 minutes, then continue rinsing eye. • Call a poison control center or doctor for treatment advice.
HOT LINE NUMBER	
Note to Physician	Probable mucosal damage may contraindicate the use of gastric lavage.
Have the product container or label with you when calling a poison control center or doctor, or going for treatment. For further information call National Pesticide Telecommunications Network (NPTN) at 1-800-858-7378.	

Net Contents: Two anti-foulant devices

Sea-Bird Electronics, Inc.
1808 - 136th Place Northeast
Bellevue, WA 98005

EPA Registration No. 74489-1
EPA Establishment No. 74489-WA-1

PRECAUTIONARY STATEMENTS

HAZARD TO HUMANS AND DOMESTIC ANIMALS

DANGER

Corrosive - Causes irreversible eye damage and skin burns. Harmful if swallowed. Harmful if absorbed through the skin or inhaled. Prolonged or frequently repeated contact may cause allergic reactions in some individuals. Wash thoroughly with soap and water after handling.

PERSONAL PROTECTIVE EQUIPMENT

USER SAFETY RECOMMENDATIONS

Users should:

- Remove clothing immediately if pesticide gets inside. Then wash thoroughly and put on clean clothing.
- Wear protective gloves (rubber or latex), goggles or other eye protection, and clothing to minimize contact.
- Follow manufacturer's instructions for cleaning and maintaining PPE. If no such instructions for washables, use detergent and hot water. Keep and wash PPE separately from other laundry.
    - Wash hands with soap and water before eating, drinking, chewing gum, using tobacco or using the toilet.

ENVIRONMENTAL HAZARDS

Do not discharge effluent containing this product into lakes, streams, ponds, estuaries, oceans, or other waters unless in accordance with the requirements of a National Pollutant Discharge Elimination System (NPDES) permit and the permitting authority has been notified in writing prior to discharge. Do not discharge effluent containing this product to sewer systems without previously notifying the local sewage treatment plant authority. For guidance contact your State Water Board or Regional Office of EPA. This material is toxic to fish. Do not contaminate water when cleaning equipment or disposing of equipment washwaters.

PHYSICAL OR CHEMICAL HAZARDS

Do not use or store near heat or open flame. Avoid contact with acids and oxidizers.

DIRECTIONS FOR USE

It is a violation of Federal Law to use this product in a manner inconsistent with its labeling. For use only in Sea-Bird Electronics' conductivity sensors. Read installation instructions in the applicable Conductivity Instrument Manual.

STORAGE AND DISPOSAL

PESTICIDE STORAGE: Store in original container in a cool, dry place. Prevent exposure to heat or flame. Do not store near acids or oxidizers. Keep container tightly closed.

PESTICIDE SPILL PROCEDURE: In case of a spill, absorb spills with absorbent material. Put saturated absorbent material to a labeled container for treatment or disposal.

PESTICIDE DISPOSAL: Pesticide that cannot be used according to label instructions must be disposed of according to Federal or approved State procedures under Subtitle C of the Resource Conservation and Recovery Act.

CONTAINER DISPOSAL: Dispose of in a sanitary landfill or by other approved State and Local procedures.

Sea-Bird Electronics/label revised 01-31-05

Appendix VI: Replacement Parts

Part Number	Part	Application Description	Quantity in 16*plus*-IM V2
22018	Batteries, alkaline D-cell, Duracell MN 1300 (LR20)	Power 16*plus*-IM V2	9
801294	Battery cover plate	Retains batteries	1
801483	9D (10.8V / 42 amp-hour) lithium battery pack kit	For longer deployments; **batteries not included in kit, and not available from Sea-Bird**	-
801479	3DD (10.8V / 30 amp-hour) lithium battery pack kit	For longer deployments; **batteries not included in kit, and not available from Sea-Bird**	-
30411	Triton X-100	Octyl Phenol Ethoxylate – Reagent grade non-ionic cleaning solution for conductivity cell (supplied in 100% strength; dilute as directed)	1
801542	AF24173 Anti-Foulant Device	bis(tributyltin) oxide device inserted into anti-foulant device cup, for moored applications	1 (set of 2)
231505	Anti-foulant device cap	Secures AF24173 Anti-Foulant Device in cup	2
30984	Anti-foulant device plug	Seals end of anti-foulant assembly when not deployed	2
30900	Machine screw, 1/4-20 x 2" hex head, titanium	Secures mounting clamp	4
30633	Washer, 1/4" split ring lock, titanium	For screw 30900 (secures mounting clamp)	4
30634	Washer 1/4" flat, titanium	For screw 30900 (secures mounting clamp)	4
31019	O-ring 2-088 N674-70	For screw 30900 (retains mounting clamp hardware)	4
801880	4-pin Molex to 9-pin DB-9S I/O cable, 0.9 m (3 ft) long	From internal RS-232 connector to computer, for fast upload and/or for updating firmware	-
171887	9-pin DB-9P to 9-pin DB-9S I/O cable, 3 m (10 ft) long	From SIM to computer	1
171888	25-pin DB-25S to 9-pin DB-9P cable adapter	For use with computer with DB-25 connector	1
17133*	2-pin RMG-4FS to 2-pin RMG-4FS cable, 1.1 m (3.7 ft) long	From 16*plus*-IM V2 to optional pump	1
17044.1*	2-pin RMG-2FS dummy plug and locking sleeve	For when pump not used	1
17046.1 *	4-pin RMG-4FS dummy plug and locking sleeve	For when RS-232 connector not used	1
17047.1*	6-pin AG-206 dummy plug and locking sleeve	For when auxiliary differential input sensors not used	3
171503	2-pin MCIL-2FS to 2-pin MCIL-2FS (wet-pluggable connector) cable, 1.1 m (3.7 ft) long	From 16*plus*-IM V2 to optional pump	1
171497.1	2-pin MCDC-2-F wet-pluggable dummy plug and locking sleeve	For when pump not used	1
171398.1	4-pin MCDC-4-F wet-pluggable dummy plug and locking sleeve	For when RS-232 auxiliary sensor connector not used	1
171498.1	6-pin MCDC-6-F wet-pluggable dummy plug and locking sleeve	For when auxiliary differential input sensors not used	3
30388	Tygon tube, ½ inch ID x ¾ inch OD	Main plumbing tubing for pumped configuration	-
30579	Tygon tube, 3/8 inch ID x ½ inch OD	13 mm (0.5 inch) long pieces used for pumped configurations on conductivity cell exhaust cap and for SBE 43 intake and exhaust to fit to main plumbing	-

* For standard bulkhead connectors

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Part Number	Part	Application Description	Quantity in 16*plus*-IM V2
22009	Panasonic BR-2/3A lithium batteries	Back-up lithium cells on Power PCB	3
60021	Spare battery end cap hardware and o-rings	O-rings and hardware, including: • 30145 Screw, 6-32 x 1/2 Phillips-head, stainless steel (secures battery cover plate to battery posts) • 30242 Washer, #6 flat, stainless steel (for 30145) • 30816 Parker 2-234E603-70 (battery end cap to housing piston seals, sensor end cap to housing seals)	-
50274	Spare o-ring kit	Assorted o-rings, including: • 30816 Parker 2-234E603-70 (battery end cap to housing piston seals, sensor end cap to housing seals) • 30507 Parker 2-206N674-70 (each end of conductivity cell) • 30802 Parker 2-110DUR070, ethylene (titanium conductivity cell tray face seal, groove surface) • 30809 Morrison seal, .047" hole, NIT (temperature probe Morrison seal) • 30072 Parker 2-017N674-70 (bulkhead connector seal) • 30070 Parker 3-904N674-70 (pressure sensor mounting seal) • 30087 Parker 2-232N674-70 (buffer for top retainer of PCB sandwich assembly) • 30801 Parker 5-374E603-70 (base of battery bulkhead seal)	-
50273	Spare hardware kit	Assorted hardware, including: • 30145 Screw, 6-32 x 1/2 Phillips-head, stainless steel (secures battery cover plate to battery posts) • 30242 Washer, #6 flat, stainless steel (for 30145) • 30414 Washer, #12, internal tooth (secures battery bulkhead retainer) • 30954 Screw 4-40 x 3/16 Phillips-head, stainless steel (securing screw for PCB retainer rod) • 31119 Screw 6-32 x 5/8 Truss Head (secures battery bulkhead retainer to bulkhead bottom plate) • 30176 Screw, 10-24 x 3/4, Phillips-head, stainless steel (secures Celcon threaded ring inside titanium battery end cap) • 30249 Washer #10, Flat, stainless steel (for 30176) • 30447 Bolt, ¼-20 x 1 ¼ Hex, titanium (secures lift eye to battery end cap) • 31089 Screw, 10-32 x 1/2 flat Phillips-head, titanium (secures sensor end cap to housing - side opposite conductivity cell guard) • 31090 Screw, 10-32 x 5/8 flat Phillips-head, titanium (secures conductivity cell guard to housing) • 31118 Screw, 10-32 x 3/8 Phillips-head, titanium (secures conductivity cell guard to sensor end cap) • 30875 Bolt ¼-20 x 5/8 Hex, titanium (secures connector guard to sensor end cap) • 30633 Washer, ¼" split ring lock, titanium (for 30875) • 30919 Screw, 6-32 x 3/8 flat slotted, titanium (secures anti-foulant device cup to conductivity cell guard) • 31066 Screw, 8-32 x ¾ socket, titanium (secures conductivity cell and TC duct to sensor end cap)	-
50323	Seaspares kit, standard connectors	Includes o-rings, hardware, bulkhead connectors, dummy plugs, etc.: • 50087 Conductivity cell filling and storage kit • 50273 Spare hardware kit (see above) • 50274 Spare o-ring kit (see above) • 801294 Battery cover plate • 17044.1 2-pin RMG-2FS dummy plug with locking sleeve • 17047.1 6-pin AG-206 dummy plug with locking sleeve • 17652 2-pin XSG-2-BCL-HP-SS bulkhead connector • 17628 6-pin AG-306-HP-SS bulkhead connector • 30388 Vinyl tube, ¾" x ½" (main sensor plumbing tubing) • 30409 Teflon tape (for insides of hose clamps) • 30411 Triton X100 (for cell cleaning) • 30457 Parker O-Lube (o-ring lubricant)	-

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Part Number	Part	Application Description	Quantity in 16*plus*-IM V2
50324	Seaspares kit, wet-pluggable connectors	Includes o-rings, hardware, bulkhead connectors, dummy plugs, etc.: • 50087 Conductivity cell filling and storage kit • 50273 Spare hardware kit (see above) • 50274 Spare o-ring kit (see above) • 801294 Battery cover plate • 171192 Locking sleeve • 171497 2-pin MCDC-2-F wet-pluggable dummy plug • 171498 6-pin MCDC-6-F wet-pluggable dummy plug • 172019 2-pin MCBH-2MP(WB) ½-20 bulkhead connector • 172022 6-pin MCBH-6MP(WB) ½-20 bulkhead connector • 30388 Vinyl tube, ¾" x ½" (main sensor plumbing tubing) • 30409 Teflon tape (for insides of hose clamps) • 30411 Triton X100 (for cell cleaning) • 30457 Parker O-Lube (o-ring lubricant)	-

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SBE 16*plus*-IM V2 SEACAT Reference Sheet

(see SBE 16*plus*-IM V2 User's Manual for complete details)

Sampling Modes

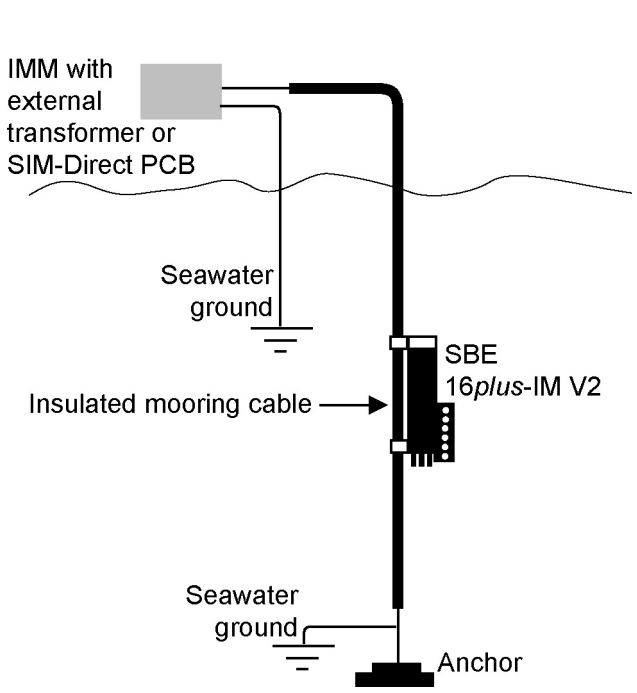
- **Polled** – 16*plus*-IM V2 takes one sample and transmits data.
- **Autonomous** – At pre-programmed intervals, 16*plus*-IM V2 wakes up, samples, stores data in FLASH memory, and powers off.
- **Combo** – Last Autonomous sampling data is transmitted.

Communication Setup Parameters

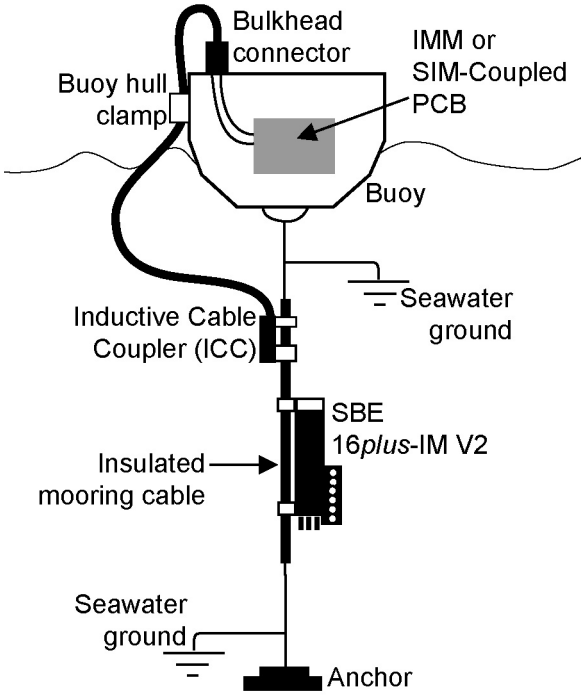
1. Double click on SeatermV2.exe. In Instruments menu, select *SBE 16plus V2 IM*. SeatermIM opens.
2. In Communications menu, select *Configure*. In dialog box, input Comm port and baud rate. Set ID to *Automatically get ID* for 1 16*plus*-IM V2 on line; set ID to *Use fixed ID* for multiple 16*plus*-IM V2s on line.

Deployment

1. Install fresh batteries:
   A. *Remove modem end cap*: Wipe dry housing/end cap seam. Remove 3 flat Phillips-head screws from end cap. Pull end cap out. Disconnect Molex connector connecting end cap to battery pack. Wipe O-ring mating surfaces in housing with lint-free cloth.
   B. *Remove battery cover plate and batteries*: Remove 3 Phillips-head screws and washers from battery cover plate; remove cover plate. Turn 16*plus*-IM V2 over and remove batteries.
   C. *Reinstall batteries, cover plate, and end cap*: Install new batteries, with + terminals against flat battery contacts and - terminals against spring contacts. Reinstall battery cover plate and 3 screws/washers. Remove water from O-rings and mating surfaces with lint-free cloth. Inspect O-rings and mating surfaces for dirt, nicks, and cuts. Clean as necessary. Apply light coat of O-ring lubricant to O-ring and mating surfaces. Plug Molex connector together. Fit end cap into housing. Reinstall 3 Phillips-head screws to secure.
2. Attach 16*plus*-IM V2 to insulated mooring cable with Sea-Bird mounting brackets. Install (optional) ICC on mooring cable.
3. SIM wiring and configuration (or see IMM manual for wiring if applicable):
   A. *Power* – Normal Setting: Power common to JP1 pin 1, 7-25 VDC to JP1 pin 2, jumper on J3.
   B. *Interface* – Connect I/O cable to JP2 and to computer serial port.
   RS-232: J1 pins 2 and 3, J2 pins 2 and 3, J4 no jumper. RS-485: J1 pins 1 and 2, J2 pins 1 and 2, J4 jumper.
   C. *Inductive Cable Connection* –
   With ICC: Connect ICC to JP4; Without ICC: Connect mooring cable and seawater ground to JP4.
   D. *Deployed Operation* – Jumper J5 *Instrument Setup and Lab Testing* – No jumper on J5.



Direct Connection



Connection with Inductive Cable Coupler (ICC)

Command Instructions and List

Shown below are the commands used most commonly in the field. See the Manual for complete listing and detailed descriptions.

Function	Category	Command	Description
IMM Commands	**-**	See the IMM manual.	
SIM Commands	**Power-On**	**PwrOn**	Send wakeup tone to **all** 16*plus*-IM V2s.
		PwrOff	Send power off command to **all** 16*plus*-IM V2s. Logging and memory unaffected.
		AutoPwrOn=x	**x=Y** (default): Send **PwrOn** to 16*plus*-IM V2s when power applied to SIM. **x=N**: Do not.
	Status	**DS**	Display SIM firmware version and setup parameters.
	Comms	**Baud=x**	**x=** baud from SIM to computer (1200, 2400, 4800, or 9600). Default 9600.
		DataNNMax=x	**x=** timeout that applies to **iiData** or **Dataii**; default 1000 milliseconds.
		RelayMax=x	**x=** timeout that applies to all other commands; default 20 seconds.
		EchoOn EchoOff	Echo characters received from computer. Do not.
16*plus*-IM V2 Communication Microcontroller Commands	**Global**	**DateTime= mmddyyyyhhmmss**	Set **all** real-time clocks: month, day, year, hour, minute, second.
		GData	Command **all** 16*plus*-IM V2 communication microcontrollers to get data from 16*plus*-IM V2 acquisition microcontrollers. Communication microcontrollers hold data in buffer until receiving **iiData** or **Dataii**.
	Get Data	**iiData** or **Dataii**	Get data obtained with **GData** from 16*plus*-IM V2 with ID=ii.
	16*plus*-IM V2 ID	**ID?**	Display 16*plus*-IM V2 ID (ID = ii, where ii=0 to 99)
		***ID=ii**	Set ID to **ii** (ii=0 to 99). Only one 16*plus*-IM V2 can be on line or all 16*plus*-IM V2s on line will have same ID. Computer responds by requesting verification.
	Status	**!iiDS**	Display communication microcontroller status.
	Timeout	**!iiWait=x**	**x=** time for communication microcontroller to wait for response from acquisition microcontroller. Range 2 – 600 seconds.
16*plus*-IM V2 Acquisition Microcontroller Commands (ii = 16*plus*-IM V2 ID)	**Status**	**#iiGetCD**	Get and display configuration data (setup parameters).
		#iiGetSD	Get and display status data.
		#iiGetCC	Get and display calibration coefficients.
		#iiGetEC	Get and display event counter data.
		#iiResetEC	Reset all events in event counter.
		#iiGetHD	Get and display hardware data.
		#iiDS	Display status and setup parameters.
		#iiDCal	Display calibration coefficients.
	General Setup	**#iiDateTime= mmddyyyyhhmmss**	Set real-time clock month, day, year, hour, minute, second.
		#iiOutputExecutedTag=x	**x=Y**: Display XML Executing and Executed tags. **x=N**: Do not.
		#iiPumpMode=x	**x=0**: No pump. **x=1**: Run pump for 0.5 seconds before each sample. **x=2**: Run pump during each sample.
		#iiNCycles=x	**x=** number of samples to take and average every **#iiSampleInterval** seconds.
		#iiInitLogging	After uploading all data, send this command before starting to log to make entire memory available for recording. If not sent, data stored after last sample.
	Pressure Setup	**#iiRefPress=x**	**x=** reference pressure (decibars) (for 16*plus*-IM V2 without pressure sensor).
		#iiParosIntegration=x	**x=** integration time (sec) for Quartz pressure sensor (1 – 600 sec; default 1 sec).
	Voltage Sensor Setup	**#iiVolt0=x, #iiVolt1=x, #iiVolt2=x, #iiVolt3=x, #iiVolt4=x, #iiVolt5=x**	**x=Y**: Enable external voltage (voltage 0, 1, 2, 3, 4, or 5). **x=N**: Do not.
		#iiDelayBeforeSampling=x	**x=** time (sec) to wait after powering external voltage before sampling (0-600 sec).
		#iiBioWiper=x	**x=Y**: Configuration includes ECO-FL fluorometer with Bio-Wiper. **x=N**: Does not.
	RS-232 Setup	**#iiSBE38=x**	**x=Y**: Enable SBE 38 secondary temperature sensor. **x=N**: Do not.
		#iiSBE50=x	**x=Y**: Enable SBE 50 secondary pressure sensor. **x=N**: Do not.
		#iiGTD=x	**x=Y**: Enable GTD. **x=N**: Do not.
		#iiDualGTD=x	**x=Y**: Enable dual GTDs. **x=N**: Do not.
		#iiOptode=x	**x=Y**: Enable Aanderaa Optode. **x=N**: Do not.
	Output Format Setup	**#iiOutputFormat=x**	**x=0**: output raw data, Hex. **x=1**: converted data, Hex. **x=2**: raw data, decimal. **x=3**: converted data, decimal. **x=5**: converted data, decimal, XML.
		#iiOutputSal=x	**x=Y**: Calculate salinity (psu) (if **#iiOutputFormat=3** or **5**). **x=N**: Do not.
		#iiOutputSV=x	**x=Y**: Calculate sound velocity (m/sec) (if **#iiOutputFormat=3** or **5**). **x=N**: Do not.
		#iiOutputUCSD=x	**x=Y**: Calculate sigma-t, battery voltage, operating current (if **#iiOutputFormat=3** or **5**). **x=N**: Do not.
		#iiOutputSampleNumber=x	**x=Y**: Output sample number with data (if **#iiOutputFormat=3** or **5**). **x=N**: Do not.
	Autonomous Sampling (Logging)	**#iiSampleInterval=x**	**x** = interval between samples (10 - 14400 seconds).
		#iiStartNow	Start logging now. Data stored in FLASH memory.
		#iiStartDateTime= mmddyyyyhhmmss	Delayed logging start: month day year, hour, minute, second.
		#iiStartLater	Start logging at delayed start date and time. Data stored in FLASH memory.
		#iiStop	Stop logging or waiting to log. Must send this command before uploading data.
	Polled Sampling	**#iiSL**	Output last sample from buffer.
		#iiSLT	Output last sample from buffer, take new sample, and store in buffer.
		#iiTS	Take sample, store data in buffer, and output data.
		#iiTSS	Take sample, **store in buffer and FLASH memory**, and output data.
		GetLastSamples:x	Output last **x** samples from FLASH memory.
	Data Upload	**GetSamples:b,e** or **#iiDDb,e**	Upload data from scan **b** to **e**. Send **#iiStop** before sending this.
		GetHeaders:b,e or **#iiDHb,e**	Upload headers from header **b** to **e**.

SPECIFICATIONS

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ICC Specification Sheet..... 5

SBE 16plusIM-V2 Specification Sheet..... 6

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SEACAT C-T Recorder (Inductive Modem)

SBE 16*plus*-IM V2

The SBE 16*plus*-IM **V2** (Version 2) SEACAT is a high-accuracy conductivity and temperature recorder (pressure is optional) with built-in **I**nductive **M**odem. The V2 is the most versatile successor in the line of SEACAT Recorders begun with the original SBE 16 SEACAT in 1987.



Compared to the previous 16*plus*-IM, the V2 incorporates an electronics upgrade and additional features. The V2 has two additional (six total) differentially-amplified A/D input channels, FLASH memory is increased from 8 to 64 MB, and one RS-232 data input channel is added. Data can be output in XML as well as ASCII and HEX formats.

The inductive modem provides reliable, low-cost, real-time data transmission using plastic-coated wire rope (typically 3 x 19 galvanized steel) as both the transmission line and mooring tension member. IM instruments clamp anywhere along the rugged mooring wire. Expensive and potentially unreliable multi-conductor electrical cables with fixed-position underwater connectors are not required. IM moorings are easily reconfigured for changing deployments (positions can be changed or instruments added or removed), by sliding and re-clamping sensors on the cable. Inductive modem systems are much less expensive and more power-efficient than acoustic modems, and offer reliable communication over greater distances.

In a typical real-time surface mooring, a **S**urface **I**nductive **M**odem (SIM) housed in the buoy communicates with the underwater IM instruments and is interfaced to a computer or data logger via an RS-232 serial port. The computer or data logger (not supplied by Sea-Bird) is programmed to poll each IM instrument on the mooring for its data, assemble all the instrument data into files, and send the files to a telemetry transmitter (satellite link, cell phone, RF modem, etc.). The 16*plus*-IM V2 simultaneously saves its data in memory for upload after recovery, providing a backup against lost data in the event real-time telemetry is interrupted.

The SBE 16*plus*-IM V2 uses the same temperature and conductivity sensors (and optional silicon strain gauge or Digiquartz® pressure sensors) proven in 10,000 SEACATs and MicroCATs. Calibration coefficients are stored in memory, permitting data output in ASCII engineering units (°C, S/m, decibars, salinity [PSU], sound velocity [m/sec], etc.). The sample interval, ranging from 10 to 14,400 seconds, is user-programmable in 1-second increments. Between samples, the 16*plus*-IM V2 powers down, drawing only 140 microamps. Alkaline D-cells provide power for approximately 290,000 samples of C and T, depending on the sampling and telemetry schedule. Six differentially amplified A/D input channels and one RS-232 channel provide conditioned power (500 ma) for, and obtain data from, optional auxiliary sensors (oxygen, turbidity, fluorescence, etc.).

COMMUNICATIONS AND INTERFACING

Both ends of the jacketed (insulated) wire rope connecting the buoy to its anchor are grounded to seawater via metal connection terminals (eyes) swaged to its steel core. This completes a conductive loop through the wire rope and the water. An Inductive Cable Coupler (ICC) serves as a coupling transformer similar to the one built into the SBE 16*plus*-IM V2, but clamped to the jacketed mooring wire just under the buoy, and connects to the SIM (SIM and ICC available separately). Commands and data are transmitted half-duplex between the SIM and 16*plus*-IM V2 using DPSK (differential-phase-shift-keyed) telemetry. DPSK telemetry provides a high degree of immunity from “fish bite” or other cable degradation and provides a maximum transmission distance of 8000 meters between the SIM and an underwater IM instrument. Lab diagnostics, setup, and data extraction are performed by looping an insulated wire through the inductive core on the 16*plus*-IM V2 and connecting the wire ends to the SIM.

Upon receipt of a wake-up command from a computer or data logger, the SIM sends a tone for 2 seconds, waking all IMs on the wire. Each 16*plus*-IM V2 has a programmable ID number (0-99). A 16*plus*-IM V2 only replies to a command containing its individual ID. After replying, it returns to listening mode, waiting for commands. A global power-off command returns all IM instruments to standby (sleep) state. The16*plus*-IM V2 automatically returns to sleep state if there is no line activity for 2 minutes.

CONFIGURATION, OPTIONS, AND ACCESSORIES

A standard SBE 16*plus*-IM V2 is supplied with plastic housing for depths to 600 meters, 64 Mbyte FLASH memory, alkaline batteries, glass-reinforced epoxy bulkhead connectors, and expendable anti-foulant devices.

Options and accessories include:
- Titanium housing for depths to 7000 meters
- Semi-conductor strain gauge pressure sensor or Digiquartz® pressure sensor
- Wet-pluggable MCBH series connectors
- SBE 5M pump (conductivity only) or SBE 5P / 5T for pumped conductivity and pumped auxiliary sensors
- Auxiliary sensors for dissolved oxygen, fluorescence, turbidity, etc. (consult factory)
- Battery pack kit for lithium batteries (lithium batteries **not** supplied by Sea-Bird)

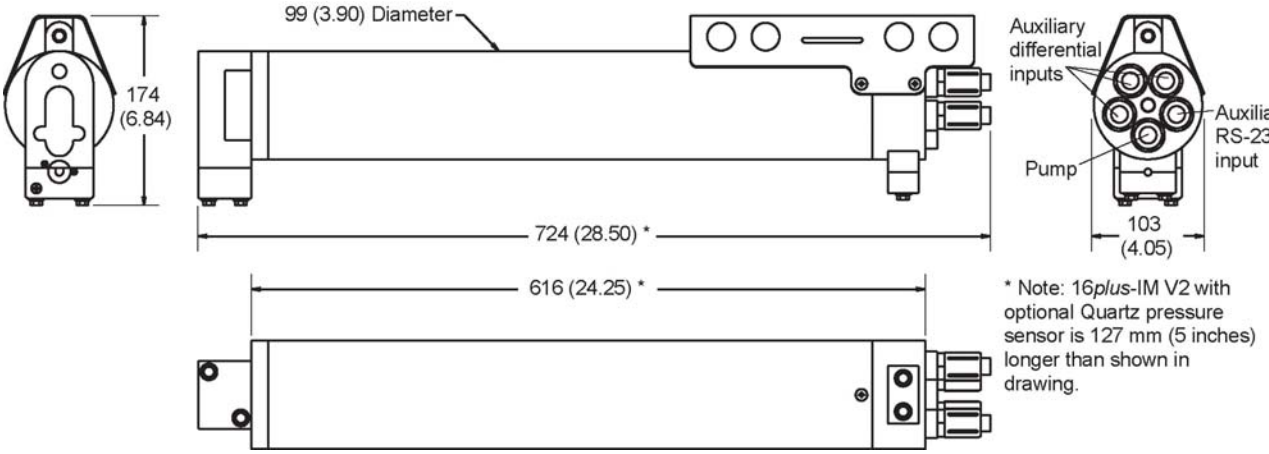
SOFTWARE

The SBE 16*plus*-IM V2 is supplied with a powerful Windows 2000/XP software package, SEASOFT©-Win32, which includes programs for communication and data retrieval, and data processing (filtering, aligning, averaging) and plotting of CTD and auxiliary sensor data and derived variables.

Sea-Bird Electronics, Inc.
1808 136th Place NE, Bellevue, Washington 98005 USA
Website: http://www.seabird.com
E-mail: seabird@seabird.com
Telephone: (425) 643-9866
Fax: (425) 643-9954

SEACAT C-T Recorder (Inductive Modem)

SBE 16*plus*-IM V2



Dimensions in millimeters (inches)

* Note: 16*plus*-IM V2 with optional Quartz pressure sensor is 127 mm (5 inches) longer than shown in drawing.

SPECIFICATIONS

Measurement Range

Temperature	-5 to +35 °C
Conductivity	0 to 9 S/m
Pressure (optional)	Strain-gauge — 0 to 20/100/350/600/1000/2000/3500/7000 m
	Quartz — 0 to 20/60/130/200/270/680/1400/2000/4200/7000 m

Initial Accuracy

Temperature	0.005 °C
Conductivity	0.0005 S/m
Pressure (optional)	Strain-gauge — 0.1% of full scale range
	Quartz — 0.02% of full scale range

Typical Stability

Temperature	0.0002 °C/month
Conductivity	0.0003 S/m/month
Pressure (optional)	Strain-gauge — 0.1% of full scale range/year
	Quartz — 0.025% of full scale range/year

Resolution

Temperature	0.0001 °C
Conductivity	0.00005 S/m typical
Pressure (optional)	Strain-gauge — 0.002% of full scale range
	Quartz — depends on sample integration time; consult factory

Memory 64 Mbyte non-volatile FLASH memory

Data Storage

Recorded Parameter	Bytes/Sample
T + C	6 (3 each)
Pressure - *strain gauge* or *Quartz*	5
each external voltage	2
auxiliary RS-232 sensor	sensor dependent
date and time	4

Real-Time Clock 32,768 Hz TCXO accurate to ±1 minute/year

Internal Batteries 9 alkaline D-cells

Battery Endurance [1]

CT only — 290,000 samples
CTD only — 200,000 samples
CTD & 5M pump — 110,000 samples

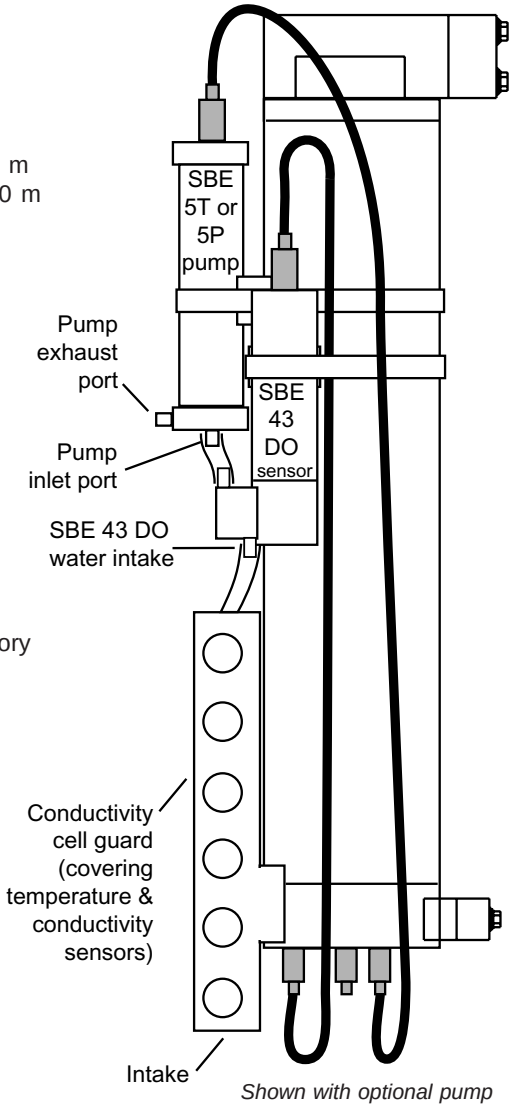
[1] With Duracell MN1300 cells. Dependent on sampling scheme.

Auxiliary Voltage Sensors

Auxiliary power out	up to 500 mA at 10.5 - 11 VDC
A/D resolution	14 bits
Input range	0 - 5 VDC

Housing Materials — Depth Rating — Weight

Acetal Copolymer *Plastic* housing — 600 m (1950 ft) — *in air* 9 kg (20 lbs), *in water* 4 kg (9 lbs)
3AL-2.5V *Titanium* housing — 7000 m (22,900 ft) — *in air* 17 kg (38 lbs), *in water* 12 kg (27 lbs)



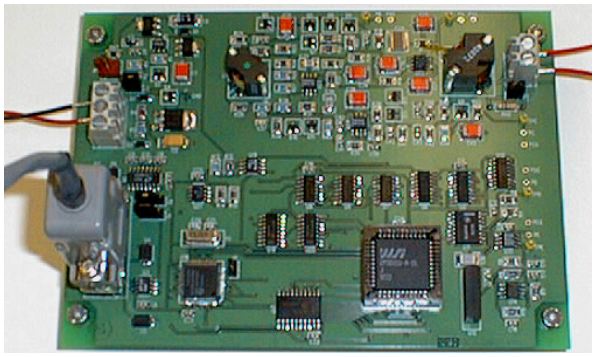
Shown with optional pump and dissolved oxygen sensor

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Surface Inductive Modem

SIM



The Surface Inductive Modem (SIM) is a vital link in Sea-Bird's inductive modem (IM) telemetry systems, which provide data communications without the need for underwater electrical connections. Each system requires:

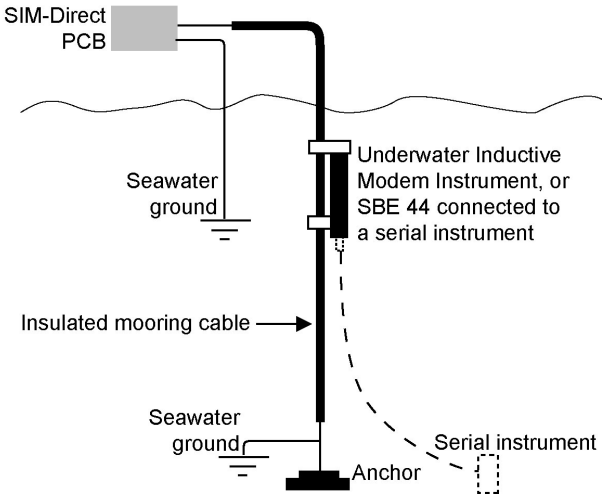
- **SIM**, housed in a buoy or on land. The SIM provides the link between the underwater IM instruments and computer / buoy controller. Communication with the computer / buoy controller is via RS-232 (optional RS-485).
- **Underwater IM instruments**. The SIM can link to up to 100 inductively coupled instruments on a jacketed mooring wire. Compatible instruments include:
  - SBE 37 MicroCAT C-T (optional pressure) Recorder – 37-IM, 37-IMP (integral Pump), or 37-IMP-IDO (integral Pump and integrated Dissolved Oxygen)
  - SBE 39-IM Temperature (optional pressure) Recorder
  - SBE 16*plus*-IM or 16*plus*-IM V2 SEACAT C-T Recorder (optional pressure), which can acquire additional data from optional auxiliary sensors (oxygen, fluorescence, etc.).
  - SBE 44 Underwater IM, which links to a current meter, Doppler profiler, etc. with a standard serial interface.
  - Instruments by other manufacturers with built-in Sea-Bird underwater IMs.

The SIM (a modem is a *modulator/demodulator*) impresses (*modulates*) the mooring cable with a DPSK signal that is encoded with the commands received from the user's computer/controller. The encoded signal is *demodulated* by underwater inductive modem instruments coupled to the mooring cable. The underwater inductive modem instrument interprets the commands and transmits replies via the mooring cable, which are *demodulated* by the SIM. The DPSK communication link between the SIM and underwater modem is half-duplex, so talking and listening is sequential only. Although the data link between the SIM and the user's computer/controller is established at 1200, 2400, 4800, or 9600 baud, the DPSK modem communication between SIM and underwater modem operates at 1200 baud.

SIM VERSIONS

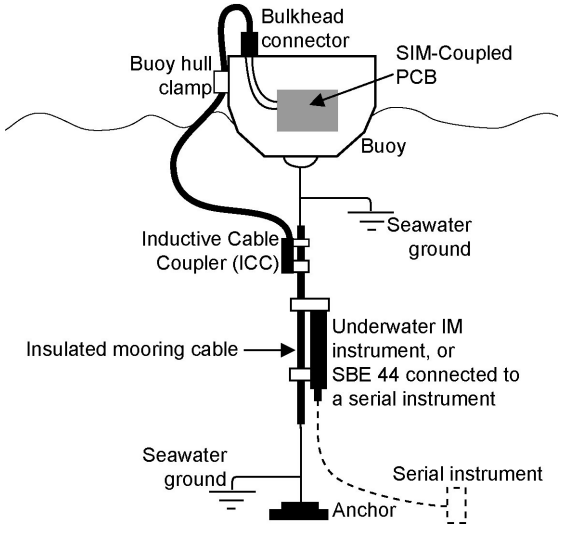
The SIM is available in two models, SIM-Direct and SIM-Coupled:

SIM-Direct: In a direct connection (typical cable to shore applications), the bottom end of the wire is grounded to seawater, and the top end remains insulated all the way to the connection to the SIM. A second wire from the SIM connects to seawater ground, completing the circuit.



SIM-Direct: Direct Connection

SIM-Coupled: In typical surface buoys it is often preferable to connect the jacketed mooring wire to the buoy with a length of chain, grounding the jacketed wire to seawater at each end. An Inductive Cable Coupler (ICC) connects the SIM to the jacketed wire above the uppermost underwater inductive instrument and below the point where the wire is grounded.



SIM-Coupled: ICC Connection

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Surface Inductive Modem SIM

DPSK (Differential Phase Shift Keyed) DATA TRANSMISSION

Sea-Bird's Inductive Modem telemetry system uses a DPSK data transmission method that overcomes most of the disadvantages of Frequency Shift Keyed (FSK) transmission, resulting in superior transmission efficiency and much lower error rates. The Sea-Bird system uses a carrier frequency of 4800 Hz, permitting four cycles of carrier frequency during the time allotted to each data bit (i.e., 1200 baud).

The encoding scheme is straightforward: if the next bit is a one, the phase of the carrier is inverted (shifted 180 degrees); if the next bit is a zero, the carrier phase does not change. With DPSK, both the modulation and demodulation hardware are extremely simple. Modulation requires only an OR gate and flip-flop, and demodulation is inherently coherent (bit energy is averaged rather than spot-sampled) using minimal hard logic, a shift register implementing a one-bit delay being the principle component. Further advantages are that the transmission of all zeros creates a single coherent frequency (4800 Hz) that is readily detected in inductive modem instruments as the *wake up* signal, and that - unlike FSK - the connection polarity of the transformers used for coupling does not matter.

COMMANDS

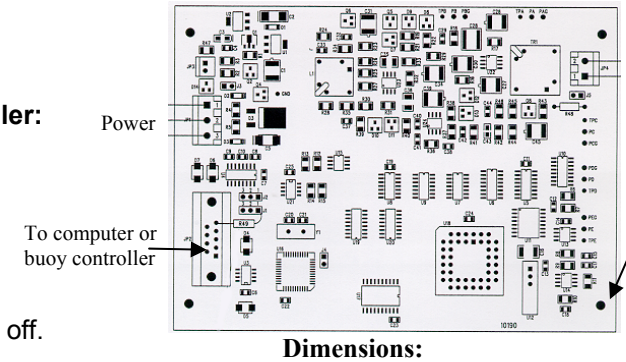
Commands sent to the SIM can be directed to the SIM, the underwater inductive modem, or the serial instrument connected to the underwater modem (if applicable). The commands below apply only to the SIM – see the appropriate underwater inductive modem manual for its commands.

COMMAND	DESCRIPTION
PwrOn	Send wakeup tone to **all** underwater modems.
PwrOff	Send power off command to **all** underwater modems, and turn off transmitter. Underwater modems enter quiescent (sleep) state. Any data in underwater modem buffer is erased.
AutoPwrOn=x	**x=Y** (default): Send **PwrOn** to underwater modems when power applied to SIM. This wakes up all UIMs on line. **x=N**: Do not send **PwrOn** to underwater modems when power applied to SIM.
DS	Display SIM firmware version and status.
Baud=x	**x** = baud rate between SIM and computer/controller (1200, 2400, 4800, 9600). Default 9600.
DataNNMax=x	**x** = timeout that applies to **Dataii** or **!iiData** only. If no reply received within **x** (0-32,767 milliseconds), control returned to computer and other commands can be sent. Default 1000 milliseconds.
RelayMax=x	**x** = timeout that applies to all other commands. If no reply received within **x** (0-3276 seconds), control returned to computer and other commands can be sent. Default 20 seconds.
EchoOn	Echo characters received from computer (default).
EchoOff	Do not echo characters received from computer.
BinaryGap=x	**x** = termination timeout (0 – 65,535 milliseconds) that applies to commands requesting binary response from SBE 44. Gap of **x** since last byte received acts as termination character. Bytes sent after gap are ignored; control is returned to computer and other commands can be sent. Default 1000 milliseconds.

Note:
When using RS-232 communication from the computer to the SIM, control of the SIM can be re-established sooner than the timeout by pressing the Esc key and then the Enter key. When the S> prompt is displayed, new commands can be sent.

SPECIFICATIONS

SIM Specifications
Sensor Interface to computer or buoy controller:
Standard: RS-232C; 1200, 2400, 4800, or 9600 baud; 8 data bits; no parity; echoing or no echoing of characters
Optional: RS-485
Current: 30 mA when communicating, 27 mA in quiescent state (**PwrOff**). With control line, < 10 microamps when turned off.
Power: 7-25 VDC



Dimensions:
PCB: 109 mm x 147.5 mm (4 1/4 x 5 3/4 inches)
Mounting holes: 90.5 mm x 138.1 mm (3 9/16 x 5 7/16 inches)

Underwater Inductive Modem Instrument Specifications –
See SBE 37-IMP, 37-IM, 37-IMP-IDO, 39-IM, 16*plus*-IM, 16*plus*-IM V2, and 44 datasheets

ICC Specifications –
See Inductive Cable Coupler datasheet

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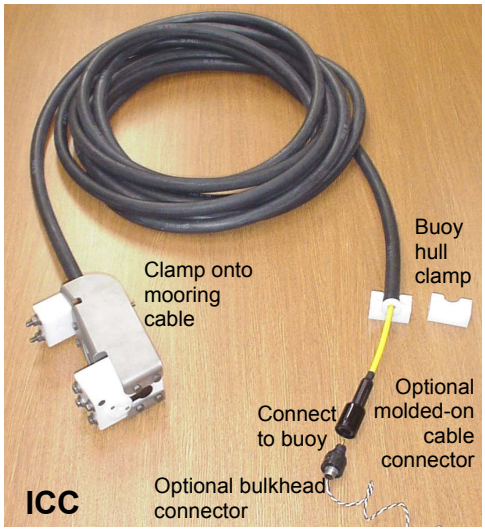
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Inductive Cable Coupler (Version 4) ICC

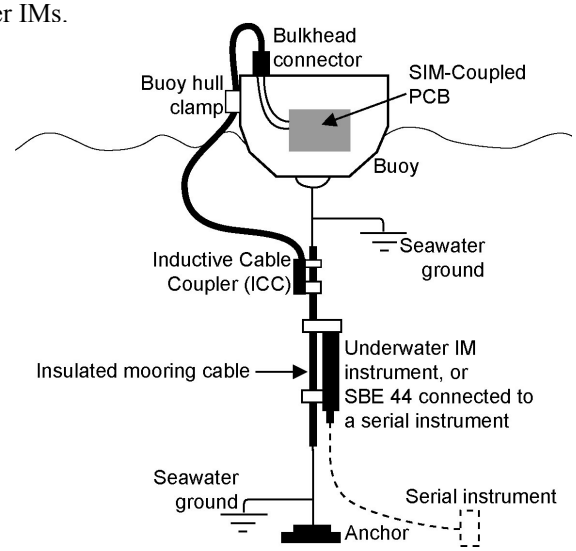
The ICC is a link in Sea-Bird's inductive modem (IM) telemetry systems. The ICC is used in applications where the plastic-jacketed wire termination is grounded to seawater (at a chain, for example). The ICC clamps to the jacketed mooring wire, and makes electrical connection with the Surface Inductive Modem (SIM) via a cable housed in reinforced-rubber conduit. The conduit's upper end is fixed to the buoy hull with the provided clamps. The conduit/cable must be long enough to prevent buoy motion from pulling it completely straight and putting tension on the ICC.

An IM telemetry system typically includes:

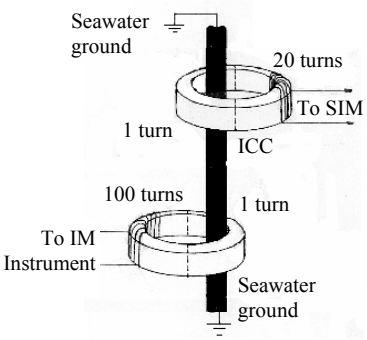
- **Surface Inductive Modem (SIM)**, housed in a buoy or on land. The SIM provides the link between the underwater IM instruments and computer / buoy controller.
- **Inductive Cable Coupler (ICC)**, which links the underwater IM and SIM *for typical buoy applications*.
- **Underwater IM instruments**, up to 100 inductively coupled instruments on a jacketed mooring wire. Compatible instruments include:
  - SBE 37-IMP (or 37-IM) MicroCAT C-T (optional pressure) Recorder.
  - SBE 39-IM Temperature (optional pressure) Recorder
  - SBE 16*plus*-IM SEACAT C-T (optional pressure) Recorder, which can acquire additional data from optional auxiliary sensors (oxygen, fluorescence, etc.).
  - SBE 44 Underwater IM, which links to a current meter, Doppler profiler, etc. with a standard serial interface.
  - Instruments by other manufacturers with built-in Sea-Bird underwater IMs.



Note: ICC includes pigtail cable, conduit, and buoy hull clamp; molded-on cable connector and bulkhead connector optional.



Inductive Modem System



PRINCIPLES OF INDUCTIVE COUPLING

A transformer has two or more coils that share a magnetic field. Materials such as ferrite can be used to form a transformer *core* that ensures the necessary sharing of magnetic fields.

When using the ICC with Sea-Bird's IM telemetry system, the ends of the mooring cable are grounded to the seawater. This causes a current to flow through the mooring wire and seawater. The ICC senses this current, providing a voltage for presentation to the SIM.

ICC CONFIGURATION CHOICES

- Mooring cable diameter - 1/4 inch, 5/16 inch, 3/8 inch, 1/2 inch, 6 mm, 8 mm, 10 mm, 12 mm, or 16 mm (5/8 inch)
- Cable length specified up to 10 meters (32.8 feet); longer lengths available – over 50 meters (164 feet) not recommended
- ICC comes with pigtail cable, conduit, and buoy hull clamp. Optional molded-on cable connector and matching bulkhead connector can be ordered; consult factory for availability.

ICC DEPTH RATING

To 7000 meters (23,000 ft).

ADDITIONAL INFORMATION

See SBE 37-IMP, SBE 37-IM, SBE 39-IM, SBE 16*plus*-IM, SBE 44, and SIM datasheets.

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SEACAT C-T Recorder (Inductive Modem)

SBE 16*plus*-IM V2

The SBE 16*plus*-IM **V2** (Version 2) SEACAT is a high-accuracy conductivity and temperature recorder (pressure is optional) with built-in **I**nductive **M**odem. The V2 is the most versatile successor in the line of SEACAT Recorders begun with the original SBE 16 SEACAT in 1987.



Compared to the previous 16*plus*-IM, the V2 incorporates an electronics upgrade and additional features. The V2 has two additional (six total) differentially-amplified A/D input channels, FLASH memory is increased from 8 to 64 MB, and one RS-232 data input channel is added. Data can be output in XML as well as ASCII and HEX formats.

The inductive modem provides reliable, low-cost, real-time data transmission using plastic-coated wire rope (typically 3 x 19 galvanized steel) as both the transmission line and mooring tension member. IM instruments clamp anywhere along the rugged mooring wire. Expensive and potentially unreliable multi-conductor electrical cables with fixed-position underwater connectors are not required. IM moorings are easily reconfigured for changing deployments (positions can be changed or instruments added or removed), by sliding and re-clamping sensors on the cable. Inductive modem systems are much less expensive and more power-efficient than acoustic modems, and offer reliable communication over greater distances.

In a typical real-time surface mooring, a **S**urface **I**nductive **M**odem (SIM) housed in the buoy communicates with the underwater IM instruments and is interfaced to a computer or data logger via an RS-232 serial port. The computer or data logger (not supplied by Sea-Bird) is programmed to poll each IM instrument on the mooring for its data, assemble all the instrument data into files, and send the files to a telemetry transmitter (satellite link, cell phone, RF modem, etc.). The 16*plus*-IM V2 simultaneously saves its data in memory for upload after recovery, providing a backup against lost data in the event real-time telemetry is interrupted.

The SBE 16*plus*-IM V2 uses the same temperature and conductivity sensors (and optional silicon strain gauge or Digiquartz® pressure sensors) proven in 10,000 SEACATs and MicroCATs. Calibration coefficients are stored in memory, permitting data output in ASCII engineering units (°C, S/m, decibars, salinity [PSU], sound velocity [m/sec], etc.). The sample interval, ranging from 10 to 14,400 seconds, is user-programmable in 1-second increments. Between samples, the 16*plus*-IM V2 powers down, drawing only 140 microamps. Alkaline D-cells provide power for approximately 290,000 samples of C and T, depending on the sampling and telemetry schedule. Six differentially amplified A/D input channels and one RS-232 channel provide conditioned power (500 ma) for, and obtain data from, optional auxiliary sensors (oxygen, turbidity, fluorescence, etc.).

COMMUNICATIONS AND INTERFACING

Both ends of the jacketed (insulated) wire rope connecting the buoy to its anchor are grounded to seawater via metal connection terminals (eyes) swaged to its steel core. This completes a conductive loop through the wire rope and the water. An Inductive Cable Coupler (ICC) serves as a coupling transformer similar to the one built into the SBE 16*plus*-IM V2, but clamped to the jacketed mooring wire just under the buoy, and connects to the SIM (SIM and ICC available separately). Commands and data are transmitted half-duplex between the SIM and 16*plus*-IM V2 using DPSK (differential-phase-shift-keyed) telemetry. DPSK telemetry provides a high degree of immunity from “fish bite” or other cable degradation and provides a maximum transmission distance of 8000 meters between the SIM and an underwater IM instrument. Lab diagnostics, setup, and data extraction are performed by looping an insulated wire through the inductive core on the 16*plus*-IM V2 and connecting the wire ends to the SIM.

Upon receipt of a wake-up command from a computer or data logger, the SIM sends a tone for 2 seconds, waking all IMs on the wire. Each 16*plus*-IM V2 has a programmable ID number (0-99). A 16*plus*-IM V2 only replies to a command containing its individual ID. After replying, it returns to listening mode, waiting for commands. A global power-off command returns all IM instruments to standby (sleep) state. The16*plus*-IM V2 automatically returns to sleep state if there is no line activity for 2 minutes.

CONFIGURATION, OPTIONS, AND ACCESSORIES

A standard SBE 16*plus*-IM V2 is supplied with plastic housing for depths to 600 meters, 64 Mbyte FLASH memory, alkaline batteries, glass-reinforced epoxy bulkhead connectors, and expendable anti-foulant devices.

Options and accessories include:
- Titanium housing for depths to 7000 meters
- Semi-conductor strain gauge pressure sensor or Digiquartz® pressure sensor
- Wet-pluggable MCBH series connectors
- SBE 5M pump (conductivity only) or SBE 5P / 5T for pumped conductivity and pumped auxiliary sensors
- Auxiliary sensors for dissolved oxygen, fluorescence, turbidity, etc. (consult factory)
- Battery pack kit for lithium batteries (lithium batteries **not** supplied by Sea-Bird)

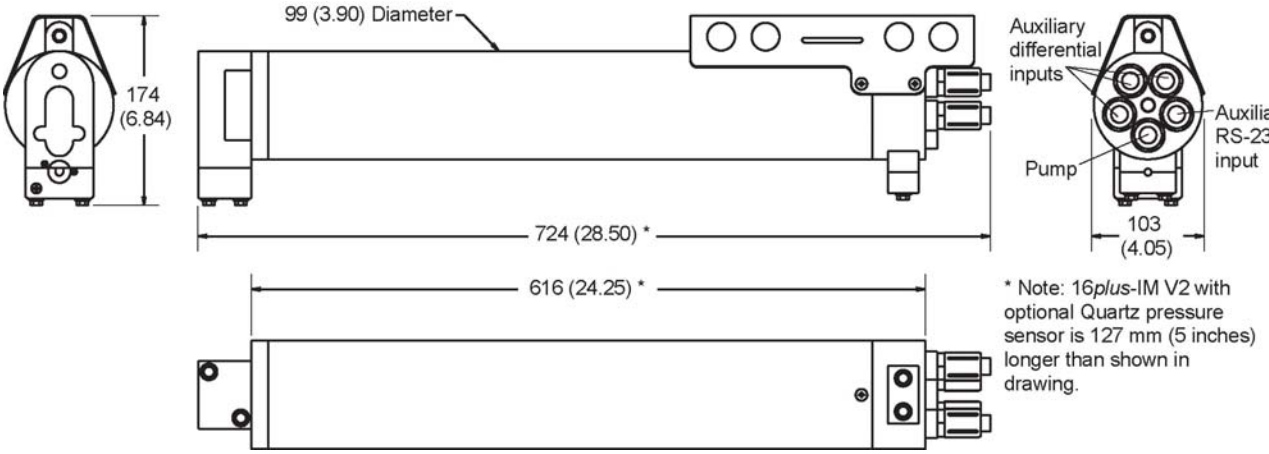
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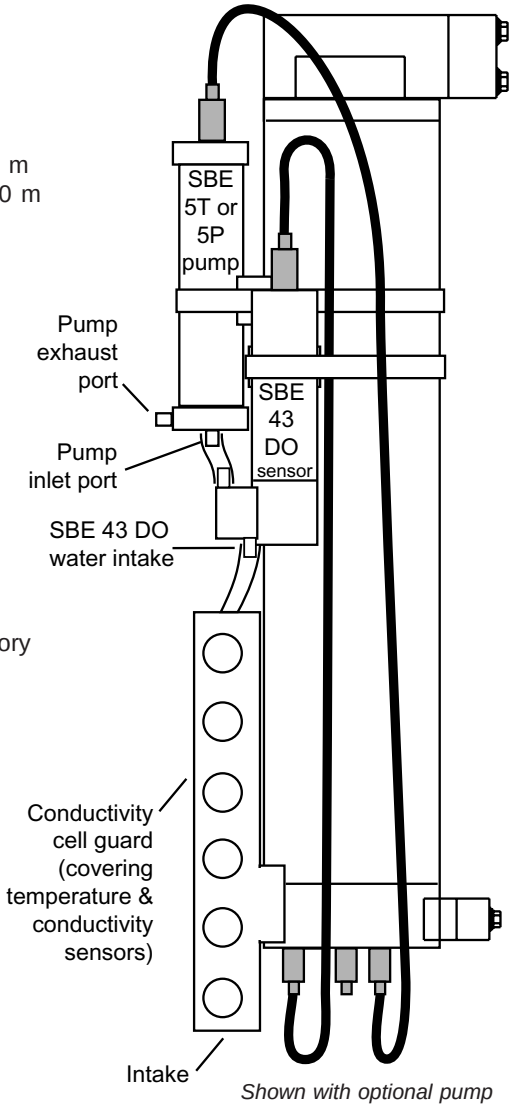
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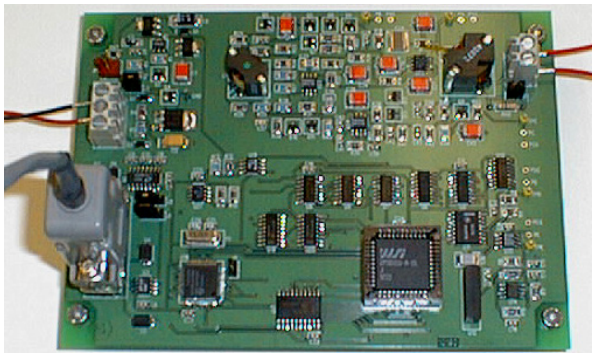
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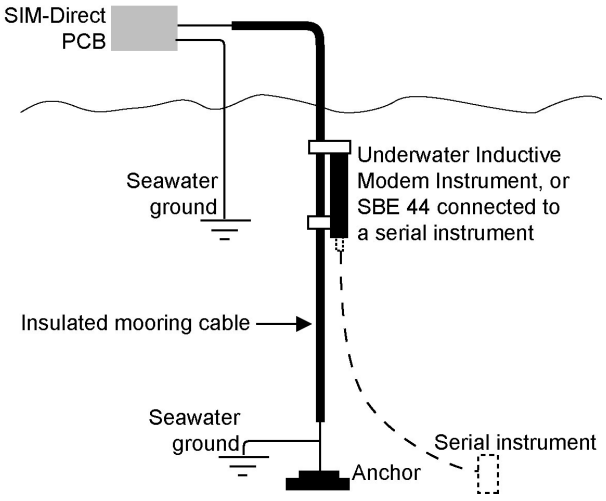
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SIM VERSIONS

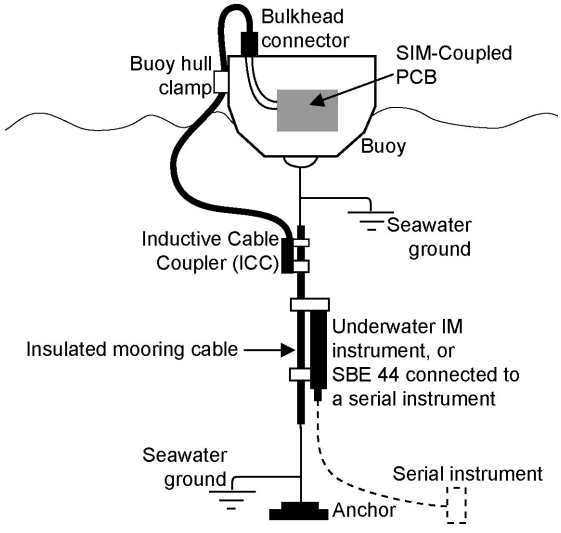
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SIM-Direct: In a direct connection (typical cable to shore applications), the bottom end of the wire is grounded to seawater, and the top end remains insulated all the way to the connection to the SIM. A second wire from the SIM connects to seawater ground, completing the circuit.



SIM-Direct: Direct Connection

SIM-Coupled: In typical surface buoys it is often preferable to connect the jacketed mooring wire to the buoy with a length of chain, grounding the jacketed wire to seawater at each end. An Inductive Cable Coupler (ICC) connects the SIM to the jacketed wire above the uppermost underwater inductive instrument and below the point where the wire is grounded.



SIM-Coupled: ICC Connection

Sea-Bird Electronics, Inc.
1808 136th Place NE, Bellevue, Washington 98005 USA
Website: http://www.seabird.com
E-mail: seabird@seabird.com
Telephone: (425) 643-9866
Fax: (425) 643-9954

Surface Inductive Modem SIM

DPSK (Differential Phase Shift Keyed) DATA TRANSMISSION

Sea-Bird's Inductive Modem telemetry system uses a DPSK data transmission method that overcomes most of the disadvantages of Frequency Shift Keyed (FSK) transmission, resulting in superior transmission efficiency and much lower error rates. The Sea-Bird system uses a carrier frequency of 4800 Hz, permitting four cycles of carrier frequency during the time allotted to each data bit (i.e., 1200 baud).

The encoding scheme is straightforward: if the next bit is a one, the phase of the carrier is inverted (shifted 180 degrees); if the next bit is a zero, the carrier phase does not change. With DPSK, both the modulation and demodulation hardware are extremely simple. Modulation requires only an OR gate and flip-flop, and demodulation is inherently coherent (bit energy is averaged rather than spot-sampled) using minimal hard logic, a shift register implementing a one-bit delay being the principle component. Further advantages are that the transmission of all zeros creates a single coherent frequency (4800 Hz) that is readily detected in inductive modem instruments as the *wake up* signal, and that - unlike FSK - the connection polarity of the transformers used for coupling does not matter.

COMMANDS

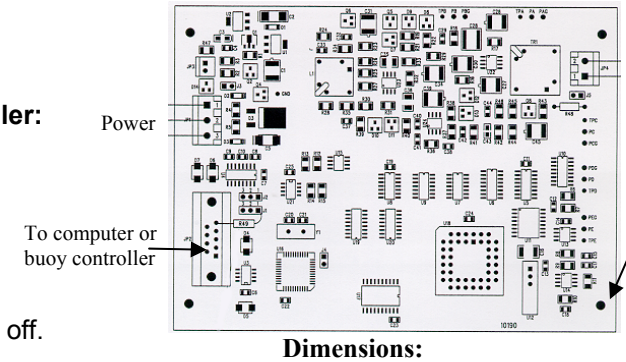
Commands sent to the SIM can be directed to the SIM, the underwater inductive modem, or the serial instrument connected to the underwater modem (if applicable). The commands below apply only to the SIM – see the appropriate underwater inductive modem manual for its commands.

COMMAND	DESCRIPTION
PwrOn	Send wakeup tone to **all** underwater modems.
PwrOff	Send power off command to **all** underwater modems, and turn off transmitter. Underwater modems enter quiescent (sleep) state. Any data in underwater modem buffer is erased.
AutoPwrOn=x	**x=Y** (default): Send **PwrOn** to underwater modems when power applied to SIM. This wakes up all UIMs on line. **x=N**: Do not send **PwrOn** to underwater modems when power applied to SIM.
DS	Display SIM firmware version and status.
Baud=x	**x** = baud rate between SIM and computer/controller (1200, 2400, 4800, 9600). Default 9600.
DataNNMax=x	**x** = timeout that applies to **Dataii** or **!iiData** only. If no reply received within **x** (0-32,767 milliseconds), control returned to computer and other commands can be sent. Default 1000 milliseconds.
RelayMax=x	**x** = timeout that applies to all other commands. If no reply received within **x** (0-3276 seconds), control returned to computer and other commands can be sent. Default 20 seconds.
EchoOn	Echo characters received from computer (default).
EchoOff	Do not echo characters received from computer.
BinaryGap=x	**x** = termination timeout (0 – 65,535 milliseconds) that applies to commands requesting binary response from SBE 44. Gap of **x** since last byte received acts as termination character. Bytes sent after gap are ignored; control is returned to computer and other commands can be sent. Default 1000 milliseconds.

Note:
When using RS-232 communication from the computer to the SIM, control of the SIM can be re-established sooner than the timeout by pressing the Esc key and then the Enter key. When the S> prompt is displayed, new commands can be sent.

SPECIFICATIONS

SIM Specifications
Sensor Interface to computer or buoy controller:
Standard: RS-232C; 1200, 2400, 4800, or 9600 baud; 8 data bits; no parity; echoing or no echoing of characters
Optional: RS-485
Current: 30 mA when communicating, 27 mA in quiescent state (**PwrOff**). With control line, < 10 microamps when turned off.
Power: 7-25 VDC



Dimensions:
PCB: 109 mm x 147.5 mm (4 1/4 x 5 3/4 inches)
Mounting holes: 90.5 mm x 138.1 mm (3 9/16 x 5 7/16 inches)

Underwater Inductive Modem Instrument Specifications –
See SBE 37-IMP, 37-IM, 37-IMP-IDO, 39-IM, 16*plus*-IM, 16*plus*-IM V2, and 44 datasheets

ICC Specifications –
See Inductive Cable Coupler datasheet

01/09

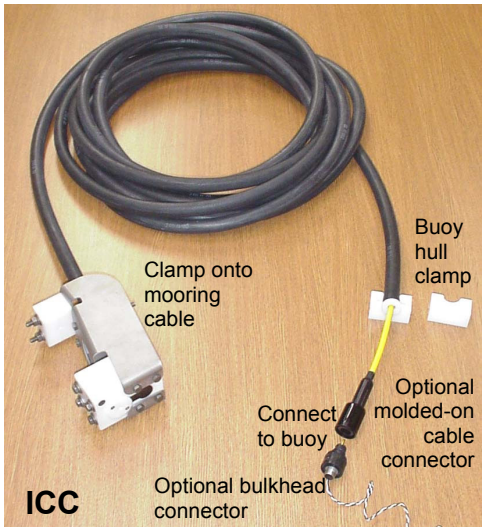
Sea-Bird Electronics, Inc.
1808 136th Place NE, Bellevue, Washington 98005 USA
Website: http://www.seabird.com
E-mail: seabird@seabird.com
Telephone: (425) 643-9866
Fax: (425) 643-9954

Inductive Cable Coupler (Version 4) ICC

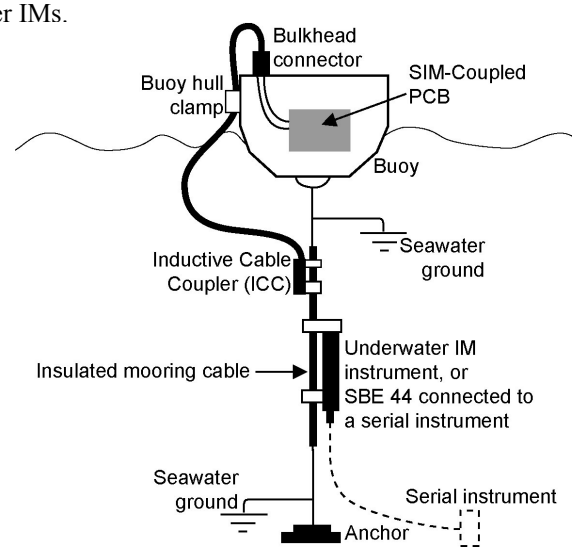
The ICC is a link in Sea-Bird's inductive modem (IM) telemetry systems. The ICC is used in applications where the plastic-jacketed wire termination is grounded to seawater (at a chain, for example). The ICC clamps to the jacketed mooring wire, and makes electrical connection with the Surface Inductive Modem (SIM) via a cable housed in reinforced-rubber conduit. The conduit's upper end is fixed to the buoy hull with the provided clamps. The conduit/cable must be long enough to prevent buoy motion from pulling it completely straight and putting tension on the ICC.

An IM telemetry system typically includes:

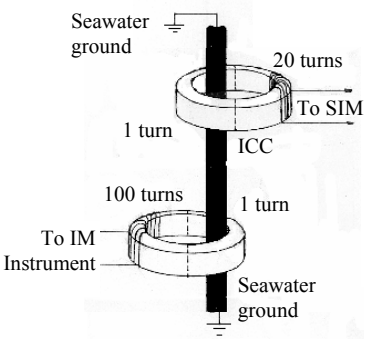
- **Surface Inductive Modem (SIM)**, housed in a buoy or on land. The SIM provides the link between the underwater IM instruments and computer / buoy controller.
- **Inductive Cable Coupler (ICC)**, which links the underwater IM and SIM *for typical buoy applications*.
- **Underwater IM instruments**, up to 100 inductively coupled instruments on a jacketed mooring wire. Compatible instruments include:
  - SBE 37-IMP (or 37-IM) MicroCAT C-T (optional pressure) Recorder.
  - SBE 39-IM Temperature (optional pressure) Recorder
  - SBE 16*plus*-IM SEACAT C-T (optional pressure) Recorder, which can acquire additional data from optional auxiliary sensors (oxygen, fluorescence, etc.).
  - SBE 44 Underwater IM, which links to a current meter, Doppler profiler, etc. with a standard serial interface.
  - Instruments by other manufacturers with built-in Sea-Bird underwater IMs.



Note: ICC includes pigtail cable, conduit, and buoy hull clamp; molded-on cable connector and bulkhead connector optional.



Inductive Modem System



PRINCIPLES OF INDUCTIVE COUPLING

A transformer has two or more coils that share a magnetic field. Materials such as ferrite can be used to form a transformer *core* that ensures the necessary sharing of magnetic fields.

When using the ICC with Sea-Bird's IM telemetry system, the ends of the mooring cable are grounded to the seawater. This causes a current to flow through the mooring wire and seawater. The ICC senses this current, providing a voltage for presentation to the SIM.

ICC CONFIGURATION CHOICES

- Mooring cable diameter - 1/4 inch, 5/16 inch, 3/8 inch, 1/2 inch, 6 mm, 8 mm, 10 mm, 12 mm, or 16 mm (5/8 inch)
- Cable length specified up to 10 meters (32.8 feet); longer lengths available – over 50 meters (164 feet) not recommended
- ICC comes with pigtail cable, conduit, and buoy hull clamp. Optional molded-on cable connector and matching bulkhead connector can be ordered; consult factory for availability.

ICC DEPTH RATING

To 7000 meters (23,000 ft).

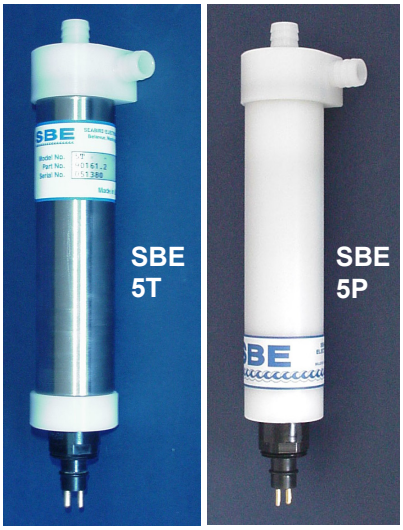
ADDITIONAL INFORMATION

See SBE 37-IMP, SBE 37-IM, SBE 39-IM, SBE 16*plus*-IM, SBE 44, and SIM datasheets.

Sea-Bird Electronics, Inc.
1808 136th Place NE, Bellevue, Washington 98005 USA
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Fax: (425) 643-9954

Submersible Pump — SBE 5T (titanium) & SBE 5P (plastic)

The pump module is a compact unit consisting of a centrifugal pump head and a long-life, brushless, DC, ball-bearing motor. The pump impeller and electric drive motor are coupled magnetically through the housing, providing high reliability by eliminating moving seals. The **5T** has a 10,500-meter (34,400-ft) titanium housing; the **5P** has a 600-meter (1960-ft) plastic housing. The operational characteristics of the 5T and 5P are identical.



APPLICATIONS

The pump is a primary component in the SBE 9*plus* CTD and 25 SEALOGGER CTD. It is also used as optional equipment on SBE 16*plus* V2, 16*plus*-IM V2, and 19*plus* V2 SEACAT CTDs. The pump flushes water through the conductivity cell at a constant rate, independent of the CTD's motion, improving dynamic performance. It may also be suitable for custom applications, where pressure heads are less than 300 cm of water and flow rates are less than 100 ml/sec.

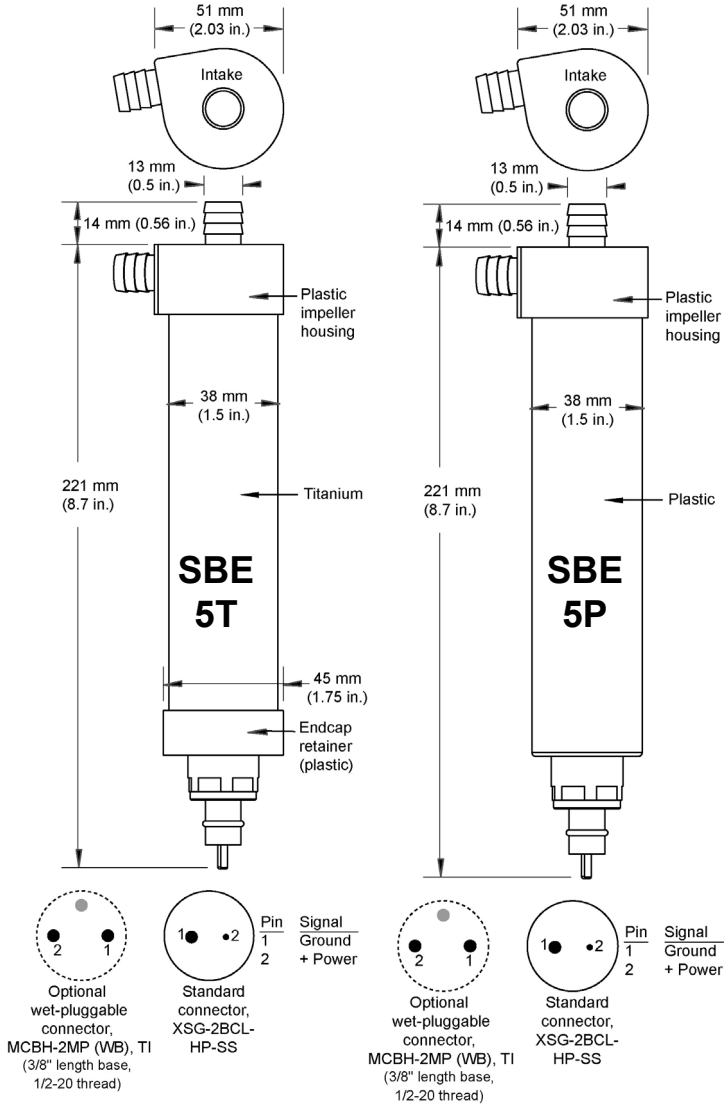
CONFIGURATION

The pump is configured by selecting standard or low voltage, and one of several motor speed options. Speed options of 1300, 2000, or 3000 rpm have been established to meet flow requirements for Sea-Bird applications. Other speeds can be set by adjusting a potentiometer.

- #3 winding, low voltage, 2000 rpm – typical for SBE 25
- # 3 winding, standard voltage, 2000 rpm – typical for SBE 16*plus* V2, 16*plus*-IM V2, or 19*plus* V2 with pumped auxiliary sensor(s)
- #3 winding, standard voltage, 3000 rpm – typical for SBE 9*plus*

OPERATION

Motor speed and pumping rate remain nearly constant over the entire input voltage range (less than 1% change in speed for a 1-volt change in supply voltage). The unrestricted flow rate with no head is approximately 100 ml/second at 2000 rpm. Flow changes are nearly linear with changes in speed. With unlimited supply current, turn-on surge is approximately 1.8 Amps (maximum), which drops to steady state in approximately 0.25 seconds. If power supply current is limited to approximately 200 milliAmps, the motor comes up to speed in approximately 0.30 seconds. A series diode is installed in the input power line to prevent damage if wires are accidentally reversed. Pumping rates and motor current for various applications are shown on the next page.



SPECIFICATIONS

Input Voltage:

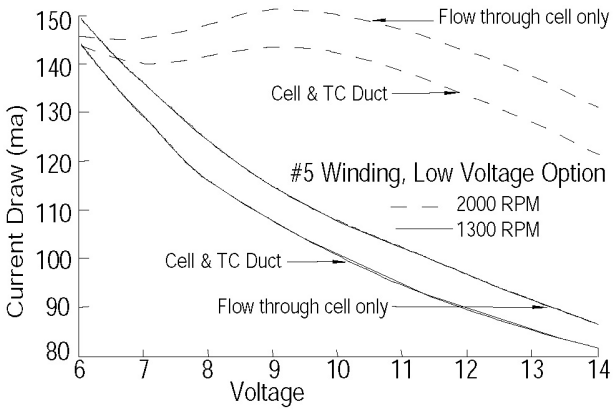
Standard input range (#3 winding; 1300 - 3000 RPM):
10 - 18 VDC
Low input range (#3 or #5 winding; 1300, 2000 RPM only):
6 - 16 VDC

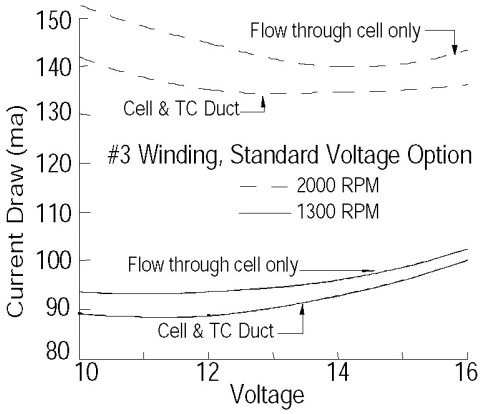
Weight:

SBE 5T - 0.7 kg (1.5 lbs) in air, 0.3 kg (0.7 lbs) in water;
SBE 5P – 0.5 kg (1.0 lb) in air, 0.1 kg (0.2 lbs) in water

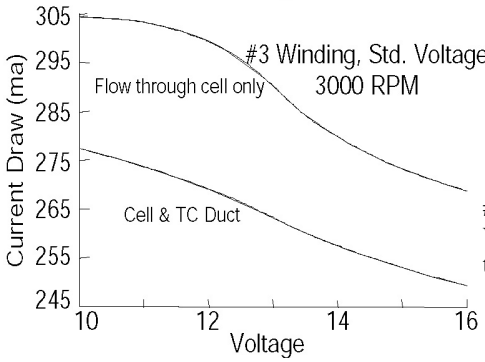
Sea-Bird Electronics, Inc.
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Website: http://www.seabird.com
E-mail: seabird@seabird.com
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Submersible Pump SBE 5T (titanium) & SBE 5P (plastic)

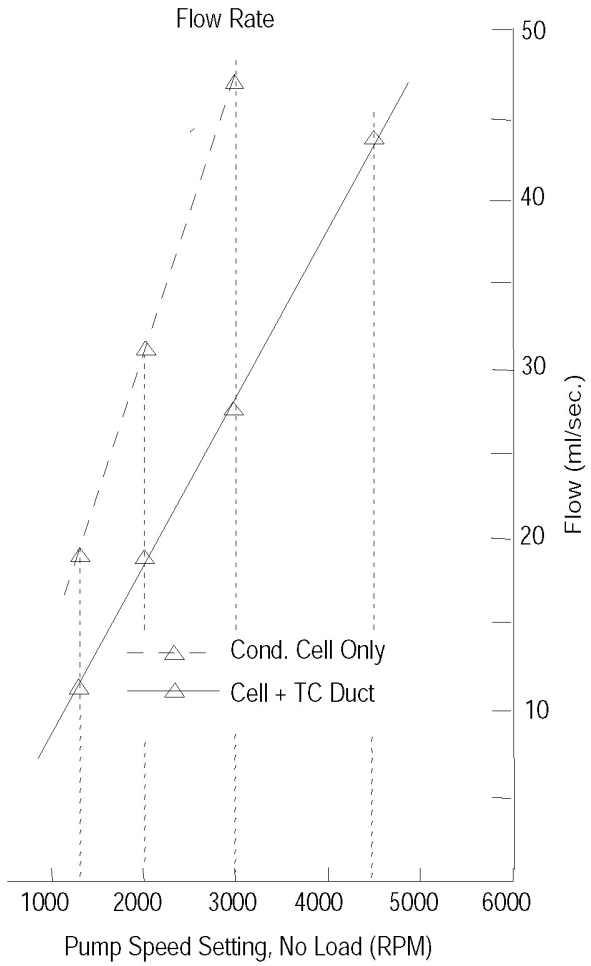


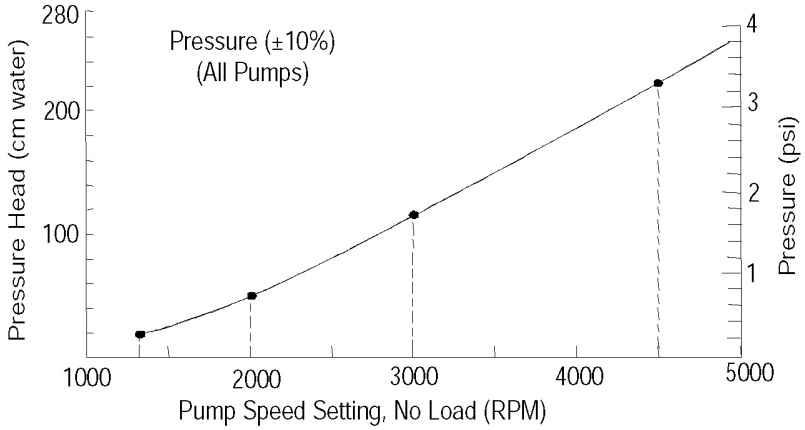


#3 Winding, Standard Voltage, 2000 RPM – typical for **SBE 16*plus***, **16*plus*-IM**, or **19*plus*** with pumped auxiliary sensor(s)



#3 Winding, Standard Voltage, 3000 RPM – typical for **SBE 9*plus***



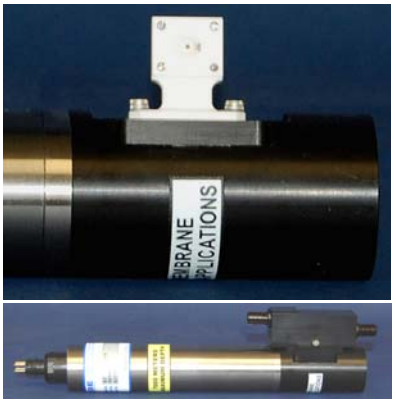


07/08

Sea-Bird Electronics, Inc.
1808 136th Place NE, Bellevue, Washington 98005 USA
Website: http://www.seabird.com
E-mail: seabird@seabird.com
Telephone: (425) 643-9866
Fax: (425) 643-9954

Sea-Bird Dissolved Oxygen Sensor

SBE 43



The SBE 43 sets the oxygen measurement standard for oceanographic research. The SBE 43 sensor is a complete redesign of the Clark polarographic membrane type, in which careful choices of materials, geometry, and sensor chemistry are combined with superior electronics interfacing and calibration methodology to yield major gains in performance.

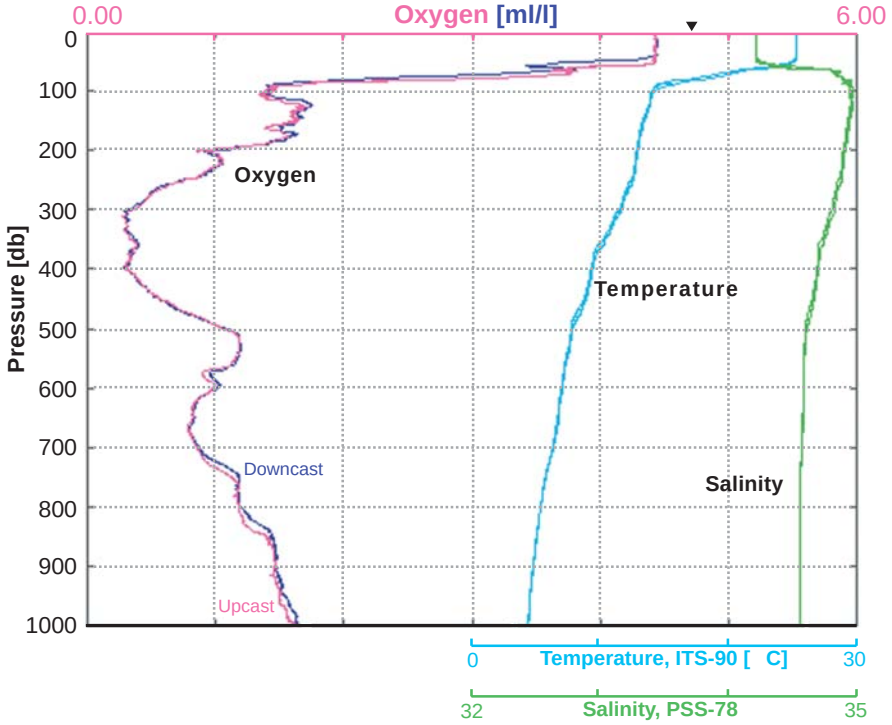
Calibration stability is improved by an order of magnitude, and the sensor requires less frequent calibration. Calibration drift is caused primarily by membrane fouling from ocean contaminants, and less so by chemical processes inside the sensor. If the membrane is kept clean, the sensor's improved chemical stability yields demonstrated calibration drift rates of less than 0.5% over 1000 hours of operation (*on* time).

Temperature response is dramatically improved. The chemical and physical processes that underlay the oxygen measurement are very sensitive to temperature. Accurate characterization of the internal sensor temperatures that control these processes, especially when water temperature is changing rapidly, is a key accomplishment of the design. Not only does the SBE 43 sensor measure temperature in the right place: the temperature equilibration time of the entire sensor head has been reduced to a few seconds, so it tracks changing water temperature much more faithfully.

Hysteresis is largely eliminated in the upper ocean (1000 meters) due to improved temperature response of the sensor. Residual mismatch between up and down casts in this part of the ocean is due to sensor alignment, correctable in post-processing. At higher pressures, changes occur in gas-permeable Teflon membranes that affect their permeability characteristics. These changes have long time constants, depend on the sensor's time-pressure history, and result in hysteresis at depths greater than 1000 meters. These effects are predictable and are also correctable in post-processing. The resultant SBE 43 measurement resolves oxygen features more precisely, reducing the ambiguity about locking measured sensor values to bottle Winklers.

Continuous polarization eliminates stabilization wait-time after power-up. The sensor is always ready for immediate use. Earlier sensors required several minutes to *polarize* following power-up. During that time, sensor readings were inaccurate. In the SBE 43, micropower electronics and an internal, five-year, board-mounted battery eliminate power-up delay.

Poisoning in hydrogen sulfide environments was a phenomenon common to early oxygen sensor designs that used silver as the cathode element. The SBE 43 uses a noble metal (gold) as the cathode and silver as the anode, and shows no degradation of signal or calibration when used for profiling in hydrogen sulfide environments.



Equatorial Pacific
2° 0.9' N, 110° 2.2' W
25 Oct 2000

24 Hz SBE 911*plus* data; oxygen measurements were time shifted 6 seconds relative to pressure to account for water transit time through TC Duct and plumbing. No other processing was performed.

▼ surface oxsat = 4.7 ml/l

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Sea-Bird Dissolved Oxygen Sensor

SBE 43

Signal resolution is increased by on-board temperature compensation, and a CTD channel is made available for other purposes because there is no *temperature* output signal. Even when oxygen concentration is constant, the normal range of ocean temperatures causes the output of earlier sensors to vary by a factor of two. The SBE 43's internal temperature compensation eliminates this variation, allowing the sensor to pre-amplify the signal proportionately; resolution with existing CTD systems is correspondingly increased.

Effective bio-fouling strategies allow for longer moored deployments. Plumbing isolates the SBE 43 from continuous exposure to the external fouling environment; allows trapped water to go anoxic, minimizing electrolyte consumption between samples; and holds anti-foulant in the trapped water. The black plenum and installing black tubing blocks light, reducing in-situ algal growth.

A 5-year warranty backs the sensor's integrity. During the warranty period, one sensor re-charge (electrolyte refill, membrane replacement, and recalibration) will be performed at Sea-Bird free of charge.

Configuration Options

The SBE 43 **voltage output** sensor can be integrated with any Sea-Bird CTD that accepts input from a 0 - 5 volt auxiliary sensor (for example, SBE 9*plus*, 16/16*plus*/16*plus* V2, 16*plus*-IM/16*plus*-IM V2, 19/19*plus*/19*plus* V2, or 25). SBE 43 configuration choices include:

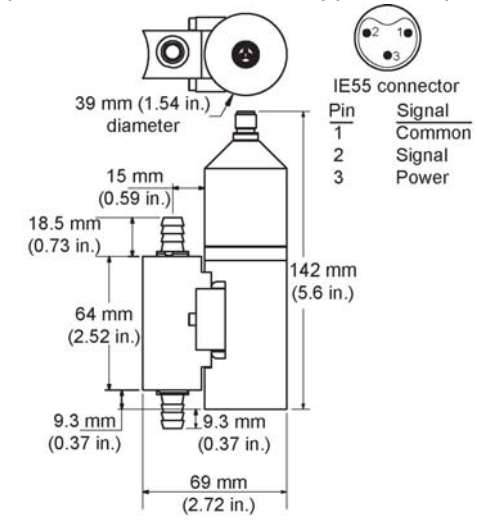
- Housing: 7000-meter titanium or 600-meter plastic housing
- Connector: XSG or wet-pluggable MCBH connector
- Membrane: 0.5-mil (fast response, typically for profiling applications) or 1-mil (slower response but more rugged for enhanced long-term stability, typically for moored applications)

The SBE 43**F frequency output** sensor can be integrated with an SBE 52-MP or used for OEM applications (requires OEM circuit board). The SBE 43F is available with a 600-meter plastic or 7000-meter titanium housing.

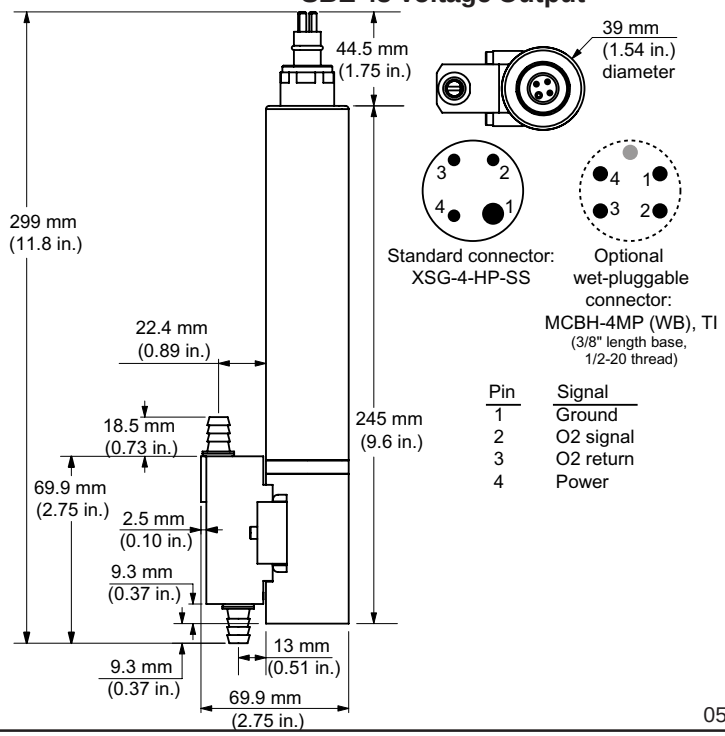
Specifications

Measurement range:	120% of surface saturation in all natural waters, fresh and salt
Initial accuracy:	2% of saturation
Typical stability:	0.5% per 1000 hours (clean membrane)
Input power:	6.5 - 24 VDC, 60 milliwatts
Output signal:	0 - 5 VDC (SBE 43), frequency (SBE 43F)
Housing/depth rating:	600-meter plastic or 7000-meter titanium housing (10,500-meter titanium housing available on request)
Weight (in air):	SBE 43 — 0.7 kg (1.5 lbs) with titanium housing, 0.5 kg (1.0 lb) with plastic housing SBE 43F — 0.4 kg (0.9 lbs) with titanium housing

SBE 43F Frequency Output Sensor
(for SBE 52-MP and OEM applications)



SBE 43 Voltage Output



05/09

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1808 136th Place NE, Bellevue, Washington 98005 USA
Website: http://www.seabird.com
Email: seabird@seabird.com
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Fax: (425) 643-9954

CALIBRATION SHEETS

Temperature Calibration - S/N 6405..... 1

Conductivity Calibration - S/N 6405..... 2

Pressure Calibration - S/N 6405..... 3

SBE 5P Configuration - S/N 055414..... 4

SBE 43 Oxygen Calibration - 431663..... 5

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Phone: (425) 643 - 9866 Fax (425) 643 - 9954 Email: seabird@seabird.com

SENSOR SERIAL NUMBER: 6405
CALIBRATION DATE: 10-Sep-09

SBE19plus TEMPERATURE CALIBRATION DATA
ITS-90 TEMPERATURE SCALE

ITS-90 COEFFICIENTS

a0 = 1.255325e-003
a1 = 2.548023e-004
a2 = 3.052741e-007
a3 = 1.229458e-007

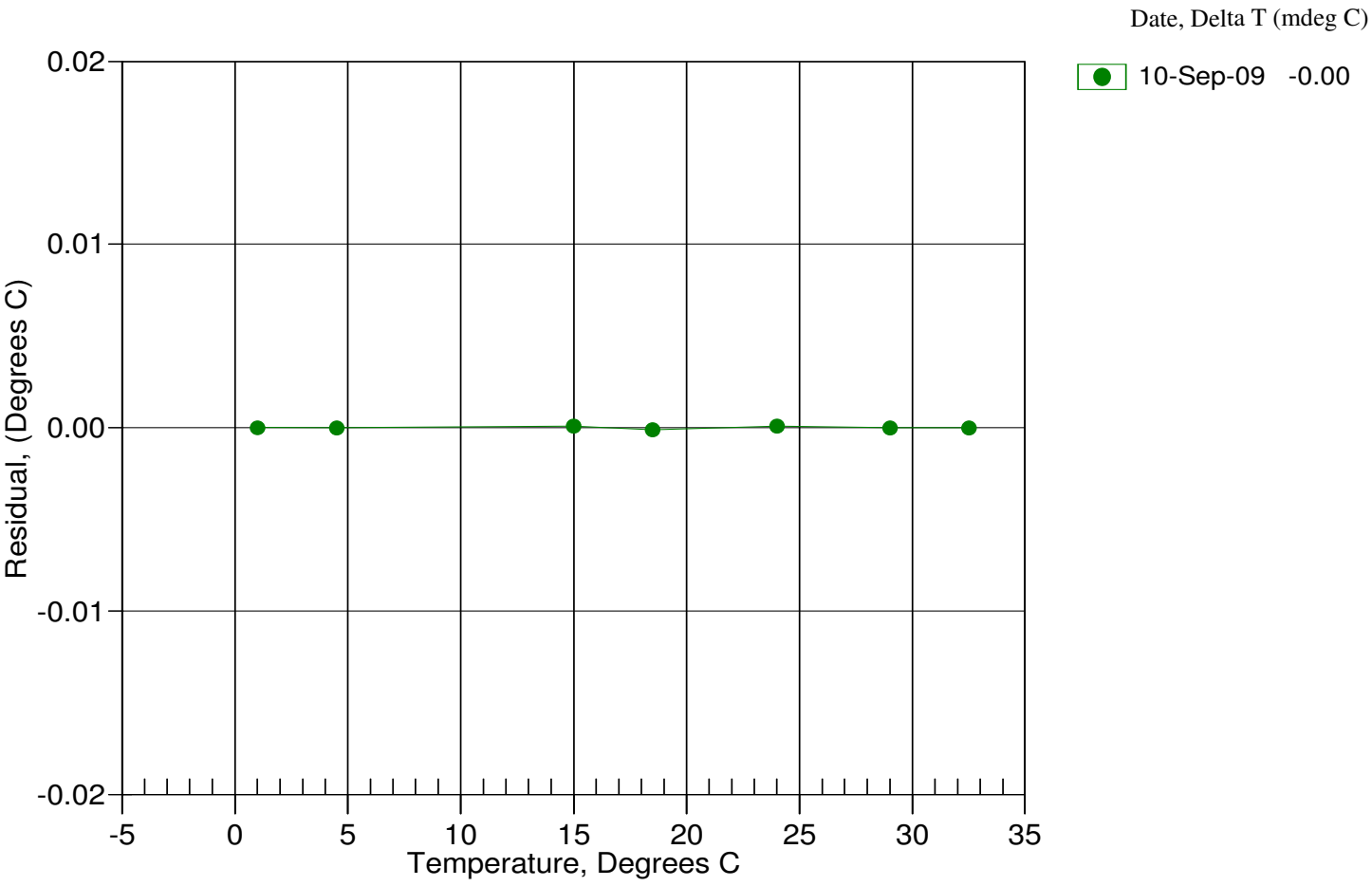
BATH TEMP (ITS-90)	INSTRUMENT OUTPUT(n)	INST TEMP (ITS-90)	RESIDUAL (ITS-90)
1.0000	722750.900	1.0000	0.0000
4.5001	645478.900	4.5001	-0.0000
15.0000	449739.400	15.0001	0.0001
18.4999	396291.300	18.4998	-0.0001
24.0000	323180.500	24.0001	0.0001
29.0000	267159.800	29.0000	-0.0000
32.5000	233187.200	32.5000	-0.0000

MV = (n - 524288) / 1.6e+007

R = (MV * 2.900e+009 + 1.024e+008) / (2.048e+004 - MV * 2.0e+005)

Temperature ITS-90 = $1/\{a0 + a1[ln(R)] + a2[ln^2(R)] + a3[ln^3(R)]\} - 273.15$ (°C)

Residual = instrument temperature - bath temperature



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SENSOR SERIAL NUMBER: 6405
CALIBRATION DATE: 10-Sep-09

SBE19plus CONDUCTIVITY CALIBRATION DATA
PSS 1978: C(35,15,0) = 4.2914 Siemens/meter

COEFFICIENTS:

```
g = -1.036438e+000
h =  1.548499e-001
i = -2.485998e-004
j =  3.969783e-005

CPcor = -9.5700e-008
CTcor =  3.2500e-006
```

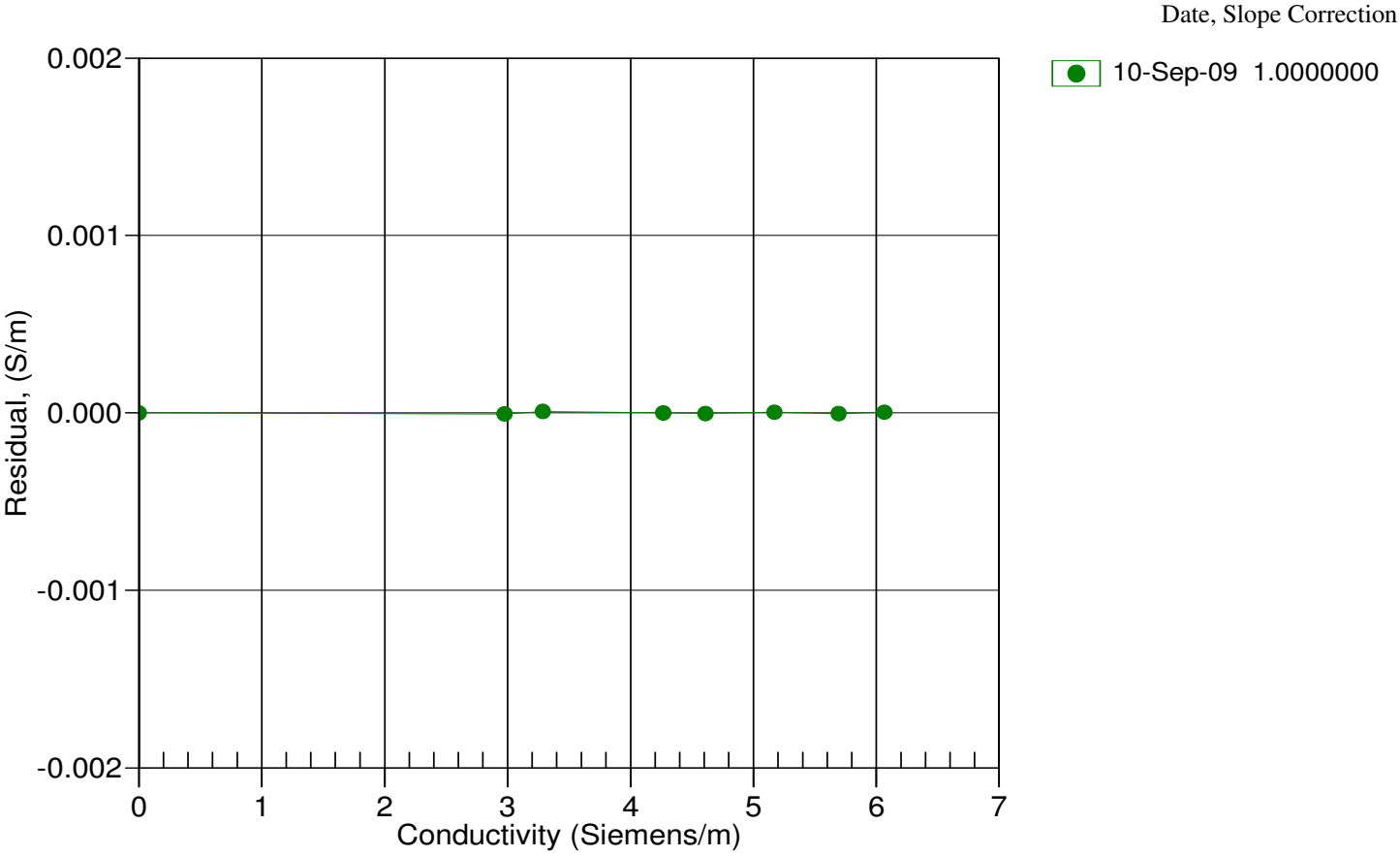
BATH TEMP (ITS-90)	BATH SAL (PSU)	BATH COND (Siemens/m)	INST FREQ (Hz)	INST COND (Siemens/m)	RESIDUAL (Siemens/m)
22.0000	0.0000	0.00000	2590.28	0.0000	0.00000
1.0000	34.8354	2.97744	5095.17	2.9774	-0.00001
4.5001	34.8151	3.28463	5286.04	3.2846	0.00001
15.0000	34.7720	4.26675	5854.03	4.2668	0.00000
18.4999	34.7627	4.61202	6040.80	4.6120	-0.00000
24.0000	34.7525	5.17018	6330.85	5.1702	0.00000
29.0000	34.7469	5.69223	6590.31	5.6922	-0.00000
32.5000	34.7443	6.06485	6769.27	6.0649	0.00000

f = INST FREQ / 1000.0

Conductivity = $(g + hf^2 + if^3 + jf^4) / (1 + \delta t + \varepsilon p)$ Siemens/meter

t = temperature[°C)]; p = pressure[decibars]; δ = CTcor; ε = CPcor;

Residual = instrument conductivity - bath conductivity



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Phone: (425) 643 - 9866 Fax (425) 643 - 9954 Email: seabird@seabird.com

SENSOR SERIAL NUMBER: 6405
CALIBRATION DATE: 04-Sep-09

SBE19plus PRESSURE CALIBRATION DATA
870 psia S/N 2882779

COEFFICIENTS:

PA0 =	-2.047830e+000	PTCA0 =	5.250051e+005
PA1 =	2.636779e-003	PTCA1 =	-3.342612e+001
PA2 =	2.503989e-011	PTCA2 =	-2.741031e-001
PTEMPA0 =	-6.603726e+001	PTCB0 =	2.506550e+001
PTEMPA1 =	5.519076e+001	PTCB1 =	-1.100000e-003
PTEMPA2 =	4.918032e-004	PTCB2 =	0.000000e+000

PRESSURE SPAN CALIBRATION

PRESSURE PSIA	INST OUTPUT	THERMISTOR OUTPUT	COMPUTED PRESSURE	ERROR %FSR
14.64	530540.0	1.6	14.62	-0.00
179.89	593102.0	1.6	179.88	-0.00
539.92	729167.0	1.6	539.92	0.00
719.91	797067.0	1.6	719.93	0.00
874.90	855443.0	1.6	874.88	-0.00
719.92	797071.0	1.6	719.94	0.00
539.94	729171.0	1.6	539.92	-0.00
359.93	661184.0	1.6	359.92	-0.00
179.92	593116.0	1.6	179.93	0.00
14.62	530533.0	1.6	14.65	0.00

THERMAL CORRECTION

TEMP ITS90	THERMISTOR OUTPUT	INST OUTPUT
32.50	1.80	530054.10
29.00	1.70	530235.85
24.00	1.60	530484.06
18.50	1.50	530727.67
15.00	1.50	530867.85
4.50	1.30	531264.41
1.00	1.20	531409.20

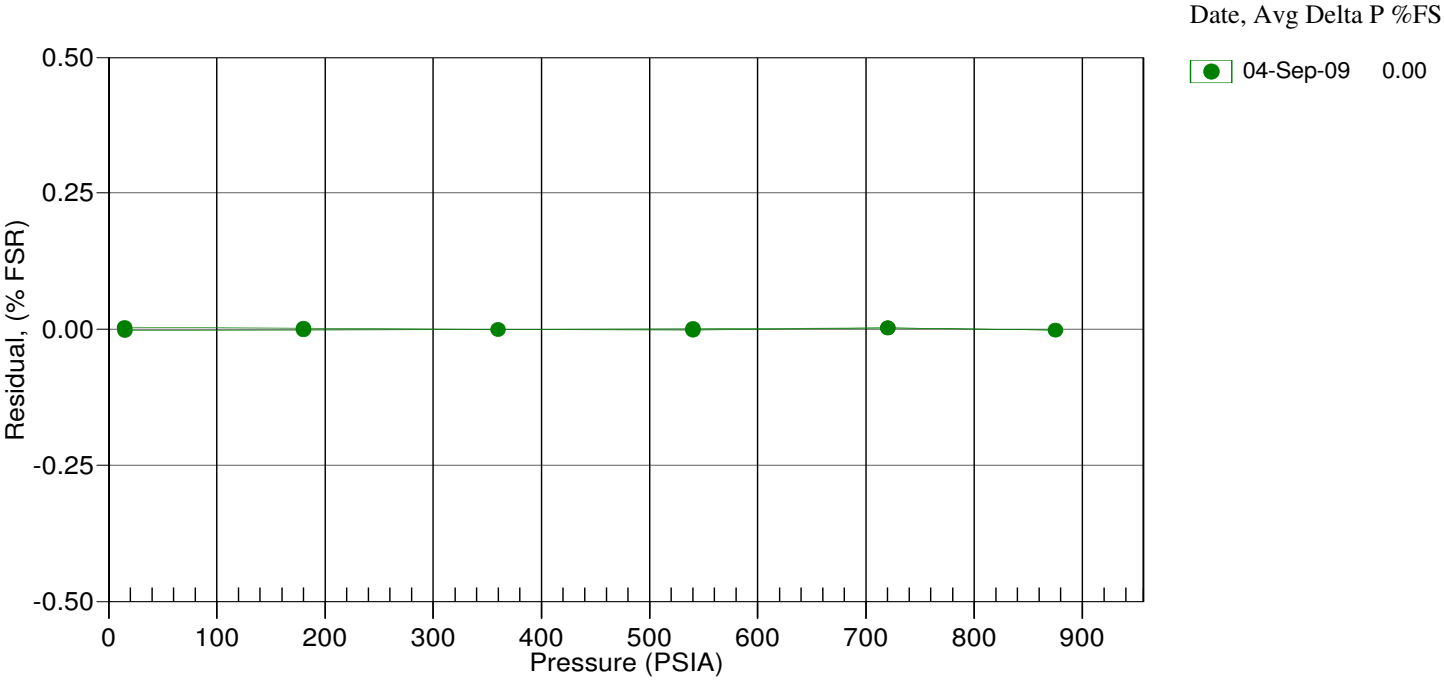
TEMP(ITS90)	SPAN(mV)
-5.00	25.07
35.00	25.03

y = thermistor output; $t = PTEMPA0 + PTEMPA1 * y + PTEMPA2 * y^2$

x = pressure output - $PTCA0 - PTCA1 * t - PTCA2 * t^2$

$n = x * PTCB0 / (PTCB0 + PTCB1 * t + PTCB2 * t^2)$

pressure (psia) = $PA0 + PA1 * n + PA2 * n^2$



Sea-Bird Electronics, Inc.
1808 136th Place NE, Bellevue, Washington 98005 USA
Website: http://www.seabird.com
Tel: (425) 643-9866
Email: seabird@seabird.com
Fax: (425) 643-9866

SBE 5P SUBMERSIBLE PUMP CONFIGURATION SHEET

Customer: MBARI
Delivery Date: 9/21/2009
Serial Number: 5414
MRP PN: 90617
Job Number: 55726

Pressure Case: 600 meters (Plastic)

Pittman Motor Type:

P/N 3711B113-R1, 18.02 ohms nominal (For applications up to 2000 RPM MAX) ☐

- 5 Winding, low voltage input (jump P5 to P7) (80676 assy/3711B113-R1 motor) ☐
- 5 Winding, standard voltage input (jump P5 to P6) (80676 assy/3711B113-R1 motor) ☐

P/N 3711B112-R1, 7.40 ohms nominal (For applications up to 4500 RPM MAX) ☐

- 3 Winding, low voltage input (jump P5 to P7) (80675 assy/3711B112-R1 motor) ☐
- 3 Winding, standard voltage input (jump P5 to P6) (80675 assy/3711B112-R1 motor) ☐

P/N 3711B112-R2, 3.55 ohms nominal (For applications up to 4500 RPM MAX) ☑

- 3 Winding, low voltage input (jump P5 to P7) (801572 assy/3711B112-R2 motor) ☐
- 3 Winding, standard voltage input (jump P5 to P6) (801572 assy/3711B112-R2 motor) ☑

Speed Adjust Range: Min: 927 RPM Max: 5205 RPM (@ 12 Vin/300mA load)

Final Speed Setting: 2000 RPM (TP1 = 66.6 Hz)

Low voltage pumps only:

Motor speed at 7.5 Vin with no load: 0 RPM (TP1 = 0.0 Hz)

Motor speed at 7.5 Vin with 200mA load: 0 RPM (TP1 = 0.0 Hz)

Motor dropout voltage: 9.3

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1808 136th Place N.E., Bellevue, Washington, 98005 USA

Phone: (425) 643 - 9866 Fax (425) 643 - 9954 Email: seabird@seabird.com

SENSOR SERIAL NUMBER: 1663
CALIBRATION DATE: 01-Sep-09p

SBE 43 OXYGEN CALIBRATION DATA

COEFFICIENTS

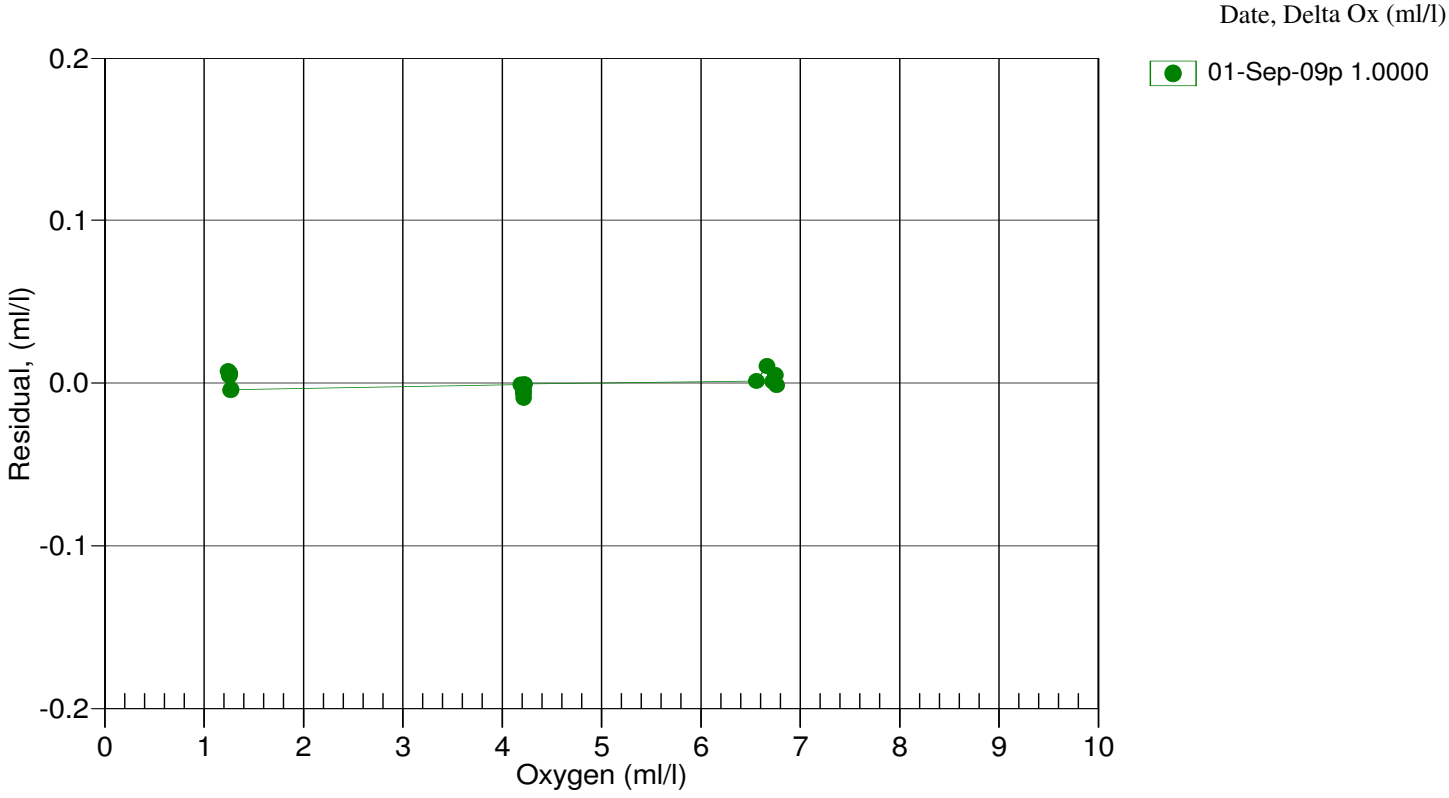
```
Soc =  0.3785
Voffset = -0.4608
Tau20 = 4.54
A = -3.0088e-003
B =  2.2646e-004
C = -3.8992e-006
E nominal =  0.036
```

NOMINAL DYNAMIC COEFFICIENTS

```
D1 =  1.92634e-4   H1 = -3.30000e-2
D2 = -4.64803e-2   H2 =  5.00000e+3
                   H3 =  1.45000e+3
```

BATH OX (ml/l)	BATH TEMP ITS-90	BATH SAL PSU	INSTRUMENT OUTPUT(VOLTS)	INSTRUMENT OXYGEN(ml/l)	RESIDUAL (ml/l)
1.25	2.00	0.00	0.805	1.25	0.01
1.25	6.00	0.00	0.846	1.26	0.00
1.25	12.00	0.00	0.907	1.26	0.01
1.27	20.00	0.00	0.987	1.26	-0.00
1.27	26.00	0.00	1.046	1.27	-0.00
1.27	30.00	0.00	1.090	1.27	-0.00
4.19	2.00	0.00	1.609	4.18	-0.00
4.21	6.00	0.00	1.750	4.21	-0.01
4.21	20.00	0.00	2.209	4.21	-0.01
4.21	26.00	0.00	2.406	4.21	-0.01
4.22	30.00	0.00	2.548	4.21	-0.00
4.22	12.00	0.00	1.956	4.22	-0.00
6.56	30.00	0.00	3.709	6.56	0.00
6.67	26.00	0.00	3.549	6.68	0.01
6.72	2.00	0.00	2.307	6.73	0.00
6.75	12.00	0.00	2.852	6.75	0.01
6.76	20.00	0.00	3.269	6.76	-0.00
6.76	6.00	0.00	2.533	6.76	-0.00

Oxygen (ml/l) = Soc * (V + Voffset) * (1.0 + A * T + B * T^2 + C * T^3) * OxSol(T,S) * exp(E * P / K)
V = voltage output from SBE43, T = temperature [deg C], S = salinity [PSU] K = temperature [deg K]
OxSol(T,S) = oxygen saturation [ml/l], P = pressure [dbar], Residual = instrument oxygen - bath oxygen



PRESSURE TEST CERTIFICATES

SBE 16plus Pressure Test Certificate - S/N 6405..... 1

SBE 5P Pressure Test Certificate - S/N 055414..... 2

SBE 43 Pressure Test Certificate - S/N 431663..... 3

Sea-Bird Electronics, Inc.
1808 136th Place NE, Bellevue, Washington 98005 USA
Website: http://www.seabird.com

Phone: (425) 643-9866
FAX: (425) 643-9954
Email: seabird@seabird.com

SBE Pressure Test Certificate

Test Date: **9/3/2009** Description **SBE-16Plus SeaCat**

Job Number: **55726** Customer Name **MBARI**

SBE Sensor Information:

Model Number: **16P**
Serial Number: **6405**

Pressure Sensor Information:

Sensor Type: **Druck**
Sensor Serial Number: **2882779**
Sensor Rating: **870**

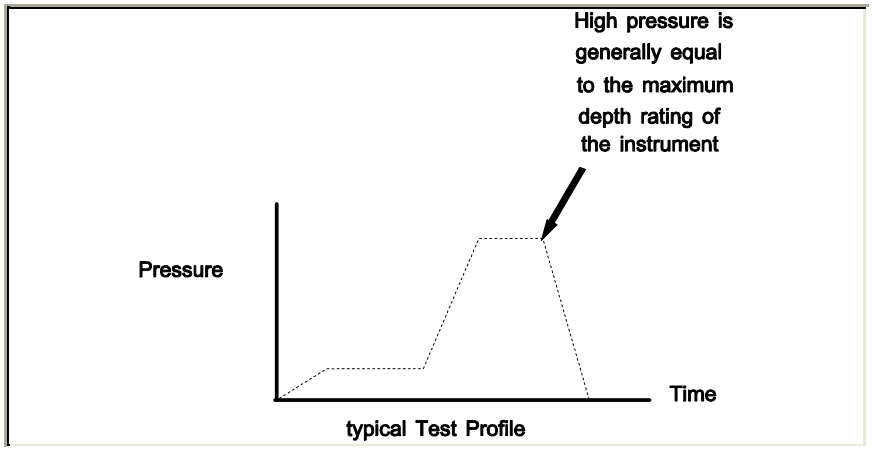
Pressure Test Protocol:

Low Pressure Test: **40** PSI Held For **15** Minutes

High Pressure Test: **800** PSI Held For **15** Minutes

Passed Test: ☑

Tested By: ND



typical Test Profile

Sea-Bird Electronics, Inc.
1808 136th Place NE, Bellevue, Washington 98005 USA
Website: http://www.seabird.com

Phone: (425) 643-9866
FAX: (425) 643-9954
Email: seabird@seabird.com

SBE Pressure Test Certificate

Test Date: **9/4/2009** Description **SBE-5P Submersible Pump**

Job Number: **55726** Customer Name **MBARI**

SBE Sensor Information:

Model Number: **5P**
Serial Number: **5414**

Pressure Sensor Information:

Sensor Type: **None**
Sensor Serial Number: **None**
Sensor Rating: **0**

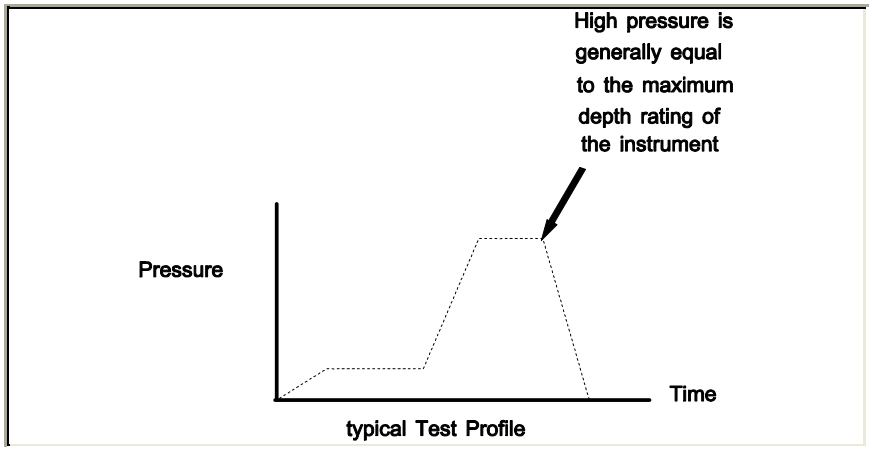
Pressure Test Protocol:

Low Pressure Test: **40** PSI Held For **15** Minutes

High Pressure Test: **800** PSI Held For **15** Minutes

Passed Test: ☑

Tested By: AS



typical Test Profile

Sea-Bird Electronics, Inc.
1808 136th Place NE, Bellevue, Washington 98005 USA
Website: http://www.seabird.com

Phone: (425) 643-9866
FAX: (425) 643-9954
Email: seabird@seabird.com

SBE Pressure Test Certificate

Test Date: **7/6/2009** Description **SBE-43 DO Sensor**

Job Number: **55726** Customer Name **MBARI**

SBE Sensor Information:

Model Number: **43**
Serial Number: **1663**

Pressure Sensor Information:

Sensor Type: **None**
Sensor Serial Number: **None**
Sensor Rating: **0**

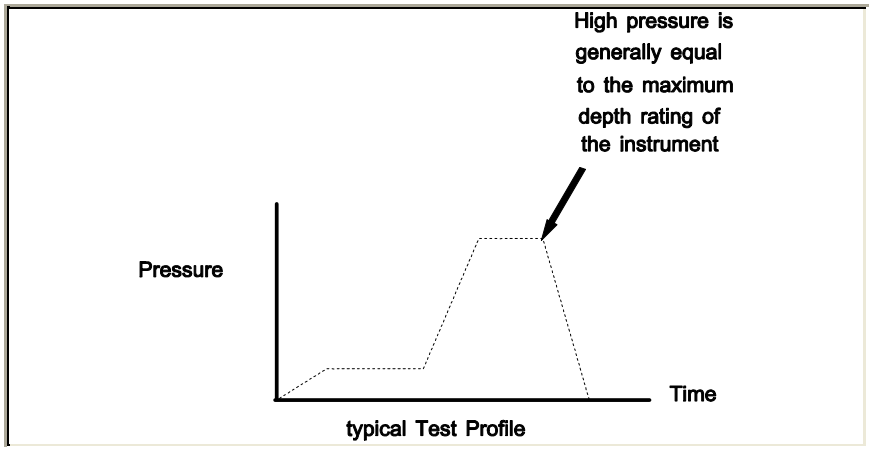
Pressure Test Protocol:

Low Pressure Test: **50** PSI Held For **15** Minutes

High Pressure Test: **800** PSI Held For **30** Minutes

Passed Test: ☑

Tested By: jt



typical Test Profile

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Sea-Bird Electronics, Inc.
1808 136th Place NE
Bellevue, WA 98005
USA

Phone: (425) 643-9866
Fax: (425) 643-9954
E-mail: seabird@seabird.com
Web: www.seabird.com

APPLICATION NOTE NO. 2D **Revised September 2008**

Instructions for Care and Cleaning of Conductivity Cells

This application note presents new recommendations (as of October 2006), based on our recent research, for cleaning and storing conductivity sensors. In the past, Sea-Bird had recommended cleaning and storing conductivity sensors with a Triton X-100 solution, and cleaning conductivity sensors with an acid solution. **Our latest research leads us to recommend adding the use of a dilute bleach solution to eliminate growth of bio-organisms, and eliminating the use of acid in most cases**.

The application note is divided into three sections:
- General discussion
- Rinsing, cleaning, and storage procedures
- Cleaning materials

General Discussion

Since any conductivity sensor's output reading is proportional to its cell dimensions, it is important to keep the cell clean of internal coatings. Also, cell electrodes contaminated with oil, biological growths, or other foreign material will cause low conductivity readings. A desire to provide better control of growth of bio-organisms in the conductivity cell led us to develop revised rinsing and cleaning recommendations.

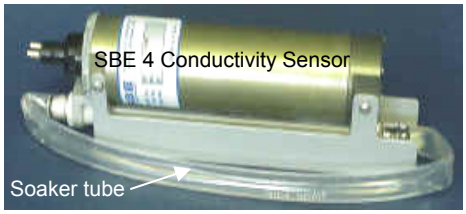
- A dilute bleach solution is extremely effective in controlling the growth of bio-organisms in the conductivity cell. Lab testing at Sea-Bird indicates no damaging effect from use of a dilute bleach solution in cleaning the conductivity cell. Sea-Bird now recommends cleaning the conductivity sensor in a bleach solution.
- Triton X-100 is a mild, non-ionic surfactant (detergent), valuable for removal of surface and airborne oil ingested into the CTD plumbing as the CTD is removed from the water and brought on deck. Sea-Bird had previously recommended, and continues to recommend, rinsing and cleaning the conductivity sensor in a Triton solution.
- Sea-Bird had previously recommended acid cleaning for eliminating bio-organisms or mineral deposits on the inside of the cell. However, bleach cleaning has proven to be effective in eliminating growth of bio-organisms; bleach is much easier to use and to dispose of than acid. Furthermore, data from many years of use shows that mineral deposits are an unusual occurrence. Therefore, Sea-Bird now recommends that, in most cases, acid should not be used to clean the conductivity sensor. ***In rare instances***, acid cleaning may still be required for mineral contamination of the conductivity cell. ***Sea-Bird recommends that you return the equipment to the factory for this cleaning if it is necessary***.

Sea-Bird had previously recommended storing the conductivity cell filled with water to keep the cell wetted, unless the cell was in an environment where freezing is a possibility (the cell could break if the water freezes). However, no adverse affects have been observed as a result of dry storage, if the cell is rinsed with fresh, clean water before storage to remove any salt crystals. This leads to the following revised conductivity cell storage recommendations:

- Short term storage (less than 1 day, typically between casts): If there is no danger of freezing, store the conductivity cell with a dilute bleach solution in Tygon tubing looped around the cell. If there is danger of freezing, store the conductivity cell dry, with Tygon tubing looped around the cell.
- Long term storage (longer than 1 day): Since conditions of transport and long term storage are not always under the control of the user, we now recommend storing the conductivity cell dry, with Tygon tubing looped around the cell ends. Dry storage eliminates the possibility of damage due to unforeseen freezing, as well as the possibility of bio-organism growth inside the cell. Filling the cell with a Triton X-100 solution for 1 hour before deployment will *rewet* the cell adequately.

Note that the Tygon tubing looped around the ends of the conductivity cell, whether dry or filled with a bleach or Triton solution, has the added benefit of keeping air-borne contaminants (abundant on most ships) from entering the cell.

Rinsing, Cleaning, and Storage Procedures



Note: See *Cleaning Materials* below for discussion of appropriate sources / concentrations of water, Triton X-100, bleach, and tubing.

CAUTIONS:

- The conductivity cell is primarily glass, and can break if mishandled. Use the correct size Tygon tubing; using tubing with a smaller ID will make it difficult to remove the tubing, and the cell end may break if excessive force is used. **The correct size tubing for use in cleaning / storing all conductivity cells produced since 1980 is 7/16" ID, 9/16" OD**. Instruments shipped prior to 1980 had smaller retaining ridges at the ends of the cell, and 3/8" ID tubing is required for these older instruments.
- **Do not put a brush or object (e.g., Q-Tip) inside the conductivity cell to clean it or dry it.** Touching and bending the electrodes can change the calibration; large bends and movement of the electrodes can damage the cell.
- **If an SBE 43 dissolved oxygen (DO) sensor is plumbed to the CTD** - Before soaking the conductivity cell for more than 1 minute in Triton X-100 solution, **disconnect the tubing between the conductivity cell and DO sensor** to prevent extended Triton contact with the DO sensor membrane (extended Triton contact can damage the membrane). See *Application Note 64* for rinsing, cleaning, and storage recommendations for the SBE 43.

Active Use (after each cast)

1. Rinse: Remove the plumbing (Tygon tubing) from the exhaust end of the conductivity cell. **Flush** the cell with a **0.1% Triton X-100** solution. **Rinse** thoroughly with **fresh, clean water** and drain.
   - If not rinsed between uses, salt crystals may form on the conductivity cell platinized electrode surfaces. When the instrument is used next, sensor accuracy may be temporarily affected until these crystals dissolve.
2. Store: The intent of these storage recommendations is to keep contamination from aerosols and spray/wash on the ship deck from harming the sensor's calibration.
   - ***No danger of freezing***: **Fill** the cell with a **500 – 1000 ppm bleach** solution, using a length of Tygon tubing attached to each end of the conductivity sensor to close the cell ends.
   - ***Danger of freezing***: Remove larger droplets of water by blowing through the cell. **Do not use compressed air**, which typically contains oil vapor. Attach a length of Tygon tubing to each end of the conductivity cell to close the cell ends.

Routine Cleaning (no visible deposits or marine growths on sensor)

1. **Agitate** a **500 – 1000 ppm Bleach** solution warmed to 40 °C through the cell in a washing action (this can be accomplished with Tygon tubing and a syringe kit – see *Application Note 34*) for **2 minutes**. **Drain and flush** with warm (not hot) fresh, clean water for **5 minutes**.
2. **Agitate** a **1%-2% Triton X-100** solution warmed to 40 °C through the cell many times in a washing action (this can be accomplished with Tygon tubing and a syringe kit). Fill the cell with the solution and let it **soak** for **1 hour**. **Drain and flush** with warm (not hot) fresh, clean water for **5 minutes**.

Cleaning Severely Fouled Sensors (visible deposits or marine growths on sensor)

Repeat the *Routine Cleaning* procedure up to 5 times.

Long-Term Storage (after field use)

1. Rinse: Remove the plumbing (Tygon tubing) from the exhaust end of the conductivity cell. **Flush** the cell with a **0.1% Triton X-100** solution. **Rinse** thoroughly with **fresh, clean water** and drain. Remove larger droplets of water by blowing through the cell. **Do not use compressed air**, which typically contains oil vapor.
2. Store: Attach a length of Tygon tubing to each end of the conductivity cell to close the cell ends. The loop prevents any contaminants from entering the cell.
   - Storing the cell dry prevents the growth of any bio-organisms, thus preserving the calibration.
3. When ready to deploy again: **Fill** the cell with a **0.1% Triton X-100** solution for **1 hour** before deployment. Drain the Triton X-100 solution; there is no need to rinse the cell.

Cleaning Materials

Water

De-ionized (DI) water, commercially distilled water, or fresh, clean, tap water is recommended for rinsing, cleaning, and storing sensors.

- On ships, **fresh water is typically made in large quantities by a distillation process, and stored in large tanks. This water may be contaminated with small amounts of oil, and should not be used for rinsing, cleaning, or storing sensors**.

Where fresh water is in extremely limited supply (for example, a remote location in the Arctic), you can substitute **clean seawater** for rinsing and cleaning sensors. If not immediately redeploying the instrument, follow up with a **brief fresh water rinse** to eliminate the possibility of salt crystal formation (salt crystal formation could cause small shifts in calibration).

- **The seawater must be extremely clean, free of oils that can coat the conductivity cell. To eliminate any bio-organisms in the water, Sea-Bird recommends boiling the water or filtering it with a 0.5 micron filter.**

Triton X-100

Triton X-100 is Octyl Phenol Ethoxylate, a mild, non-ionic surfactant (detergent). Triton X-100 is included with every CTD shipment and can be ordered from Sea-Bird, but may be available locally from a chemical supply or lab products company. It is manufactured by Mallinckrodt Baker (see http://www.mallbaker.com/changecountry.asp?back=/Default.asp for local distributors). Other liquid detergents can probably be used, but scientific grades (with no colors, perfumes, glycerins, lotions, etc.) are required because of their known composition. It is better to use a non-ionic detergent, since conductivity readings taken immediately after use are less likely to be affected by any residual detergent left in the cell.

100% Triton X-100 is supplied by Sea-Bird; dilute the Triton as directed in *Rinsing, Cleaning, and Storage Procedures*.

Bleach

Bleach is a common household product used to whiten and disinfect laundry. Commercially available bleach is typically 4 % - 7% (40,000 – 70,000 ppm) sodium hypochlorite (Na-O-Cl) solution that includes stabilizers. Some common commercial product names are Clorox (U.S.) and eau de Javel (French).

Dilute to 500 – 1000 ppm. For example, if starting with 5% (50,000 ppm) sodium hypochlorite, diluting 50 to 1 (50 parts water to 1 part bleach) yields a 1000 ppm (50,000 pm / 50 = 1000 ppm) solution.

Tygon Tubing

Sea-Bird recommends use of Tygon tubing, because it remains flexible over a wide temperature range and with age. Tygon is manufactured by Saint-Gobain (see *www.tygon.com*). It is supplied by Sea-Bird, but may be available locally from a chemical supply or lab products company.

Keep the Tygon in a clean place (so that it does not pick up contaminants) while the instrument is in use.

Acid

In rare instances, acid cleaning is required for mineral contamination of the conductivity cell. ***Sea-Bird recommends that you return the equipment to the factory for this cleaning***. Information below is provided if you cannot return the equipment to Sea-Bird.

CAUTIONS:

- **SBE 37-IMP, 37-SMP, or 37-SIP MicroCAT; SBE 49 FastCAT; SBE 52-MP Moored Profiler CTD; or other instruments with an integral, internal pump - Do not perform acid cleaning.** Acid cleaning may damage the internal, integral pump. Return these instruments to Sea-Bird for servicing if acid cleaning is required.
- **SBE 9*plus* or SBE 25 CTD** – Remove the SBE 4 conductivity cell from the CTD and remove the TC Duct before performing the acid cleaning procedure.
- **All instruments which include AF24173 Anti-Foulant Devices** – Remove the AF24173 Anti-Foulant Devices before performing the acid cleaning procedure. See the instrument manual for details and handling precautions when removing AF24173 Anti-Foulant Devices.

WARNING! Observe all precautions for working with strong acid. Avoid breathing acid fumes. Work in a well-ventilated area.

The acid cleaning procedure for the conductivity cell uses approximately 50 - 100 cc of acid. Sea-Bird recommends using a 20% concentration of HCl. However, acid in the range of 10% to full strength (38%) is acceptable.

If starting with a strong concentration of HCl that you want to dilute:
For each 100 cc of concentrated acid, to get a 20% solution, mix with this amount of water -
Water = [(conc% / 20%) – 1] * [100 + 10 (conc% / 20%)] cc
Always add acid to water; never add water to acid.

Example -- concentrated solution 31.5% that you want to dilute to 20%:
[(31.5% / 20%) – 1] * [100 + 10 (31.5% / 20%)] = 66.6 cc of water.
So, adding 100 cc of 31.5% HCl to 66.6 cc of water provides 166.6 cc of the desired concentration.
For 100 cc of solution:
100 cc * (100 / 166.6) = 60 cc of 31.5% HCl
66.6 cc * (100 / 166.6) = 40 cc of water

For acid disposal, dilute the acid heavily or neutralize with bicarbonate of soda (baking soda).

1. Prepare for cleaning:
   A. Place a 0.6 m (2 ft) length of Tygon tubing over the end of the cell.
   B. Clamp the instrument so that the cell is vertical, with the Tygon tubing at the bottom end.
   C. Loop the Tygon tubing into a U shape, and tape the open end of the tubing in place at the same height as the top of the glass cell.
2. Clean the cell:
   A. Pour **10% to 38% HCl** solution into the open end of the tubing until the cell is nearly filled. **Let it soak for 1 minute only.**
   B. Drain the acid from the cell and flush for 5 minutes with warm (not hot), clean, de-ionized water.
   C. Rinse the exterior of the instrument to remove any spilled acid from the surface.
   D. Fill the cell with a **1% Triton X-100** solution and let it stand for 5 minutes.
   E. Drain and flush with warm, clean, de-ionized water for 1 minute.
   F. Carefully remove the 0.6 m (2 ft) length of Tygon tubing.
3. Prepare for deployment, **or** follow recommendations above for storage.

Sea-Bird Electronics, Inc.
1808 136th Place NE
Bellevue, WA 98005
USA

Phone: (425) 643-9866
Fax: (425) 643-9954
E-mail: seabird@seabird.com
Web: www.seabird.com

APPLICATION NOTE NO. 6 **Revised August 2004**

DETERMINATION OF SOUND VELOCITY FROM CTD DATA

Use of CTD measurement for determination of sound velocity is appealing because these instruments are simpler and more rugged, and because their resolution, accuracy, and stability lead to far better **precision** than can be obtained with direct SV measuring devices. For example, specifications of 0.01 mS/cm conductivity, 0.01 degrees C temperature, and 1 meter in depth are readily achieved with good quality CTD equipment. Assuming that the relationship between C, T, and D *and* SV is exactly known (see below), the resulting uncertainty in SV would be as follows:

Error Type	Sound Velocity Error
temperature error of 0.01 deg C	0.021 meters/second
conductivity error of 0.01 mS/cm	0.011 meters/second
salinity error of 0.01 psu	0.012 meters/second
depth error of 1 meter	0.017 meters/second

The equivalent SV errors (considered at 15 degrees C, 42.9 mS/cm, 35 psu, and 0 pressure, i.e., typical open-ocean surface conditions) are much smaller than those usually claimed for direct-measurement instruments.

The question about the **absolute** accuracy of the inference of SV from CTD data is more difficult to answer. The main reason for this is apparently the result of differences in the instrumentation used by various researchers and is compounded by the difficulty of performing direct measurements of sound velocity under controlled conditions of temperature, salinity, and (especially) pressure. For example, three widely used equations (Wilson, 1959; Del Grosso, 1972; Millero and Chen, 1977) show differences in absolute sound speed on the order of 0.5 meters/second for various combinations of water temperature, salinity, and pressure, despite being based on careful measurements made under laboratory conditions.

The work of Millero and Chen is, however, the most modern, and it builds upon and attempts to incorporate the work of earlier investigators. Accordingly, the SV/CTD relationship described by these researchers in their paper of 1977 was used as a major component in the derivation of the Equation of State (Unesco technical papers in marine science no. 44). Millero and Chen's 1977 equation is also the one endorsed by the Unesco/SCOR/ICES/IASPO Joint Panel on Oceanographic Tables and Standards, which comprises the internationally recognized authority for measurements of ocean parameters (in Sea-Bird's SEASOFT software, users may select any of the 3 equations mentioned above).

Pike and Beiboer, 1993, made a careful comparison of algorithms used to calculate sound velocity. They concluded that use of the Wilson equation should be discontinued, and that the Chen and Millero algorithm should be used on the continental shelf while the Del Grosso formula is more appropriate for deep ocean waters and long path lengths. Their paper includes tables showing valid temperature and salinity ranges for each of the algorithms.

We draw the following conclusions from the research papers listed above:

1) Investigators using specialized equipment under scrupulously controlled laboratory conditions report measurements of SV vs. changes in temperature, salinity, and pressure which differ by 0.5 meters/second and more. *It is unrealistic to expect that commercial direct-measurement instruments will be more accurate under field conditions than the laboratory equipment used by successions of careful researchers.*

2) The claimed *accuracy* of commercial direct-measurement SV probes probably more legitimately represents their *precision* (compare with CTD/SV uncertainties tabulated above) rather than their absolute accuracy. The relationship between what these instruments read and true sound velocity is probably just as dependent on the same vagaries that are also the only significant sources of error when employing the CTD approach.

3) Because of the uncertainties in the time-delays associated with the acoustic transducers and electronics (and because of the difficulty of measuring with sufficient accuracy the length of the acoustic path), direct-measurement probes must be calibrated in water. As suggested by the research under controlled laboratory conditions, this is not an easy task, especially over a range of temperature, pressure, and salinity. On the other hand, a CTD probe can easily be calibrated using accepted methods.

4) A CTD can predict **absolute** SV to something better than 0.5 meters/second (a judgment seconded by Professor Millero in a private conversation), while its **relative accuracy** (precision) is probably better than 0.05 meters/second under the most demanding conditions of field use.

5) The very high precision associated with CTD measurements and the existence of an internationally accepted relationship (even if imperfect) between CTD and SV permits very consistent intercomparison and a high degree of uniformity among CTD-derived SV data sets, no matter when and where taken.

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Wilson W D, 1960, Equation for the Speed of Sound in Seawater. J Acoust Soc Am, 32(10), p 1357.

Sea-Bird Electronics, Inc.
1808 136th Place NE
Bellevue, WA 98005
USA

Phone: (425) 643-9866
Fax: (425) 643-9954
E-mail: seabird@seabird.com
Web: www.seabird.com

APPLICATION NOTE NO. 10 **Revised March 2008**

COMPRESSIBILITY COMPENSATION OF SEA-BIRD CONDUCTIVITY SENSORS

Sea-Bird conductivity sensors provide precise characterization of deep ocean water masses. To achieve the accuracy of which the sensors are capable, an accounting for the effect of hydrostatic loading (pressure) on the conductivity cell is necessary. Conductivity calibration certificates show an equation containing the appropriate pressure-dependent correction term, which has been derived from mechanical principles and confirmed by field observations. The form of the equation varies somewhat, as shown below:

SBE 4, 9, 9*plus*, 16, 19, 21, 25, 26, 26*plus*, and 53 BPR

$$\text{Conductivity (Siemens/meter)} = \text{slope}\ \frac{(g + h f^2 + i f^3 + j f^4)/10}{1 + [\text{CTcor}]\, t + [\text{CPcor}]\, p} + \text{offset} \qquad \textbf{(recommended)}$$

or

$$\text{Conductivity (Siemens/meter)} = \text{slope}\ \frac{(a f^m + b f^2 + c + dt)/10}{1 + [\text{CPcor}]\, p} + \text{offset}$$

SBE 16*plus*, 16*plus*-IM, 16*plus* V2, 16*plus*-IM V2, 19*plus*, 19*plus* V2, 37, 45, 49, and 52-MP

$$\text{Conductivity (Siemens/meter)} = \text{slope}\ \frac{g + h f^2 + i f^3 + j f^4}{1 + [\text{CTcor}]\, t + [\text{CPcor}]\, p} + \text{offset}$$

where

- a, b, c, d, m, and CPcor are the calibration coefficients used for older sensors (prior to January 1995). Sea-Bird continues to calculate and print these coefficients on the calibration sheets for use with old software, but recommends use of the g, h, i, j, CTcor, CPcor form of the equation for most accurate results.
- g, h, i, j, CTcor, and CPcor are the calibration coefficients used for newer sensors.
  Note: The SBE 26, 26*plus*, and 53 BPR use the SBE 4 conductivity sensor, so both sets of calibration coefficients are reported on the calibration sheet. *SEASOFT for Waves* **for DOS**, which can be used with the SBE 26 only, only supports use of the a, b, c, d, CTcor, and CPcor coefficients. The current processing software for these instruments, *SEASOFT for Waves* **for Windows**, only supports use of the g, h, i, j, CTcor, CPcor coefficients.
- **CPcor is the correction term for pressure effects on conductivity (see below for discussion)**
- slope and offset are correction coefficients used to make corrections for sensor drift between calibrations; set to 1.0 and 0 respectively on initial calibration by Sea-Bird (see Application Note 31 for details on calculating slope and offset)
- f is the instrument frequency (kHz) for all instruments except the SBE 52-MP.
  For the SBE 52-MP, f = instrument frequency (kHz) * $(1.0 + \text{WBOTC} * t)^{0.5} / 1000.00$
- t is the water temperature (°C).
- p is the water pressure (decibars).

Sea-Bird CTD data acquisition, display, and post-processing software *SEASOFT for Waves* (for SBE 26, 26*plus*, and 53 only) and *SEASOFT* (for all other instruments) automatically implement these equations.

DISCUSSION OF PRESSURE CORRECTION

Conductivity cells do not measure the specific conductance (the desired property), but rather the conductance of a *specific geometry* of water. The ratio of the cell's length to its cross-sectional area (*cell constant*) is used to relate the measured conductance to specific conductance. Under pressure, the conductivity cell's length and diameter are reduced, leading to a lower indicated conductivity. The magnitude of the effect is not insignificant, reaching 0.0028 S/m at 6800 dbars.

The compressibility of the borosilicate glass used in the conductivity cell (and all other homogeneous, noncrystalline materials) can be characterized by E (Young's modulus) and ν (Poisson's ratio). For the Sea-Bird conductivity cell, $E = 9.1 \times 10^6$ psi, ν = 0.2, and the ratio of indicated conductivity divided by true conductivity is:

$1 + s$
where s = (CPcor) (p)
Typical value for CPcor is -9.57×10^{-8} for pressure in decibars **or** -6.60×10^{-8} for pressure in psi

Note: This equation and the mathematical derivations below deal only with the pressure correction term, and do not address the temperature correction term.

MATHEMATICAL DERIVATION OF PRESSURE CORRECTION

For a cube under hydrostatic load:

$\Delta L / L = s = -p (1 - 2 \nu) / E$
where

- p is the hydrostatic pressure
- E is Young's modulus
- ν is Poisson's ratio
- $\Delta L / L$ and s are strain (change in length per unit length)

Since this relationship is linear in the forces and displacements, the relationship for strain also applies for the length, radius, and wall thickness of a cylinder.

To compute the effect on conductivity, note that $R_0 = \rho L / A$, where R_0 is resistance of the material at 0 pressure, ρ is volume resistivity, L is length, and A is cross-sectional area. For the conductivity cell $A = \pi r^2$, where r is the cell radius. Under pressure, the new length is $L (1 + s)$ and the new radius is $r (1 + s)$. If R_p is the cell resistance under pressure:

$$R_p = \rho L (1 + s) / (\pi r^2 [1 + s]^2) = \rho L / \pi r^2 (1 + s) = R_0 / (1 + s)$$

Since conductivity is 1/R:

$C_p = C_0 (1 + s)$ and $C_0 = C_p / (1 + s) = C_p / (1 + [\text{Cpcor}] [p])$
where

- C_0 is conductivity at 0 pressure
- C_p is conductivity measured at pressure

A less rigorous determination may be made using the material's bulk modulus. For small displacements in a cube:

$\Delta V / V = 3\Delta L / L = -3p (1 - 2 \nu) / E$ or $\Delta V/V = -p / K$
where

- $\Delta V / V$ is the change in volume per volume or volume strain
- K is the bulk modulus. K is related to E and ν by $K = E / 3 (1 - 2 \nu)$.

In this case, $\Delta L / L = -p / 3K$.

Sea-Bird Electronics, Inc.
1808 136th Place NE
Bellevue, WA 98005
USA

Phone: (425) 643-9866
Fax: (425) 643-9954
E-mail: seabird@seabird.com
Web: www.seabird.com

APPLICATION NOTE NO. 14 **January 1989**

1978 PRACTICAL SALINITY SCALE

Should you not be already familiar with it, we would like to call your attention to the January 1980 issue of the IEEE Journal of Oceanic Engineering, which is dedicated to presenting the results of a multi-national effort to obtain a uniform repeatable Practical Salinity Scale, based upon electrical conductivity measurements. This work has been almost universally accepted by researchers, and all instruments delivered by Sea-Bird since February 1982 have been supplied with calibration data based upon the new standard.

The value for conductivity at 35 ppt, 15 degrees C, and 0 pressure [C(35,15,0)] was not agreed upon in the IEEE reports -- Culkin & Smith used 42.914 mmho/cm (p 23), while Poisson used 42.933 mmho/cm (p 47). It really does not matter which value is used, provided that the same value is used during data reduction that was used to compute instrument calibration coefficients. Our instrument coefficients are computed using C(35,15,0) = 42.914 mmho/cm.

The PSS 1978 equations and constants for computing salinity from *in-situ* measurements of conductivity, temperature, and pressure are given in the 'Conclusions' section of the IEEE journal (p 14) and are reproduced back of this note. In the first equation, 'R' is obtained by dividing the conductivity value measured by your instrument by C(35,15,0), or 42.914 mmho/cm. Note that the PSS equations are based upon conductivity in units of mmho/cm, which are equal in magnitude to units of mS/cm. **If you are working in conductivity units of Siemens/meter (S/m), multiply your conductivity values by 10 before using the PSS 1978 equations**.

Also note that the equations assume pressure relative to the sea-surface. Absolute pressure gauges (as used in all Sea-Bird CTD instruments) have a vacuum on the reference side of their sensing diaphragms and indicate atmospheric pressure (nominally 10.1325 dBar) at the sea-surface. This reading must be subtracted to obtain pressure as required by the PSS equations. The pressure reading displayed when using Sea-Bird's SEASOFT CTD acquisition, display, and post-processing software is the corrected sea-surface pressure and is used by SEASOFT to compute salinity, density, etc in accordance with the PSS equations.

1978 PRACTICAL SALINITY SCALE EQUATIONS, from IEEE Journal of Oceanic Engineering, Vol. OE-5, No. 1, January 1980, page 14.

CONCLUSIONS

Using Newly generated data, a fit has been made giving the following algorithm for the calculation of salinity from data of the form:

$$R = \frac{C(S, T, P)}{C(35, 15, 0)}$$

T in °C (IPTS '68), P in decibars.

$$R_T = \frac{R}{R_P r_T}; R_P = 1 + \frac{P \times (A_1 + A_2 P + A_3 P^2)}{1 + B_1 T + B_2 T^2 + B_3 R + B_4 R T}$$

$$r_T = c_0 + c_1 T + c_2 T^2 + c_3 T^3 + c_4 T^4$$

$A_1 = 2.070 \times 10^{-5}$ $B_1 = 3.426 \times 10^{-2}$

$A_2 = -6.370 \times 10^{-10}$ $B_2 = 4.464 \times 10^{-4}$

$A_3 = 3.989 \times 10^{-15}$ $B_3 = 4.215 \times 10^{-1}$

$B_4 = -3.107 \times 10^{-3}$

$c_0 = 6.766097 \times 10^{-1}$

$c_1 = 2.00564 \times 10^{-2}$

$c_2 = 1.104259 \times 10^{-4}$

$c_3 = -6.9698 \times 10^{-7}$

$c_4 = 1.0031 \times 10^{-9}$

$$S = \sum_{j=0}^{5} a_j R_T^{j/2} + \frac{(T-15)}{1 + k(T-15)} \sum_{j=0}^{5} b_j R_T^{j/2}$$

$a_0 = 0.0080$ $b_0 = 0.0005$ $k = 0.0162.$

$a_1 = -0.1692$ $b_1 = -0.0056$

$a_2 = 25.3851$ $b_2 = -0.0066$

$a_3 = 14.0941$ $b_3 = -0.0375$

$a_4 = -7.0261$ $b_4 = 0.0636$

$a_5 = 2.7081$ $b_5 = -0.0144$

Sea-Bird Electronics, Inc.
1808 136th Place NE
Bellevue, WA 98005
USA

Phone: (425) 643-9866
Fax: (425) 643-9954
E-mail: seabird@seabird.com
Web: www.seabird.com

APPLICATION NOTE NO. 31 **Revised July 2007**

Computing Temperature and Conductivity *Slope* and *Offset* Correction Coefficients from Laboratory Calibrations and Salinity Bottle Samples

Conductivity Sensors

The conductivity sensor *slope* and *offset* entries in the configuration (.con) file in SEASOFT permit the user to make corrections for sensor drift between calibrations. The correction formula is:

(corrected conductivity) = slope * (computed conductivity) + offset

where :
slope = (true conductivity span) / (instrument reading conductivity span)
offset = (true conductivity - instrument reading conductivity) * slope *measured at 0 S/m*

For newly calibrated sensors, use slope = 1.0, offset = 0.0.

Sea-Bird conductivity sensors usually drift by changing span (the slope of the calibration curve), and changes are typically toward lower conductivity readings with time. Any offset error in conductivity (error at 0 S/m) is usually due to electronics drift, typically less than ±0.0001 S/m per year. Offsets greater than ±0.0002 S/m per year are symptomatic of sensor malfunction. **Therefore, Sea-Bird recommends that conductivity drift corrections be made by assuming no offset error, unless there is strong evidence to the contrary or a special need.**

Example
true conductivity =3.5 S/m
instrument reading conductivity = 3.49965 S/m
slope = 3.5 / 3.49965 = 1.000100

Correcting for Conductivity Drift Based on Pre- and Post-Cruise Laboratory Calibrations

Suppose a conductivity sensor is calibrated (pre-cruise), then immediately used at sea, and then returned for post-cruise calibration. The pre- and post-cruise calibration data can be used to generate a slope correction for data obtained between the pre- and post-cruise calibrations.

If **α** is the conductivity computed from the **pre-cruise bath data** (temperature and frequency) using **post-cruise calibration coefficients** and **β** is the true conductivity in the **pre-cruise bath**, then:

$$\textbf{postslope} = \frac{\sum_{i=1}^{n} (\alpha_i)(\beta_i)}{\sum_{i=1}^{n} (\alpha_i)(\alpha_i)}$$

(postslope is typically < 1.0)

Sea-Bird calculates and prints the value for postslope on the conductivity calibration sheet for all calibrations since February 1995 (see *Appendix I: Example Conductivity Calibration Sheet*)
.

To correct conductivity data taken between pre- and post-cruise calibrations:

islope = 1.0 + (b / n) [(1 / postslope) - 1.0]

where

islope = interpolated slope; this is the value to enter in the .con file

b = number of days between pre-cruise calibration and the cast to be corrected

n = number of days between pre- and post-cruise calibrations

postslope = slope from calibration sheet as calculated above (see *Appendix I: Example Conductivity Calibration Sheet*)

In the .con file, use the **pre-cruise calibration coefficients** and use **islope** for the value of slope.*

Note: In our SEASOFT-Win32 suite of programs, edit the CTD configuration (.con) file using the Configure Inputs menu in SEASAVE V7 (real-time data acquisition software) or the Configure menu in SBE Data Processing (data processing software).

For typical conductivity drift rates (equivalent to -0.003 PSU/month), islope does not need to be recalculated more frequently than at weekly intervals.

* You can also calculate preslope. If **α** is the conductivity computed from **post-cruise bath data** (temperature and frequency) using **pre-cruise calibration coefficients** and **β** is the true conductivity in the **post-cruise bath**, then:

$$\textbf{preslope} = \frac{\sum_{i=1}^{n} (\alpha_i)(\beta_i)}{\sum_{i=1}^{n} (\alpha_i)(\alpha_i)}$$ (preslope is typically > 1.0)

In this case, pre-cruise calibration coefficients would be used and:
islope = 1.0 + (b / n) (preslope - 1.0)

Correcting for Conductivity Drift Based on Salinity Bottles Taken At Sea

For this situation, the **pre-cruise** calibration coefficients are used to compute conductivity and CTD salinity. Salinity samples are obtained using water sampler bottles during CTD profiles, and the difference between CTD salinity and bottle salinity is used to determine the drift in conductivity.

In using this method to correct conductivity, it is important to realize that differences between CTD salinity and hydrographic bottle salinity are due to errors in conductivity, temperature, and pressure measurements, as well as errors in obtaining and analyzing bottle salinity values. For typical Sea-Bird sensors that are calibrated regularly, 70 - 90% of the CTD salinity error is due to conductivity calibration drift, 10 - 30% is due to temperature calibration drift, and 0 - 10% is due to pressure calibration drift. All CTD temperature and pressure errors and bottle errors must first be corrected before attributing the remaining salinity difference as due to CTD conductivity error and proceeding with conductivity corrections.

Example

Three salinity bottles are taken during a CTD profile; assume for this discussion that shipboard analysis of the bottle salinities is perfect. The **uncorrected** CTD data (from SEASAVE V7) and bottle salinities are:

Approximate Depth (m)	CTD Raw Pressure (dbar)	CTD Raw Temperature (°C) *	CTD Raw Conductivity (S/m)	CTD Raw Salinity	Bottle Salinity
200	202.7	18.3880	4.63421	34.9705	34.9770
1000	1008.8	3.9831	3.25349	34.4634	34.4710
4000	4064.1	1.4524	3.16777	34.6778	34.6850

****** Temperatures shown are **ITS-90**. However, the salinity equation is in terms of IPTS-68; you must convert ITS-90 to IPTS-68 (IPTS-68 = 1.00024 * ITS-90) before calculating salinity. SEASOFT does this automatically.*

The uncorrected salinity differences (CTD raw salinity - bottle salinity) are approximately -0.007 psu. To determine conductivity drift, first correct the CTD temperature and pressure data. Suppose that the error in temperature is +0.0015 °C uniformly at all temperatures, and the error in pressure is +0.5 dbar uniformly at all pressures (drift offsets are obtained by projecting the drift history of both sensors from pre-cruise calibrations). Enter these offsets in the .con file to calculate the corrected CTD temperature and pressure, and calculate the CTD salinity using the corrected CTD temperature and pressure. This correction method assumes that the pressure coefficient for the conductivity cell is correct. The CTD data with **corrected** temperature (ITS-90) and pressure are:

Corrected CTD Pressure (dbar)	Corrected CTD Temperature (°C)	CTD Raw Conductivity (S/m)	CTD Salinity [T,P Corrected]	Bottle Salinity
202.2	18.3865	4.63421	34.9719	34.9770
1008.3	3.9816	3.25349	34.4653	34.4710
4063.6	1.4509	3.16777	34.6795	34.6850

The salinity difference (CTD salinity – bottle salinity) of approximately -0.005 psu is now properly categorized as conductivity error, equivalent to about -0.0005 S/m at 4.0 S/m.

Compute bottle conductivity (conductivity calculated from bottle salinity and CTD temperature and pressure) using SeacalcW (in SBE Data Processing); enter bottle salinity for *salinity*, corrected CTD temperature for *ITS-90 temperature*, and corrected CTD pressure for *pressure*:

CTD Raw Conductivity (S/m)	Bottle Conductivity (S/m)	[CTD - Bottle] Conductivity (S/m)
4.63421	4.63481	-0.00060
3.25349	3.25398	-0.00049
3.16777	3.16822	-0.00045

By plotting conductivity error versus conductivity, it is evident that the drift is primarily a slope change. If **α** is the CTD conductivity computed with **pre-cruise** coefficients and **β** is the true bottle conductivity, then:

$$\textbf{slope} = \frac{\sum_{i=1}^{n} (\alpha_i)(\beta_i)}{\sum_{i=1}^{n} (\alpha_i)(\alpha_i)} \qquad \text{(slope is typically > 1.0)}$$

Using the above data, the slope correction coefficient for conductivity at this station is:

Slope = [(4.63421 * 4.63481) + (3.25349 * 3.25398) + (3.16777 * 3.16822)] /
[(4.63421 * 4.63421) + (3.25349 * 3.25349) + (3.16777 * 3.16777)] = **+1.000138**

Following Sea-Bird's recommendation of assuming no offset error in conductivity, **set offset to 0.0**.

Temperature Sensors

The temperature sensor *slope* and *offset* entries in the configuration (.con) file in SEASOFT permit the user to make corrections for sensor drift between calibrations. The correction formula is:

corrected temperature = slope * (computed temperature) + offset

where :

slope = (true temperature span) / (instrument reading temperature span)

offset = (true temperature - instrument reading temperature) * slope *measured at 0.0 °C*

For newly calibrated sensors, use slope = 1.0, offset = 0.0.

Sea-Bird temperature sensors usually drift by changing offset (an error of equal magnitude at all temperatures). In general, the drift can be toward higher or lower temperature with time; however, for a specific sensor the drift remains the same sign (direction) for many consecutive years. Many years of experience with thousands of sensors indicates that the drift is smooth and uniform with time, allowing users to make very accurate drift corrections to field data based only on pre- and post-cruise laboratory calibrations.

Span errors cause slope errors, as described in the equation for slope above. Sea-Bird temperature sensors rarely exhibit span errors larger than 0.005 °C over the range -5 to 35 °C, even after years of drift. Temperature calibrations performed at Sea-Bird since January 1995 have slope errors less than 0.0002 °C in 30 °C. Prior to January 1995, some calibrations were delivered that include slope errors up to 0.004 °C in 30 °C because of undetected systematic errors in calibration. A slope error that increases by more than ±0.0002 [°C per °C per year] indicates an unusual aging of electronic components and is symptomatic of sensor malfunction. **Therefore, Sea-Bird recommends that drift corrections**
to temperature sensors be made assuming no slope error, unless there is strong evidence to the contrary or a special need.

Calibration checks at-sea are advisable for consistency checks of the sensor drift rate and for early detection of sensor malfunction. However, data from reversing thermometers is rarely accurate enough to make calibration corrections that are better than those possible by shore-based laboratory calibrations. **For the SBE 9*plus***, a proven alternate consistency check is to use dual SBE 3 temperature sensors on the CTD and to track the difference in drift rates between the two sensors. In the deep ocean, where temperatures are uniform, the difference in temperature measured by two sensors can be resolved to better than 0.0002 °C and will change smoothly with time as predicted by the difference in drift rates of the two sensors.

Correcting for Temperature Drift Based on Pre- and Post-Cruise Laboratory Calibrations

Suppose a temperature sensor is calibrated (pre-cruise), then immediately used at-sea, and then returned for post-cruise calibration. The pre-and post-cruise calibration data can be used to generate an offset correction for data obtained between the pre- and post-cruise calibrations.

Calibration coefficients are calculated with the post-cruise calibration. Using the pre-cruise bath data and the post-cruise calibration coefficients, a mean residual over the calibration temperature range is calculated.

residual = instrument temperature – bath temperature

Sea-Bird calculates and prints the value for the residual on the temperature calibration sheet (see *Appendix II: Example Temperature Calibration Sheet*).

To correct temperature data taken between pre- and post-cruise calibrations:

Offset = b * (residual / n)

where

b = number of days between pre-cruise calibration and the cast to be corrected
n = number of days between pre- and post-cruise calibrations
residual = residual from calibration sheet as described above (see *Appendix II: Example Temperature Calibration Sheet*)

In the .con file, use the **pre-cruise calibration coefficients** and use the calculated **offset** for the value of offset.

Note: In our SEASOFT-Win32 suite of programs, edit the CTD configuration (.con) file using the Configure Inputs menu in SEASAVE V7 (real-time data acquisition software) or the Configure menu in SBE Data Processing (data processing software).

Example
Instrument was calibrated (pre-cruise), used at sea for 4 months, and returned for post-cruise calibration. Using **pre-cruise bath data** and **post-cruise coefficients**, the calibration sheet shows a mean residual of -0.2 millidegrees C (-0.0002 °C).

For preliminary work at sea, use the **pre-cruise calibration coefficients** and **slope = 1.0, offset = 0.0**. After the cruise, correct temperature data obtained during the cruise for drift using properly scaled values of correction coefficients:

For data from the end of the first month (30 days) at sea:
Offset = b * (residual / n) = 30 * (0.0002 / 120) = - 0.00005;
Convert data using **pre-cruise coefficients** and **-0.00005** as the offset in the .con file.

For data from the end of the second month (60 days) at sea:
Offset = b * (residual / n) = 60 * (0.0002 / 120) = - 0.0001;
Convert data using **pre-cruise coefficients** and **-0.0001** as the offset in the .con file.

For data from the end of the third month (90 days) at sea:
Offset = b * (residual / n) = 90 * (0.0002 / 120) = - 0.00015;
Convert data using **pre-cruise coefficients** and **-0.00015** as the offset in the .con file.

For data from the end of the 4-month cruise:
Offset = - 0.0002;
Convert data using **pre-cruise coefficients** and **-0.0002** as the offset in the .con file, or using **post-cruise** coefficients and **0** as the offset in the .con file.

Appendix I: Example Conductivity Calibration Sheet

SEA-BIRD ELECTRONICS, INC.
1808 136th Place N.E., Bellevue, Washington, 98005 USA
Phone: (425) 643 - 9866 Fax (425) 643 - 9954 Email: seabird@seabird.com

SENSOR SERIAL NUMBER: 2218
CALIBRATION DATE: 30-Dec-99

SBE4 CONDUCTIVITY CALIBRATION DATA
PSS 1978: C(35,15,0) = 4.2914 Seimens/meter

GHIJ COEFFICIENTS

```
g = -1.02414422e+001
h =  1.49331006e+000
i = -1.50844862e-003
j =  1.99364517e-004
CPcor = -9.5700e-008 (nominal)
CTcor =  3.2500e-006 (nominal)
```

Coefficients from *30-Dec-99* calibration.

ABCDM COEFFICIENTS

```
a =  3.56563909e-006
b =  1.48964234e+000
c = -1.02346588e+001
d = -8.62052534e-005
m =  5.4
CPcor = -9.5700e-008 (nominal)
```

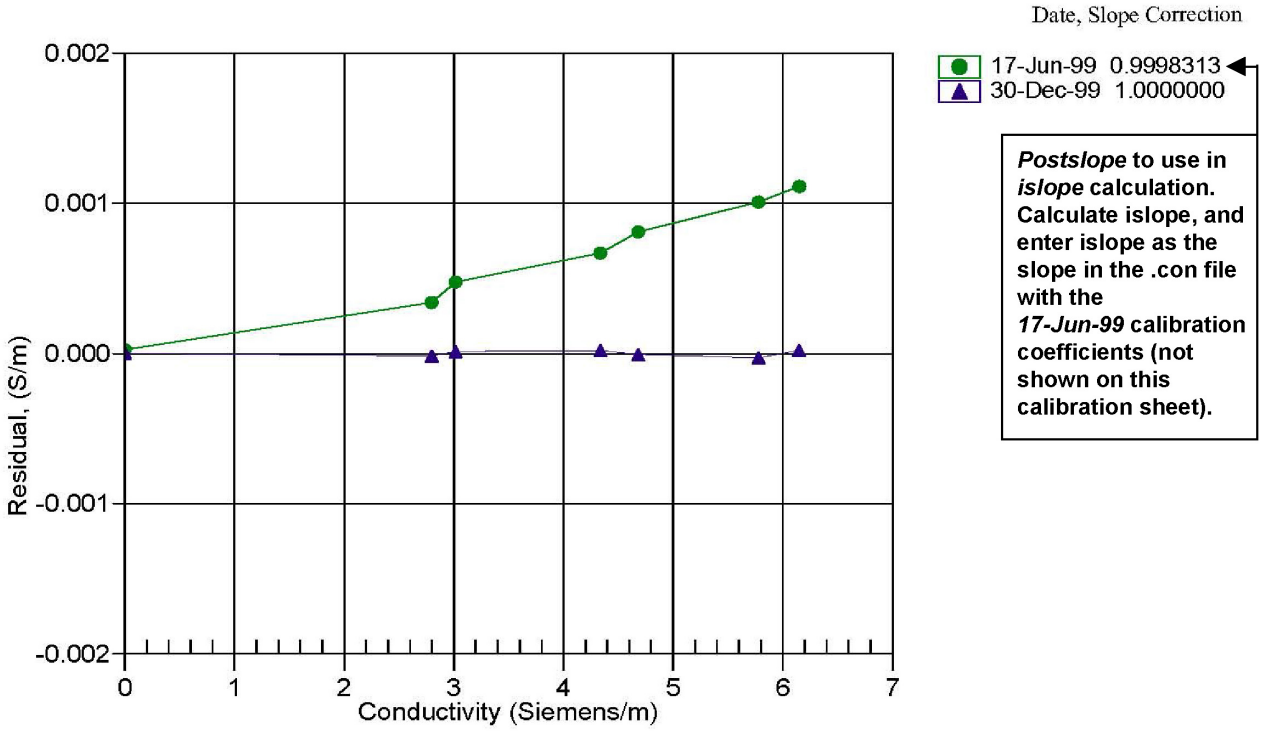
BATH TEMP (ITS-90)	BATH SAL (PSU)	BATH COND (Siemens/m)	INST FREQ (kHz)	INST COND (Siemens/m)	RESIDUAL (Siemens/m)
0.0000	0.0000	0.00000	2.62109	0.00000	0.00000
-1.3895	35.1839	2.79817	5.06354	2.79815	-0.00002
1.1492	35.1843	3.01746	5.20666	3.01747	0.00001
15.2688	35.1829	4.33837	5.99642	4.33839	0.00002
18.7065	35.1798	4.68224	6.18534	4.68224	-0.00001
29.2500	35.1699	5.78041	6.75306	5.78038	-0.00003
32.6897	35.1622	6.15002	6.93359	6.15004	0.00002

Conductivity = $(g + hf^2 + if^3 + jf^4) / 10(1 + \delta t + \varepsilon p)$ Siemens/meter

Conductivity = $(af^m + bf^2 + c + dt) / [10 (1 + \varepsilon p)$ Siemens/meter

t = temperature[°C)]; p = pressure[decibars]; δ = CTcor; ε = CPcor;

Residual = (instrument conductivity - bath conductivity) using g, h, i, j coefficients



***Poststope* to use in *islope* calculation. Calculate islope, and enter islope as the slope in the .con file with the *17-Jun-99* calibration coefficients (not shown on this calibration sheet).**

Appendix II: Example Temperature Calibration Sheet

SEA-BIRD ELECTRONICS, INC.

1808 136th Place N.E., Bellevue, Washington, 98005 USA

Phone: (425) 643 - 9866 Fax (425) 643 - 9954 Email: seabird@seabird.com

SENSOR SERIAL NUMBER: 2700
CALIBRATION DATE: 28-Dec-99

SBE3 TEMPERATURE CALIBRATION DATA
IPTS-90 TEMPERATURE SCALE

ITS-90 COEFFICIENTS

g = 4.36260004e-003
h = 6.49083037e-004
i = 2.42497805e-005
j = 2.36365545e-006
f0 = 1000.0

Coefficients from *28-Dec-99* calibration.

ITS-68 COEFFICIENTS

a = 3.67991178e-003
b = 6.04738390e-004
c = 1.65374250e-005
d = 2.36525963e-006
f0 = 2978.914

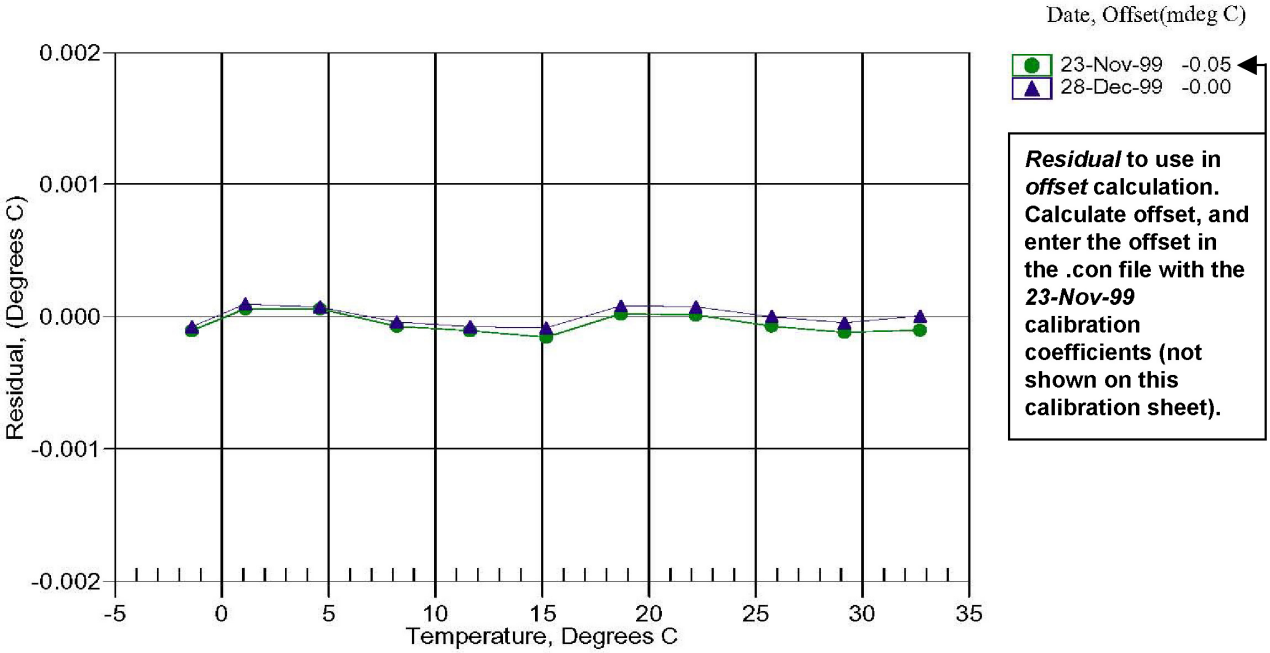
BATH TEMP (ITS-90)	INSTRUMENT FREQ (Hz)	INST TEMP (ITS-90)	RESIDUAL (ITS-90)
-1.4039	2978.914	-1.4040	-0.00008
1.1062	3149.847	1.1063	0.00009
4.5979	3399.248	4.5980	0.00007
8.1955	3670.718	8.1954	-0.00004
11.6295	3943.970	11.6295	-0.00007
15.1862	4241.874	15.1861	-0.00009
18.6903	4550.560	18.6904	0.00008
22.1892	4874.139	22.1893	0.00007
25.7491	5219.423	25.7491	-0.00000
29.1638	5566.173	29.1637	-0.00005
32.6970	5941.274	32.6970	0.00001

Temperature ITS-90 = $1/\{g + h[ln(f_0/f)] + i[ln^2(f_0/f)] + j[ln^3(f_0/f)]\} - 273.15$ (°C)

Temperature IPTS-68 = $1/\{a + b[ln(f_0/f)] + c[ln^2(f_0/f)] + d[ln^3(f_0/f)]\} - 273.15$ (°C)

Following the recommendation of JPOTS: T_{68} is assumed to be 1.00024 * T_{90} (-2 to 35 °C)

Residual = instrument temperature - bath temperature



***Residual* to use in *offset* calculation. Calculate offset, and enter the offset in the .con file with the *23-Nov-99* calibration coefficients (not shown on this calibration sheet).**

Sea-Bird Electronics, Inc.
1808 136th Place NE
Bellevue, WA 98005
USA

Phone: (425) 643-9866
Fax: (425) 643-9954
E-mail: seabird@seabird.com
Web: www.seabird.com

APPLICATION NOTE NO. 34 **Revised March 2008**

Instructions for Use of Conductivity Cell Filling and Storage Device PN 50087 and 50087.1

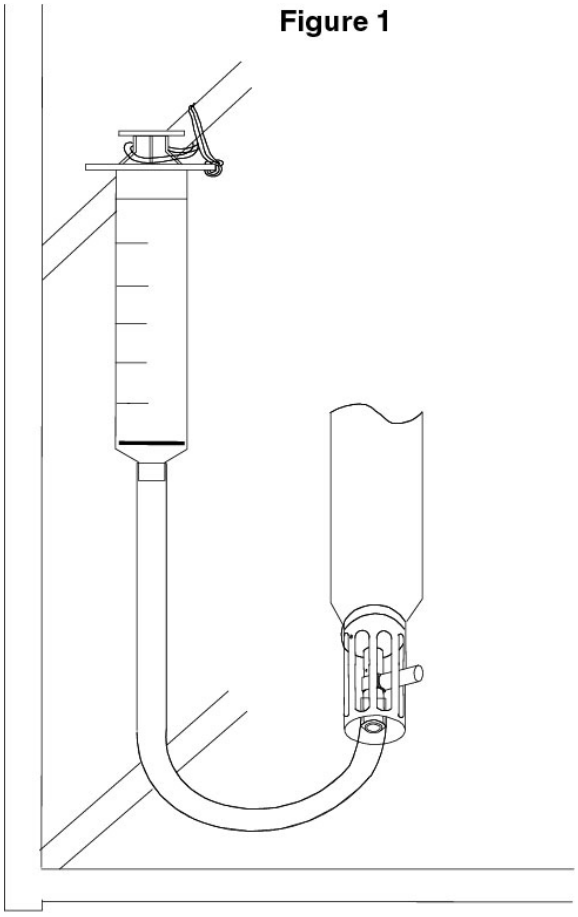


Figure 1

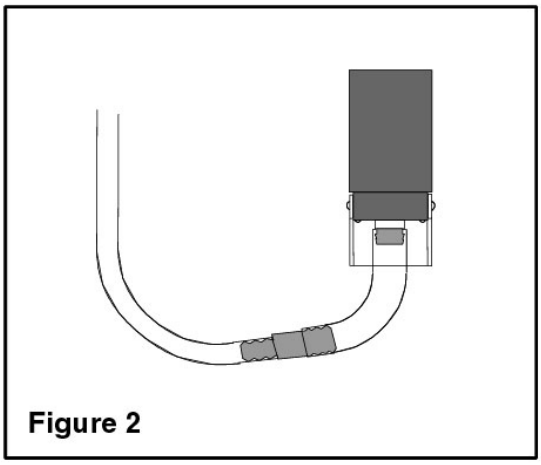


Figure 2

This application note provides instructions for use of PN 50087 / 50087.1 syringe and tubing assembly in rinsing, cleaning, and storing conductivity sensors. The tubing assembly consists of a length of 6.35 mm (1/4 inch) I.D. tube connected by a plastic reducing union to a short piece of 11.1 mm (7/16 inch) I.D. tube. Refer to *Application Note 2D: Instructions for Care and Cleaning of Conductivity Cells* for information on water and solutions recommended for use.

- SBE 9*plus*, 19*plus* V2, 25, and 49 are shipped with PN 50087.
- SBE 16*plus* V2 and 16*plus*-IM V2 are shipped with PN 50087.1, which includes the parts in 50087, plus hose barbs to replace the anti-foulant cap on the instrument. The hose barbs allow for connection of the tubing for cleaning and storing, as described below.

Note: This procedure can also be used with the SBE 16, 16*plus*, 16*plus*-IM, 19, and 19*plus*, which are no longer in production.

Procedure for Use

1. To fill the conductivity cell, draw about 40-60 cc of solution into the syringe.
2. Connect the plastic tubing to the TC duct intake on the temperature sensor [Figure 1] (or to the open end of the conductivity cell on systems without the TC duct [Figure 2]), and inject solution into the cell and pump plumbing.
   - CTDs with a TC duct or hose barb fitting - remove the plastic reducing union and connect the smaller diameter tubing directly to the TC duct / fitting.
   - CTDs without a TC duct or hose barb fitting (older instruments) - leave the reducing union and large diameter tubing attached and carefully connect the tubing directly to the end of the glass conductivity cell [Figure 2].
3. (If applicable) Loop the rubber band around a bar on the CTD cage and back over the top of the syringe to secure the apparatus for storage.

REMOVE THE SYRINGE AND TUBING ASSEMBLY BEFORE DEPLOYMENT!

Sea-Bird Electronics, Inc.
1808 136th Place NE
Bellevue, WA 98005
USA

Phone: (425) 643-9866
Fax: (425) 643-9954
E-mail: seabird@seabird.com
Web: www.seabird.com

APPLICATION NOTE NO. 42 **Revised March 2008**

ITS-90 TEMPERATURE SCALE

Beginning in January 1995, Sea-Bird's temperature metrology laboratory (based upon water triple-point and gallium melt cell, SPRT, and ASL F18 Temperature Bridge) converted to ITS-90 (T90). These T90 standards are employed in calibrating *all* Sea-Bird temperature sensors, and as the reference temperature used in conductivity calibrations.

The international oceanographic research community continues to use IPTS-68 (T68) for computation of salinity and other seawater properties. Therefore, following the recommendations of Saunders (1990) and as supported by the Joint Panel on Oceanographic Tables and Standards (1991), our software and our instrument firmware (for instruments that can calculate and output salinity and other seawater properties directly) converts between T68 and T90 according to the linear relationship:

$$T_{68} = 1.00024 * T_{90}$$

The use of T68 for salinity and other seawater calculations is automatic in our software and in those instruments that directly output salinity and other seawater parameters.

Note: In our SEASOFT-Win32 suite of software programs, edit the CTD configuration (.con) file to enter calibration coefficients using the Configure Inputs menu in SEASAVE V7 (real-time data acquisition software) or the Configure menu in SBE Data Processing (data processing software).

SBE 9*plus* (using SBE 3*plus* temperature sensor), 16, 19, 21, and 25 (using SBE 3F temperature sensor)

Beginning in January 1995, Sea-Bird temperature calibration certificates began listing a set of coefficients labeled *g*, *h*, *i*, *j*, and *F0*, corresponding to ITS-90 (T90) temperatures. For user convenience and for historical comparison with older calibrations, the certificates also continue to list *a*, *b*, *c*, *d*, and *F0* coefficients corresponding to IPTS-68 (T68) temperatures. The T90 coefficients result directly from T90 standards; the T68 coefficients are computed using the Saunders linear approximation.

SEASOFT supports entry of either the T90 or the T68 coefficients for these instruments. When selecting temperature as a display/output variable, you must select which standard (T90 or T68) is to be used to compute temperature. SEASOFT recognizes whether you have entered T90 or T68 coefficients in the configuration (.con) file, and performs the calculations accordingly, depending on which coefficients were used and which display variable type is selected.

- If *g, h, i, j, F0* coefficients (T90) are entered in the .con file and you select temperature display/output variable type as T68, SEASOFT computes T90 temperature directly and multiplies it by 1.00024 to display or output T68.
- If *a, b, c, d,* and *F0* coefficients (T68) are entered in the .con file and you select temperature display/output variable type as T90, SEASOFT computes T68 directly and divides by 1.00024 to display or output T90.

SBE 16*plus*, 16*plus*-IM, 16*plus* V2, 16*plus*-IM V2, 19*plus*, 19*plus* V2, 26*plus*, 35, 35RT, 37 (all), 38, 39 and 39-IM, 45, 49, 51, 52-MP, 53, *and all higher numbered instruments*

For these instruments, all first manufactured after the switch of our metrology lab to ITS-90, Sea-Bird provides only one set of temperature calibration coefficients, based on the T90 standards. These instruments all have user-programmable internal calibration coefficients, and can output data in engineering units (°C, S/m, dbar, etc. as applicable to the instrument). When outputting temperature in engineering units, these instruments always output T90 temperatures.

- Instruments that can internally compute and then output salinity and other seawater parameters (for example, SBE 37-SI) - Use of T68 for salinity and other seawater calculations is automatic; the instrument internally performs the conversion between T90 and T68 according to the Saunders equation.
- Instruments supported in SEASOFT (for example, SBE 19*plus* V2) - Use of T68 for salinity and other seawater calculations is automatic; the software performs the conversion between T90 and T68 according to the Saunders equation. When selecting temperature as a display/output variable, you must select which standard (T90 or T68) is to be used to compute temperature.

Sea-Bird Electronics, Inc.
1808 136th Place NE
Bellevue, WA 98005
USA

Phone: (425) 643-9866
Fax: (425) 643-9954
E-mail: seabird@seabird.com
Web: www.seabird.com

APPLICATION NOTE NO. 57 **Revised May 2003**

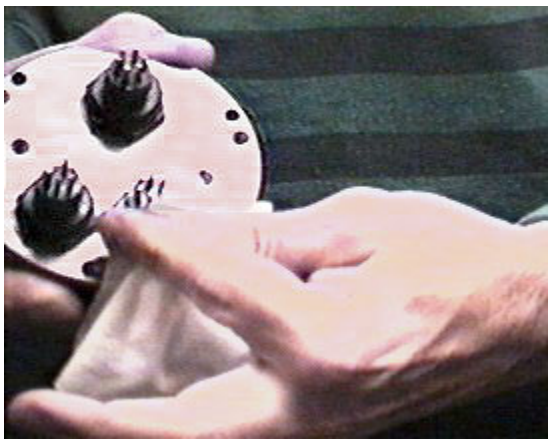
I/O Connector Care and Installation

This Application Note describes the proper care and installation of standard I/O connectors for Sea-Bird CTD instruments. Once properly installed, the connections require minimal care. Unless access to the bulkhead is required, the connections can be left in place indefinitely.

The Application Note is divided into three sections:
- Connector Cleaning and Installation
- Locking Sleeve Installation
- Cold Weather Tips

Connector Cleaning and Installation

1. Carefully clean the bulkhead connector and the inside of the mating inline (cable end) connector with a Kimwipe. Remove all grease, hair, dirt, and other contamination.



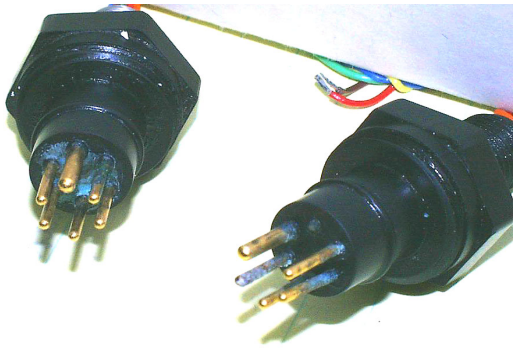
Clean bulkhead connector



Clean inside of connector

2. Inspect the connectors:
   A. Inspect the pins on the bulkhead connector for signs of corrosion. The pins should be bright and shiny, with no discoloration. If the pins are discolored or corroded, clean with alcohol and a Q-tip.
   B. Inspect the bulkhead connector for chips, cracks, or other flaws that may compromise the seal.
   C. Inspect the inline connector for cuts, nicks, breaks, or other problems that may compromise the seal.

   Replace severely corroded or otherwise damaged connectors - contact SBE for instructions or a Return Authorization Number (RMA number).



Corroded pins on bulkhead connectors - Connector on right has a missing pin

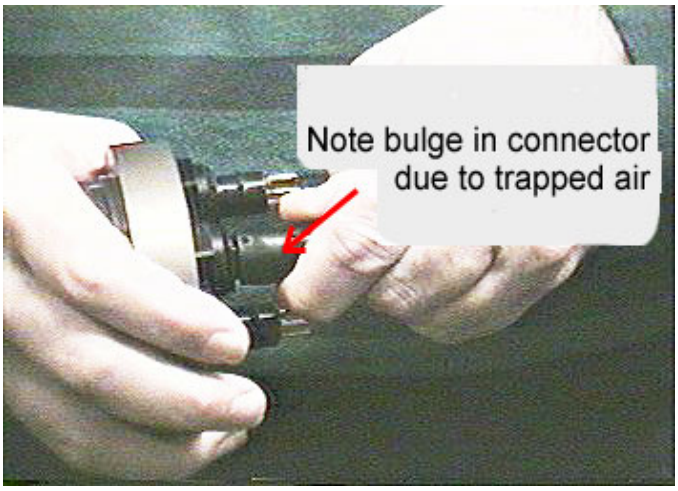
3. Using a tube of 100% silicone grease (Dow DC-4 or equivalent), squeeze approximately half the size of a pea onto the end of your finger.

CAUTION:
Do not use WD-40 or other petroleum-based lubricants, as they will damage the connectors.



4. Apply a light, even coating of grease to the molded ridge around the base of the bulkhead connector. The ridge looks like an o-ring molded into the bulkhead connector base and fits into the groove of the mating inline connector.



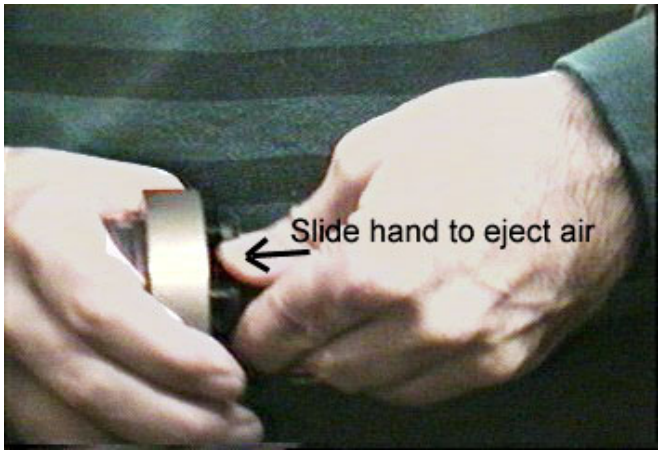


5. Mate the inline connector to the bulkhead, being careful to align the pins with the sockets. Do not twist the inline connector on the bulkhead connector. Twisting can lead to bent pins, which will soon break.

6. Push the connector all the way onto the bulkhead. There may be an audible pop, which is good. With some newer cables, or in cold weather, there may not be an initial audible pop.

7. After the cable is mated, run your fingers along the inline connector toward the bulkhead, *milking* any trapped air out of the connector. You should hear the air being ejected.

   CAUTION:
   Failure to eject the trapped air will result in the connector leaking.



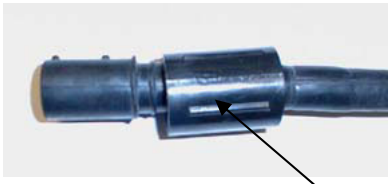
Locking Sleeve Installation

After the connectors are mated, install the locking sleeve. The locking sleeve secures the inline connector to the bulkhead connector and prevents the cable from being inadvertently removed.
Important points regarding locking sleeves:

- Tighten the locking sleeve by hand. **Do not** use a wrench or pliers to tighten the locking sleeve. Overtightening will gall the threads, which can bind the locking sleeve to the bulkhead connector. Attempting to remove a tightly bound locking sleeve may instead result in the bulkhead connector actually unthreading from the end cap. A loose bulkhead connector will lead to a flooded instrument. **Pay particular attention when removing a locking sleeve to ensure the bulkhead connector is not loosened**.

- It is a common misconception that the locking sleeve provides watertight integrity. **It does not, and continued re-tightening of the locking sleeve will not *fix* a leaking connector**.

- As part of routine maintenance at the end of every cruise, remove the locking sleeve, slide it up the cable, and rinse the connection (still mated) with fresh water. This will prevent premature cable failure.



Cold Weather Tips

In cold weather, the connector may be hard to install and remove.

Removing a *frozen* inline connector:

1. Wrap the connector with a washrag or other cloth.

2. Pour hot water on the cloth and let the connector sit for a minute or two. The connector should thaw and become flexible enough to be removed.

Installing an inline connector:
When possible, mate connectors in warm environments before the cruise and leave them connected.
If not, warm the connector sufficiently so it is flexible. A flexible connector will install properly.

By following these procedures, you will have many years of reliable service from your cables!

Sea-Bird Electronics, Inc.
1808 136th Place NE
Bellevue, WA 98005
USA

Phone: (425) 643-9866
Fax: (425) 643-9954
E-mail: seabird@seabird.com
Web: www.seabird.com

APPLICATION NOTE NO. 67 October 2001

Editing Sea-Bird .hex Data Files

After acquiring real-time .hex data or uploading .hex data from CTD memory, users sometimes want to edit the header to add or change explanatory notes about the cast. Some text editing programs modify the file in ways that are not visible to the user (such as adding or removing carriage returns and line feeds), but that corrupt the format and prevent further processing by SEASOFT (both DOS and Windows versions). **This Application Note provides details on one way to edit a .hex data file with a text editor while retaining the required format.** The procedure described below has been found to work correctly on computers running Win 98, Win 2000, and Win NT. If the editing is not performed using this technique, SEASOFT may reject the data file and give you an error message.

1. Make a back-up copy of your .hex data file before you begin.

2. Run **WordPad**.

3. In the File menu, select Open. The Open dialog box appears. For *Files of type*, select *All Documents (*.*)*. Browse to the desired .hex data file and click Open.

4. Edit the file as desired, **inserting any new header lines after the System Upload Time line**. Note that all header lines must begin with an asterisk (*), and *END* indicates the end of the header. An example is shown below, with the added lines in bold:

```
* Sea-Bird SBE 21 Data File:
* FileName = C:\Odis\SAT2-ODIS\oct14-19\oc15_99.hex
* Software Version Seasave Win32 v1.10
* Temperature SN = 2366
* Conductivity SN = 2366
* System UpLoad Time = Oct 15 1999  10:57:19
* Testing adding header lines
* Must start with an asterisk
* Can be placed anywhere between System Upload Time and END of header
* NMEA Latitude = 30 59.70 N
* NMEA Longitude = 081 37.93 W
* NMEA UTC (Time) = Oct 15 1999  10:57:19
* Store Lat/Lon Data = Append to Every Scan and Append to .NAV File When <Ctrl F7> is Pressed
** Ship:      Sea-Bird
** Cruise:    Sea-Bird Header Test
** Station:
** Latitude:
** Longitude:
*END*
```

5. In the File menu, select Save (**not** Save As). If you are running Windows 2000, the following message displays:
   You are about to save the document in a Text-Only format, which will remove all formatting. Are you sure you want to do this?
   Ignore the message and click *Yes*.

6. In the File menu, select Exit.

NOTE: This Application Note **does not apply to .dat data files**. Sea-Bird is not aware of a technique for editing a .dat file that will not corrupt the file.

Sea-Bird Electronics, Inc.
1808 136th Place NE
Bellevue, WA 98005
USA

Phone: (425) 643-9866
Fax: (425) 643-9954
E-mail: seabird@seabird.com
Web: www.seabird.com

APPLICATION NOTE NO. 68

Revised June 2009

Using USB Ports to Communicate with Sea-Bird Instruments

Most Sea-Bird instruments use the RS-232 protocol for transmitting setup commands to the instrument and receiving data from the instrument. However, most newer PCs and laptop computers have USB port(s) instead of RS-232 serial port(s).

USB serial adapters are available commercially. These adapters plug into the USB port, and allow one or more serial devices to be connected through the adapter. Sea-Bird tested USB serial adapters from several manufacturers on computers at Sea-Bird, and verified compatibility with our instruments. These manufacturers and the tested adapters are:

- **FTDI** (www.ftdichip.com) -
  "ChiPi" USB-RS232 Converter (model # FTDI UC232R-10).
  Note: This adapter can also be purchased from Sea-Bird, as Sea-Bird part # 20200.
  Drivers for this adapter can be found at http://www.ftdichip.com/Drivers/VCP.htm.

- **IOGEAR** (www.iogear.com) –
  USB 1.1 to Serial Converter Cable (model # GUC232A).
  Note: We have had several reports from customers that they could not communicate with their instrument using a laptop computer and this adapter.

- **Keyspan** (www.keyspan.com) -
  USB 4-Port Serial Adapter (part # USA-49WLC, replacing part # USA-49W)
  Note: We have one report from a customer that he could not communicate with his instrument using a notebook computer and this adapter. He was able to successfully communicate with the instrument using an XH8290 DSE Serial USB Adapter (www.dse.co.nz).

- **Edgeport** (www.ionetworks.com) -
  Standard Serial Converter Edgeport/2 (part # 301-1000-02)

Other USB adapters from these manufacturers, and adapters from other manufacturers, **may** also be compatible with Sea-Bird instruments.

We recommend testing any adapters, *including those listed above*, with the instrument and the computer you will use it with before deployment, to verify that there is no problem.

See Application Note 56: Interfacing to RS-485 Sensors for information on using a USB port to communicate with a Sea-Bird instrument that communicates via RS-485 telemetry.

Sea-Bird Electronics, Inc.
1808 136th Place NE
Bellevue, WA 98005
USA

Phone: (425) 643-9866
Fax: (425) 643-9954
E-mail: seabird@seabird.com
Web: www.seabird.com

APPLICATION NOTE NO. 71 Revised March 2008

Desiccant Use and Regeneration (drying)

This application note applies to all Sea-Bird instruments intended for underwater use. The application note covers:
- When to replace desiccant
- Storage and handling of desiccant
- Regeneration (drying) of desiccant
- Material Safety Data Sheet (MSDS) for desiccant

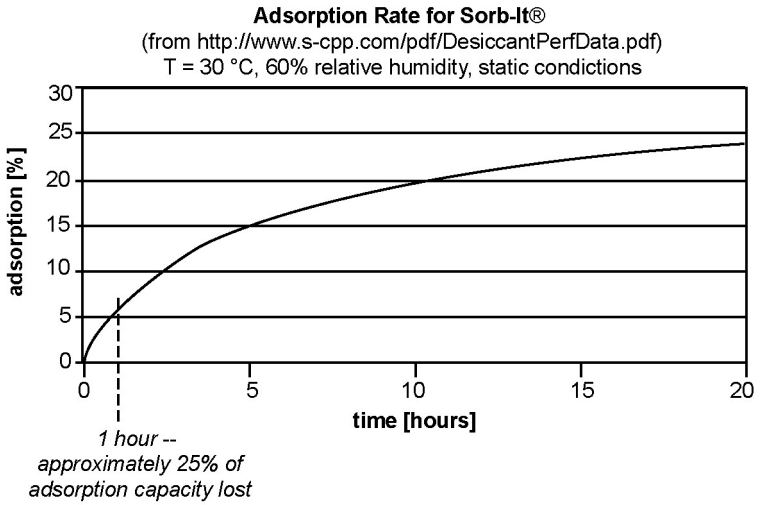
When to Replace Desiccant Bags

Before delivery of the instrument, a desiccant package is placed in the housing, and the electronics chamber is filled with dry Argon. These measures help prevent condensation. To ensure proper functioning:
1. Install a new desiccant bag each time you open the housing and expose the electronics.
2. If possible, dry gas backfill each time you open the housing and expose the electronics. If you cannot, wait at least 24 hours before redeploying, to allow the desiccant to remove any moisture from the chamber.

What do we mean by *expose the electronics*?
- For most battery-powered Sea-Bird instruments (such as SBE 16, 16*plus*, 16*plus* V2, 16*plus*-IM, 16*plus*-IM V2, 17*plus*, 19, 19*plus*, 19*plus* V2, 25, 26, 26*plus*, 37-SM, 37-SMP, 37-IM, 37-IMP, 44, 53, 54, 55, Auto Fire Module [AFM]), there is a bulkhead between the battery and electronics compartments. Battery replacement does not affect desiccation of the electronics, as the batteries are removed without removing the electronics and no significant gas exchange is possible through the bulkhead. Therefore, opening the battery compartment to replace the batteries does not expose the electronics; you do not need to install a new desiccant bag in the electronics compartment each time you open the battery compartment. For these instruments, install a new desiccant bag if you open the electronics compartment to access the printed circuit boards.
- For the SBE 39, 39-IM, and 48, the electronics must be removed or exposed to access the battery. Therefore, install a new desiccant bag each time you open the housing to replace a battery.

Storage and Handling

Testing by Süd-Chemie (desiccant's manufacturer) at 60% relative humidity and 30 °C shows that approximately 25% of the desiccant's adsorbing capacity is used up after only 1 hour of exposure to a constantly replenished supply of moisture in the air. In other words, if you take a bag out of a container and leave it out on a workbench for 1 hour, one-fourth of its capacity is gone before you ever install it in the instrument. Therefore:
- Keep desiccant bags in a tightly sealed, impermeable container until you are ready to use them. Open the container, remove a bag, and quickly close the container again.
- Once you remove the bag(s) from the sealed container, rapidly install the bag(s) in the instrument housing and close the housing. **Do not use the desiccant bag(s) if exposed to air for more than a total of 30 minutes.**



Regeneration (drying) of Desiccant

Replacement desiccant bags are available from Sea-Bird:

- PN 60039 is a metal can containing 25 1-gram desiccant bags and 1 humidity indicator card. The 1-gram bags are used in our smaller diameter housings, such as the SBE 3 (*plus*, F, and S), 4 (M and C), 5T and 5P, 37 (-SI, -SIP, -SM, -SMP, -IM, and –IMP), 38, 39, 39-IM, 43, 44, 45, 48, 49, and 50.
- PN 31180 is a 1/3-ounce desiccant bag, used in our SBE 16*plus*, 16*plus* V2, 16*plus*-IM, 16*plus*-IM V2, 19*plus*, 19*plus* V2, 21, and 52-MP.
- PN 30051 is a 1-ounce desiccant bag. The 1-ounce bags are used in our larger diameter housings, such as the SBE 9*plus*, 16, 17*plus*, 19, 25, 26, 26*plus*, 32, 53 BPR, 54, 55, AFM, and PDIM.

However, if you run out of bags, you can regenerate your existing bags using the following procedure provided by the manufacturer (Süd-Chemie Performance Packaging, a Division of United Catalysts, Inc.):

MIL-D-3464 Desiccant Regeneration Procedure

Regeneration of the United Desiccants' Tyvek Desi Pak® or Sorb-It® bags or United Desiccants' X-Crepe Desi Pak® or Sorb-It® bags can be accomplished by the following method:

1. Arrange the bags on a wire tray in a single layer to allow for adequate air flow around the bags during the drying process. The oven's inside temperature should be room or ambient temperature (25 – 29.4 °C [77 – 85 °F]). **A convection, circulating, forced-air type oven is recommended for this regeneration process. Seal failures may occur if any other type of heating unit or appliance is used.**

2. When placed in forced air, circulating air, or convection oven, allow a minimum of 3.8 to 5.1 cm (1.5 to 2.0 inches) of air space between the top of the bags and the next metal tray above the bags. If placed in a radiating exposed infrared-element type oven, shield the bags from direct exposure to the heating element, giving the closest bags a minimum of 40.6 cm (16 inches) clearance from the heat shield. Excessive surface film temperature due to infrared radiation will cause the Tyvek material to melt and/or the seals to fail. Seal failure may also occur if the temperature is allowed to increase rapidly. This is due to the fact that the water vapor is not given sufficient time to diffuse through the Tyvek material, thus creating internal pressure within the bag, resulting in a seal rupture. Temperature should not increase faster than 0.14 to 0.28 °C (0.25 to 0.50 °F) per minute.

3. Set the temperature of the oven to 118.3 °C (245 °F), and allow the bags of desiccant to reach equilibrium temperature. **WARNING**: Tyvek has a melt temperature of 121.1 – 126.7 °C (250 – 260 °F) (Non MIL-D-3464E activation or reactivation of both silica gel and Bentonite clay can be achieved at temperatures of 104.4 °C [220 °F]).

4. Desiccant bags should be allowed to remain in the oven at the assigned temperature for 24 hours. At the end of the time period, the bags should be immediately removed and placed in a desiccator jar or dry (0% relative humidity) airtight container for cooling. If this procedure is not followed precisely, any water vapor driven off during reactivation may be re-adsorbed during cooling and/or handling.

5. After the bags of desiccant have been allowed to cool in an airtight desiccator, they may be removed and placed in either an appropriate type polyliner tightly sealed to prevent moisture adsorption, or a container that prevents moisture from coming into contact with the regenerated desiccant.

NOTE: Use only a metal or glass container with a tight fitting metal or glass lid to store the regenerated desiccant. Keep the container lid **closed tightly** to preserve adsorption properties of the desiccant.

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Creating Performance Technology
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Sud-Chemie Performance Packaging
101 Christine Dr.
Belen, New Mexico 87002
Phone: (505) 864-6691
Fax: (505) 864-9296

MATERIAL SAFETY DATA SHEET – August 13, 2002
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SECTION I -- PRODUCT IDENTIFICATION

Trade Name and Synonyms:	Silica Gel, Synthetic Amorphous Silica, Silicon, Dioxide
Chemical Family:	Synthetic Amorphous Silica
Formula:	SiO_2.x H_2O

SECTION II -- HAZARDOUS INGREDIENTS

Components in the Solid Mixture

COMPONENT	CAS No	%	ACGIH/TLV (PPM)	OSHA-(PEL)
Amorphous Silica	63231-67-4	>99	PEL - 20 (RESPIRABLE), TLV – 5	LIMIT – NONE, HAZARD - IRRITANT

Synthetic amorphous silica is not to be confused with crystalline silica such as quartz, cristobalite or tridymite or with diatomaceous earth or other naturally occurring forms of amorphous silica that frequently contain crystalline forms.

This product is in granular form and packed in bags for use as a desiccant. Therefore, no exposure to the product is anticipated under normal use of this product. Avoid inhaling desiccant dust.

SECTION III -- PHYSICAL DATA

Appearance and Odor:	White granules; odorless.
Melting Point:	>1600 Deg C; >2900 Deg F
Solubility in Water:	Insoluble.
Bulk Density:	>40 lbs./cu. ft.
Percent Volatile by Weight @ 1750 Deg F:	<10%.

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SECTION IV -- FIRE EXPLOSION DATA

Fire and Explosion Hazard - Negligible fire and explosion hazard when exposed to heat or flame by reaction with incompatible substances.

Flash Point - Nonflammable.

Firefighting Media - Dry chemical, water spray, or foam. For larger fires, use water spray fog or foam.

Firefighting - Nonflammable solids, liquids, or gases: Cool containers that are exposed to flames with water from the side until well after fire is out. For massive fire in enclosed area, use unmanned hose holder or monitor nozzles; if this is impossible, withdraw from area and let fire burn. Withdraw immediately in case of rising sound from venting safety device or any discoloration of the tank due to fire.

SECTION V -- HEALTH HAZARD DATA

Health hazards may arise from inhalation, ingestion, and/or contact with the skin and/or eyes. Ingestion may result in damage to throat and esophagus and/or gastrointestinal disorders. Inhalation may cause burning to the upper respiratory tract and/or temporary or permanent lung damage. Prolonged or repeated contact with the skin, in absence of proper hygiene, may cause dryness, irritation, and/or dermatitis. Contact with eye tissue may result in irritation, burns, or conjunctivitis.

First Aid (Inhalation) - Remove to fresh air immediately. If breathing has stopped, give artificial respiration. Keep affected person warm and at rest. Get medical attention immediately.

First Aid (Ingestion) - If large amounts have been ingested, give emetics to cause vomiting. Stomach siphon may be applied as well. Milk and fatty acids should be avoided. Get medical attention immediately.

First Aid (Eyes) - Wash eyes immediately and carefully for 30 minutes with running water, lifting upper and lower eyelids occasionally. Get prompt medical attention.

First Aid (Skin) - Wash with soap and water.

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Sud-Chemie Performance Packaging
101 Christine Dr.
Belen, New Mexico 87002
Phone: (505) 864-6691
Fax: (505) 864-9296

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NOTE TO PHYSICIAN: This product is a desiccant and generates heat as it adsorbs water. The used product can contain material of hazardous nature. Identify that material and treat accordingly.

SECTION VI -- REACTIVITY DATA

Reactivity - Silica gel is stable under normal temperatures and pressures in sealed containers. Moisture can cause a rise in temperature which may result in a burn.

SECTION VII --SPILL OR LEAK PROCEDURES

Notify safety personnel of spills or leaks. Clean-up personnel need protection against inhalation of dusts or fumes. Eye protection is required. Vacuuming and/or wet methods of cleanup are preferred. Place in appropriate containers for disposal, keeping airborne particulates at a minimum.

SECTION VIII -- SPECIAL PROTECTION INFORMATION

Respiratory Protection - Provide a NIOSH/MSHA jointly approved respirator in the absence of proper environmental control. Contact your safety equipment supplier for proper mask type.

Ventilation - Provide general and/or local exhaust ventilation to keep exposures below the TLV. Ventilation used must be designed to prevent spots of dust accumulation or recycling of dusts.

Protective Clothing - Wear protective clothing, including long sleeves and gloves, to prevent repeated or prolonged skin contact.

Eye Protection - Chemical splash goggles designed in compliance with OSHA regulations are recommended. Consult your safety equipment supplier.

SECTION IX -- SPECIAL PRECAUTIONS

Avoid breathing dust and prolonged contact with skin. Silica gel dust causes eye irritation and breathing dust may be harmful.

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Sud-Chemie Performance Packaging
101 Christine Dr.
Belen, New Mexico 87002
Phone: (505) 864-6691
Fax: (505) 864-9296

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* No Information Available

HMIS (Hazardous Materials Identification System) for this product is as follows:

Health Hazard	0
Flammability	0
Reactivity	0
Personal Protection	HMIS assigns choice of personal protective equipment to the customer, as the raw material supplier is unfamiliar with the condition of use.

The information contained herein is based upon data considered true and accurate. However, United Desiccants makes no warranties expressed or implied, as to the accuracy or adequacy of the information contained herein or the results to be obtained from the use thereof. This information is offered solely for the user's consideration, investigation and verification. Since the use and conditions of use of this information and the material described herein are not within the control of United Desiccants, United Desiccants assumes no responsibility for injury to the user or third persons. The material described herein is sold only pursuant to United Desiccants' Terms and Conditions of Sale, including those limiting warranties and remedies contained therein. It is the responsibility of the user to determine whether any use of the data and information is in accordance with applicable federal, state or local laws and regulations.

Sea-Bird Electronics, Inc.
1808 136th Place NE
Bellevue, WA 98005
USA

Phone: (425) 643-9866
Fax: (425) 643-9954
E-mail: seabird@seabird.com
Web: www.seabird.com

APPLICATION NOTE NO. 83 **revised March 2008**

Deployment of Moored Instruments

This Application Note applies to Sea-Bird instruments intended to provide time series data on a mooring or fixed site:
- SBE 16*plus*, 16*plus*-IM, 16*plus* V2, and 16*plus*-IM V2 SEACAT Conductivity and Temperature Recorder
- SBE 19*plus* and 19*plus* V2 SEACAT Profiler CTD (in moored mode)
- SBE 26*plus* SEAGAUGE Wave and Tide Recorder
- SBE 37 (-IM, -IMP, -SM, -SMP, -SI, -SIP) MicroCAT Conductivity and Temperature Recorder
- SBE 39 and 39-IM Temperature Recorder
- SBE 53 BPR Bottom Pressure Recorder

We have developed a check list to assist users in deploying moored instruments. **This checklist is intended as a guideline to assist you in developing a checklist specific to your operation and instrument setup.** The actual procedures and procedure order may vary, depending on such factors as:
- Instrument communication interface - RS-232, RS-485, or inductive modem
- Deployment interface for RS-232 or RS-485 - with I/O cable for real-time data or dummy plug for self-contained operation
- Sampling initiation - using delayed start commands to set a date and time for sampling to automatically begin or starting sampling just before deploying the instrument
- Sensors included in your instrument –
  - Pressure is optional in the SBE 16*plus*, 16*plus*-IM, 16*plus* V2, 16*plus*-IM V2, 37 (all), 39, and 39-IM.
  - Conductivity is optional in the SBE 26*plus* and 53, and is not provided in the SBE 39 and 39-IM.
  - Optional auxiliary sensors can be integrated with the SBE 16*plus*, 16*plus*-IM, 16*plus* V2, 16*plus*-IM V2, 19*plus*, and 19*plus* V2.

Deployment Summary

Instrument serial number	
Mooring number	
Date of deployment	
Depth of instrument	
Intended date of recovery	
Capture file printout(s) attached, or file name and location (showing status command, calibration coefficients command if applicable, any other applicable commands)	
Actual date of recovery	
Condition of instrument at recovery	
Notes	

Preparation for Deployment

Task	Completed ?
If applicable, upload existing data in memory. Perform preliminary processing / analysis of data to ensure you have uploaded all data, that data was not corrupted in upload process, and that (if uploading converted data) instrument EEPROM was programmed with correct calibration coefficients. If there is a problem with data, you can try to upload again now. Once you record over data in next deployment, opportunity to correct any upload problem is gone.	
Initialize memory to make entire memory available for recording. If memory is not initialized, data will be stored after last recorded sample.	
Calculate battery endurance to ensure sufficient power for intended sampling scheme. See instrument manual for example calculations.	
Calculate memory endurance to ensure sufficient memory for intended sampling scheme. See instrument manual for example calculations.	
Install fresh batteries. Even if you think there is adequate battery capacity left for another deployment, cost of fresh batteries is small price to pay to ensure successful deployment.	
Establish setup / operating parameters. 1. Click Capture in terminal program and enter file name to record instrument setup, so you have complete record of communication with instrument. 2. Set current date and time. 3. Establish setup / operating parameters. 4. If desired, set date and time for sampling to automatically begin. 5. Send *Status* command (**DS** or **#iiDS**) to verify and provide record of setup. ** 6. Send *Calibration Coefficients* command (**DC**, **#iiDC**, **DCal**, or **#iiDCal**) to verify and provide record of calibration coefficients. **	
Get conductivity sensor ready for deployment: Remove protective plugs that were placed in Anti-Foulant Device caps **or** remove Tygon tubing that was looped end-to-end around conductivity cell to prevent dust / dirt from entering cell. *Note*: Deploying instrument with protective plugs or looped Tygon tubing in place will prevent instrument from measuring conductivity during deployment, and may destroy cell.	
Install fresh AF24173 Anti-Foulant Devices for conductivity sensor. Rate of anti-foul use varies greatly, depending on location and time of year. If you think there is adequate capability remaining, and previous deployment(s) in this location and at this time of year back up that assumption, you may not choose to replace Anti-Foulant Devices for every deployment. However, as for batteries, cost of fresh Anti-Foulant Devices is small price to pay to ensure successful deployment.	
For instrument with external pump (16*plus*, 16*plus*-IM, 16*plus* V2, 16*plus*-IM V2, 19*plus*, 19*plus* V2), verify that system plumbing is correctly installed. See instrument manual for configuration.	
Start sampling (if you did not set up instrument with a delayed start command), or verify that sampling has begun (if you set up instrument with a delayed start command). 1. Click Capture in terminal program and enter file name to record instrument setup, so you have a complete record of communication with instrument. 2. If you did not set up instrument with a delayed start command, send command to start sampling. 3. Send *Status* command (**DS** or **#iiDS**) to verify and provide record that instrument is sampling. ** 4. Send *Send Last* command (**SL** or **#iiSL**) to look at most recent sample and verify that output looks reasonable (i.e., ambient temperature, zero conductivity, atmospheric pressure). ** 5. If instrument has pressure sensor, record atmospheric pressure with barometer. You can use this information during data processing to check and correct for pressure sensor drift, by comparing to instrument's pressure reading in air (from Step 4). Note: For instrument with pump (external **or** integral), avoid running pump *dry* for extended period of time.	
If cable connectors or dummy plugs were unmated, reinstall cables or dummy plugs as described in *Application Note 57: Connector Care and Cable Installation*. Failure to correctly install cables may result in connector leaking, causing data errors as well as damage to bulkhead connector.	
Install mounting hardware on instrument. Verify that hardware is secure.	

** **Note:** Actual instrument command is dependent on communication interface and instrument.

Recovery

Immediately upon recovery

Task	Completed?
Rinse instrument with fresh water.	
Remove locking sleeve on dummy plug or cable, slide it up cable (if applicable), and rinse connection (still mated) with fresh water.	
For instrument with pump (external or integral), stop sampling. Connect to instrument in terminal program and send command to stop sampling (**Stop** or **#iiStop**). Stop sampling as soon as possible upon recovery to avoid running pump *dry* for an extended period of time. **	
If instrument has pressure sensor, record atmospheric pressure with barometer. You can use this information during data processing to check and correct for pressure sensor drift, by comparing to instrument's pressure reading in air.	
Gently rinse conductivity cell with clean de-ionized water, drain, and gently blow through cell to remove larger water droplets. • If cell is not rinsed between uses, salt crystals may form on platinized electrode surfaces. When instrument is used next, sensor accuracy may be temporarily affected until these crystals dissolve. • Note that **vigorous flushing is not recommended** if you will be sending instrument to Sea-Bird for post-deployment calibration to establish drift during deployment.	
For instrument with external pump (16*plus*, 16*plus*-IM, 16*plus* V2, 16*plus*-IM V2, 19*plus*, 19*plus* V2): Remove Tygon tubing from pump head's hose barbs, and rinse inside of pump head, pouring fresh water through a hose barb. If pump head is not rinsed between uses, salt crystals may form on impeller. Over time, this may *freeze* impeller in place, preventing pump from working.	
Install protective plugs in Anti-Foulant Device caps or loop Tygon tubing end-to-end around conductivity cell for *long term* storage. This will prevent dust / dirt from entering conductivity cell. *Note*: For short term (< 1 day) storage, see *Application Note 2D: Instructions for Care and Cleaning of Conductivity Cells*.	
Upload data in memory. 1. Connect to instrument in terminal program. 2. If you have not already done so, send command to stop sampling (**Stop** or **#iiStop**). ** 3. Click Upload in terminal program to upload data in memory. 4. Perform preliminary processing / data analysis to ensure you have uploaded all data, data was not corrupted in upload process, and (if uploading converted data) instrument EEPROM was programmed with correct calibration coefficients. If there is a problem with data, you can try to upload again now. Once you record over data in next deployment, opportunity to correct any upload problem is gone.	

** **Note:** Actual instrument command is dependent on communication interface and instrument.

Later

Task	Completed?
Clean conductivity cell, as needed: • Do not clean cell if you will be sending instrument to Sea-Bird for post-deployment calibration to establish drift during deployment. • Clean cell if you will not be performing a post-deployment calibration to establish drift. See cleaning instructions in instrument manual and *Application Note 2D: Instructions for Care and Cleaning of Conductivity Cells*.	
For instrument with external pump (16*plus*, 16*plus*-IM, 16*plus* V2, 16*plus*-IM V2, 19*plus*, 19*plus* V2): Clean pump as described in *Application Note 75: Maintenance of SBE 5T and 5M Pumps*.	
(Annually) Inspect and (if applicable) rinse pressure port. See instructions in instrument manual.	
Send instrument to Sea-Bird for calibrations / regular inspection and maintenance. We typically recommend that instrument be recalibrated once a year, but possibly less often if used only occasionally. Return instrument to Sea-Bird for recalibration. Between lab calibrations, take field salinity samples to document conductivity cell drift. ***Notes:*** 1. We cannot place instrument in our calibration bath if heavily covered with biological material or painted with anti-foul paint. Remove as much material as possible before shipping to Sea-Bird; if we need to clean instrument before calibrating it, we will charge you for cleaning. To remove barnacles, plug ends of conductivity cell to prevent cleaning solution from getting into cell, then soak instrument in white vinegar *for a few minutes*. To remove anti-foul paint, use Heavy Duty Scotch-Brite pad or similar material. 2. If using lithium batteries, do not ship batteries installed in instrument. See http://www.seabird.com/customer_support/LithiumBatteriesRev2005.htm for shipping details.	

Sea-Bird Electronics, Inc.
1808 136th Place NE
Bellevue, WA 98005
USA

Phone: (425) 643-9866
Fax: (425) 643-9954
E-mail: seabird@seabird.com
Web: www.seabird.com

APPLICATION NOTE 27Druck **Revised April 2008**

Minimizing Strain Gauge Pressure Sensor Errors

The following Sea-Bird instruments use strain gauge pressure sensors manufactured by GE Druck:

- SBE 16*plus*, 16*plus*-IM, 16*plus* V2, and 16*plus*-IM V2 SEACAT (not 16*) with optional strain gauge pressure sensor
- SBE 19*plus* and 19*plus* V2 SEACAT Profiler (not 19*)
- SBE 25 SEALOGGER CTD, which uses SBE 29 Strain-Gauge Pressure Sensor (built after March 2001)
- SBE 26*plus* SEAGAUGE Wave and Tide Recorder with optional strain gauge pressure sensor in place of Quartz pressure sensor
- SBE 37 MicroCAT (-IM, -IMP, -SM, -SMP, -SI, and -SIP) with optional pressure sensor (built after September 2000)
- SBE 39 Temperature Recorder with optional pressure sensor (built after September 2000) and 39-IM Temperature Recorder with optional pressure sensor
- SBE 49 FastCAT CTD Sensor
- SBE 50 Digital Oceanographic Pressure Sensor
- SBE 52-MP Moored Profiler CTD and DO Sensor

*** Note:** SBE 16 and SBE 19 SEACATs were originally supplied with other types of pressure sensors. However, a few of these instruments have been retrofitted with Druck sensors.

The Druck sensors are designed to respond to pressure in nominal ranges 0 - 20 meters, 0 - 100 meters, 0 - 350 meters, 0 – 600 meters, 0 – 1000 meters, 0 – 2000 meters, 0 – 3500 meters, and 0 – 7000 meters (with pressures expressed in meters of deployment depth capability). The sensors offer an initial accuracy of 0.1% of full scale range.

DEFINITION OF PRESSURE TERMS

The term *psia* means *pounds per square inch, absolute* (*absolute* means that the indicated pressure is referenced to a vacuum).

For oceanographic purposes, pressure is most often expressed in *decibars* (1 dbar = 1.4503774 psi). A dbar is 0.1 bar; a bar is approximately equal to a standard atmosphere (1 atmosphere = 1.01325 bar). For historical reasons, pressure at the water surface (rather than absolute or total pressure) is treated as the reference pressure (0 dbar); this is the value required by the UNESCO formulas for computation of salinity, density, and other derived variables.

Some oceanographers express pressure in Newtons/meter^2 or *Pascals* (the accepted SI unit). A Pascal is a very small unit (1 psi = 6894.757 Pascals), so the mega-Pascal (MPa = 10^6 Pascals) is frequently substituted (1 MPa = 100 dbar).

Since the pressure sensors used in Sea-Bird instruments are *absolute* types, their raw data inherently indicate atmospheric pressure (about 14.7 psi) when in air at sea level. Sea-Bird outputs pressure in one of the following ways:

- CTDs that output **raw data** (**SBE 16*plus*, 16*plus*-IM, 16*plus* V2, 16*plus*-IM V2, 19*plus*, 19*plus* V2, 25, and 49**) and are supported by SEASOFT's Seasave V7 (real-time data acquisition) and SBE Data Processing (data processing) software – In SEASOFT, user selects pressure output in psi (*not* psia) or dbar. SEASOFT subtracts 14.7 psi from the raw absolute reading and outputs the remainder as psi or converts the remainder to dbar.
- **SBE 26*plus*** – Real-time wave and tide data is output in psia. Wave and tide data stored in memory is processed using SEASOFT for Waves' Convert Hex module, and output in psia. Tide data can be converted to psi by subtracting a barometric pressure file using SEASOFT for Waves' Merge Barometric Pressure module.
- **SBE 50** – User selects pressure output in psia (including atmospheric pressure) or dbar. Calculation of dbar is as described above.
- All other instruments that can output **converted data in engineering units** (**SBE 16*plus*, 16*plus*-IM, 16*plus* V2, 16*plus*-IM V2, 19*plus*, 19*plus* V2, 37, 39, 39-IM, 49, and 52-MP**) – Instrument subtracts 14.7 psi from the raw absolute reading and converts the remainder to dbar.

Note: SBE 16*plus*, 16*plus*-IM, 16*plus* V2, 16*plus*-IM V2, 19*plus*, 19*plus* V2, 49, and 52-MP can output raw **or** converted data.

RELATIONSHIP BETWEEN PRESSURE AND DEPTH

Despite the common nomenclature (CTD = **C**onductivity - **T**emperature - **D**epth), all CTDs measure *pressure*, which is not quite the same thing as depth. The relationship between pressure and depth is a complex one involving water density and compressibility as well as the strength of the local gravity field, but it is convenient to think of a decibar as essentially equivalent to a meter, an approximation which is correct within 3% for almost all combinations of salinity, temperature, depth, and gravitational constant.

SEASOFT (most instruments)

SEASOFT offers two methods for estimating depth from pressure.

- For **oceanic applications**, salinity is presumed to be 35 PSU, temperature to be 0° C, and the compressibility of the water (with its accompanying density variation) is taken into account. This is the method recommended in UNESCO Technical Paper No. 44 and is a logical approach in that by far the greatest part of the deep-ocean water column approximates these values of salinity and temperature. Since pressure is also proportional to gravity and the major variability in gravity depends on latitude, the latitude is used to estimate the magnitude of the local gravity field.
  - SBE 16*plus*, 16*plus*-IM, 16*plus* V2, 16*plus*-IM V2, 19*plus*, 19*plus* V2, 25, and 49 -
    Seasave V7 - User enters latitude on the Miscellaneous tab in the Configure Inputs dialog box; the entry is used if Depth [salt water] is selected as a display or output variable.
    SBE Data Processing - User is prompted to enter latitude if Depth [salt water] is selected as an output variable in the Data Conversion or Derive module. Latitude can also be changed on the Miscellaneous tab in those modules.
    Note: For both Seasave V7 and SBE Data Processing, if the data includes NMEA data, the software uses the latitude from the NMEA data instead of the user entry for latitude when calculating depth.
  - SBE 37-SM, 37-SMP, 37-IM, and 37-IMP - User is prompted to enter latitude if Depth [salt water] is selected as an output variable in SBE Data Processing's Derive module. Latitude can also be changed on the Miscellaneous tab in that module.
  - SBE 37-SI, 37-SIP, and 50 - Latitude is entered in the instrument's EEPROM using the **Latitude=** command in SEASOFT's SEATERM (terminal program) software.
  - SBE 39 and 39-IM – User is prompted to enter latitude if conversion of pressure to depth is requested when converting an uploaded .asc file to a .cnv file in SEATERM.
- For **fresh water applications**, compressibility is not significant in the shallow depths encountered and is ignored, as is the latitude-dependent gravity variation. Fresh water density is presumed to be 1 gm/cm, and depth (in meters) is calculated as 1.019716 * pressure (in dbars). No latitude entry is required for freshwater applications for the following:
  - SBE 16*plus*, 16*plus*-IM, 16*plus* V2, 16*plus*-IM V2, 19*plus*, 19*plus* V2, 25, and 49
  - SBE 37-SM, 37-SMP, 37-IM, and 37-IMP
  - SBE 50

  Notes:
  - The SBE 37-SI and 37-SIP firmware does not differentiate between freshwater and saltwater applications when calculating depth; the **Latitude=** entry is always used for the depth calculation.
  - The Convert utility in SEATERM for the SBE 39 and 39-IM does not differentiate between freshwater and saltwater applications when calculating depth; the user is always prompted to enter latitude if conversion of pressure to depth is requested.

SEASOFT for Waves (SBE 26plus SEAGAUGE Wave and Tide Recorder)

SEASOFT for Waves' Merge Barometric Pressure module subtracts a user-input barometric pressure file from the tide data file, and outputs the remainder as pressure in psi or as depth in meters. When converting to depth, the compressibility of the water is taken into account by prompting for user-input values for average density and gravity. See the SBE 26*plus* manual's appendix for the formulas for conversion of pressure to depth.

CHOOSING THE RIGHT SENSOR

Initial accuracy and resolution are expressed as a percentage of the full scale range for the pressure sensor. The initial accuracy is 0.1% of the full scale range. Resolution is 0.002% of full scale range, except for the SBE 25 (0.015% resolution). For best accuracy and resolution, select a pressure sensor full scale range to correspond to no more than the greatest depths to be encountered. The effect of this choice on CTD accuracy and resolution is shown below:

Range (meters)	Maximum Initial Error (meters)	SBE 16*plus*, 16*plus*-IM, 16*plus* V2, 16*plus*-IM V2, 19*plus*, 19*plus* V2, 37, 39, 39-IM, 49, 50, and 52-MP - Resolution (meters)	SBE 25 - Resolution (meters)
0 – 20	0.02	0.0004	0.003
0 – 100	0.10	0.002	0.015
0 – 350	0.35	0.007	0.052
0 – 600	0.60	0.012	0.090
0 – 1000	1.0	0.02	0.15
0 - 2000	2.0	0.04	0.30
0 - 3500	3.5	0.07	0.52
0 - 7000	7.0	0.14	1.05

Note: See the SBE 26*plus* manual or brochure for its resolution specification; 26*plus* resolution is a function of integration time as well as pressure sensor range.

The meaning of *accuracy*, as it applies to these sensors, is that the indicated pressure will conform to true pressure to within ± *maximum error* (expressed as equivalent depth) throughout the sensor's operating range. Note that a 7000-meter sensor reading + 7 meters at the water surface is operating within its specifications; the same sensor would be expected to indicate 7000 meters ± 7 meters when at full depth.

Resolution is the magnitude of indicated increments of depth. For example, a 7000-meter sensor on an SBE 25 (resolution 1.05 meters) subjected to slowly increasing pressure will produce readings approximately following the sequence *0, 1.00, 2.00, 3.00* (meters). Resolution is limited by the design configuration of the CTD's A/D converter. For the SBE 25, this restricts the possible number of discrete pressure values for a given sample to somewhat less than 8192 (13 bits); an approximation of the ratio 1 : 7000 is the source of the SBE 25's 0.015% resolution specification.

Note: SEASOFT (and other CTD software) presents temperature, salinity, and other variables as a function of depth or pressure, so the CTD's pressure resolution limits the number of plotted data points in the profile. For example, an SBE 25 with a 7000-meter sensor might acquire several values of temperature and salinity during the time required to descend from 1- to 2-meters depth. However, all the temperature and salinity values will be graphed in clusters appearing at either 1 or 2 meters on the depth axis.

High-range sensors used in shallow water generally provide better accuracy than their *absolute* specifications indicate. With careful use, they may exhibit *accuracy* approaching their *resolution* limits. For example, a 3500-meter sensor has a nominal accuracy (irrespective of actual operating depth) of ± 3.5 meters. Most of the error, however, derives from variation over time and temperature of the sensor's *offset*, while little error occurs as a result of changing *sensitivity*.

MINIMIZING ERRORS

Offset Errors

Note: Follow the procedures below for all instruments except the SBE 26*plus* (see the 26*plus* manual for details).

The primary *offset* error due to drift over time can be eliminated by comparing CTD readings in air before beginning the profile to readings from a barometer. Follow this procedure:

1. Allow the instrument to equilibrate in a reasonably constant temperature environment for at least 5 hours. Pressure sensors exhibit a transient change in their output in response to changes in their environmental temperature; allowing the instrument to equilibrate before starting will provide the most accurate calibration correction.

2. Place the instrument in the orientation it will have when deployed.

3. Set the pressure offset to 0.0:
   - In the .con file, using Seasave V7 or SBE Data Processing (for SBE 16*plus*, 16*plus*-IM, 16*plus* V2, 16*plus*-IM V2, 19*plus*, 19*plus* V2, 25, or 49).
   - In the CTD's EEPROM, using the appropriate command in the terminal program (for SBE 16*plus*, 16*plus*-IM, 16*plus* V2, 16*plus*-IM V2, 19*plus*, 19*plus* V2, 37, 39, 39-IM, 49, 50, or 52-MP).

4. Collect pressure data from the instrument using Seasave V7 or the terminal program, as appropriate (see instrument manual for details). If the instrument is not outputting data in decibars, convert the output to decibars.

5. Compare the instrument output to the reading from a good barometer placed at the same elevation as the pressure sensor. Calculate *offset* (decibars) = barometer reading (converted to decibars) – instrument reading (decibars).

6. Enter calculated offset (positive or negative) in decibars:
   - In the .con file, using Seasave V7 or SBE Data Processing (for SBE 16*plus*, 16*plus*-IM, 16*plus* V2, 16*plus*-IM V2, 19*plus*, 19*plus* V2, 25, or 49). **AND**
   - In the CTD's EEPROM, using the appropriate command in the terminal program (for SBE 16*plus*, 16*plus*-IM, 16*plus* V2, 16*plus*-IM V2, 19*plus*, 19*plus* V2, 37, 39, 39-IM, 49, 50, or 52-MP).

Note: For instruments that store calibration coefficients in EEPROM and **also** use a .con file (SBE 16*plus*, 16*plus*-IM, 16*plus* V2, 16*plus*-IM V2, 19*plus*, 19*plus* V2, and 49), set the pressure offset (Steps 3 and 6 above) in both the EEPROM and in the .con file.

Offset Correction Example
Absolute pressure measured by a barometer is 1010.50 mbar. Pressure displayed from instrument is -2.5 dbars.
Convert barometer reading to dbars using the relationship: mbar * 0.01 = dbars
Barometer reading = 1010.50 mbar *0.01 = 10.1050 dbars
Instrument's internal calculations and/or our processing software output gage pressure, using an assumed value of 14.7 psi for atmospheric pressure. Convert instrument reading from gage to absolute by adding 14.7 psia to instrument output:
- 2.5 dbars + (14.7 psi * 0.689476 dbar/psia) = - 2.5 + 10.13 = 7.635 dbars
Offset = 10.1050 – 7.635 = + 2.47 dbar Enter offset in .con file (if applicable) and in instrument EEPROM (if applicable).

Another source of *offset* error results from temperature-induced drifts. Because Druck sensors are carefully temperature compensated, errors from this source are small. Offset errors can be estimated for the conditions of your profile, and eliminated when post-processing the data in SBE Data Processing by the following procedure:

1. **Immediately** before beginning the profile, take a pre-cast *in air* pressure reading.

2. **Immediately** after ending the profile, take a post-cast *in air* pressure reading with the instrument at the same elevation and orientation. This reading reflects the change in the instrument temperature as a result of being submerged in the water during the profile.

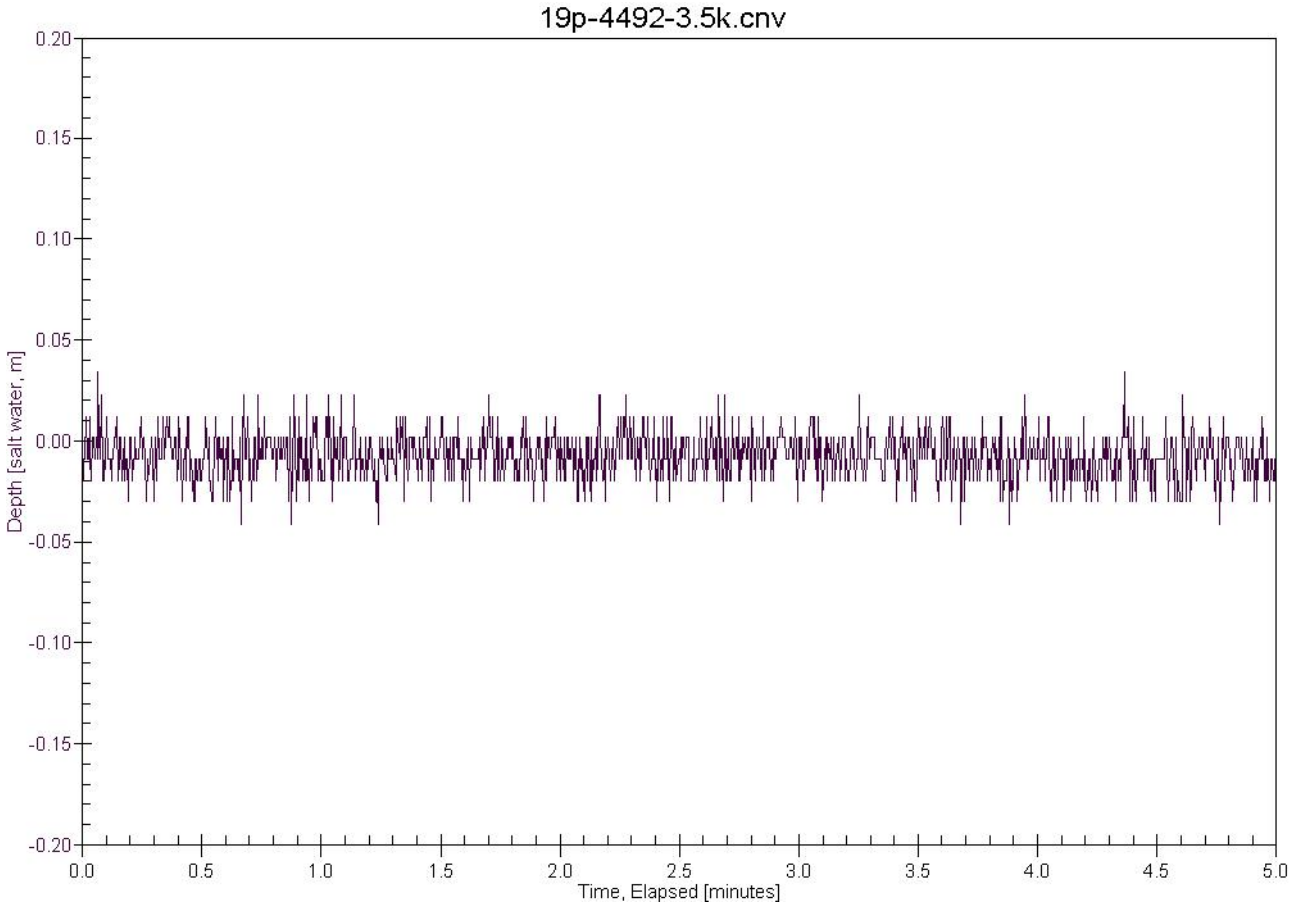
3. Calculate the average of the pre- and post-cast readings. Enter the negative of the average value (in decibars) as the *offset* in the .con file.

Hysteresis Errors

Hysteresis is the term used to describe the failure of pressure sensors to repeat previous readings after exposure to other (typically higher) pressures. The Druck sensor employs a micro-machined silicon diaphragm into which the strain elements are implanted using semiconductor fabrication techniques. Unlike metal diaphragms, silicon's crystal structure is perfectly elastic, so the sensor is essentially free of pressure hysteresis.

Power Turn-On Transient

Druck pressure sensors exhibit virtually no power turn-on transient. The plot below, for a 3500-meter pressure sensor in an SBE 19*plus* SEACAT Profiler, is representative of the power turn-on transient for all pressure sensor ranges.



Thermal Transient

Pressure sensors exhibit a transient change in their output in response to changes in their environmental temperature, so the thermal transient resulting from submersion in water must be considered when deploying the instrument.

During calibration, the sensors are allowed to *warm-up* before calibration points are recorded. Similarly, for best depth accuracy the user should allow the CTD to *warm-up* for several minutes before beginning a profile; this can be part of the *soak* time in the surface water. *Soaking* also allows the CTD housing to approach thermal equilibrium (minimizing the housing's effect on measured temperature and conductivity) and permits a Beckman- or YSI-type dissolved oxygen sensor (if present) to polarize.

Sea-Bird Electronics, Inc.
1808 136th Place NE
Bellevue, WA 98005
USA

Phone: (425) 643-9866
Fax: (425) 643-9954
E-mail: seabird@seabird.com
Web: www.seabird.com

APPLICATION NOTE NO. 69 **July 2002**

Conversion of Pressure to Depth

Sea-Bird's SEASOFT software can calculate and output depth, if the instrument data includes pressure. Additionally, some Sea-Bird instruments (such as the SBE 37-SI or SBE 50) can be set up by the user to internally calculate depth, and to output depth along with the measured parameters.

Sea-Bird uses the following algorithms for calculating depth:

Fresh Water Applications

Because most fresh water applications are shallow, and high precision in depth not too critical, Sea-Bird software uses a very simple approximation to calculate depth:

depth (meters) = pressure (decibars) * 1.019716

Seawater Applications

Sea-Bird uses the formula in UNESCO Technical Papers in Marine Science No. 44. This is an empirical formula that takes compressibility (that is, density) into account. An ocean water column at 0 °C (t = 0) and 35 PSU (s = 35) is assumed.

The gravity variation with latitude and pressure is computed as:

$$g\ (m/sec^2) = 9.780318 * [\ 1.0 + (\ 5.2788x10^{-3} + 2.36x10^{-5} * x) * x\ ] + 1.092x10^{-6} * p$$

where
x = [sin (latitude / 57.29578)] ^{2}
p = pressure (decibars)

Then, depth is calculated from pressure:

$$depth\ (meters) = [(((-1.82x10^{-15} * p + 2.279x10^{-10}) * p - 2.2512x10^{-5}) * p + 9.72659) * p] / g$$

where
p = pressure (decibars)
g = gravity (m/sec^2)

Sea-Bird Electronics, Inc.
1808 136th Place NE
Bellevue, WA 98005
USA

Phone: (425) 643-9866
Fax: (425) 643-9954
E-mail: seabird@seabird.com
Web: www.seabird.com

APPLICATION NOTE NO. 73 **Revised February 2009**

Using Instruments with Pressure Sensors at Elevations Above Sea Level

This application note covers use of a Sea-Bird instrument that includes a pressure sensor at elevations above sea level, such as in a mountain lake or stream.

Background

Sea-Bird pressure sensors are absolute sensors, so their raw output includes the effect of atmospheric pressure. As shown on the Calibration Sheet that accompanies the instrument, our calibration (and resulting calibration coefficients) is in terms of psia. However, when outputting pressure in engineering units, most of our instruments output pressure relative to the ocean surface (i.e., at the surface the output pressure is 0 decibars). Sea-Bird uses the following equation in our instruments and/or software to convert psia to decibars:

Pressure (db) = [pressure (psia) – 14.7] * 0.689476

where 14.7 psia is the assumed atmospheric pressure (based on atmospheric pressure at sea level).

This conversion is based on the assumption that the instrument is being used in the ocean; the surface of the ocean water is by definition at sea level. However, if the instrument is used in a mountain lake or stream, the assumption of sea level atmospheric pressure (14.7 psia) in the instrument and/or software can lead to incorrect results. Procedures are provided below for measuring the pressure *offset* from the assumed sea level atmospheric pressure, and entering the offset in the instrument and/or software to make the appropriate correction.

- **Perform the correction procedure at the elevation at which the instrument will be deployed.** Allow the instrument to equilibrate in a reasonably constant temperature environment for at least 5 hours before starting. Pressure sensors exhibit a transient change in their output in response to changes in their environmental temperature. Sea-Bird instruments are constructed to minimize this by thermally decoupling the sensor from the body of the instrument. However, there is still some residual effect; allowing the instrument to equilibrate before starting will provide the most accurate calibration correction.

Inclusion of calibration coefficients in the instrument itself or in a file used by our software to interpret raw data varies, depending on the instrument. Commands used to program the instrument vary as well. Therefore, there are variations in the correction procedure, depending on the instrument. These instruments are addressed below:

- SBE **9*plus*** CTD and SBE **25** SEALOGGER CTD
- SBE **16*plus*** and **16*plus* V2 (RS-232 versions)** SEACAT C-T (pressure optional) Recorder, SBE **19*plus*** and **19*plus* V2** SEACAT Profiler CTD, and SBE **49** FastCAT CTD Sensor
- SBE **16*plus*** and **16*plus* V2 (RS-485 versions)** SEACAT C-T (pressure optional) Recorder, and SBE **16*plus*-IM** and **16*plus*-IM V2** SEACAT C-T (pressure optional) Recorder
- SBE **37** MicroCAT (all models, firmware version $\geq$ 3.0)
- SBE **37** MicroCAT (all models, firmware version < 3.0)
- SBE **50** Digital Oceanographic Pressure Sensor
- SBE **52-MP** Moored Profiler CTD and DO Sensor
- SBE **39-IM** Temperature (pressure optional) Recorder
- SBE **39** Temperature (pressure optional) Recorder
- SBE **26*plus*** SEAGAUGE Wave and Tide Recorder and SBE **53** BPR Bottom Pressure Recorder

SBE 9*plus* and 25

Sea-Bird real-time data acquisition software (SEASAVE) and post-processing software (SBE Data Processing) use calibration coefficients programmed in a configuration (.con) file to convert raw data from these instruments to engineering units.

Follow this procedure to correct the pressure:
1. With the instrument in the air, place it in the orientation it will have when deployed.
2. In SEASAVE, in the .con file, set the pressure offset to 0.0.
3. Acquire data in SEASAVE, and display the pressure sensor output in decibars.
4. Calculate *offset* = (0 – instrument reading).
5. Enter the calculated offset in the .con file.

Offset Correction Example:
Pressure displayed at elevation is -1.655 db. *Offset* = 0 – (-1.655) = + 1.655 db
Enter offset in .con file.

SBE 16*plus* and 16*plus* V2 (RS-232 versions), 19*plus* and 19*plus* V2, and 49

Sea-Bird real-time data acquisition software (SEASAVE) and post-processing software (SBE Data Processing) use calibration coefficients programmed in a configuration (.con) file to convert raw data from these instruments to engineering units. These instruments are also able to directly output data that is already converted to engineering units (pressure in decibars), using calibration coefficients that are programmed into the instrument.

Follow this procedure to correct the pressure:
1. With the instrument in the air, place it in the orientation it will have when deployed.
2. In SEASAVE, in the .con file, set the pressure offset to 0.0.
3. Acquire data in SEASAVE, and display the pressure sensor output in decibars.
4. Calculate *offset* = (0 – instrument reading).
5. Enter the calculated offset in the .con file.
6. Also enter the calculated offset in the instrument (using the **POffset=** command in the terminal program*).
   *Note: SBE 16*plus* V2 and 19*plus* V2 use SeatermV2 terminal program; the other instruments use SEATERM.

Offset Correction Example:
Pressure displayed at elevation is -1.655 db. *Offset* = 0 – (-1.655) = + 1.655 db
Enter offset in .con file and in instrument.

SBE 16*plus* and 16*plus* V2 (RS-485 versions), and 16*plus*-IM and 16*plus*-IM V2

Sea-Bird real-time data acquisition software (SEASAVE) and post-processing software (SBE Data Processing) use calibration coefficients programmed in a configuration (.con) file to convert raw data from these instruments to engineering units. These instruments are also able to directly output data that is already converted to engineering units (pressure in decibars), using calibration coefficients that are programmed into the instrument.

Follow this procedure to correct the pressure:
1. With the instrument in the air, place it in the orientation it will have when deployed.
2. In the terminal program*, set the pressure offset to 0.0 (**#iiPOffset=0**) and set the output format to converted data in decimal form (**#iiOutputFormat=3**).
   *Note: 16*plus* V2 and 16*plus*-IM V2 use SeatermV2; the other instruments use SEATERM.
3. Acquire data using the **#iiTP** command.
4. Calculate *offset* = (0 – instrument reading).
5. Enter the calculated offset in the instrument (using the **#iiPOffset=** command).
6. Also enter the calculated offset in the .con file, using SBE Data Processing.

Offset Correction Example:
Pressure displayed at elevation is -1.655 db. *Offset* = 0 – (-1.655) = + 1.655 db
Enter offset in .con file and in instrument.

SBE 37 (all models, firmware version ≥ 3.0)

The SBE 37 is able to directly output data that is already converted to engineering units (pressure in decibars), using calibration coefficients that are programmed into the instrument. The SBE 37 does not use a .con file.

Follow this procedure to correct the pressure:
1. With the SBE 37 in the air, place it in the orientation it will have when deployed.
2. In the SeatermV2 terminal program, set the pressure offset to 0.0 and pressure sensor output to decibars. *
3. Acquire data. *
4. Calculate *offset* = (0 – instrument reading).
5. Enter the calculated offset in the SBE 37 in SeatermV2. *

Offset Correction Example:
Pressure displayed at elevation is -1.655 db. *Offset* = 0 – (-1.655) = + 1.655 db
Enter offset in the SBE 37.

* NOTE: Commands for setting pressure offset, setting output format, and acquiring data vary:

Instrument	Pressure Offset Command	Output Format Command	Command to Acquire Data **
MicroCATs with Inductive Modem (IM) or RS-485 telemetry	**#iiPOffset=**	**#iiOutputFormat=1**	**#iiTSn:100** (measures and outputs data 100 times)
MicroCATs with RS-232 telemetry	**POffset=**	**OutputFormat=1**	**TSn:100** (measures and outputs data 100 times)

** See MicroCAT manual for location of pressure data in output data string.

SBE 37 (all models, firmware version < 3.0)

The SBE 37 is able to directly output data that is already converted to engineering units (pressure in decibars), using calibration coefficients that are programmed into the instrument. The SBE 37 does not use a .con file.

Follow this procedure to correct the pressure:
1. With the SBE 37 in the air, place it in the orientation it will have when deployed.
2. In the SEATERM terminal program, set the pressure offset to 0.0 and pressure sensor output to decibars. *
3. Acquire data. *
4. Calculate *offset* = (0 – instrument reading).
5. Enter the calculated offset in the SBE 37 in SEATERM. *

Offset Correction Example:
Pressure displayed at elevation is -1.655 db. *Offset* = 0 – (-1.655) = + 1.655 db
Enter offset in the SBE 37.

* NOTE: Commands for setting pressure offset, setting output format, and acquiring data vary:

Instrument	Pressure Offset Command	Output Format Command	Command to Acquire Data
MicroCATs with Inductive Modem (IM) or RS-485 telemetry	**#iiPOffset=**	**#iiFormat=1**	**#iiTP** (measures and outputs pressure 30 times)
MicroCATs with RS-232 telemetry	**POffset=**	**Format=1**	**TP** (measures and outputs pressure 100 times)

SBE 50

The SBE 50 is able to directly output data that is already converted to engineering units (psia, decibars, or depth in feet or meters), using calibration coefficients that are programmed into the instrument. The SBE 50 does not use a .con file.

Follow this procedure to correct the pressure:
1. With the SBE 50 in the air, place it in the orientation it will have when deployed.
2. In the SEATERM terminal program, set the pressure offset to 0.0 (**POffset=0**) and set the output format to the desired format (**OutputFormat=**).
3. Acquire data using the **TS** command a number of times.
4. Calculate *offset* = (0 – instrument reading).
5. Enter the calculated offset in the SBE 50 (use **POffset=** in SEATERM). The offset must be entered in units consistent with **OutputFormat=**. For example, if the output format is decibars (**OutputFormat=2**), enter the offset in decibars.

   Offset Correction Example:
   Pressure displayed at elevation with **OutputFormat=2** (db) is -1.655 db. *Offset* = 0 – (-1.655) = + 1.655 db
   Enter offset in the SBE 50.

SBE 52-MP

The SBE 52-MP is able to directly output data that is already converted to engineering units (pressure in decibars), using calibration coefficients that are programmed into the instrument. The SBE 52-MP does not use a .con file.

Follow this procedure to correct the pressure:
1. With the SBE 52-MP in the air, place it in the orientation it will have when deployed.
2. In the SEATERM terminal program, set the pressure offset to 0.0 (**POffset=0**).
3. Acquire data using the **TP** command.
4. Calculate *offset* = (0 – instrument reading).
5. Enter the calculated offset in the SBE 52-MP (use **POffset=** in SEATERM).

   Offset Correction Example:
   Pressure displayed at elevation is -1.655 db. *Offset* = 0 – (-1.655) = + 1.655 db
   Enter offset in the SBE 52-MP.

SBE 39-IM

The SBE 39-IM directly outputs data that is already converted to engineering units (pressure in decibars), using calibration coefficients that are programmed into the SBE 39-IM. The SBE 39-IM does not use a .con file.

Follow this procedure to correct the pressure:
1. With the SBE 39-IM in the air, place it in the orientation it will have when deployed.
2. In the SEATERM terminal program, set the pressure offset to 0.0 (**#iiPOffset=0**).
3. Acquire data using the **#iiTP** command.
4. Calculate *offset* = (0 – instrument reading).
5. Enter the calculated offset in the SBE 39-IM (use **#iiPOffset=** in SEATERM)

   Offset Correction Example:
   Pressure displayed at elevation is -1.655 db. *Offset* = 0 – (-1.655) = + 1.655 db
   Enter offset in the SBE 39-IM.

SBE 39

The SBE 39 directly outputs data that is already converted to engineering units (pressure in decibars), using calibration coefficients that are programmed into the SBE 39. The SBE 39 does not use a .con file. The SBE 39 is a special case, because its programmed calibration coefficients do not currently include a pressure offset term. The lack of a pressure offset term creates two difficulties when deploying at elevations above sea level:

- After the data is recorded and uploaded, you must perform post-processing to adjust for the pressure offset. Sea-Bird software cannot currently perform this adjustment for the SBE 39.
- Without adjusting the instrument range, internal calculation limitations prevent the SBE 39 from providing accurate data at high elevations. Specifically, if (0.1 * sensor range) < (decrease in atmospheric pressure from sea level to elevation), an error condition in the SBE 39's internal calculations occurs. The table below tabulates the atmospheric pressure and approximate elevation at which this calculation limitation occurs for different pressure sensor ranges.

Range (m or db) *	Range (psi) = Range (db) / 0.689476	0.1 * Range (psi)	Atmospheric Pressure (psi) at elevation at which error occurs = [14.7 – 0.1 * Range (psi)]	Approximate Corresponding Elevation (m)
20	29	2.9	11.8	1800
100	145	14.5	0.2	No where on Earth!
350	507	50.7	-	-
1000	1450	145	-	-
2000	2900	290	-	-
3500	5076	507	-	-
7000	10152	1015	-	-

* Notes:

- Although decibars and meters are not strictly equal, this approximation is close enough for this Application Note. See Application Note 69 for conversion of pressure (db) to depth (m) for fresh or salt water applications.
- Equations used in conversions -
  As shown on page 1: pressure (db) = [pressure (psia) – 14.7] * 0.689476;
  Rearranging: pressure (psia) = [Pressure (db) / 0.689476] + 14.7
  Measuring relative to atmospheric: pressure (psi; relative to atmospheric pressure) = Pressure (db) / 0.689476

From the table, it is apparent that the only practical limitation occurs with a 20 meter pressure sensor. To use the SBE 39 in this situation, change the sensor range internally to 100 meters by entering **PRange=100** in the SBE 39 (using SEATERM). This changes the electronics' operating range, allowing you to record pressure data at high elevations, but slightly decreases resolution. After the data is recorded and uploaded, perform post-processing to adjust for the pressure offset. Note that Sea-Bird software cannot currently perform this adjustment for the SBE 39.

CAUTION: Changing **PRange** in the SBE 39 does not increase the actual maximum water depth at which the instrument can be used (20 meters) without damaging the sensor.

> *Example 1*: You want to deploy the SBE 39 with a 20 m pressure sensor in a mountain lake at 1400 meters (4590 feet). This is lower than 1800 meters shown in the table, so you do not need to adjust the sensor range. After the data is recorded and uploaded, perform post-processing to adjust for the pressure offset.
>
> *Example 2*: You want to deploy the SBE 39 with a 20 m pressure sensor in a mountain lake at 2000 meters (6560 feet). This is higher than 1800 meters shown in the table, so you need to adjust the sensor range. In SEATERM, set **PRange=100** to allow use of the SBE 39 at this elevation. After the data is recorded and uploaded, perform post-processing to adjust for the pressure offset.

SBE 26*plus* and 53

Unlike our other instruments that include a pressure sensor, the SBE 26*plus* and 53 output absolute pressure (i.e., at the surface the output pressure is atmospheric pressure at the deployment elevation). Therefore, no corrections are required when using these instruments above sea level. SBE 26*plus* / 53 software (SEASOFT for Waves) includes a module that can subtract measured barometric pressures from tide data, and convert the resulting pressures to water depths.

Sea-Bird Electronics, Inc.
1808 136th Place NE
Bellevue, WA 98005
USA

Phone: (425) 643-9866
Fax: (425) 643-9954
E-mail: seabird@seabird.com
Web: www.seabird.com

APPLICATION NOTE NO. 84 **July 2006**

Using Instruments with Druck Pressure Sensors in Muddy or Biologically Productive Environments

This Application Note applies to Sea-Bird instruments with **Druck** pressure sensors, for moored applications or other long deployments that meet **either** of the following conditions:

- used in a **high-sediment (muddy)** environment, in a **pressure sensor end up** orientation
- used in a **biologically productive** environment, in **any** orientation



Standard pressure sensor port plug

At Sea-Bird, a pressure port plug with a small (0.042-inch diameter) vent hole in the center is inserted in the pressure sensor port. The vent hole allows hydrostatic pressure to be transmitted to the pressure sensor inside the instrument.

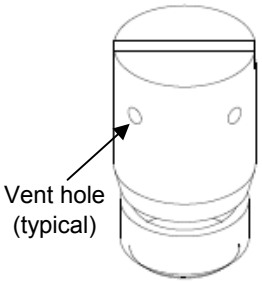
- If the instrument is deployed in a **high-sediment (muddy)** environment **with the pressure sensor end up**, the pressure port may partially fill with sediment (through the vent hole) over time, causing a delay in the pressure response.
- If the instrument is deployed in a **biologically productive** environment, the vent hole may be covered with biological growth over time, causing a delay in the pressure response, or in extreme cases completely blocking the pressure signal.

***Note**:* Photo is for an SBE 37-SM. Pressure port details are similar for all instruments included in this application note.

Sea-Bird has developed a high-head pressure port plug for deployment in muddy and/or biologically productive environments. The high-head plug extends beyond the surface of the instrument end cap, and has *four* horizontal vent holes connecting *internally* to a vertical vent hole.

- The horizontal orientation of the external holes prevents the deposit of sediment inside the pressure port.
- Each of the four vent holes is larger (0.062-inch vs. 0.042-inch diameter) than the single vent hole in the standard pressure port plug, significantly reducing the possibility that biological growth will cover all of the hole(s).

To purchase the high-head pressure port plug, Part Number 233186, contact Sea-Bird.



High-Head
Pressure Port Plug,
Part Number 233186

High-Head Pressure Port Plug Installation

1. Unscrew the standard pressure port plug from the pressure port.
2. Rinse the pressure port with warm, de-ionized water to remove any particles, debris, etc. **Do not put a brush or any object in the pressure port;** doing so may damage or break the pressure sensor.
3. Install the *high-head* pressure port plug in the pressure port.

Note: Until several years ago, Sea-Bird filled the pressure port with silicon oil at the factory. For **Druck** pressure sensors, we determined that this was unnecessary, and no longer do so. It is not necessary to refill the oil in the field. However, for **Paine** or **Paroscientific Digiquartz** pressure sensors, the pressure port **does** need to be refilled with silicon oil. Please contact Sea-Bird with the serial number of your instrument if you are unsure of the type of pressure sensor installed in your instrument.

Sea-Bird Electronics, Inc.
1808 136th Place NE
Bellevue, WA 98005
USA

Phone: (425) 643-9866
Fax: (425) 643-9954
E-mail: seabird@seabird.com
Web: www.seabird.com

APPLICATION NOTE NO. 40 **Revised June 2007**

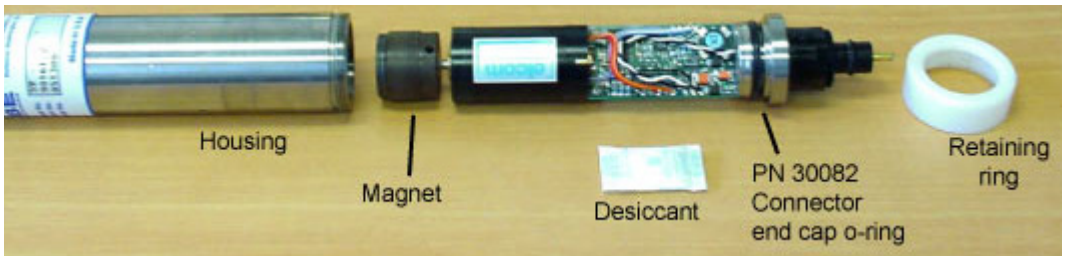
SBE 5T and SBE 5P PUMP SPEED ADJUSTMENT

Equipment: DC power supply
Frequency counter

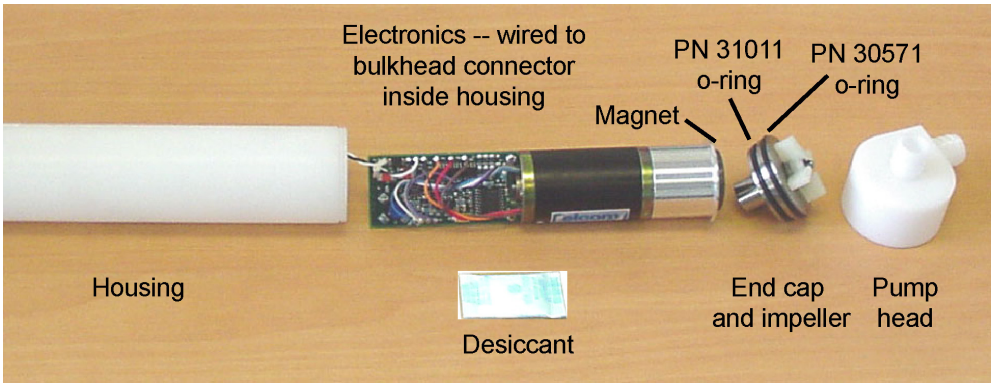
Drawings: 31441B (schematic)
41250A (assembly)

The pump housing must be disassembled to adjust the pump speed. The SBE 5P and 5T electronics are the same, but separate instructions for removing and reinstalling the electronics in the housing are provided for each pump, because of differences in the mechanical details.

1. Remove the electronics from the housing:
   - **SBE 5T Titanium Pump** –
     A. Unscrew the white plastic end cap retainer ring.
     B. Install a 2-pin dummy plug with locking sleeve over the bulkhead connector to provide a good grip and protect the connector pins. Rotate the end cap back and forth while carefully pulling the end cap away from the housing. Pull the end cap and attached electronics out of the housing.

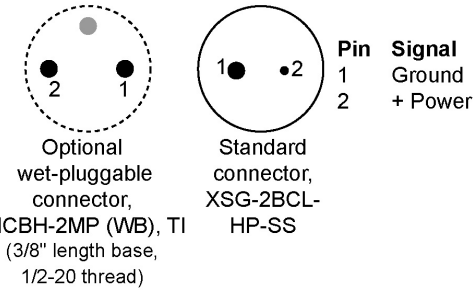


   - **SBE 5P Plastic Pump** -
     A. Unscrew the pump head from the housing.
     B. Pull out the end cap from the housing.
     C. Pull out the electronics from the housing. Note that the electronics are wired to the bulkhead connector inside the housing.



2. Connect the positive lead of your frequency counter to the yellow test post (T1) (drawing 41250A). Connect the frequency counter ground (negative) to the power supply ground (negative).

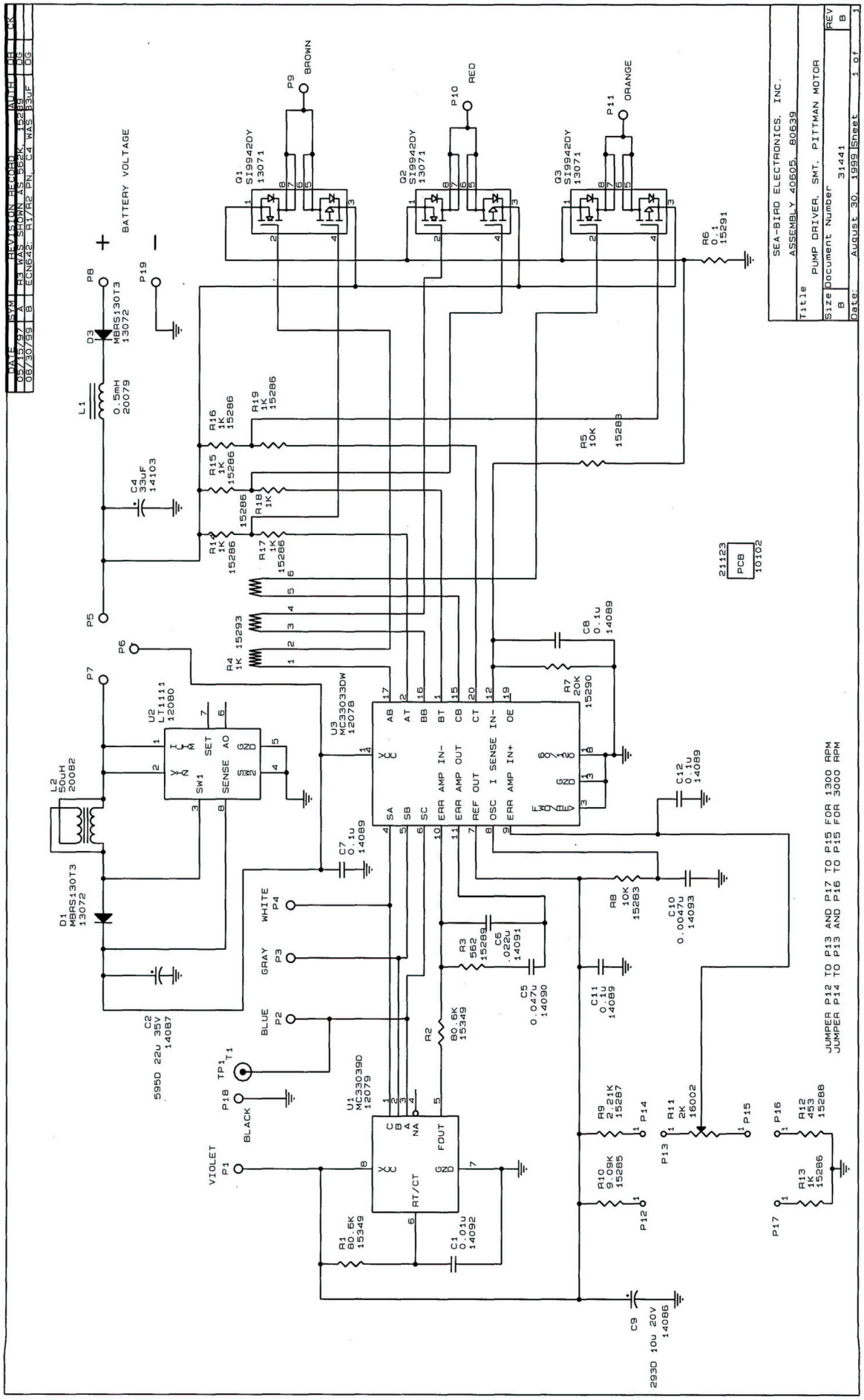
3. Supply power:
   - **Low voltage pump** (pump with **LV** in the serial number) - Supply 6 volts DC power to the bulkhead connector or directly to the PCB (P8 is positive, P19 or P18 is common, drawing 41250A).
   - **Normal voltage pump** - Supply 12 volts to the bulkhead connector or directly to the PCB (P8 is positive, P19 or P18 is common, drawing 41250A).



4. A 2K ohm potentiometer (R11, drawing 41250A) is located on the back side of the board. Adjust the potentiometer to obtain the frequency corresponding to the desired speed (Frequency * 30 = rpm):
   - Pittman **18.2Ω motor** (P/N 3711B113-R1) - Set jumper position P15 to P17 (1300 rpm) and P12 to P13 (1300 rpm), and adjust the speed as desired, up to the nominal maximum of 2000 rpm.
   - Pittman **7.4Ω motor** (P/N 3711B112-R1) - Set jumper position P15 to P16 (3000 rpm) and P14 to P13 (3000 rpm), and adjust the speed as desired, up to the nominal maximum of 4500 rpm.
     To adjust speed below approximately 2200 rpm, set jumper position P15 to P17 (1300 rpm) and P12 to P13 (1300 rpm), and adjust speed using the potentiometer.
   - Pittman **3.55Ω motor** (P/N 3711B112-R2) - Set jumper position P15 to P16 (3000 rpm) and P14 to P13 (3000 rpm), and adjust the speed as desired, up to the nominal maximum of 4500 rpm.
     To adjust speed below approximately 2200 rpm, set jumper position P15 to P17 (1300 rpm) and P12 to P13 (1300 rpm), and adjust speed using the potentiometer.

5. Disconnect the frequency counter and the power supply.

6. Reinstall the electronics in the housing:
   - **SBE 5T Titanium Pump** –
     A. Inspect the connector end cap o-ring and the mating surface in the housing for dirt, nicks, and cuts. Clean as necessary. If the o-ring or mating surface is damaged, return the pump to Sea-Bird for repairs. Note: Sea-Bird recommends that connector end cap o-ring replacement be performed at the factory, because the pump's physical configuration makes customer-replacement of this o-ring difficult to perform without special tools.
     B. Apply a light coat of o-ring lubricant (Parker Super O Lube) to the o-ring and mating surfaces. Gently place a **new desiccant bag** (PN 30558 – 1 gram) on the electronics (see Application Note 71 for desiccant use and regeneration). Reinstall the electronics in the housing, until the o-ring has fully seated. Reinstall the retaining ring on the connector end cap.
   - **SBE 5P Plastic Pump** -
     A. Inspect the connector end cap o-ring and the mating surface in the housing for dirt, nicks, and cuts. Clean and/or replace o-rings as necessary.
     B. Apply a light coat of o-ring lubricant (Parker Super O Lube) to the o-ring and mating surfaces. Gently place a **new desiccant bag** (PN 30558 – 1 gram) on the electronics (see *Application Note 71* for desiccant use and regeneration). Reinstall the electronics in the housing. Reinstall the end cap in the housing, carefully aligning the end cap with the housing and pushing hard on the end cap to seat the first o-ring in the housing (only 1 o-ring should now be visible). **CAUTION: If you are not careful, you may pinch the o-ring which may allow water to enter the housing, damaging the electronics.**
     C. Reinstall the pump head on the end cap.


SEA-BIRD ELECTRONICS, INC.
ASSEMBLY 40605, 80639
PUMP DRIVER, SMT, PITTMAN MOTOR
Document Number 31441
August 30, 1999
BATTERY VOLTAGE
BROWN
RED
ORANGE
WHITE
GRAY
BLUE
BLACK
VIOLET
JUMPER P12 TO P13 AND P17 TO P15 FOR 1300 RPM
JUMPER P14 TO P13 AND P16 TO P15 FOR 3000 RPM

DATE	SYM	REVISION RECORD	AUTH.	DR.	CK.
4/05	A	ADD 801572.* ASSY	CB	CB	

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SLB     PRINTED ON 10:10:20  13 APR 2005

PART NUMBER..... DESCRIPTION.............. QPA

80675       SBE 5T #3VDG
            MOTOR/DRIVER, 7.4 OHM
            /41250
   20081    MOTOR, PUMP, 7.4 OHM                1.0000
   23595    PITTMAN 3711B112-R1
   23595    SBEST PUMP PCB MOUNT                1.0000
   30235    BLOCK /DWG 206249
            WASHER, WN-2, #2 NYLON              2.0000
   30357    MACH SCREW, 2-56 X 1/4              2.0000
            PH, SS
   30560    MACH SCREW, 2-56 X 9/16             2.0000
   80639    FH, PHILIPS, SS
            PUMP DRIVER, SURFACE                1.0000
            MOUNT /DWG 40605C

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SLB     PRINTED ON 10:10:21  13 APR 2005

PART NUMBER..... DESCRIPTION.............. QPA

80676       SBE 5T #3VDG
            MOTOR/DRIVER, 18.02 OHM
            /41250
   20080    MOTOR, PUMP, 18 OHM                 1.0000
   23595    PITTMAN 3711B113-R1
   23595    SBEST PUMP PCB MOUNT                1.0000
   30235    BLOCK /DWG 206243
            WASHER, WN-2, #2 NYLON              2.0000
   30357    WASHER
            MACH SCREW, 2-56 X 1/4              2.0000
            PH, SS
   30560    MACH SCREW, 2-56 X 9/16             2.0000
   80639    FH, PHILIPS, SS
            PUMP DRIVER, SURFACE                1.0000
            MOUNT /DWG 40605C

***

PART NUMBER..... DESCRIPTION.............. QPA

801572      SBE 5T #3VDG
            MOTOR/DRIVER, 3.55 OHM
            /41250
   20176    MOTOR, PUMP, 3.55 OHM               1.0000
   23595    PITTMAN 3711B122
   23595    SBEST PUMP PCB MOUNT                1.0000
   30235    BLOCK /DWG 206248
            WASHER, WN-2, #2 NYLON              2.0000
   30357    WASHER
            MACH SCREW, 2-56 X 1/4              2.0000
            PH, SS
   30560    MACH SCREW, 2-56 X 9/16             2.0000
   80639    FH, PHILIPS, SS
            PUMP DRIVER, SURFACE                1.0000
            MOUNT /DWG 40605C

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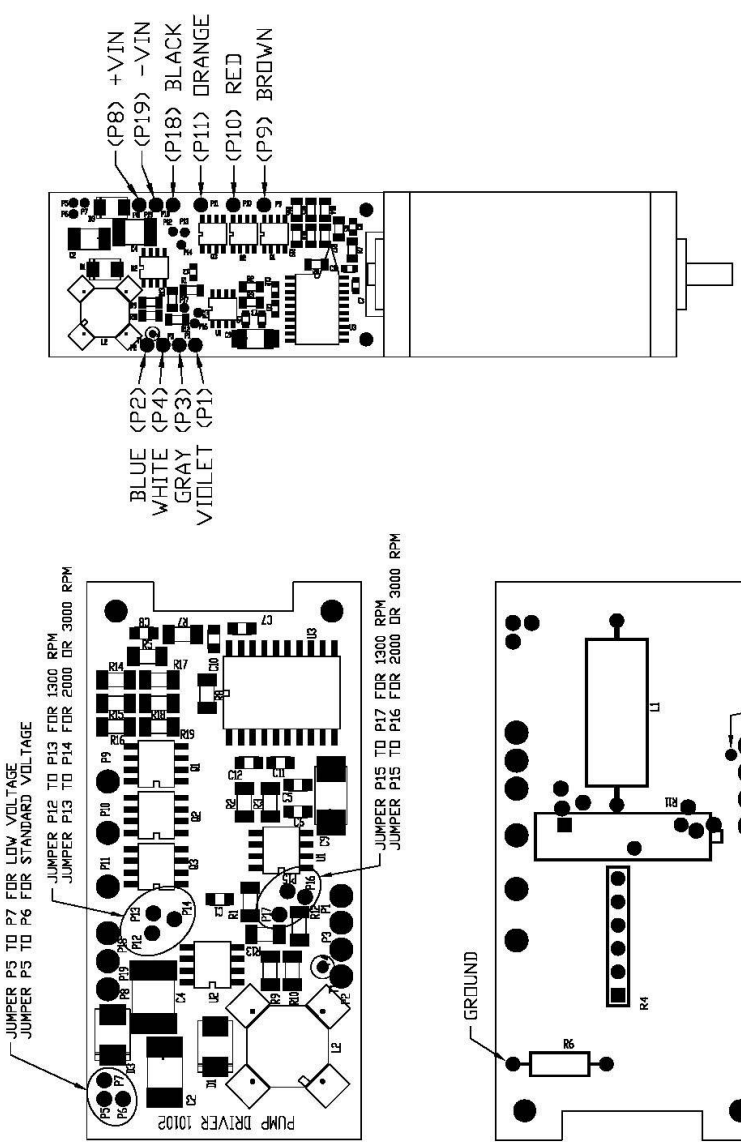
FINISH GENERIC ASSEMBLY TO SPECIFIC ASSEMBLY
BY INSTALLING VOLTAGE AND SPEED JUMPERS
AS SHOWN ON THE CHART

SEA-BIRD ELECTRONICS, INC

PART NO. VARIOUS	BD SCALE –	DRWN BY DG
SCHEM 31441B	PL SCALE 0.90	APPR BY

TITLE: SBE 5T MOTOR/DRIVER ASSEMBLY

DATE 2/13/03 | DWG NO. 41250 | REV A



SBE PN	DESCRIPTION	VOLTAGE	SPEED	SPEED
80675.2	#3 WINDING (7.4 OHM), STANDARD VOLTAGE, 2000 RPM	P5-P6	P13-P14	P15-P16
80675.2LV	#3 WINDING (7.4 OHM), LOW VOLTAGE, 2000 RPM	P5-P7	P13-P14	P15-P16
80675.3	#3 WINDING (7.4 OHM), STANDARD VOLTAGE, 3000 RPM	P5-P6	P13-P14	P15-P16
80676.1	#5 WINDING (18.02 OHM), STANDARD VOLTAGE, 1300 RPM	P5-P6	P12-P13	P15-P17
80676.1LV	#5 WINDING (18.02 OHM), LOW VOLTAGE, 1300 RPM	P5-P7	P12-P13	P15-P17
80676.2	#5 WINDING (18.02 OHM), STANDARD VOLTAGE, 2000 RPM	P5-P6	P13-P14	P15-P16
80676.2LV	#5 WINDING (18.02 OHM), LOW VOLTAGE, 2000 RPM	P5-P7	P13-P14	P15-P16
801572.2	#3 WINDING (3.55 OHM), STANDARD VOLTAGE, 2000 RPM	P5-P6	P13-P14	P15-P16
801572.2LV	#3 WINDING (3.55 OHM), LOW VOLTAGE, 2000 RPM	P5-P7	P13-P14	P15-P16
801572.3	#3 WINDING (3.55 OHM), STANDARD VOLTAGE, 3000 RPM	P5-P6	P13-P14	P15-P16

Sea-Bird Electronics, Inc.
1808 136th Place NE
Bellevue, WA 98005
USA

Phone: (425) 643-9866
Fax: (425) 643-9954
E-mail: seabird@seabird.com
Web: www.seabird.com

APPLICATION NOTE NO. 75 **Revised June 2007**

Maintenance of SBE 5T, 5P, and 5M Pumps

This application note is intended to assist you in maintaining your pump:

- SBE **5T** Titanium Submersible Pump – titanium housing (depth to 10,500 meters).
- SBE **5P** Plastic Submersible Pump – plastic housing (depth to 600 meters).
  Note: The SBE 5P's *operational* characteristics (power requirements, flow rate, etc.) are identical to the SBE 5T. However, the SBE 5P's construction is similar to the SBE 5M; therefore, the **maintenance procedures for the SBE 5P are grouped with the SBE 5M**.
- SBE **5M** Miniature Submersible Pump – available in titanium housing (depth to 10,500 meters) or plastic housing (depth to 600 meters).

A properly maintained pump will provide constant flow for your CTD and any pumped auxiliary sensors, resulting in high quality data. The main symptom of a non-functioning or poorly functioning pump is bad conductivity data, because the pump is not pulling water through the conductivity cell.

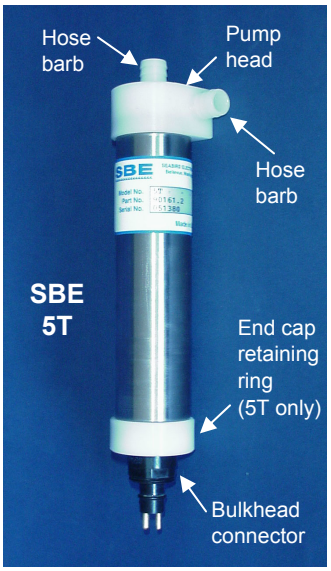
CAUTION: Do not run the pump *dry*. The pump is water lubricated; running it without water will damage it. If testing your system in dry conditions, remove the Tygon tubing from the hose barb at the top of the pump head, and fill the inside of the pump head with water. This will provide enough lubrication to prevent pump damage during testing.

The application note is organized as follows:

- Routine rinsing after recovery (applies to all pumps)

- SBE 5T -
  Periodic cleaning for SBE 5T
  Yearly maintenance for SBE 5T
  Non-functioning or poorly functioning SBE 5T

- SBE 5M or SBE 5P -
  Periodic cleaning for SBE 5M or SBE 5P
  Yearly maintenance for SBE 5M or SBE 5P
  Non-functioning or poorly functioning SBE 5M or SBE 5P







*SBE 5M with **titanium** housing*



*SBE 5M with **plastic** housing*

Routine Rinsing after Recovery (applies to all pumps)

At the end of a day of taking casts:

1. Remove the Tygon tubing from the pump head's hose barbs.

2. Leaving the pump head on the housing, thoroughly rinse the inside of the pump head, pouring clean, fresh water through a hose barb. If the pump head is not rinsed between uses, salt crystals may form on the impeller. Over time, this may *freeze* the impeller in place, preventing the pump from working.

3. Replace the Tygon tubing on the hose barbs.

4. Unscrew the cable locking sleeve from the bulkhead connector, and slide it up the cable. Thoroughly rinse the cable connection (still mated) with clean, fresh water. This will prevent premature cable failure.

5. Slide the locking sleeve back into place, and screw it back onto the bulkhead connector. Do not use a wrench or pliers to tighten the locking sleeve.



SBE 5T

Periodic Cleaning for SBE 5T

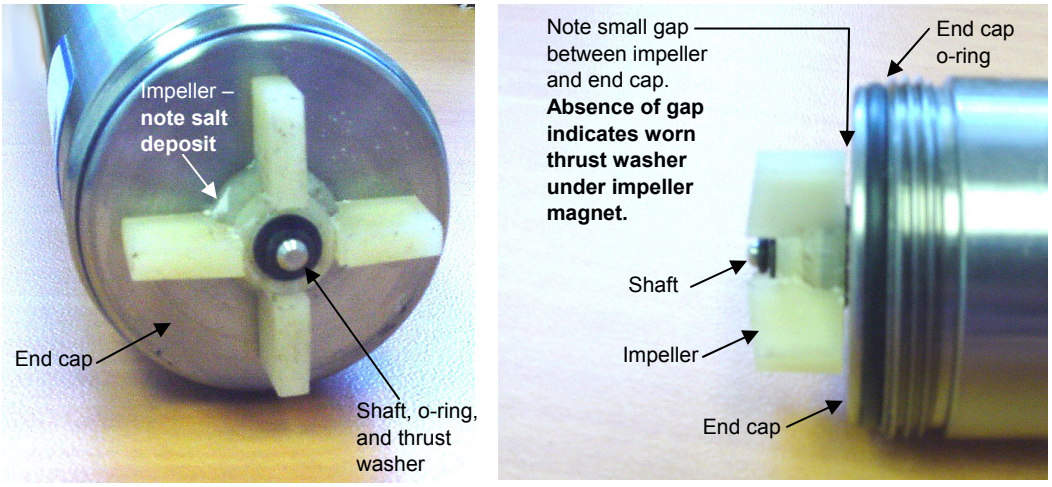
If you are going to store the pump for more than 1 week, or have removed the pump from a mooring, perform a more thorough cleaning:

1. Unscrew the pump head from the housing.

2. Using clean, fresh water, thoroughly rinse the pump head and impeller.

3. Inspect the impeller for salt deposits. Clean any deposits with clean, fresh water and a toothbrush. Verify that the impeller can turn freely.

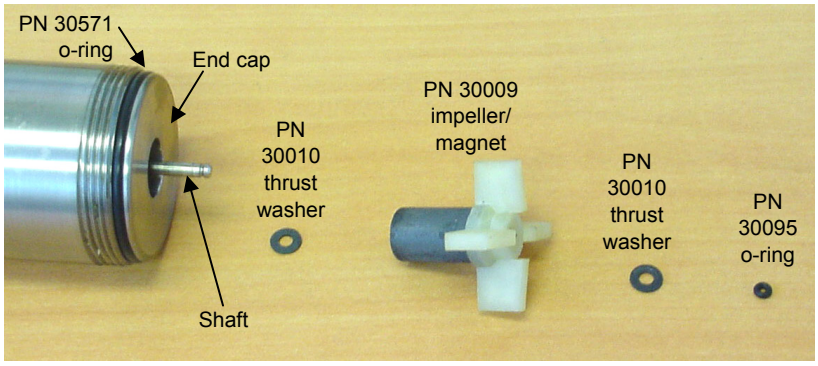
4. Inspect the shaft, and the o-ring and thrust washer holding the impeller on the shaft. There is another thrust washer underneath the impeller magnet, inside the housing. If this thrust washer is in good condition, you should observe a small gap between the bottom of the impeller and the end cap. If there is no gap, the thrust washer is worn and needs to be replaced (see *Yearly Maintenance for SBE 5T* for replacement procedure).



SBE 5T with Pump Head Removed

Yearly Maintenance for SBE 5T

1. Unscrew the pump head from the housing.



SBE 5T with Pump Head and Impeller Removed

2. Replace the o-ring and 2 thrust washers on the shaft:
   A. Remove the o-ring from the shaft. A pair of tweezers works well for this.
   B. Pull the impeller and attached magnet off the shaft. The thrust washer above the impeller will come off at the same time. Inspect the impeller for salt build-up, and clean if necessary. Inspect the magnet for wear. Particularly in sandy coastal environments, the magnet may be worn down from abrasion. If necessary, replace the impeller / magnet assembly (PN 30009).
   C. Remove the second thrust washer from the bottom of the shaft. A pair of tweezers works well for this.
   D. Inspect the shaft for wear.
   E. Rinse the shaft and depression in the housing with clean, fresh water. Allow to dry.
   F. Using new thrust washers (2 of PN 30010) and o-ring (PN 30095), replace the thrust washer and impeller / magnet on the shaft. Replace the other thrust washer and o-ring on the shaft, above the impeller, pushing hard with your fingertip to seat the thrust washer and o-ring in place.

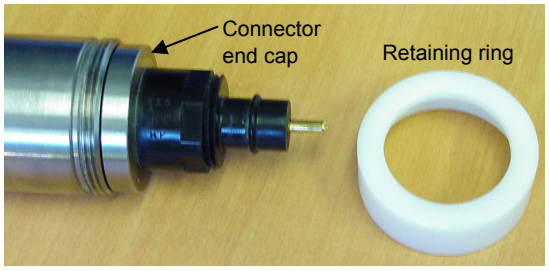
3. Inspect the end cap o-ring and the mating surface on the pump head for dirt, nicks, and cuts. Clean or replace as necessary. Apply a light coat of o-ring lubricant (Parker Super O Lube) to the o-ring and mating surfaces.

4. Reinstall the pump head on the pump housing.

5. Inspect the bulkhead connector for corrosion, which is a sign of seawater leakage between the bulkhead connector and cable. If there is corrosion, thoroughly clean the connector with water, followed by alcohol. Inspect the bulkhead connector for chips, cracks, or other flaws that may compromise the seal. Inspect the mating cable's connector for cuts, nicks, breaks, or other problems that may compromise the seal. Give the connector surfaces a light coating of **silicon** grease, and remate the connector properly; see *Application Note 57: I/O Connector Care and Installation*.
   - If the bulkhead connector is severely corroded or damaged, it must be replaced. Sea-Bird recommends that this work be performed at the factory, because the pump's physical configuration makes customer-replacement of the connector difficult.

Non-Functioning or Poorly Functioning SBE 5T

Perform the inspection procedures listed above in *Yearly Maintenance for SBE 5T*. If you do not discover the problem there, proceed as follows.



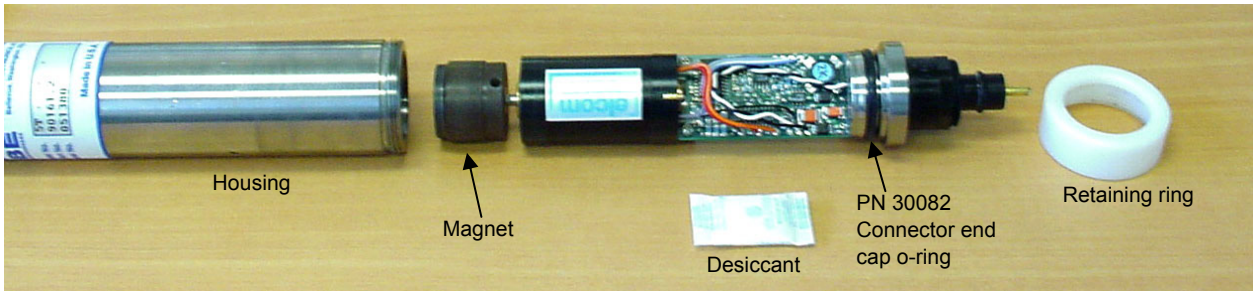
1. Unscrew the connector end cap retaining ring. Install a 2-pin dummy plug with locking sleeve over the bulkhead connector to provide a good grip and protect the connector pins. Rotate the end cap back and forth while carefully pulling the end cap away from the housing. Pull out the end cap and attached electronics from the housing.

2. Verify that the magnet can spin freely and is not broken or damaged.

3. Look for other signs of damage on the electronics.

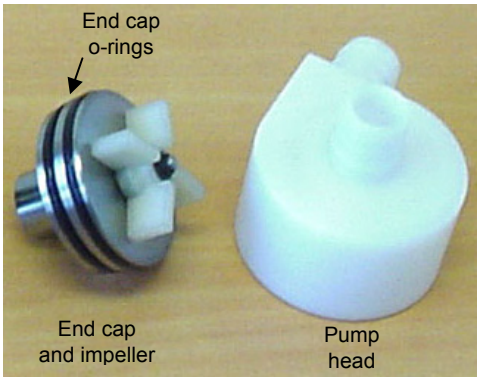
4. Inspect the connector end cap o-ring and the mating surface in the housing for dirt, nicks, and cuts. Clean as necessary. If the o-ring or mating surface is damaged, return the pump to Sea-Bird for repairs.
   - Sea-Bird recommends that connector end cap o-ring replacement be performed at the factory, because the pump's physical configuration makes customer-replacement of this o-ring difficult to perform without special tools.

5. Apply a light coat of o-ring lubricant (Parker Super O Lube) to the o-ring and mating surfaces. Gently place a **new desiccant bag** (PN 30558 – 1 gram) on the electronics (see *Application Note 71* for desiccant use and regeneration). Reinstall the electronics in the housing, until the o-ring has fully seated. Reinstall the retaining ring on the connector end cap.



SBE 5M or SBE 5P

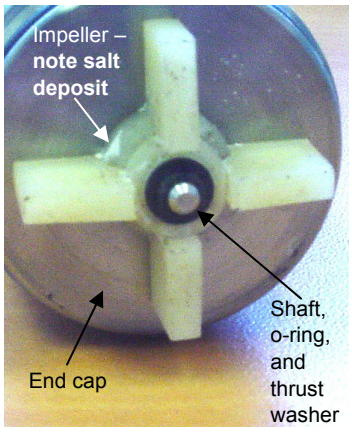
Periodic Cleaning for SBE 5M or SBE 5P

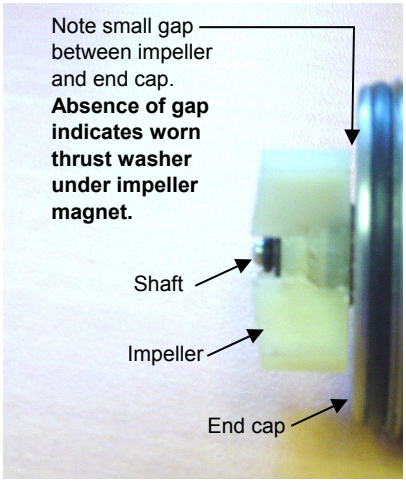


If you are going to store the pump for more than 1 week, or have removed the pump from a mooring, perform a more thorough cleaning:

CAUTION: **Remove the end cap and impeller from the housing before cleaning the impeller.** The end cap o-rings seal the electronics chamber. The end cap may *walk* out of the housing after the pump head is removed, allowing water to enter the electronics chamber if you clean the impeller without first removing the end cap from the housing.

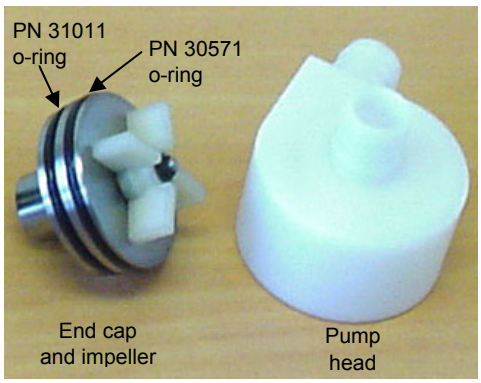
1. Unscrew the pump head from the housing.
2. Pull out the end cap from the housing.
3. Using clean, fresh water, thoroughly rinse the pump head and impeller.
4. Inspect the impeller for salt deposits. Clean any deposits with clean, fresh water and a toothbrush. Verify that the impeller can turn freely.
5. Inspect the shaft, and the o-ring and thrust washer holding the impeller on the shaft. There is another thrust washer underneath the impeller magnet, inside the housing. If this thrust washer is in good condition, you should observe a small gap between the bottom of the impeller and the end cap. If there is no gap, the thrust washer is worn and needs to be replaced (see *Yearly Maintenance for SBE 5M or SBE 5P* for replacement procedure).
6. Apply a light coat of o-ring lubricant (Parker Super O Lube) to the o-ring and mating surfaces. Reinstall the end cap in the housing, carefully aligning the end cap with the housing and pushing hard on the end cap to seat the first o-ring in the housing (only 1 o-ring should now be visible).
   CAUTION: If you are not careful, you may *pinch* the o-ring, which may allow water to enter the housing, damaging the electronics.
7. Reinstall the pump head on the end cap.





SBE 5M or 5P with Pump Head Removed

Yearly Maintenance for SBE 5M or SBE 5P

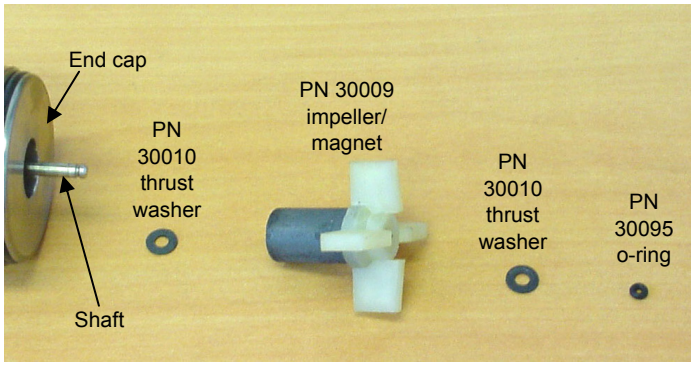


CAUTION: **Remove the end cap and impeller from the housing before cleaning the impeller.** The end cap o-rings seal the electronics chamber. The end cap may *walk* out of the housing after the pump head is removed, allowing water to enter the electronics chamber if you clean the impeller without first removing the end cap from the housing.

1. Unscrew the pump head from the housing.

2. Pull out the end cap from the housing.

3. Replace the o-ring and 2 thrust washers on the shaft:
   A. Remove the o-ring from the shaft. A pair of tweezers works well for this.
   B. Pull the impeller and attached magnet off the shaft. The thrust washer above the impeller will come off at the same time. Inspect the impeller for salt build-up, and clean if necessary. Inspect the magnet for wear. Particularly in sandy coastal environments, the magnet may be worn down from abrasion. If necessary, replace the impeller / magnet assembly (PN 30009).



SBE 5M or 5P with Pump Head and Impeller Removed

   C. Remove the second thrust washer from the bottom of the shaft. A pair of tweezers works well for this.
   D. Inspect the shaft for wear.
   E. Rinse the shaft and depression in the housing with clean, fresh water. Allow to dry.
   F. Using new thrust washers (2 of PN 30010) and o-ring (PN 30095), replace the thrust washer and impeller / magnet on the shaft. Replace the other thrust washer and o-ring on the shaft, above the impeller, pushing hard with your fingertip to seat the thrust washer and o-ring in place.

4. Inspect the end cap o-rings and the mating surface on the pump head for dirt, nicks, and cuts. Clean or replace as necessary. Apply a light coat of o-ring lubricant (Parker Super O Lube) to the o-rings and mating surfaces.

5. Reinstall the end cap in the housing, carefully aligning the end cap with the housing and pushing hard on the end cap to seat the first o-ring in the housing (only 1 o-ring should now be visible).
   CAUTION: If you are not careful, you may *pinch* the o-ring, which may allow water to enter the housing, damaging the electronics.

6. Reinstall the pump head on the end cap.

7. Inspect the bulkhead connector for corrosion, which is a sign of seawater leakage between the bulkhead connector and cable. If there is corrosion, thoroughly clean the connector with water, followed by alcohol. Inspect the bulkhead connector for chips, cracks, or other flaws that may compromise the seal. Inspect the mating cable's connector for cuts, nicks, breaks, or other problems that may compromise the seal. Give the connector surfaces a light coating of **silicon** grease, and remate the connector properly; see *Application Note 57: I/O Connector Care and Installation*.
   - If the bulkhead connector is severely corroded or damaged, it must be replaced. Sea-Bird recommends that this work be performed at the factory, because the pump's physical configuration makes customer-replacement of the connector difficult.

Non-Functioning or Poorly Functioning SBE 5M or SBE 5P

Perform the inspection procedures listed above in *Yearly Maintenance for SBE 5M or SBE 5P*. If you do not discover the problem there, proceed as follows.

1. Unscrew the pump head from the housing.

2. Pull out the end cap from the housing.

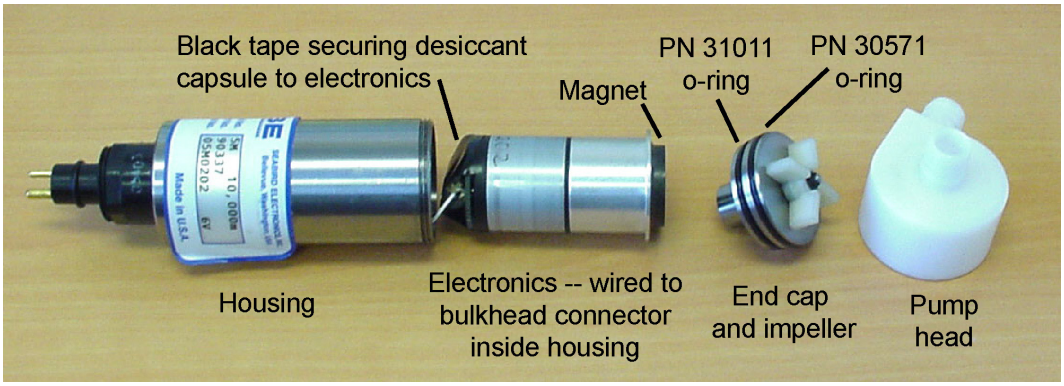
3. Pull out the electronics from the housing. Note that the electronics are wired to the bulkhead connector inside the housing.

4. Verify that the magnet can spin freely and is not broken or damaged.

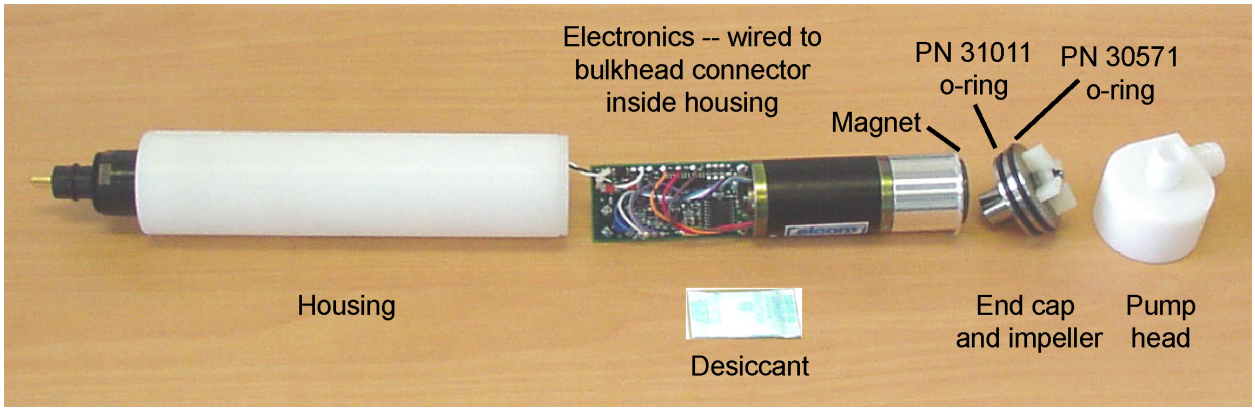
5. Look for other signs of damage on the electronics.

6. Reinstall the end cap in the housing:
   A. Apply a light coat of o-ring lubricant (Parker Super O Lube) to the o-ring and mating surfaces.
   B. **SBE 5M** – Gently place a **new desiccant capsule** (PN 31044 – 0.4 gram) on the electronics, and replace the black tape to secure it in place.
   SBE 5P - Gently place a **new desiccant bag** (PN 30558 – 1 gram) on the electronics.
   (see *Application Note 71* for desiccant use and regeneration).
   C. Reinstall the electronics in the housing.
   D. Reinstall the end cap in the housing, carefully aligning the end cap with the housing and pushing hard on the end cap to seat the first o-ring in the housing (only 1 o-ring should now be visible).
   CAUTION: If you are not careful, you may *pinch* the o-ring, which may allow water to enter the housing, damaging the electronics.

7. Reinstall the pump head on the end cap.



SBE 5M with Electronics Removed (titanium version shown; plastic version similar



SBE 5P with Electronics Removed

Sea-Bird Electronics, Inc.
1808 136th Place NE
Bellevue, WA 98005
USA

Phone: (425) 643-9866
Fax: (425) 643-9954
E-mail: seabird@seabird.com
Web: www.seabird.com

APPLICATION NOTE NO. 64-3 **April 2009**

SBE 43 Dissolved Oxygen (DO) Sensor – Hysteresis Corrections

General Description

Under extreme pressure, changes can occur in gas permeable Teflon membranes that affect their permeability characteristics. Some of these changes (plasticization and amorphous/crystalinity ratios) have long time constants and depend on the sensor's time-pressure history. These slow processes result in hysteresis in long, deep casts. The hysteresis correction algorithm operates through the entire data profile and corrects the oxygen voltage values for changes in membrane permeability as pressure varies. At each measurement, the correction to the membrane permeability is calculated based on the current pressure and how long the sensor spent at previous pressures. **Applying the hysteresis correction is recommended for profiles with depths exceeding 1000 meters.**

Sea-Bird has implemented an optional hysteresis correction for dissolved oxygen data in the first processing step of our post-processing software (Data Conversion module in SBE Data Processing). Hysteresis corrections are applied separately from the calibration equation, and can be conducted on SBE 43 voltage values or dissolved oxygen values. The correction algorithm requires a continuous time series of data, with no temporal data gaps (although a continuous time series is necessary, a constant sampling interval is not required). Prior to processing, do not remove any data from the downcast or upcast (if to be used), other than a surface soak at the beginning of the downcast.

Note: For additional SBE 43 calibration equation information and application, see:
- Application Note 64 (http://www.seabird.com/application_notes/AN64.htm)
- Application Note 64-2 (http://www.seabird.com/application_notes/AN64-2.htm)
- Sea-Bird training manual (http://www.seabird.com/training/TrainingHandouts.htm), Modules 8 and 9
- SBE Data Processing manual (http://www.seabird.com/software/SBEDataProcforWindows.htm) and Help files.

The *Appendix* contains the hysteresis algorithm for reference, and for customers creating their own software.

Installing Software

Hysteresis corrections require the use of SBE Data Processing version **7.18c or later**. If you are currently using older software:

1. Download the latest software version from our ftp site: ftp://ftp.halcyon.com/pub/seabird/OUT/Seasoft-Win32/SBEDataProcessing/
2. Double click on SBEDataProcessing_Win32_V*.**.exe (where *.** is the version number), and follow the dialog box directions to install the software.

Note:
You can overwrite the older software version on your computer, or you can install the new software to a different directory if desired (the installation procedure allows you to select the desired folder location for the software).

Checking Calibration Coefficients and Configuration (.con) File

1. Locate the SBE 43 calibration sheet that corresponds with the period of data to be processed.

   In Spring of 2008, Sea-Bird began using the *Sea-Bird* equation for calibrating the SBE 43, in place of the *Owens-Millard* equation.
   - *Sea-Bird* equation lists coefficients Soc, Voffset, A, B, C, E, tau (see note), and dynamic coefficients D1, D2.
   - *Owens-Millard* equation lists coefficients Soc, Boc, Voffset, TCor, and PCor.

   To do hysteresis corrections with our software, **you must use the *Sea-Bird* equation**. If your calibration sheet lists *Owens-Millard* coefficients, contact Sea-Bird with the SBE 43 serial number and calibration date. We will regenerate your calibration sheet, fitting bath data from the applicable calibration date to the *Sea-Bird* equation.

   Notes:
   - If tau is not listed on your *Sea-Bird* equation calibration sheet, contact Sea-Bird with the SBE 43 serial number and calibration date.
   - Soc and Voffset appear in both the *Owens-Millard* and *Sea-Bird* equations. **Do not use Soc or Voffset from *Owens-Millard* in the *Sea-Bird* equation.** Although the variable names are the same, the values are not.

   In Fall of 2008, Sea-Bird began listing default values for the hysteresis correction coefficients H1, H2, and H3 on SBE 43 calibration sheets. These coefficients are not shown if your calibration sheet was generated prior to that date; use the default values provided here, which are the same as the default values listed on newer calibration sheets (i.e., you do not need a new calibration sheet):
   - H1 = amplitude of hysteresis correction. Default = -0.033, range = -0.02 to -0.05.
   - H2 = function constant or curvature function for hysteresis.
     Default = 5000, second-order parameter that does not require tuning between sensors.
   - H3 = time constant for hysteresis (seconds). Default = 1450, range = 1200 to 2000.

   Default hysteresis coefficients are adequate for most applications. If requiring higher accuracy (±1 µmol/kg), H1 and H3 can be fine-tuned if a complete profile (downcast and upcast) is available, made preferably to greater than 3000 meters. Adjust H1 and H3 in the .con file during analysis of the complete profile, and select the best fit. These parameters are stable, and can be used without further adjustment on other casts with the same SBE 43.

2. In SBE Data Processing's Configure menu, select the CTD to view its .con file. Check the calibration coefficients for the SBE 43: verify that the *Sea-Bird* equation is selected, and that the calibration coefficients correspond to the coefficients on the calibration sheet. If desired, save the .con file with a new name (use the *Save As* button in the Configuration dialog box).

Processing Data and Removing Oxygen Hysteresis

Converting Raw Data (Data Conversion module) when Winkler Bottle Data is Available

1. In SBE Data Processing's Run menu, select Data Conversion.

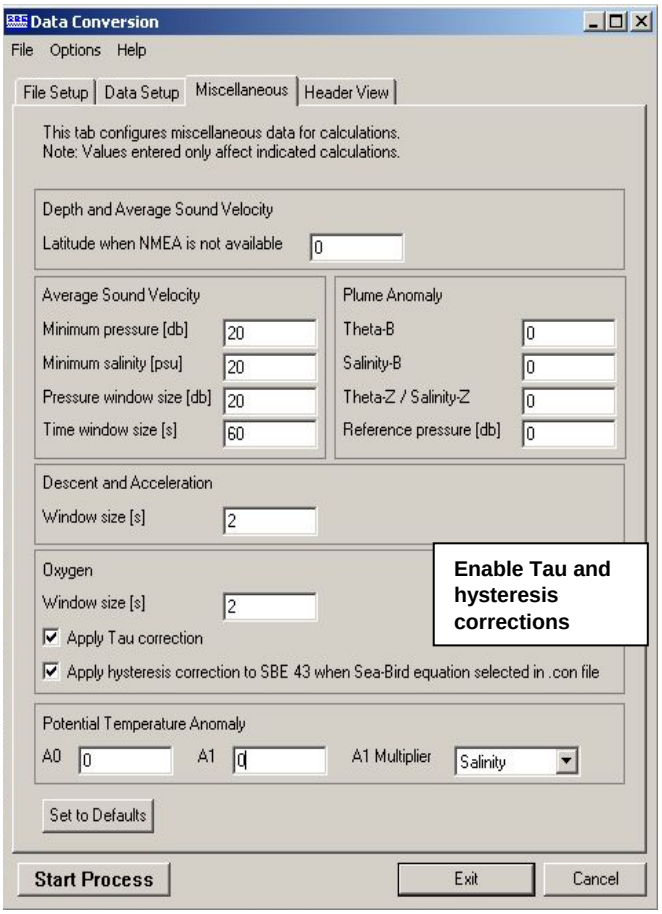
2. On the **File Setup** tab (see SBE Data Processing manual or Help files for selections not described here):
   A. Select the .con file (*Instrument configuration file*) for your CTD; see *Checking Calibration Coefficients and Configuration (.con) File* above to verify you are using the correct calibration coefficients for your SBE 43.
   B. Select the data file (*Input directory* and *Input file*) for your CTD.

3. On the **Data Setup** tab (see SBE Data Processing manual or Help files for selections not described here):
   A. For *Create file types*, select *Create both data and bottle file* (creates .cnv and .ros files).
   B. Click the *Select Output Variables* button. **As a minimum**, select the following variables for output:
      - Scan Count
      - Time, Elapsed (seconds)
      - Pressure (db)
      - Temperature (ITS-90, deg C)
      - Conductivity (S/m)
      - Oxygen Voltage, SBE 43 (V)
      - (if bottle data available) Oxygen, SBE 43, ml/l or other units*
        (*select DO concentration units to correspond with units from your Winkler samples)

      Click OK to exit the Select Output Variables dialog box.

4. On the **Miscellaneous** tab, in the *Oxygen* section (see SBE Data Processing manual or Help files for selections not described here):
   A. Enter *Window size* for oxygen calculation (use default value of 2 seconds).
   B. Select *Apply Tau correction*.
   C. Select *Apply hysteresis correction to SBE 43 when Sea-Bird equation selected in .con file.*

5. Click the *Start Process* button.



Data Conversion performs the hysteresis corrections on the SBE 43 voltage values, and then uses the corrected voltages to convert to DO concentration units (ml/l, or other selected units). Therefore, both columns of output DO data (voltage and concentration) contain data that has been corrected for hysteresis.

If requiring higher accuracy (±1 µmol/kg), plot the output DO data to determine if H1 and H3 require fine-tuning to further reduce hysteresis. As necessary, rerun Data Conversion on the raw data until the optimal H1 and H3 values are determined.

Data Conversion outputs a .cnv file and a .ros file with the selected variables. The .cnv file contains the selected output variables for all scans from the input data file. The .ros file contains a subset of the .cnv data, with a range of scans associated with each bottle firing.

Because the hysteresis corrections have been applied to the DO concentration data (ml/l or other units), comparisons to bottle Winkler data is more accurate for deep profile samples (> 1000 m). The bottle Winkler to .ros output comparisons can be used to correct the calibration equation slope, by adjusting *Soc*; if *Soc* adjustment is required, rerun Data Conversion with the updated *Soc* value (see Application Note 64-2).

Note:
At this point, DO concentration data has been calculated from oxygen voltage data that is corrected for hysteresis. However, the T, C, and P data used in the DO concentration calculation has not yet been processed for dynamic corrections (filtering, aligning, and cell thermal mass adjustments), which apply to moving platforms. Because the water sampler was presumably held at each bottle trip depth for 30 to 60 seconds or more before taking a sample, dynamic corrections are not needed for bottle-to-sensor comparisons. However, these dynamic corrections **are** required for continuous profiling data, and must be done to get the most accurate derived variable results, including DO concentration, % DO saturation, Salinity, and Density in the continuous profile data for the entire cast. Derive these variables after dynamic corrections are done.

If the bottle-to-sensor data comparisons are adequate and there is no need to adjust the slope (*Soc*) in the SBE 43 calibration, proceed with data processing (*Performing Dynamic Corrections* below) using the .cnv file created. For DO, process the Oxygen Voltage output in the .cnv file; **do not process the DO concentration data** (which was output only for comparison to bottle samples).

Converting Raw Data (Data Conversion module) when Winkler Bottle Data is NOT Available

1. In SBE Data Processing's Run menu, select Data Conversion.

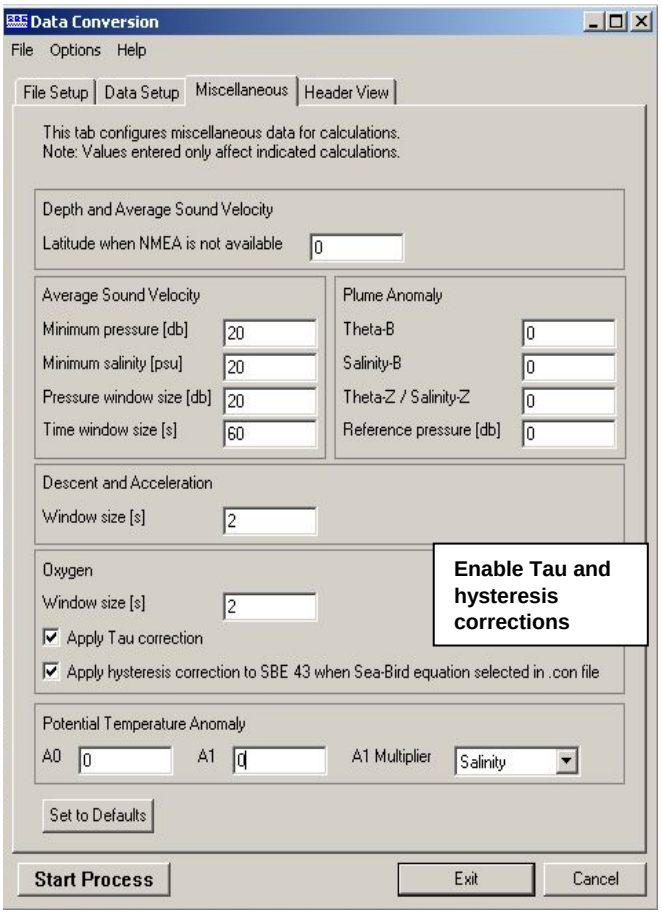
2. On the **File Setup** tab (see SBE Data Processing manual or Help files for selections not described here):
   A. Select the .con file (*Instrument configuration file*) for your CTD; see *Checking Calibration Coefficients and Configuration (.con) File* above to verify you are using the correct calibration coefficients for your SBE 43.
   B. Select the data file (*Input directory* and *Input file*) for your CTD.

3. On the **Data Setup** tab (see SBE Data Processing manual or Help files for selections not described here):
   A. For *Create file types*, select *Create converted data (.cnv) file only*.
   B. Click the *Select Output Variables* button. **As a minimum**, select the following variables for output:
      - Scan Count
      - Time, Elapsed (seconds)
      - Pressure (db)
      - Temperature (ITS-90, deg C)
      - Conductivity (S/m)
      - Oxygen Voltage, SBE 43 (V)

      Click OK to exit the Select Output Variables dialog box.

4. On the **Miscellaneous** tab, in the *Oxygen* section (see SBE Data Processing manual or Help files for selections not described here):
   A. Enter *Window size* for oxygen calculation (use default value of 2 seconds).
   B. Select *Apply Tau correction*.
   C. Select *Apply hysteresis correction to SBE 43 when Sea-Bird equation selected in .con file.*

5. Click the *Start Process* button.



Data Conversion outputs a .cnv file, containing the selected output variables for all scans from the input data file.

Note:
At this point, the oxygen voltage data has been corrected for hysteresis. However, the T, C, and P data needed for the DO concentration calculation (ml/l or other units) has not been processed for dynamic corrections (filtering, aligning, and cell thermal mass adjustments). These dynamic corrections must be done to get the most accurate derived variable results, including DO concentration, % DO saturation, Salinity, and Density. Derive these variables after dynamic corrections are done.

Proceed with data processing (*Performing Dynamic Corrections* below) using the .cnv file created.

Performing Dynamic Corrections (Filter, Align CTD, and Cell Thermal Mass modules)

Follow the processing steps and parameters recommended for your CTD; see the SBE Data Processing manual or Help files.

Deriving Oxygen Concentration corrected for Hysteresis and for Dynamic Errors (Derive module)

Note:
Run the Derive module prior to Bin Averaging your data.

1. In SBE Data Processing's Run menu, select Derive.

2. On the **File Setup** tab (see SBE Data Processing manual or Help files for selections not described here):
   A. Select the .con file (*Instrument configuration file*) for your CTD.
   B. Select the .cnv data file (*Input directory* and *Input file*) for your CTD.

3. On the **Data Setup** tab, click the *Select Derived Variables* button.
   - Select Oxygen, SBE 43, ml/l (or other units).
   - Select other variables (density, salinity, etc.) as desired.

   Click OK to exit the Select Derived Variables dialog box.

4. On the **Miscellaneous** tab, in the *Oxygen* section:

   A. Enter the *Window size* for the oxygen calculation (use default value of 2 seconds).
   B. Select *Apply Tau correction*.

Derive calculates the selected derived variables, and adds columns for those variables to the file.

Note:
If you selected DO concentration as an output variable in Data Conversion (for comparison to Winkler bottle data), the output .cnv file now contains two columns of DO concentration data. Both columns have been corrected for oxygen hysteresis, but the final column has also been corrected for dynamic errors.

Appendix – Hysteresis Algorithm

The hysteresis algorithms are included here for reference, and for customers creating their own software. Two algorithms are provided:

- Algorithm using oxygen voltage values.
- Algorithm using oxygen concentration (ml/l, etc.) values – this algorithm allows you to correct for hysteresis on a data file that has already been processed. A file that has already been processed can be corrected for hysteresis, as long as each scan contains a time stamp or the time increment between scans is known.

We recommend that you run at least a few full CTD files through SBE Data Processing as well as your own software, to verify that your software agrees in the final result.

Hysteresis Algorithm using Oxygen Voltage Values:

$D = 1 + H1 * (\text{exponential}(P(i) / H2) – 1)$

$C = \text{exponential} (-1 * (\text{Time}(i) – \text{Time}(i\text{-}1)) / H3)$

$\text{Oxygen}_{\text{volts}} (i) = \text{OxVolt}(i) + \text{Voffset}$

$\text{Oxnew}_{\text{volts}} (i) = \{(\text{Oxygen}_{\text{volts}} (i) + (\text{Oxnew}_{\text{volts}} (i\text{-}1) * C * D)) – (\text{Oxygen}_{\text{volts}} (i\text{-}1) * C)\} / D$

$\text{Oxfinal}_{\text{volts}} (i) = \text{Oxnew}_{\text{volts}} (i) – \text{Voffset}$

where

- ***i*** = indexing variable (must be a continuous time series to work; can be performed on bin averaged data), where *i* = 1:end (end is largest data index point plus 1).
- ***P(i)*** = pressure (decibars) at index point *i*.
- ***Time(i)*** = time (seconds) from start of index point *i*.
- ***OxVolt(i)*** = SBE 43 oxygen voltage output directly from sensor, with no calibration or hysteresis corrections, at index point *i*.
- ***Voffset*** = correction for an electronic offset that is applied to voltage output of sensor. *Voffset* correction is always negative (see factory calibration sheet for this coefficient). *Voffset* is added to raw voltages prior to hysteresis correction. At end of hysteresis corrections, *Voffset* is removed prior to data conversion using SBE 43 calibration equation (see $Oxfinal_{volts}(i)$).
- $\boldsymbol{Oxygen_{volts}\ (i)}$ = dissolved oxygen voltage value with *Voffset* correction (made prior to hysteresis correction) at index point *i*.
- ***D*** and ***C*** are temporary variables used to simplify expression in processing loop.
- ***H1*** = amplitude of hysteresis correction function. Default = -0.033, range = -0.02 to -0.05 (varies from sensor to sensor).
- ***H2*** = function constant or curvature function for hysteresis. Default = 5000.
- ***H3*** = time constant for hysteresis (seconds). Default = 1450, range = 1200 to 2000 (varies from sensor to sensor).
- $\boldsymbol{Oxnew_{volts}(i)}$ = hysteresis-corrected oxygen value at index point *i*.
- $\boldsymbol{Oxfinal_{volts}(i)}$ = hysteresis-corrected oxygen value at index point *i* with *Voffset* removed. This step is necessary prior to computing oxygen concentration using SBE 43 calibration equation.

Notes:

- Scan 0 –You cannot calculate $\text{Oxfinal}_{\text{volts}} (i)$ for scan 0, because the algorithm requires information about the previous scan, so skip scan 0 when correcting for hysteresis.
- Scan 1 - When calculating $\text{Oxfinal}_{\text{volts}} (i)$ for scan 1, make the following assumption about values from scan 0: $\text{Oxnew}_{\text{volts}} (0) = \text{Oxygen}_{\text{volts}} (0)$.

Hysteresis Algorithm using Oxygen Concentration Values:

D = 1 + H1 *(exponential (P(i) / H2) – 1)
C = exponential (-1 * (Time(i) – Time(i-1)) / H3)
$Oxnew_{conc}$ (i) = {($Oxygen_{conc}$ (i) + ($Oxnew_{conc}$ (i-1) * C * D)) – ($Oxygen_{conc}$ (i-1) * C)} / D

where

- ***i*** = indexing variable (must be a continuous time series to work; can be performed on bin averaged data), where *i* = 1:end (end is largest data index point plus 1)
- ***P(i)*** = pressure (decibars) at index point *i*.
- ***Time(i)*** = time (seconds) from start of index point *i*.
- ***$Oxygen_{conc}$ (i)*** = dissolved oxygen concentration at index point *i*.
- ***D and C*** are temporary variables used to simplify expression in processing loop.
- ***H1*** = amplitude of hysteresis correction function. Default = -0.033, range = -0.02 to -0.05 (varies from sensor to sensor).
- ***H2*** = function constant or curvature function for hysteresis. Default = 5000.
- ***H3*** = time constant for hysteresis (seconds). Default = 1450, range = 1200 to 2000 (varies from sensor to sensor).
- ***$Oxnew_{conc}$(i)*** = hysteresis-corrected oxygen concentration at index point i.

Notes:

- Scan 0 –You cannot calculate $Oxnew_{conc}$ (i) for scan 0, because the algorithm requires information about the previous scan, so skip scan 0 when correcting for hysteresis.
- Scan 1 - When calculating $Oxnew_{conc}$ (i) for scan 1, make the following assumption about values from scan 0: $Oxnew_{conc}$ (0) = $Oxygen_{conc}$ (0).

Sea-Bird Electronics, Inc.
1808 136th Place NE
Bellevue, WA 98005
USA

Phone: (425) 643-9866
Fax: (425) 643-9954
E-mail: seabird@seabird.com
Website: www.seabird.com

APPLICATION NOTE NO. 64-1 **revised April 2008**

Plumbing Installation - SBE 43 DO Sensor and Pump on a CTD

This Application Note describes installation of an SBE 43 Dissolved Oxygen (DO) Sensor and pump (and associated plumbing) for:

- Profiling applications – on an SBE 9*plus* CTD, using PN 90087 Universal Plumbing Kit. The plumbing guidelines for the SBE 9*plus* also apply to an SBE 19, 19*plus*, 19*plus* V2, or 25 CTD, except as noted.
- Moored applications - on an SBE 16*plus*, 16*plus*-IM, 16*plus* V2, 16*plus*-IM V2, or SBE 19*plus* or 19*plus* V2 (used in moored mode), using PN 90087 Universal Plumbing Kit.

PROFILING APPLICATIONS

Preparation

Parts Included in PN 90087 Universal Plumbing Kit

PN	Description	Quantity
23337	Pump air release valve - for vertical configuration only	1
30387	Tube, 1/2" Y-fitting - for connection to pump air release valve, vertical configuration only	1
30388	Tygon tubing, 19 mm (0.75 in.) OD, 13 mm (0.5 in.) ID	4 ft
30579	Tygon tubing, 13 mm (0.5 in.) OD, 9.5 mm (0.375 in.) ID - for connections to DO sensor	0.5 ft
30389	Cable tie, 102 mm (4 in.) - to secure tubing connections	20
30458	Cable tie, 381 mm (15 in.) - to secure Y-fitting to main housing	2

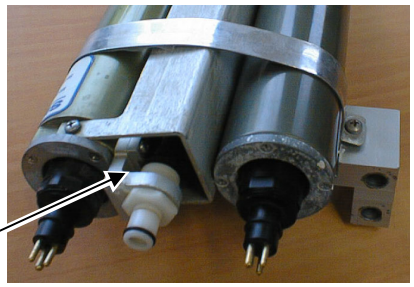
Tools Required

Sharp knife or scalpel for cutting tubing
Straight-edge ruler for measuring and cutting

Installation

Note for SBE 9*plus* or 25:
If your conductivity sensor does not have a conductivity tube support, install the conductivity tube support kit before installing the plumbing (see Application Note 36 for installation details).

Conductivity tube support kit:
Part Number 50094 for aluminum sensors
Part Number 50108 for titanium sensors



Basic considerations for plumbing installation:

- Use the minimum tubing lengths necessary, but avoid tight bends in the tubing. Tight bends place stress on the tubing connections at the sensors, which can lead to failures at the connections.
- Do not create any vertical loops in the tubing. Loops trap air, preventing the pump from working properly.
- Secure each tubing connection with two cable ties.

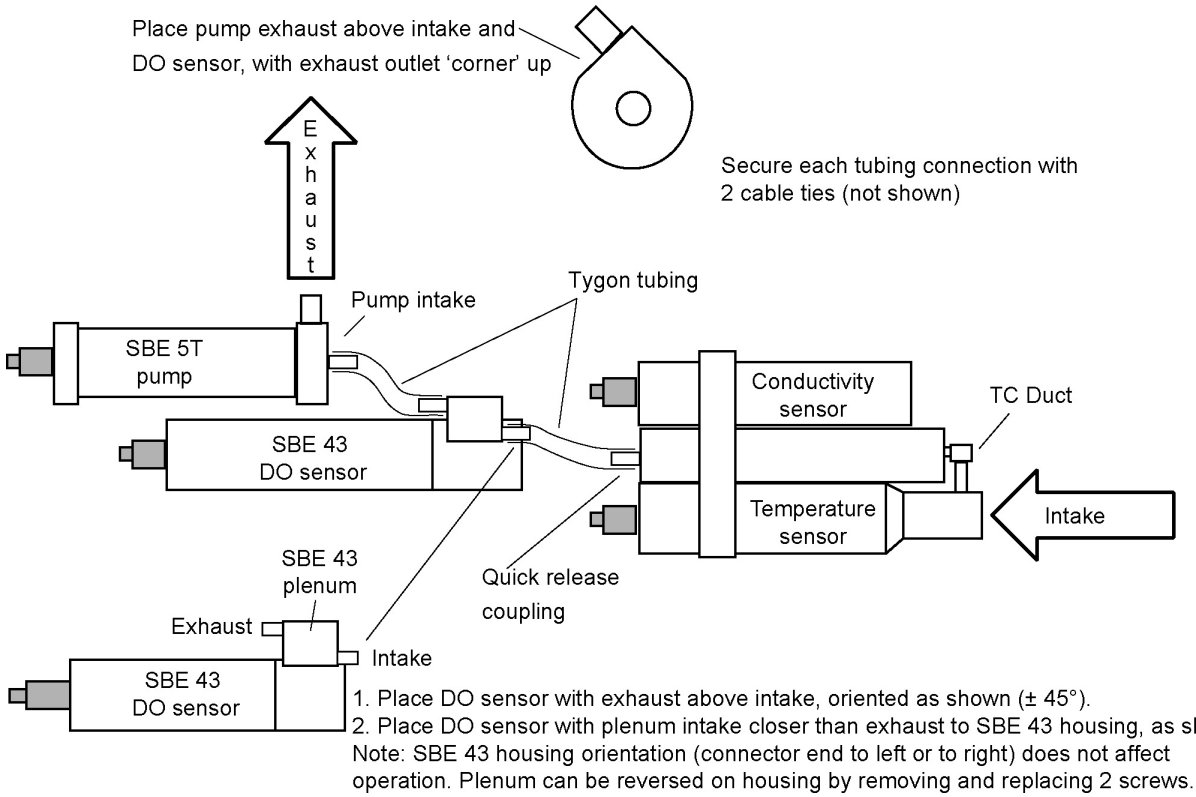
Plumbing installation details differ, depending on whether the sensors will be deployed in a horizontal or vertical configuration, as explained in the following sections.

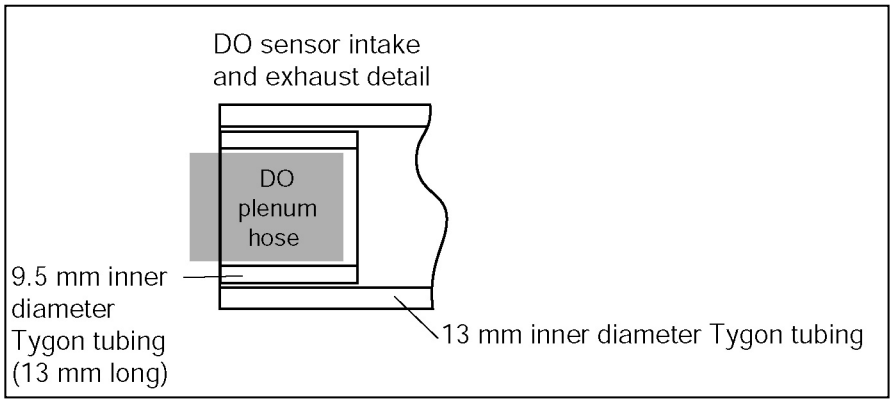
Horizontal Configuration Schematic and Details

The horizontal configuration is most commonly used when the CTD is integrated with an SBE 32 Carousel Water Sampler with an extension stand. When installing plumbing for the horizontal configuration:

- Configure the system as follows:
  - Place the DO sensor intake above the conductivity sensor exhaust.
  - Place the pump intake above the DO sensor exhaust.
  - Orient the pump with the exhaust outlet *corner* up.

  Failure to configure the system in this manner can trap air, preventing the pump from working properly.
- Place a 13 mm (0.5 inch) long piece of the 9.5 mm ID Tygon tubing at the DO sensor intake and exhaust. Slide the larger diameter tubing (13 mm ID) over the smaller diameter tubing to provide tight seals.
- SBE 5T titanium pump, which is standard for the 9*plus*, is shown in the diagram. SBE 5P plastic pump has the same operational characteristics, and may be ordered with the SBE 19, 19*plus*, 19*plus* V2, or 25 CTD for deployments to 600 m.
- If the system does not include a DO sensor, connect the tubing from the conductivity cell directly to the pump intake.

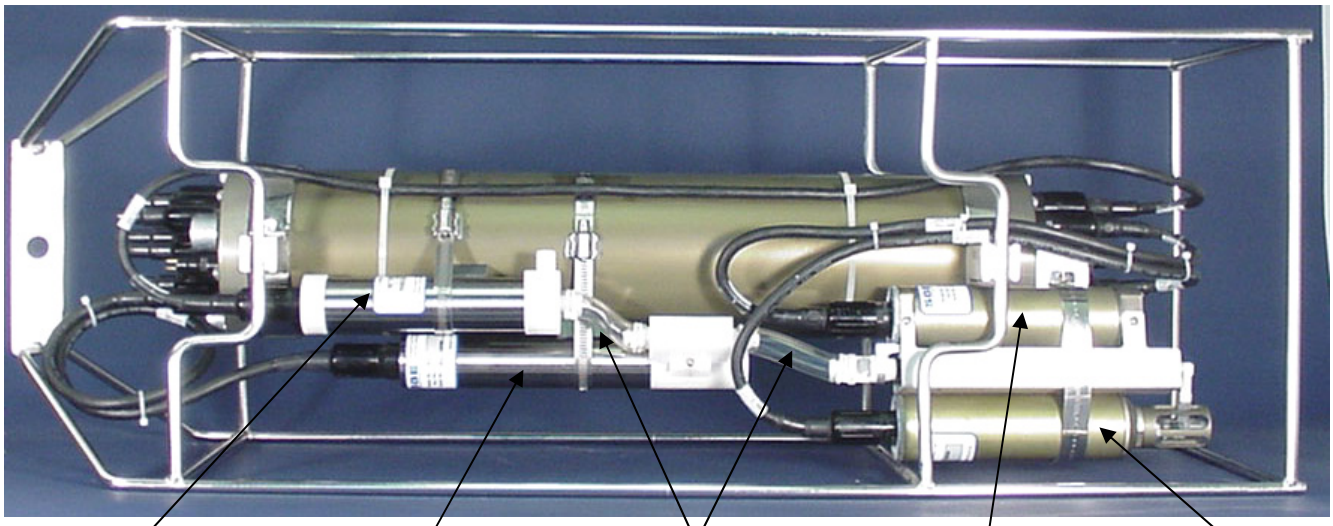




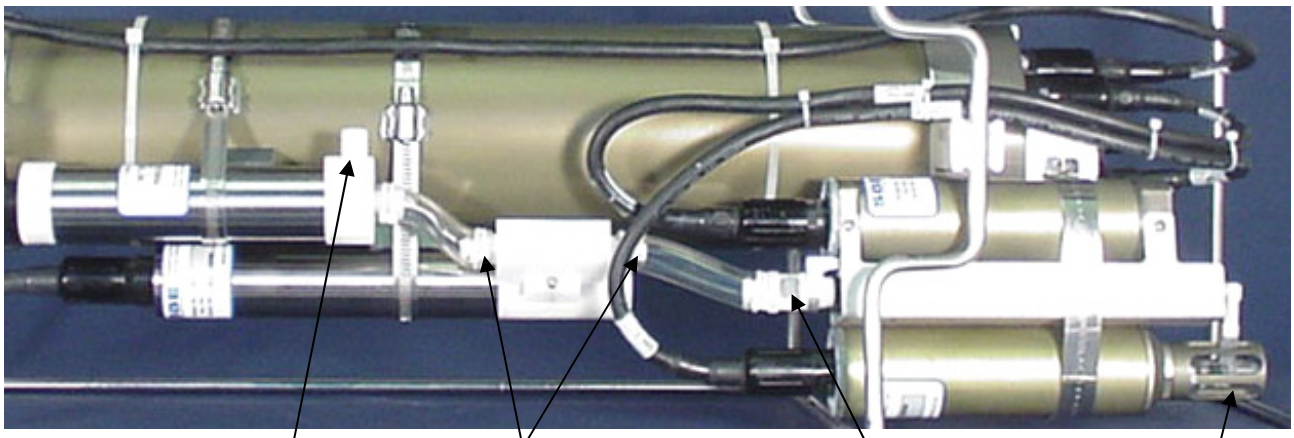
Horizontal Configuration Schematic and Details (continued)

Secure each tubing connection with two cable ties (not shown).

Overall View



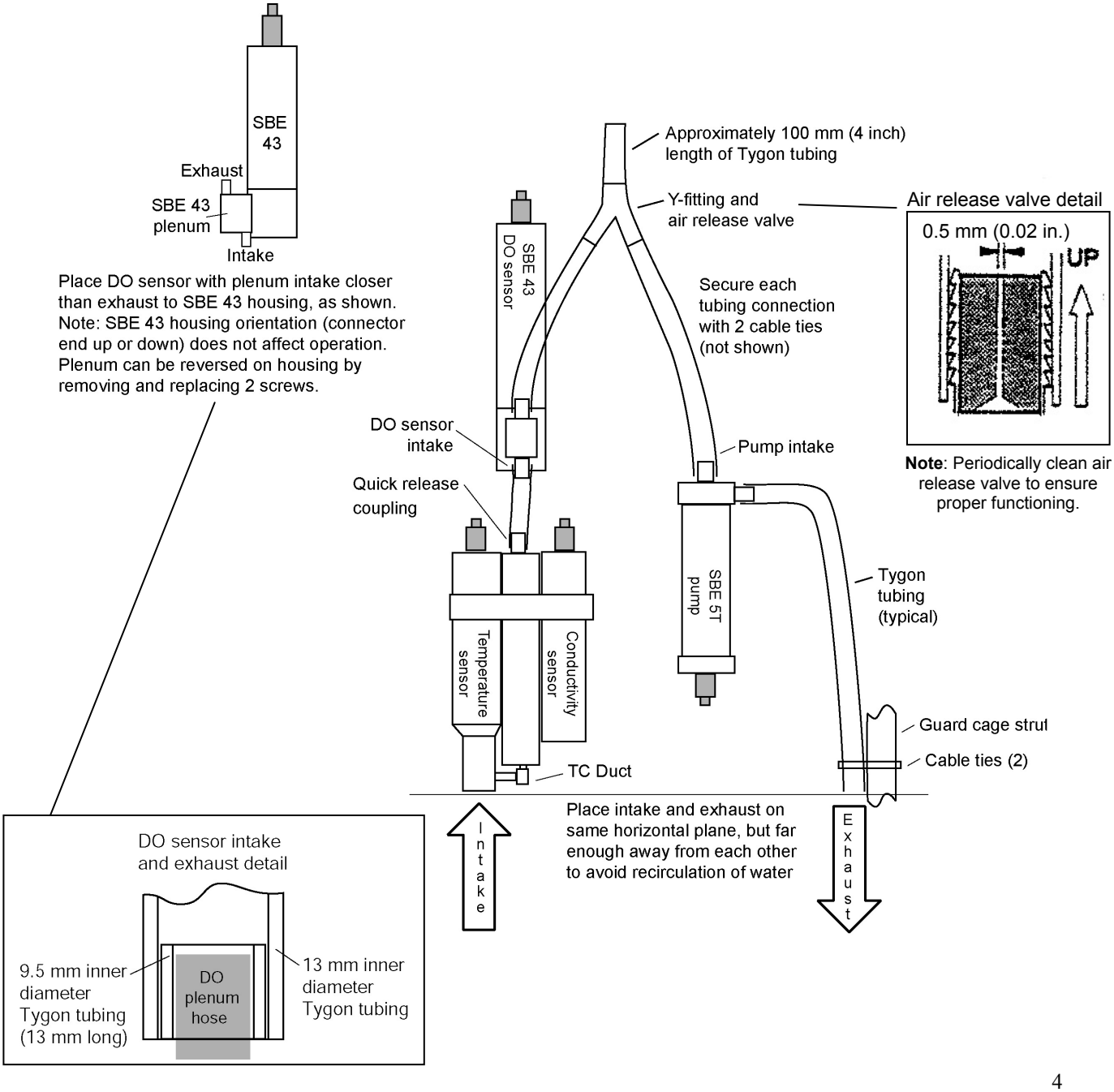
Details



Vertical Configuration Schematic and Details

When installing plumbing for the vertical configuration:

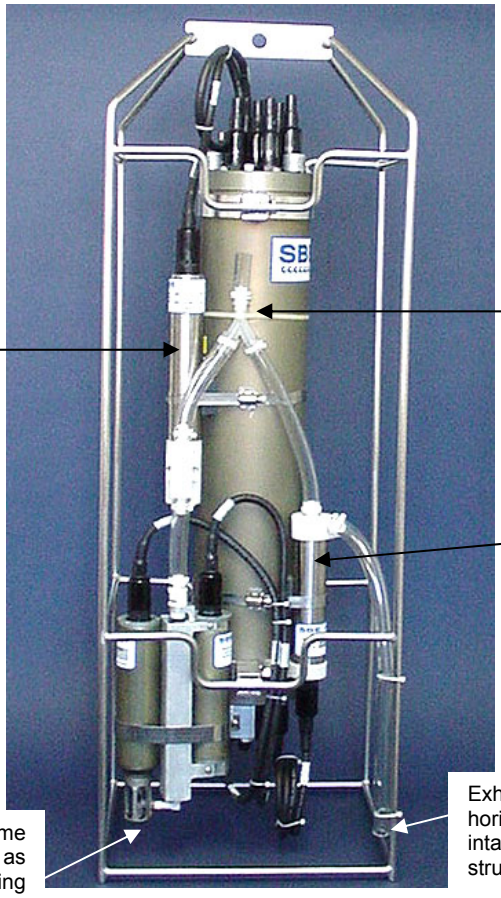
- (For SBE 9*plus* only) Place the opening of the intake and exhaust on the same horizontal plane. Attach exhaust tubing from the pump to the cage, as shown in the schematic below. Failure to place the exhaust tubing properly can lead to acceleration of water in the plumbing, with resulting errors in conductivity data.
  Note: Exhaust tubing is usually omitted by Sea-Bird for an SBE 19, 19*plus*, 19*plus* V2, or 25.
- Place the exhaust away from the intake, so that exhaust water is not pulled into the intake. If the exhaust is too close to the intake, it will cause errors in temperature data, because the pump transfers heat to the exhaust water.
- Place a 13 mm (0.5 inch) long piece of 9.5 mm ID Tygon tubing at the DO sensor intake and exhaust. Slide the larger diameter Tygon tubing (13 mm ID) over the smaller diameter tubing to provide tight seals.
- SBE 5T titanium pump, which is standard for the 9*plus*, is shown in the diagram. SBE 5P plastic pump has the same operational characteristics, and may be ordered with the SBE 19, 19*plus*, 19*plus* V2, or 25 CTD for deployments to 600 m.
- If the system does not include a DO sensor, connect the tubing from the conductivity cell directly to the Y-fitting.



Vertical Configuration Schematic and Details (continued)

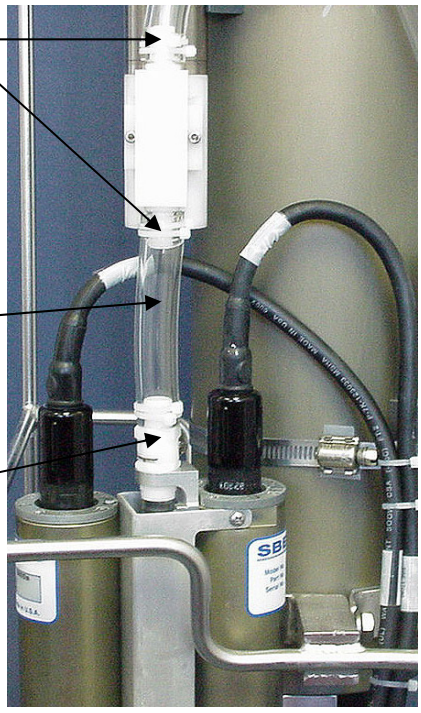
Secure each tubing connection with two cable ties.

Overall View

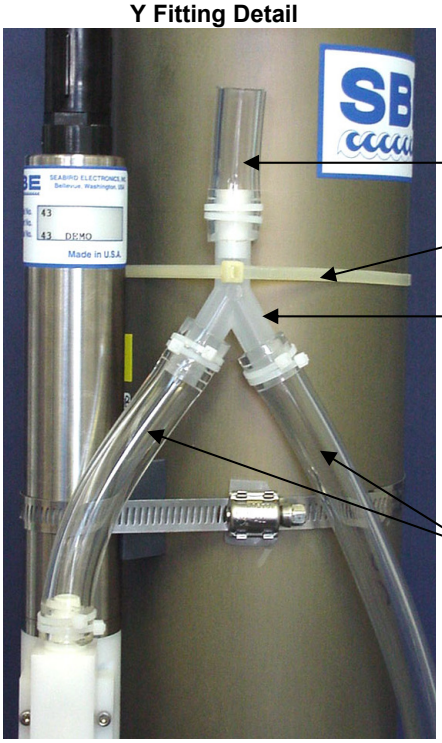


Note:
Exhaust tubing is usually omitted by Sea-Bird for an SBE 19, 19*plus*, 19*plus* V2, or 25.

Temperature/Conductivity to DO Sensor Detail



Y Fitting Detail



MOORED APPLICATIONS

Preparation

Parts Included in PN 90087 Universal Plumbing Kit

PN	Description	Quantity
30388	Tygon tubing, 19 mm (0.75 in.) OD, 13 mm (0.5 in.) ID	4 ft
30579	Tygon tubing, 13 mm (0.5 in.) OD, 9.5 mm (0.375 in.) ID - for connections to DO sensor	0.5 ft
30389	Cable tie, 102 mm (4 in.) - to secure tubing connections	20
23337	*Pump air release valve - not used for moored applications*	*1*
30387	*Tube, 1/2" Y-fitting – not used for moored applications*	*1*
30458	*Cable tie, 381 mm (15 in.) – not used for moored applications*	*2*

Tools Required

Sharp knife or scalpel for cutting tubing
Straight-edge ruler for measuring and cutting

Installation

Basic considerations for plumbing installation:

- Use the minimum tubing lengths necessary, but avoid tight bends in the tubing. Tight bends place stress on the tubing connections at the sensors, which can lead to failures at the connections.

- Do not create any vertical loops in the tubing. Loops trap air, preventing the pump from working properly.

- Secure each tubing connection with two cable ties.

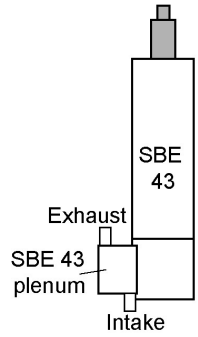
- Configure the system as follows:
  - Place the DO sensor intake above the conductivity sensor exhaust.
  - Orient the DO sensor plenum with the intake closer than the exhaust to the sensor body.
  - Place the pump intake above the DO sensor exhaust.

  Failure to configure the system in this manner can trap air, preventing the pump from working properly.

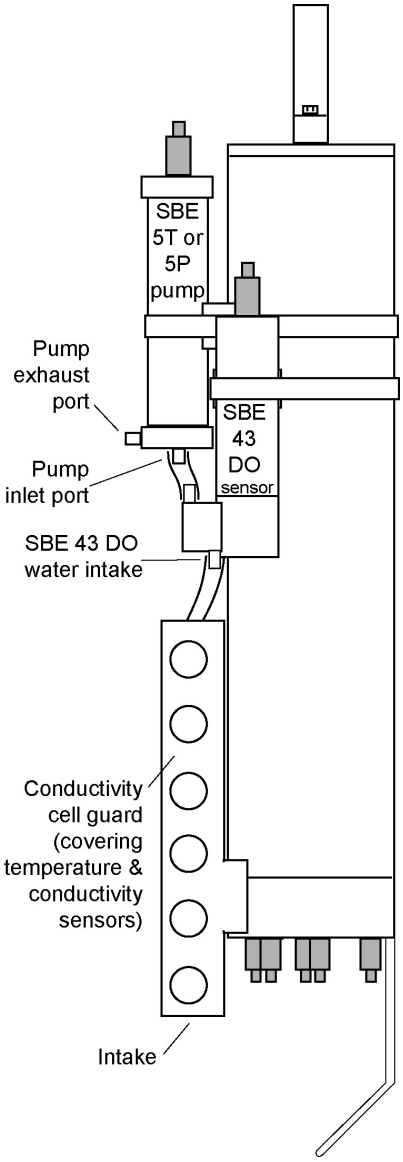
- Place a 13 mm (0.5 inch) long piece of the 9.5 mm ID Tygon tubing at the DO sensor intake and exhaust. Slide the larger diameter tubing (13 mm ID) over the smaller diameter tubing to provide tight seals.

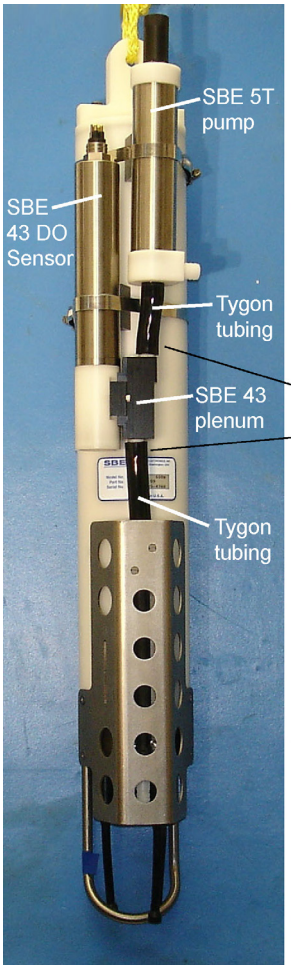
- If the system does not include a DO sensor, connect the tubing from the conductivity cell directly to the pump intake.

Schematic and Details



Place DO sensor with plenum intake closer than exhaust to SBE 43 housing, as shown.
Note: SBE 43 housing orientation (connector end up or down) does not affect operation. Plenum can be reversed on housing by removing and replacing 2 screws.





Cables omitted for clarity

At DO sensor, slide larger diameter Tygon tubing over smaller diameter Tygon tubing to provide tight seal

Orient SBE 43 plenum as shown, with intake closer to body of SBE 43

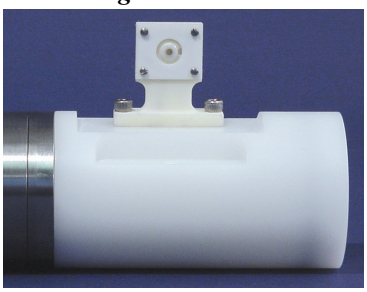
Sea-Bird Electronics, Inc.
1808 136th Place NE
Bellevue, WA 98005
USA

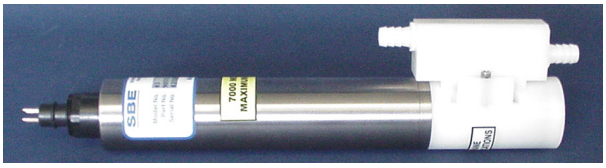
Phone: (425) 643-9866
Fax: (425) 643-9954
E-mail: seabird@seabird.com
Web: www.seabird.com

APPLICATION NOTE NO. 64-2 **Revised April 2008**

SBE 43 Dissolved Oxygen Sensor Calibration and Data Corrections using Winkler Titrations

Figure 1. SBE 43





This application note describes methods for adjusting the calibration coefficients for the SBE 43 Dissolved Oxygen (DO) sensor, and for correcting long-term moored data either in real-time or during post-processing.

The first method requires numerous Winkler titrated water samples and corresponding sensor voltages to compute new slope and offset terms for the sensor calibration. The second method is most applicable for long-term moored data applications that typically only have a few reference samples and are temporally affected by bio-fouling of the sensor membrane.

Calibration Adjustment Using Multiple Winkler Water Samples and Sensor Voltages over a Wide Range of Oxygen Calculations

This method statistically estimates calibration coefficients for calculating dissolved oxygen in milliliters per liter from SBE 43 output voltage. The technique requires dissolved oxygen concentrations reported in ml/l (determined from a range of Winkler titrated water samples) and SBE 43 oxygen voltage outputs measured at the times the water samples were collected. Sea-Bird's data processing software, SBE Data Processing, is used to produce a data table suitable for the analysis.

Basic Principal

The equation below, used in Sea-Bird's software for calculating dissolved oxygen in ml/l from SBE 43 output voltage, is a form of that given in Owens-Millard (1985):

$$Oxygen\,(ml/l) = \left\{ Soc * \left(V + Voffset + tau(T,P) * \frac{\partial V}{\partial t} \right) \right\} * Oxsol(T,S) * \left(1.0 + A*T + B*T^2 + C*T^3\right) * e^{\left(\frac{E*P}{K}\right)} \qquad eqn\ 1$$

Where:

V = SBE 43 output voltage signal (volts)

$\frac{\partial V}{\partial t}$ = time derivative of SBE 43 output signal (volts/second)

T = CTD temperature (°C)

S = CTD salinity (psu)

P = CTD pressure (dbars)

K = CTD temperature (°K)

tau(T,P) = sensor time constant at temperature and pressure

Oxsol(T,S) = oxygen solubility function (ml/l), which converts oxygen partial pressure (sensor measurement) to oxygen concentration (*Garcia and Gordon, 1992*). See Appendix A in Application Note 64 for values at various temperatures and salinities.

Soc, Voffset, A, B, C, E, and *tau20, D1*, *D2* [terms in calculation of tau (T,P)] are calibration coefficients

The SBE 43 is expected to provide an output voltage that is linear with respect to oxygen concentration. Normal calibration drift manifests itself as a loss of sensitivity and is evident as a change of slope (and less so in offset) in the linear relationship between oxygen concentration and voltage output. The coefficients *A, B, C,* and *E* correct for small secondary responses to temperature and pressure. Because these coefficients change very slowly over time, the values given on the SBE 43 calibration certificate will be used in this analysis, and we will concern ourselves with estimating changes in the slope (Soc) and offset (Voffset).

Setting $\frac{\partial V}{\partial t}$ to zero, we rearrange equation 1 into a linear form and perform a linear regression to obtain a new *Soc* and *Voffset*.

Let:

$$\phi = Oxsol(T,S) * \left(1.0 + A*T + B*T^2 + C*T^3\right) * e^{(\frac{E*P}{K})} \qquad eqn\ 2$$

The oxygen equation then reduces to the form in equation 3:

$$Oxygen(ml/l) = Soc * (V + Voffset) * \phi \qquad eqn\ 3$$

This may be expressed in a linear form in equation 4.

$$\frac{Oxygen(ml/l)}{\phi} = Soc * (V + Voffset) = M * V + B \qquad eqn\ 4$$

Where:

Soc = M

Voffset = B / M

A linear regression is calculated using Winkler oxygen concentration divided by ϕ as the dependent variable and SBE 43 output voltage as the independent variable.

Example

The example plot below shows Winkler oxygen divided by ϕ versus SBE 43 output voltage, and includes a linear regression line calculated from the data.

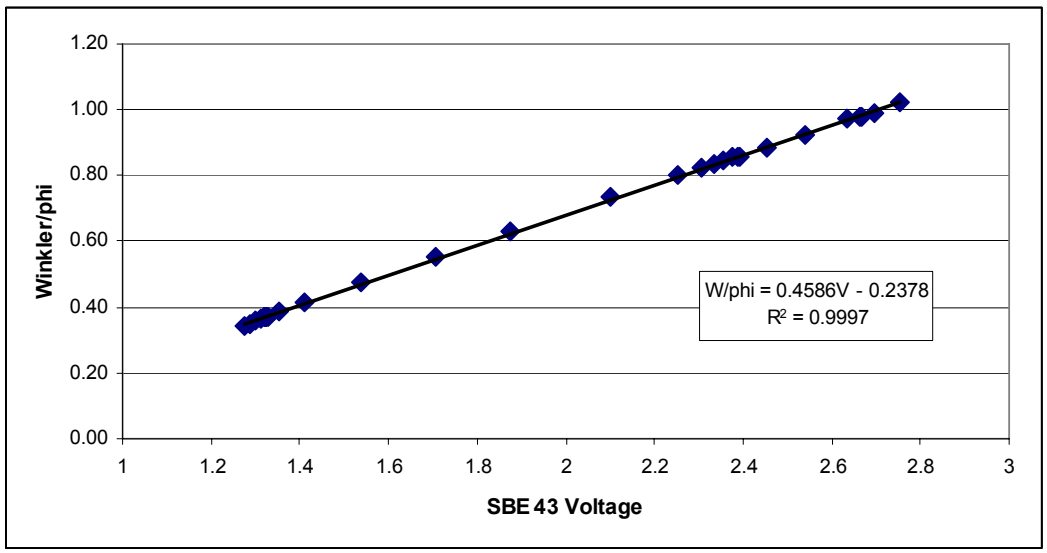


Figure 2. *Winkler oxygen / ϕ*

In this example, the new *Soc* value is 0.4586. The new *Voffset* value is:

$$Voffset = \frac{-0.2378}{Soc} = \frac{-0.2378}{0.4586} = -0.5185$$

The next plot summarizes the results of the calibration. The diamonds are differences between the SBE 43 dissolved oxygen and Winkler titration dissolved oxygen, using the original calibration. The squares are differences between SBE 43 dissolved oxygen and Winkler titration dissolved oxygen, using *Soc* and *Voffset* derived above.

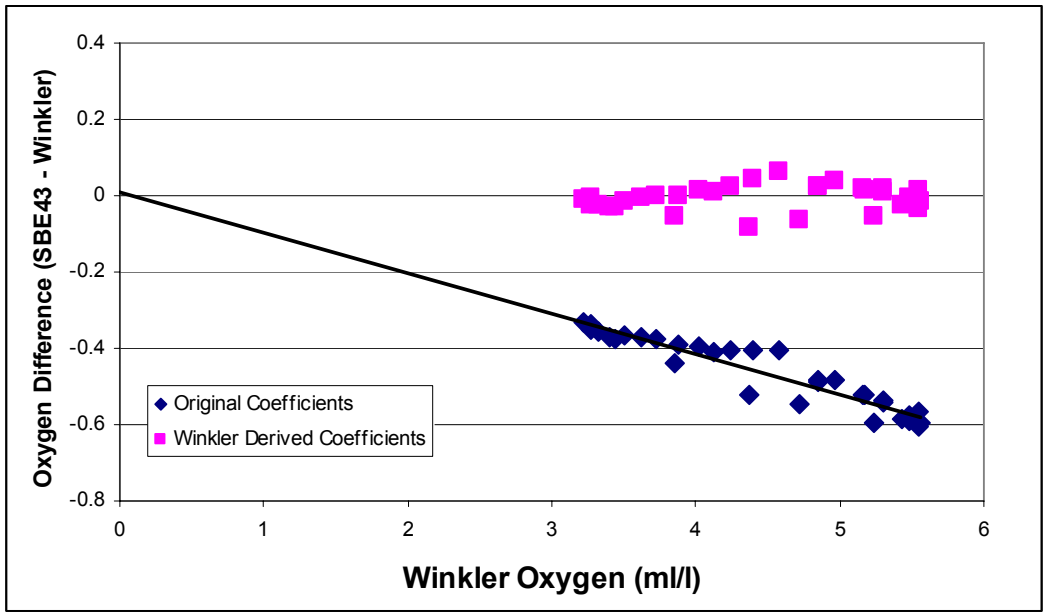


Figure 3. *Calibration results*

Processing Procedure Using SBE Data Processing

The linear regression that yields a new *Soc* and *Voffset* may be accomplished with spreadsheet software, a hand-held calculator with statistical capability, or (with perseverance) a calculator, graph paper, and pencil. As a first step, extract pressure, temperature, salinity, oxygen saturation, and SBE 43 voltage from the parts of your CTD data collected when the water sampler closures occurred.

Run SBE Data Processing, and select Data Conversion in the Run menu. Select the appropriate configuration (*.con*) and data (*.dat* or *.hex*) files on the *File Setup* tab. Click the *Data Setup* tab and set *Convert data from* to *Upcast and downcast* and *Create file types* to *Create bottle (.ros) file only*.

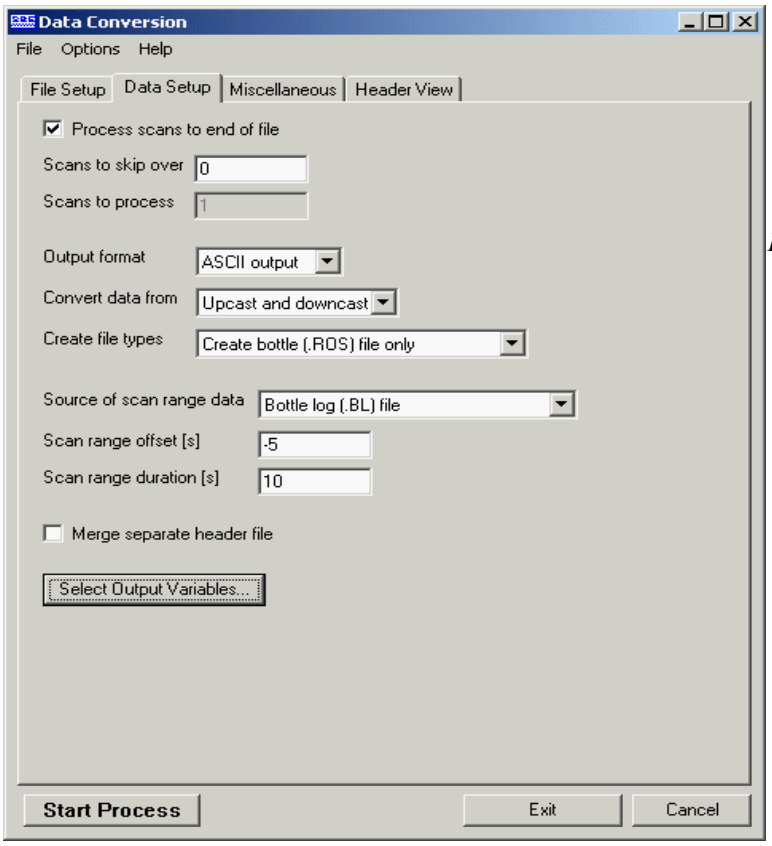


Figure 4.

To extract CTD data concurrent to the water sampler closures, Data Conversion must know when the closures occurred. Select an appropriate *Source of scan range data*, depending on your instrument type and how the sampler was commanded to close bottles:

- SBE 9*plus* with SBE 11*plus* or 17*plus* - The data stream is marked with a *bottle confirm* bit each time a closure occurred.
- Using SEASAVE to operate the water sampler - A *.bl* file, with scan ranges corresponding to closures, is created during the cast.
- SBE 19, 19*plus*, 19*plus* V2, or 25 with Auto Fire Module (AFM) and SBE 32 Carousel Water Sampler, or operated autonomously with SBE 55 ECO Water Sampler - The *.afm* file contains scan ranges.

Like all sensors, the SBE 43 has a finite response time to a change in dissolved oxygen concentration. This response time is usually on the order of 6 seconds. For this reason, good sampling procedure dictates that the instrument package should be stopped in the water column long enough for the SBE 43 and all other sensors to completely equilibrate before closing the water sampler. An equilibration time of 5 to 6 response times, or 30 to 36 seconds, is adequate.

In the example above, Data Conversion will begin extracting data 5 seconds before each water sampler closure (*Scan range offset = -5 s*) and will extract a total of 10 seconds of data (*Scan range duration = 10 s*). Note that 10 seconds is longer than the SBE 43 response time. Because we are extracting data for 5 seconds after the water sampler closure, the instrument package must remain stopped for at least this long.

To estimate *Soc* and *Voffset*, you need pressure, temperature, salinity, oxygen saturation (ml/l), and SBE 43 Oxygen Voltage to go with each Winkler titration data value. Click *Select Output Variables* and add each of the required parameters; the dialog box is shown below.

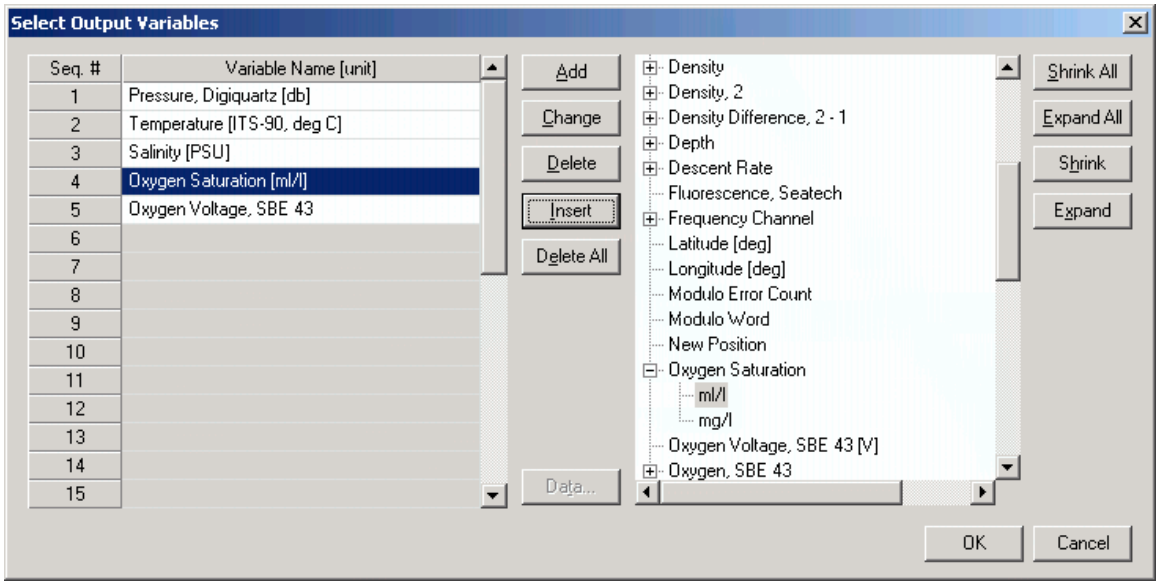


Figure 5.

After selecting all the variables, click *OK* to return to the Data Conversion Data Setup tab. Then click *Start Process* to create the *.ros* file.

For this example, the *.ros* file contains 10 seconds of data centered on the moment the bottle closure occurred for every bottle closure. To make a useful table, select Rosette Summary from SBE Data Processing's Run menu. Rosette Summary calculates averages and standard deviations for the variables selected in Data Conversion. Select the appropriate *.con* and *.ros* files on the *File Setup* tab. Click the *Data Setup* tab and then click the *Select Averaged Variables* button; the dialog box is shown below.

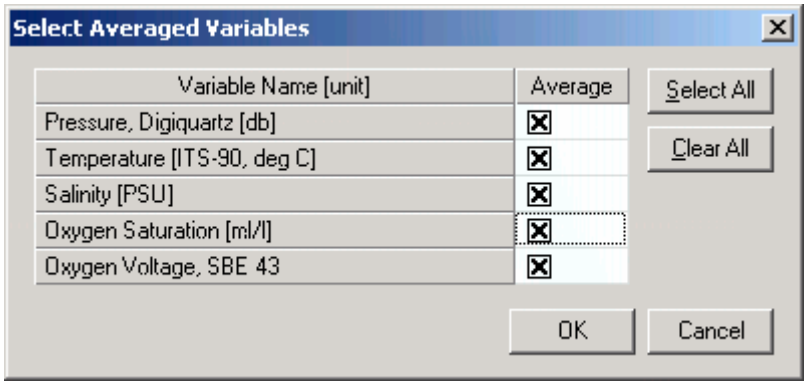


Figure 6.

After selecting all the variables, click *OK* to return to the Rosette Summary Data Setup tab. Then click *Start Process* to create a data table file with the *.btl* extension.

Create a table with average pressure, temperature, salinity, oxygen saturation, and SBE 43 output voltage for each water sampler closure depth, by importing the *.btl* file into a spreadsheet. Then, enter by hand the Winkler titration dissolved oxygen values from your titration log, matching water sampler closures to pressures.

Calculate $\phi = Oxsol(T,S) * \left(1.0 + A*T + B*T^2 + C*T^3\right) * e^{\left(\frac{E*P}{K}\right)}$,

using *A, B, C,* and *E* from the SBE 43 calibration sheet.
Then, calculate *Winkler* O_2 / ϕ .

An example table is shown below (using *A* = -0.00034959, *B* = 0.00013078, *C* = -0.0000027243, and *E* = 0.0.036), with ϕ (phi) in column 7 and *Winkler* O_2 / ϕ (Winkler/phi) in column 8.

Table 1. *Example calculation of phi and Winkler/phi.*

Pressure (db)	Temperature (°C)	Salinity (PSU)	Oxygen Solubility (ml/l)	SBE 43 Voltage Output (V)	Winkler Oxygen (ml/l)	phi	Winkler/phi
194.6	15.43	35.617	5.623	2.452	5.172	5.852	0.884
169.5	16.26	35.713	5.529	2.540	5.306	5.744	0.924
143.7	17.17	35.793	5.430	2.635	5.488	5.632	0.974
93.9	18.97	35.881	5.247	2.753	5.545	5.424	1.022
48.7	23.38	36.087	4.841	2.697	4.966	5.009	0.992
24.0	23.94	35.840	4.801	2.664	4.852	4.956	0.979
9.6	23.95	35.839	4.800	2.667	4.851	4.946	0.981

Perform a linear regression, with:

- *Winkler* O_2 / ϕ (shown as Winkler/phi in the table) as the *Y* data
- SBE 43 output voltages as the *X* data

If a spreadsheet or statistical calculator is not available, the regression equations are:

$$M = \frac{n * \sum\left(V * \frac{Winkler\,O_2}{\phi}\right) - \sum V * \sum\left(\frac{Winkler\,O_2}{\phi}\right)}{n * \sum V^2 - \left(\sum V\right)^2}$$

$$B = \frac{\sum\left(\frac{Winkler\,O_2}{\phi}\right) - M * \sum V}{n}$$

Where:

n = number of data pairs
M = Slope
B = Offset

And:

Soc = *M*
Voffset = *B/M*

SBE 43 Calibration Adjustment or Data Correction for Long-Term Deployments using Sparse Reference Values

The following methods are used to correct fouled SBE 43 sensor data collected primarily in moored applications. They can be applied to oxygen data when only sparse reference samples are available to verify sensor calibration. The methods should be applied only to individual sensors (i.e., a correction calculated for one sensor cannot be applied to other sensors on the mooring). Once a sensor on a mooring is serviced (cleaned) or swapped out, the process should be repeated. Specific applications for moored oxygen sensors include:

- Data correction when periodic reference check values are collected while the sensor continues sampling *in situ* (but no sensor maintenance is conducted) - This data correction is particularly useful for assessing when sensors need to be serviced for real-time data collection programs. It is also applicable for post-processing of data in non-real-time applications. See *Example of In Situ Data Correction for Continuous Real-Time Mooring Data Applications* below.
- Data correction when only pre- and post-deployment reference samples or factory calibrations are available – This data correction requires that no sensor maintenance, such as cleaning, be performed between the pre- and post-deployment reference samples or factory calibrations. See *Example of Post-Processing Data Collection* below.

Basic Principal

The SBE 43 sensor output is linear with respect to oxygen concentration and maintains a relatively stable output at zero oxygen. Electrochemical drift, a limitation in previous Clark designs, exists somewhere below the calibration uncertainty of 1 µmol/kg and has not been observed in several years of factory calibration data nor in long-deployments on Argo floats and moorings. Therefore, any sensor drift with time is attributed to fouling of the membrane, either biological or waterborne contaminants (i.e., oil). The main term of interest for correcting fouling drift is the *SOC* term in the SBE 43 sensor calibration equation, as shown here again in Equation 3:

$$Oxygen(ml/l) = Soc * (V + Voffset) * \phi \qquad eqn\ 3$$

Where:

***SOC* is the linear slope scaling coefficient**

V is the SBE 43 output voltage signal (volts)

V_{offset} is a fixed sensor voltage at zero oxygen

ϕ (defined in Equation 2 earlier in this document) includes terms that correct for the effects of temperature and pressure, and also includes oxygen solubility dependence on temperature and salinity. Because these terms remain essentially constant with fouling and sensor age, we will not concern ourselves with ϕ for this application. Furthermore, an insufficient number of water samples makes estimation of *Voffset* uncertain, therefore, we will restrict the correction derived here to the *SOC* term, which is the calibration term affected most by the fouling.

The loss of sensitivity attributed to fouling of the sensor membrane is observed as a linear change in the sensor output when compared to a set of reference samples (Figure 7 and Table 2). The ratio of the reference sample values to the SBE 43 measured DO concentrations remains constant over the range of the sensor (for multiple values of DO). This allows for the adjustment in the slope term *SOC* using just one quality reference sample, because any of the reference values would provide the same correction in an otherwise healthy sensor.

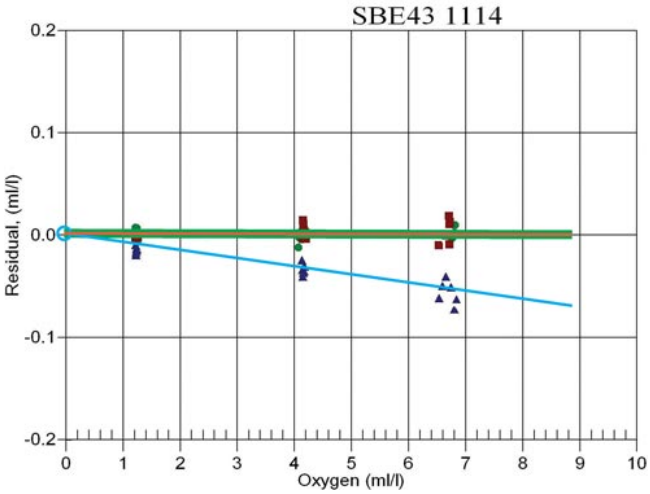


Figure 7. *Original factory calibration of SBE 43 sensor SN 1114 (green dots); post-recovery calibration prior to sensor cleaning (blue triangles); re-calibration after sensor cleaning (red squares). Notice the loss of sensitivity in the post-recovery calibration (blue triangles) is strictly linear.*

Table 2. *Reference Winkler water samples and sensor readings at 3 dissolved oxygen concentrations during post-recovery calibration of SBE 43 sensor SN 1114 (Figure 7). The ratio between the Winkler values and corresponding SBE 43 output can be used to calculate the SOC correction factor. Note the SOC correction factor remains constant at each validation point over the range of oxygen values shown, illustrating that any single validation point alone could be used to correct the slope.*

Winkler DO of Bath, ml/l	**SBE 43 Output, ml/l**	**Residual (SBE 43 – Winkler)**	**Correction factor (Winkler/SBE 43)**
6.80	6.75	-0.05	6.80/6.75=1.007
4.20	4.17	-0.03	4.20/4.17=1.007
1.20	1.19	-0.01	1.20/1.19=1.007

Simply multiplying the pre-deployment *SOC* value by the correction factor, given by the ratio

(Winkler DO Value / SBE 43 DO Value)

provides a correction to the linear slope term (*SOC*) in the calibration equation and offers a powerful and scientifically defensible way to make residual corrections to data from unattended long-term deployments.

Example of In Situ Data Correction for Continuous Real-Time Mooring Data Applications

In this example, we use data collected with an SBE 43 dissolved oxygen sensor deployed in an urban marina for 4 months during the biologically active spring and summer seasons. The integrated SBE 43 and CTD (conductivity, temperature, and depth sensor) was moored at 2 meters water depth and sampled every 10 minutes following a 30-second flush cycle. Replicate Winkler samples were collected bi-weekly from a 1.2-liter Niskin bottle adjacent to the moored SBE 43 sensor at the time of a sample. The SBE 43 measured dissolved oxygen within 5% of Winkler reference values for over 107 days (~3 months) during high biological fouling conditions (Figure 8).

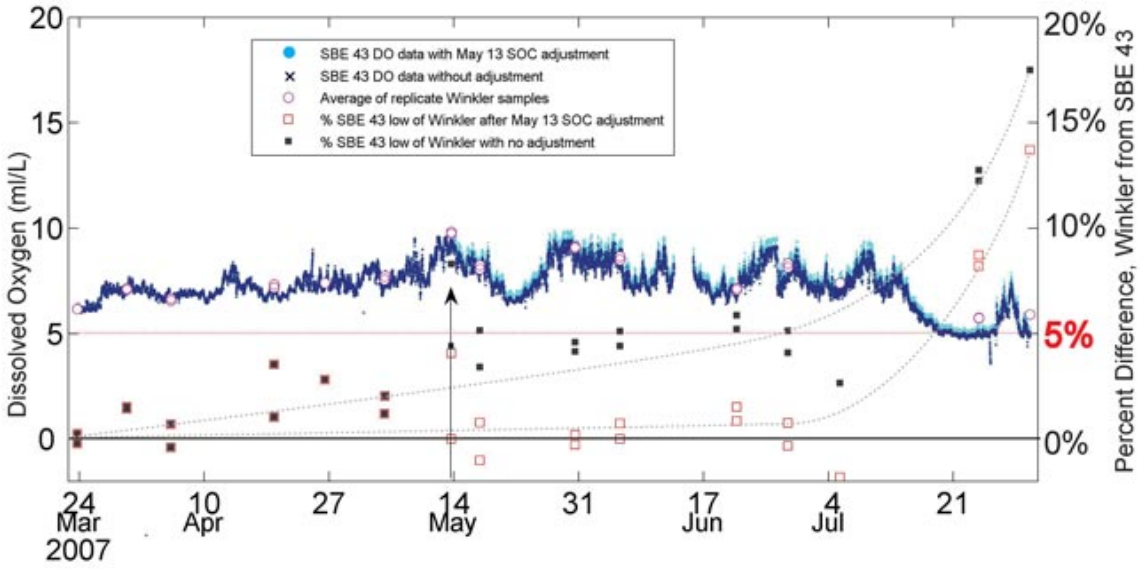


Figure 8. *SBE 43 dissolved oxygen time series plotted in dark blue, March 23 – July 31, 2007. Data with a slope adjustment made after May 13 are co-plotted in cyan. Average Winkler values are shown as open pink circles, and the percent difference between the SBE 43 and Winkler averages are co-plotted along the right y-axis as black solid squares (before the May 13 validation and slope adjustment), and as red open squares (from May 13 forward following the adjustment). The dashed curved lines are drawn to illustrate how correcting the in situ data can prolong deployment while maintaining accuracy in real-time (or post-processed) data.*
Mean standard deviation of the Winkler replicates is 0.03 ml/l.

A single validation point made on May 13 is used to demonstrate the correction of *in situ* sensor data without servicing or recovering the instrument (see arrow in Figure 8). The average of the replicate Winkler values on May 13 is 9.737 ml/l, and the SBE 43 reported 9.308 ml/l. To adjust the calibration for data after May 13, a new *SOC* value is obtained by multiplying the pre-May 13 *SOC* value (1.3256e-04) by the ratio of the reference value to the sensor value. Verify the units of each are compatible (ml/l, mg/l, µmol/kg, or % saturation).

[(Winkler value ml/l) / (SBE 43 value ml/l)] => (9.737/9.308 = 1.046):
New*SOC* = previous*SOC* * ([Winkler] / [SBE 43])
1.3866e-04 = 1.3256e-04 *1.046

The result of using the New*SOC* on data collected after May 13 demonstrates how sensor accuracy is maintained near initial calibration accuracy by using a single quality reference sample (Figure 8). See the next example for a description of how to apply a correction to data preceding the May 13 reference sample.

Note: We recommend that the sensor be returned to the factory for servicing when the New*SOC* value represents a change of 15 - 20% from the original calibration and cannot be restored with standard cleaning protocols (see Application Note 64 for cleaning recommendations).

Example of Post-Processing Data Correction

Sometimes, in-field validation is not possible. This restricts correction of possibly fouled data to post-processing, and requires a reference validation sample be taken at the end of the deployment or soon after the instrument is recovered. The reference validation sample could be a water sample taken in the field prior to recovery or a factory calibration.

A simple method for data correction in post-processing is to assume a linear fouling adjustment per day (or week, or month) for the entire period or between field validation data collection periods. The resultant rate of change in the sensor measurement can then be programmed into a simple algorithm to calculate corrected DO data with time.

Post-Processing Correction Example 1:

The fouling drift in sensor data shown in Figure 8 is linear with time. To apply a correction to the data, simply compute the rate of change per day in the Soc value from the beginning of the deployment to May 13, when an *in situ* reference sample was made (50 days).

*SOC*rate = (New*SOC* – previous*SOC*) / # of days
0.0012e-04 per day = (1.3866e-04 – 1.3256e-04) / 50

Post-Processing Correction Example 2:

For this example, pre- and post-calibration data from sensor 1114 are used (Table 2). Sensor 1114 was deployed in a high-fouling coastal lagoon for 2 months with no interim servicing. After recovery, the sensor was returned to the factory for calibration and shown to have fouled ~1% (Table 2). The post-calibration *SOC* value prior to any cleaning, and the rate of change in *SOC*, are computed as follows:

New*SOC* = previous*SOC* * ([Winkler] / [SBE 43])
0.3837 = 0.3810 * 1.007

*SOC*rate = (New*SOC* – previous*SOC*) / # of days
4.445e-05 per day = (0.3837 – 0.3810) / 60

During the 2-month deployment period, the sensor experienced an *SOC* change rate of about 0.000045/day. In reality, a sensor may not exhibit fouling for several weeks to months (as shown here, fouling was minimal), so the user will need to decide how best to determine the time span and data correction criteria of fouled data. Interim water samples or reference checks (using a CTD) between service intervals can provide valuable information on fouling. Variations on the methods used for post-correcting data are also possible.

Data corrections are only as good as the reference samples used to correct the data. We therefore recommend replicate water sample collection, or validation methods that employ a sensor that is as accurate as the moored sensor being tested.

References

Owens, W. B., and R. C. Millard Jr., 1985: A new algorithm for CTD oxygen calibration. J. Physical Oceanography., 15, 621-631.

Garcia and Gordon (1992) "Oxygen solubility in seawater: Better fitting equations", Limnology & Oceanography, vol 37(6), p1307-1312.

Sea-Bird Electronics, Inc.
1808 136th Place NE
Bellevue, WA 98005
USA

Phone: (425) 643-9866
Fax: (425) 643-9954
E-mail: seabird@seabird.com
Web: www.seabird.com

APPLICATION NOTE NO. 85 **revised April 2008**

Handling of Ferrite Core on Instruments with Inductive Modem Telemetry

This Application Note applies to instruments and accessories that include a cable coupler for inductive modem telemetry:

- SBE 16*plus*-IM and 16*plus*-IM V2 SEACAT C-T (optional pressure) Recorder
- SBE 37-IM MicroCAT C-T (optional pressure) Recorder
- SBE 37-IMP MicroCAT C-T (optional pressure) Recorder
- SBE 39-IM Temperature (optional pressure) Recorder
- SBE 44 Underwater Inductive Modem
- Inductive Cable Coupler (ICC) – clamps to the jacketed mooring wire, and makes electrical connection with the Surface Inductive Modem (SIM) or Inductive Modem Module (IMM) via a cable housed in reinforced-rubber conduit.

The ferrite modem core in these instruments and accessories is fragile, and must be handled with care. If you are having problems with inductive modem communications, check the core for misalignment or damage as follows.

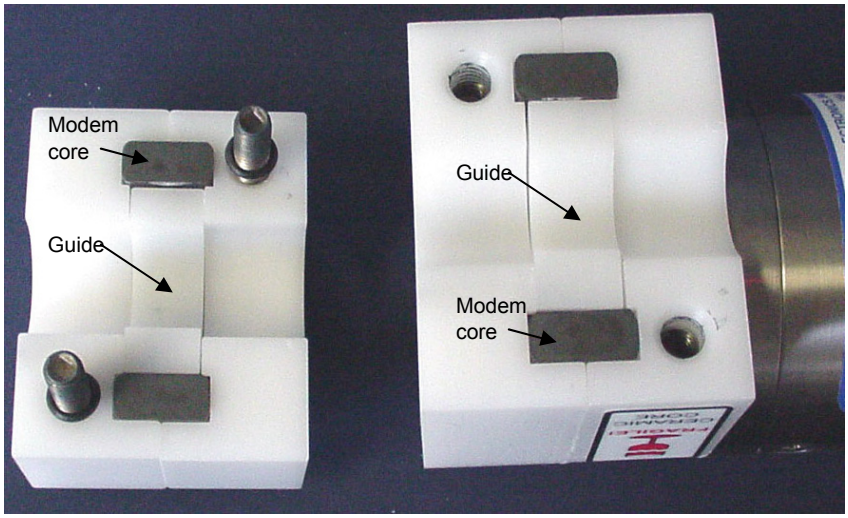
***Note**:* All photos are for an SBE 37-IMP, except as noted. Details are similar for all instruments included in this application note, except as noted.

1. Open the mounting bracket by unthreading the large hex-head bolts.

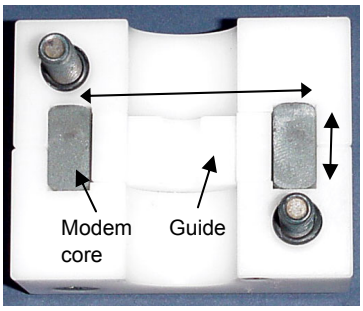


Mounting guide / Inductive Modem Coupler Detail
Guide is sized ***slightly*** bigger than specified cable diameter, to allow cable to pass through freely but limit vibration of instrument on cable

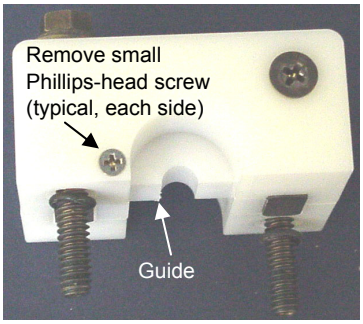
For proper communications, 2 halves of modem coupling toroid core must mate, with no gaps



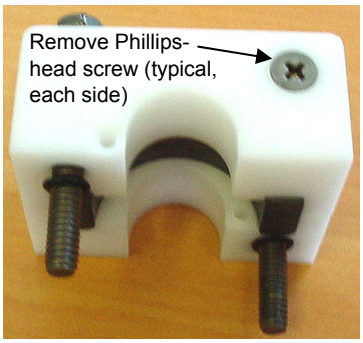
2. On the ***clamp*** side:
   A. Verify that the core provides a level surface for mating with the *instrument* side.
   B. Remove the two small Phillips-head screws securing the guide, and remove the guide.
   C. Remove the 2 larger Phillip-head screws and carefully pull the clamp apart.



Step 2A: Check that core is level in both directions shown

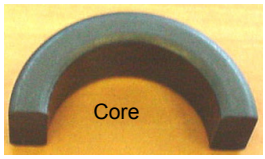


Step 2B: Remove guide



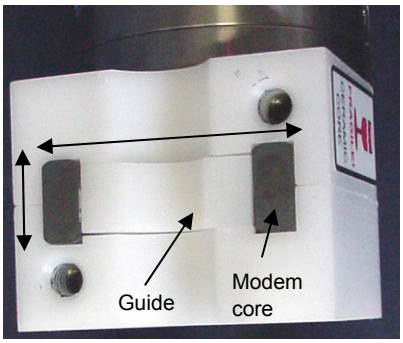
Step 2C: Pull clamp apart

   D. Examine the ferrite core for cracks or chips; replace if necessary.
   E. Reinstall the ferrite core in the two plastic pieces of the clamp, using the 2 Phillips-head screws, being careful to provide a level surface for mating with the *instrument* side.
   F. Reinstall the guide, using the 2 small Phillips-head screws.

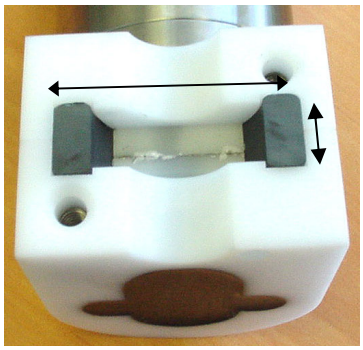


Step 2D: Examine core

3. On the ***instrument*** side:
   A. Verify that the core provides a level surface for mating with the *clamp* side.
   B. Remove the two small Phillips-head screws securing the guide, and remove the guide (similar to Step 2B).
   C. (SBE 16*plus*-IM, 16*plus*-IM V2, 37-IM, 37-IMP, 39-IM, and 44) The core cannot be removed for a complete inspection, because it is surrounded by potting compound. Inspect the visual portions of the core for damage; if damaged, the entire end cap assembly will have to be replaced at Sea-Bird.



Step 3A: Check that core is level in both directions shown

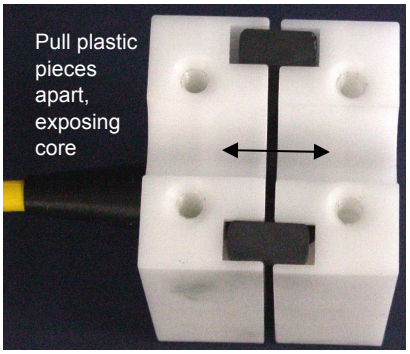


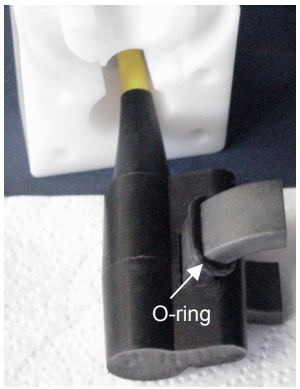
Step 3C: Examine visual portions of core

   D. (Inductive Cable Coupler) Remove the core as shown in the photos below. Examine the ferrite core for cracks or chips; replace if necessary. Reinstall the core, plastic, screws, etc.

Details for ICC Only



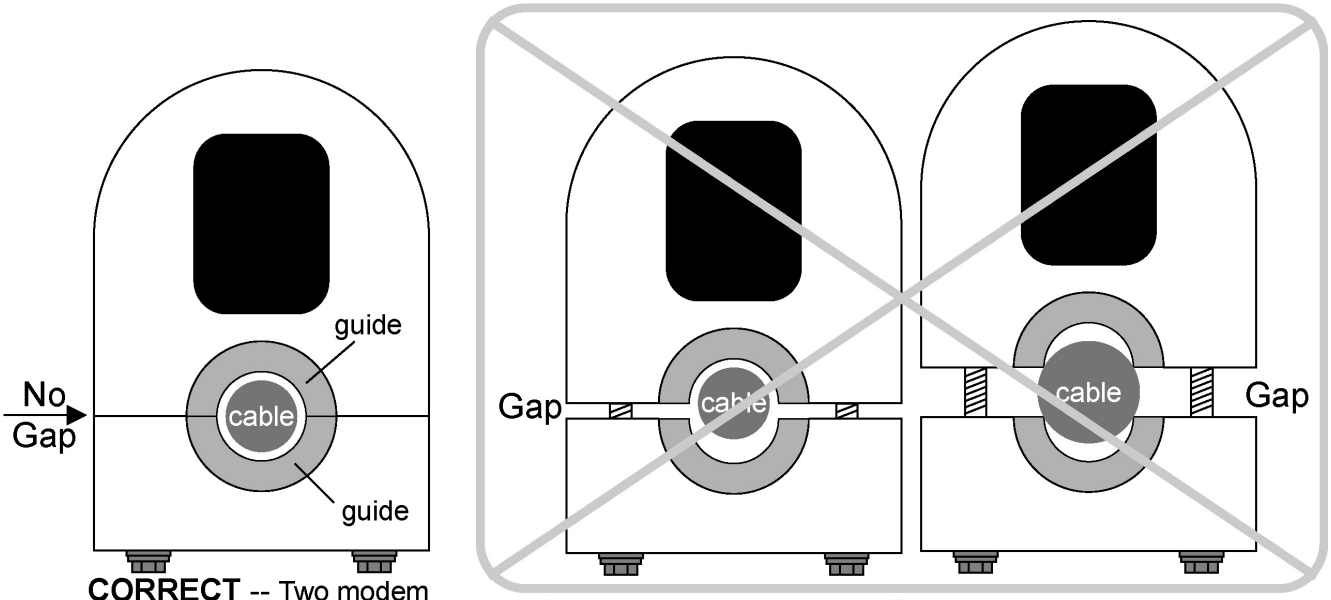




   E. Reinstall the guide, using the 2 small Phillips-head screws.

When installing the instrument or Inductive Cable Coupler on the cable, note the following:

Cable guide and clamp are sized at Sea-Bird to match cable size specified in your order.
If you will be using a different cable size, contact Sea-Bird to order new guide and clamp.



CORRECT -- Two modem halves mating closely (< 0.1 mm gap). Note that guide does not clamp cable.

INCORRECT -- Bolts not tightened completely, creating gap between modem halves. Hand-tighten bolts until snug.

INCORRECT -- Guide hole too small for cable, creating gap between modem halves. May damage cable or modem if over-tightened.

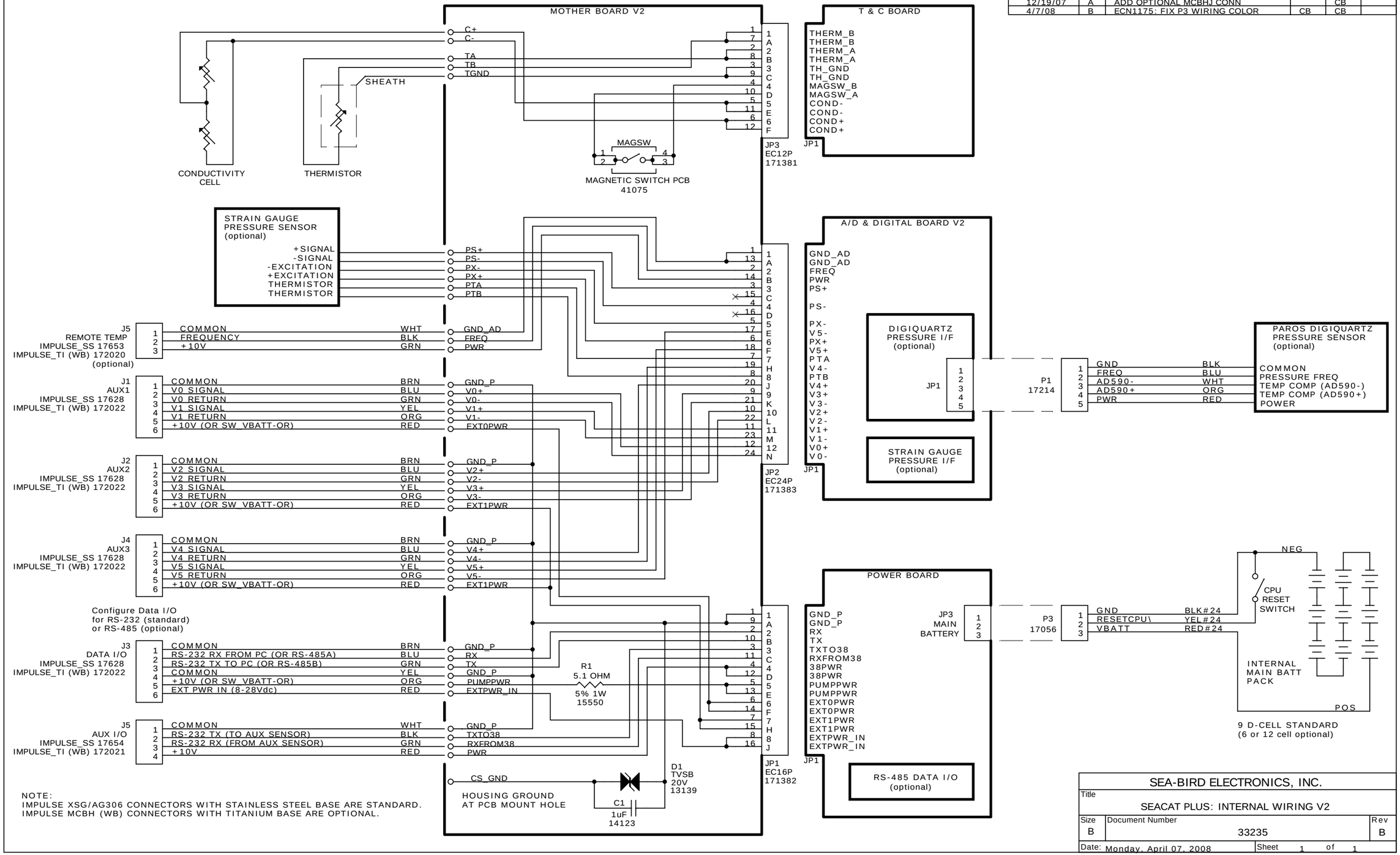
DRAWINGS

Dwg 33235B SEACAT Plus-V2 Internal Wiring..... 1

Dwg 30565 Cable, RMG-2FS to RMG-2FS, Pump Interface, PN 17133..... 2

Dwg 32496 Cable, SBE 43 Interface, PN 172447..... 3

DATE	SYM	REVISION RECORD	AUTH	DR	CK
12/19/07	A	ADD OPTIONAL MCBHJ CONN		CB	
4/7/08	B	ECN1175: FIX P3 WIRING COLOR	CB	CB	



NOTE:
IMPULSE XSG/AG306 CONNECTORS WITH STAINLESS STEEL BASE ARE STANDARD.
IMPULSE MCBH (WB) CONNECTORS WITH TITANIUM BASE ARE OPTIONAL.

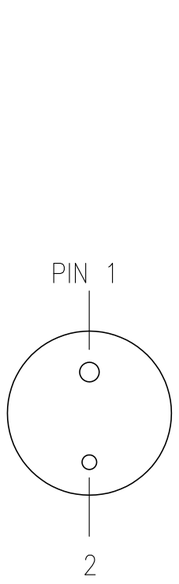
SEA-BIRD ELECTRONICS, INC.

Title: SEACAT PLUS: INTERNAL WIRING V2

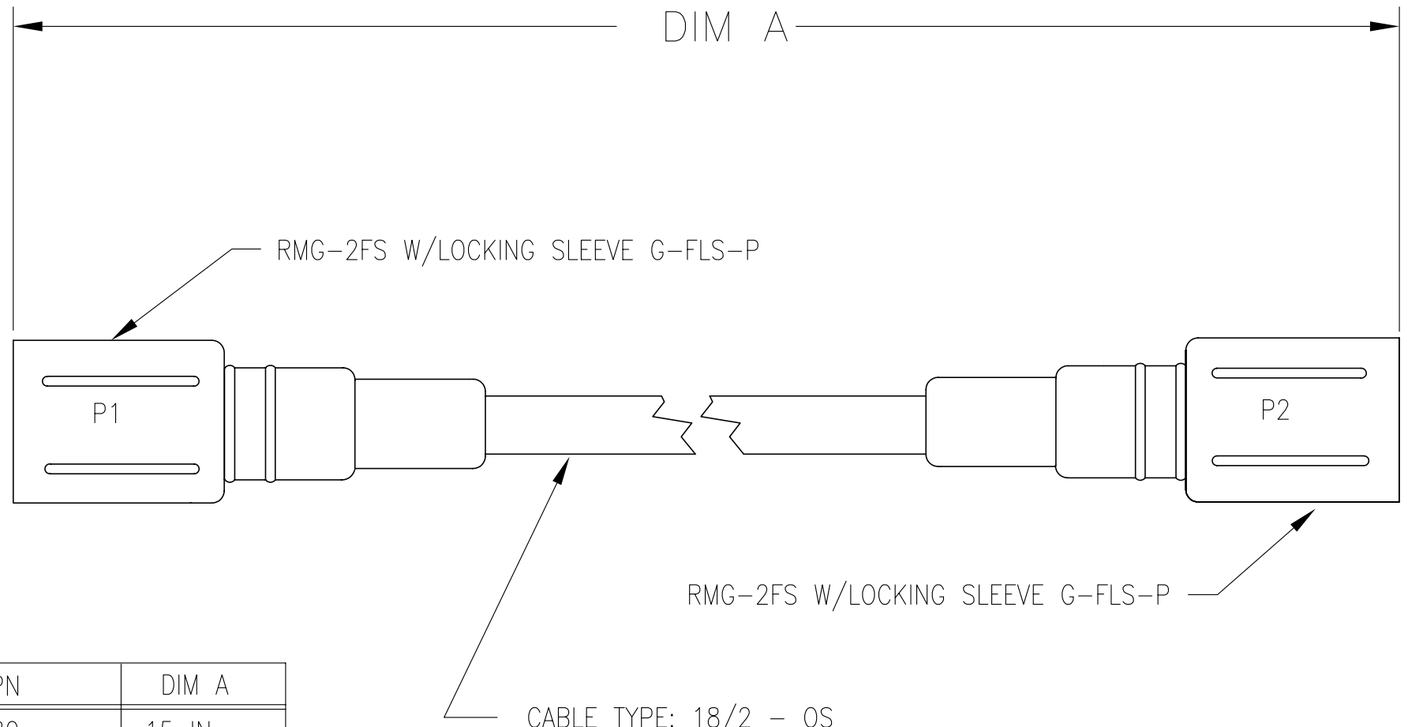
Size	Document Number	Rev
B	33235	B

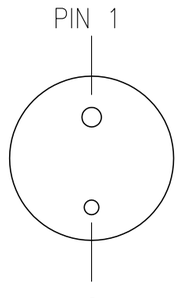
Date: Monday, April 07, 2008 Sheet 1 of 1

DATE	SYM	REVISION RECORD	AUTH.	DR.	CK.



P1





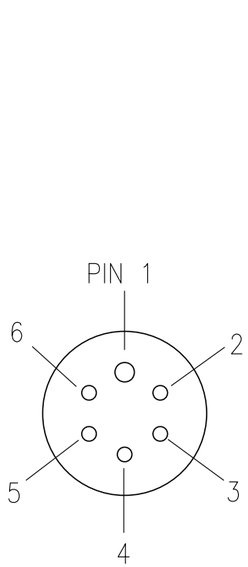
P2

SBE PN	DIM A
17080	15 IN
17100	40 IN
17101	6 FT
17127	60 IN
17133	44 IN
17159	36 IN
17188	34 IN
17200	79 IN
17259	120 IN
17285	12 IN
17394	29 IN
17450	24 IN
17584	48 IN
171229	10 M
171249	130 CM

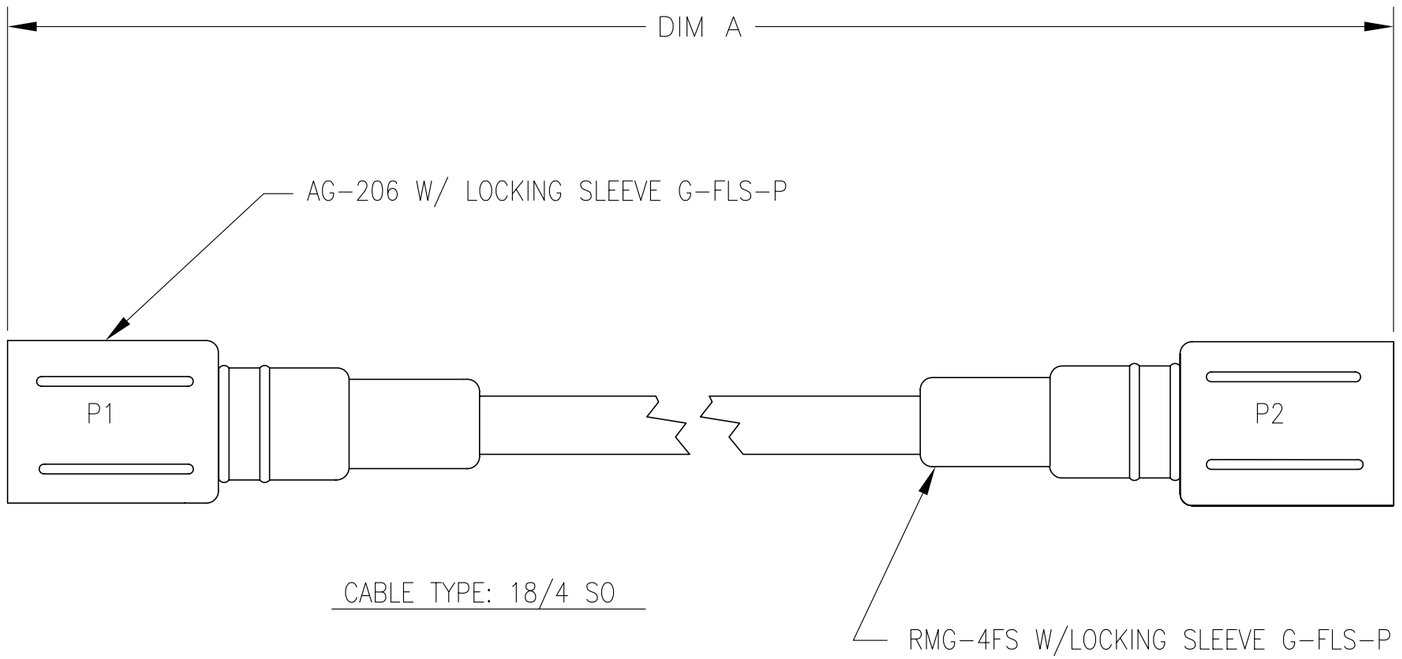
P1 (RMG-2FS)	P2 (RMG-2FS)
PIN 1	PIN 1
PIN 2	PIN 2

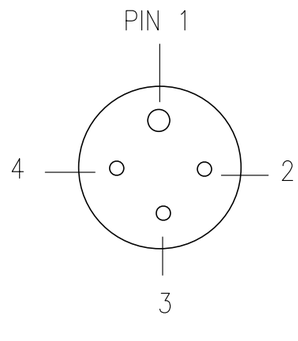
TOLERANCES	SEA-BIRD ELECTRONICS, INC		
FRACTIONAL	P/N SEE TABLE	SCALE N.T.S.	DRAWN BY CEG APPROVED BY CB
DECIMAL	TITLE CABLE, 2 PIN / 2 PIN RMG-2FS W/LOCKING SLEEVE		
ANGULAR	DATE 9.21.98	DRAWING NUMBER 30565	REV

DATE	SYM	REVISION RECORD	AUTH.	DR.	CK.



P1





P2

SBE PN	DIM A
17186	31 IN
17312	36 IN
17445	20 IN
17606	48 IN
171391	79 IN
171491	30 IN
171507	40 IN
171653	72 IN
171686	120 IN
171812	98 IN
171851	54 IN
172447	42 IN

P1 AG-206	P2 RMG-4FS
PIN 1	PIN 1
PIN 2	PIN 2
PIN 3	PIN 3
PIN 4	---
PIN 5	---
PIN 6	PIN 4

TOLERANCES	SEA-BIRD ELECTRONICS, INC			
FRACTIONAL	P/N SEE TABLE	SCALE 1:1	DRAWN BY MJ APPROVED BY	
DECIMAL	TITLE Cable, SBE43 Interface (Diff Inputs)			
ANGULAR	DATE 02.20.01	DRAWING NUMBER 32496		REV

WARRANTY POLICY 2006

5-YEAR LIMITED WARRANTY (NEW PRODUCTS)

For a period of five years after the date of original shipment from our factory, products manufactured by Sea-Bird are warranted to function properly and be free of defects in materials and workmanship. Should a Sea-Bird instrument fail during the warranty period, return it freight pre-paid to our factory. We will repair it (or at our option, replace it) at no charge, and pay the cost of shipping it back to you. Certain products and components have modified coverage under this warranty as described below.

LIMITED WARRANTY ON SERVICE & REPAIRS

Service work, repairs, replacement parts and modifications are warranted to be free of defects in materials or workmanship for the remainder of the original 5-year warranty or one year from the date of shipment from our factory after repair or service, which ever is longer. Certain products and components have modified coverage under this warranty as described below.

MODIFICATIONS / EXCEPTIONS / EXCLUSIONS

1. The SBE 43 DO sensor is warranted to function properly for 5 years. Under normal use however, the electrolyte in an SBE 43 DO sensor will require replenishment after about 3 years. Purchase of an SBE 43 includes one free electrolyte replenishment (as necessitated by chemical depletion of electrolyte) anytime during the warranty period. To obtain the replenishment, return the sensor freight pre-paid to our factory. We will refurbish it for free (electrolyte refill, membrane replacement, and recalibration) and pay the cost of shipping it back to you. Membrane damage or depletion of electrolyte caused by membrane damage is not covered by this warranty.

2. Because pH and other dissolved oxygen (DO) electrodes have a limited life caused by the depletion of their chemical constituents during normal storage and use, our warranty applies differently to such electrodes. Electrodes in SBE 13Y and 23Y DO sensors, SBE 18 pH sensors, and SBE 27 pH/ORP sensors are covered under warranty for the first 90 days only. Other components of the sensor are covered for 5 years.

3. Equipment manufactured by other companies (e.g., fluorometers, transmissometers, PAR, optical backscatter sensors, altimeters, etc.) are warranted only to the limit of the warranties provided by their original manufacturers (typically 1 year).

4. Batteries, zinc anodes or other consumable/expendable items are not covered under this warranty.

5. Electrical cables and dummy plugs are warranted to function properly and be free of defects in materials and workmanship for 1 year.

6. This warranty is void if in our opinion the instrument has been damaged by accident, mishandled, altered, improperly serviced, or repaired by the customer where such treatment has affected its performance or reliability. In the event of such misuse/abuse by the customer, costs for repairs plus two-way freight costs will be borne by the customer. Instruments found defective should be returned to the factory carefully packed, as the customer will be responsible for freight damage.

7. Incidental or consequential damages or costs incurred as a result of product malfunction are not the responsibility of SEA-BIRD ELECTRONICS, INC

Warranty Administration Policy

Sea-Bird Electronics, Inc. and its authorized representatives or resellers provide warranty support only to the original purchaser. Warranty claims, requests for information or other support, and orders for post-warranty repair and service, by end-users that did not purchase directly from Sea-Bird or an authorized representative or reseller, must be made through the original purchaser. The intent and explanation of our warranty policy follows:

1. Warranty repairs are only performed by Sea-Bird.

2. Repairs or attempts to repair Sea-Bird products performed by customers (owners) shall be called *owner repairs*.

3. Our products are designed to be maintained by competent owners. Owner repairs of Sea-Bird products will NOT void the warranty coverage (as stated above) simply as a consequence of their being performed.

4. Owners may make repairs of any part or assembly, or replace defective parts or assemblies with Sea-Bird manufactured spares or authorized substitutes without voiding warranty coverage of the entire product, or parts thereof. Defective parts or assemblies removed by the owner may be returned to Sea-Bird for repair or replacement within the terms of the warranty, without the necessity to return the entire instrument. If the owner makes a successful repair, the repaired part will continue to be covered under the original warranty, as if it had never failed. Sea-Bird is not responsible for any costs incurred as a result of owner repairs or equipment downtime.

5. We reserve the right to refuse warranty coverage *on a claim by claim basis* based on our judgment and discretion. We will not honor a warranty claim if in our opinion the instrument, assembly, or part has been damaged by accident, mishandled, altered, or repaired by the customer *where such treatment has affected its performance or reliability*.

6. For example, if the CTD pressure housing is opened, a PC board is replaced, the housing is resealed, and then it floods on deployment, we do not automatically assume that the owner is to blame. We will consider a claim for warranty repair of a flooded unit, subject to our inspection and analysis. If there is no evidence of a fault in materials (e.g., improper or damaged o-ring, or seal surfaces) or workmanship (e.g., pinched o-ring due to improper seating of end cap), we would cover the flood damage under warranty.

7. In a different example, a defective PC board is replaced with a spare and the defective PC board is sent to Sea-Bird. We will repair or replace the defective PC board under warranty. The repaired part as well as the instrument it came from will continue to be covered under the original warranty.

8. As another example, suppose an owner attempts a repair of a PC board, but solders a component in backwards, causing the board to fail and damage other PC boards in the system. In this case, the evidence of the backwards component will be cause for our refusal to repair the damage under warranty. However, this incident will NOT void future coverage under warranty.

9. If an owner's technician attempts a repair, we assume his/her qualifications have been deemed acceptable to the owner. The equipment owner is free to use his/her judgment about who is assigned to repair equipment, and is also responsible for the outcome. The decision about what repairs are attempted and by whom is entirely up to the owner.

Service Request Form

To return your instrument for calibration or other service, please take a few moments to provide us with the information we need, so we can serve you better.

PLEASE:

1. **Get a Returned Material Authorization (RMA) number from Sea-Bird (*phone 425-643-9866, fax 425-643-9954, or email seabird@seabird.com*). Reference the RMA number on this form, on the outside shipping label for the equipment, and in all correspondence related to this service request.**
2. **Fill out 1 form for each type (model) of instrument.**
3. **Include this form when shipping the instrument to Sea-Bird for servicing.**
4. **Fax us a copy of this form on the day you ship.** ***FAX: (425) 643-9954***

RETURNED MATERIAL AUTHORIZATION (RMA) NUMBER: _____

DATE EQUIPMENT REQUIRED BY: _____

DO YOU REQUIRE A WRITTEN QUOTE? _____

CONTACT INFORMATION

Your name: _____

Institution/Organization/Company: _____

Shipping/Delivery address for packages: _____

_____

_____

Telephone: _____ Fax: _____

e-mail: _____

SERVICE INFORMATION

Date Shipped: _____

Sea-Bird Model Number (for example, SBE 37-SM): _____

Quantity: _____

Serial Numbers: _____

_____

_____

(**Note**: **Specify instrument serial numbers below** if specific services are required for some instruments. For example, if 10 instruments are being returned for calibration, and 1 of the 10 also requires repairs, specify the serial number for the instrument requiring repairs in the appropriate section of the form.)

SEASOFT Version you have been using with this instrument(s): _____

[ ] Calibration Services:

___Calibration (includes basic diagnostic):

___Temperature ___Conductivity ___Pressure ___DO ___pH

(Please allow a minimum of 3 weeks after we receive the instrument(s) to complete calibration.)

___Other (specify): _____

_____

[ ] Internal Inspection and O-Ring Replacement (includes hydrostatic pressure test):

Additional charges may apply.

_____

_____

[ ] System Upgrade or Conversion:

Specify (include instrument serial number if multiple instruments are part of shipment): _____

_____

_____

[ ] Diagnose and Repair Operational Faults:

Please send a disk containing the raw data (.hex or .dat files) that shows the problems you describe. Also send the .con files you used to acquire or display the data.

Problem Description (continue on additional pages if needed; include instrument serial number if multiple instruments are part of shipment): _____

_____

_____

_____

PAYMENT/BILLING INFORMATION

Credit Card: Sea-Bird accepts payment by VISA, MasterCard, or American Express.

[ ] MasterCard [ ] Visa [ ] American Express

Account Number: _____ Expiration Date: _____

Credit Card Holder Name (printed or typed): _____

Credit Card Holder Signature: _____

Credit Card Billing Address (if different than shipping address):

_____

_____

_____

Invoice/Purchase Order: If you prefer us to invoice you, please complete the following or enclose a copy of your Purchase Order:

Purchase Order Number: _____

Billing Address (if different than shipping address):

_____

_____

_____

Instructions for Returning Goods to Sea-Bird

1. **Domestic Shipments (USA) - Ship prepaid** (via UPS, FedEx, DHL, etc.) directly to:
   Sea-Bird Electronics, Inc.
   1808 136th Place NE
   Bellevue, WA 98005, USA
   Telephone: (425) 643-9866 Fax: (425) 643-9954
2. **International Shipments** –
   Option A. Ship via **PREPAID AIRFREIGHT to SEA-TAC International Airport (IATA Code "SEA")**:
   Sea-Bird Electronics, Inc.
   1808 136th Place NE
   Bellevue, WA 98005, USA
   Telephone: (425) 643-9866 Fax: (425) 643-9954 E-mail: seabird@seabird.com

   Notify: MTI Worldwide Logistics for Customs Clearance
   Seattle, WA, USA
   Telephone: (206) 431-4366 Fax: (206) 431-4374 E-mail: bill.keebler@mti-worldwide.com

   E-mail flight details and airway bill number to seabird@seabird.com and bill.keebler@mti-worldwide.com when your shipment is en-route. Include your RMA number in the e-mail.

   Option B. Ship via **EXPRESS COURIER directly to Sea-Bird Electronics**:
   If you choose this option, **we recommend shipping via UPS, FedEx, or DHL**. Their service is door-to-door, including customs clearance. It is not necessary to notify our customs agent, MTI Worldwide, if you ship using a courier service.

   E-mail the airway bill / tracking number to seabird@seabird.com when your shipment is en-route. Include your RMA number in the e-mail.

   For All International Shipments:
   Include a **commercial invoice** showing the description of the instruments, and **Value for Customs purposes only**. Include the following statement:
   "U.S. Goods Returned for Repair/Calibration. Country of Origin: USA. Customs Code: 9801001012."
   Failure to include this statement in your invoice will result in US Customs assessing duties on the shipment, which we will in turn pass on to the customer/shipper.

Note: Due to changes in regulations, if Sea-Bird receives an instrument from outside the U.S. in a crate containing non-approved (i.e., non-heat-treated) wood, we will return the instrument in a new crate that meets the requirements of ISPM 15 (see http://www.seabird.com/customer_support/retgoods.htm for details). We will charge for the replacement crate based on the dimensions of the crate we receive, determined as follows:

1. Multiply the crate length x width x height in centimeters (overall volume in cm^3, not internal volume).
2. Determine the price based on your calculated overall volume and the following chart:

Overall Volume (cm^3)	< 52,000	52,000 to < 65,000	65,000 to < 240,000	> 240,000
Example Instrument	37-SM MicroCAT	SEACAT, no cage	CTD in cage	--
Price (USD)	$45	$70	$125	consult factory

These prices are valid only for crate replacement required in conjunction with return of a customer's instrument after servicing, and only when the instrument was shipped in a crate originally supplied by Sea-Bird.