SBE 16*plus* SEACAT

Conductivity and Temperature Recorder (pressure optional) with RS-232 Interface

User's Manual

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Manual Version #005, 02/15/02
Firmware Version 1.4a and later

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Table of Contents

Section 1: Introduction

This section includes contact information, Quick Start procedure, and photos of a standard SBE 16*plus* shipment.

About this Manual

This manual is to be used with the SBE 16*plus* SEACAT Conductivity and Temperature (pressure optional) Recorder.

It is organized to guide the user from installation through operation and data collection. We've 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 e-mail any comments or suggestions to seabird@seabird.com.

How to Contact Sea-Bird

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Monday-Friday, 0800 to 1700 Pacific Standard Time
(1600 to 0100 Universal Time)
Except from April to October, when we are on 'summer time'
(1500 to 0000 Universal Time)

Quick Start

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

1. Install batteries and test power and communications (see *Section 3: Power and Communications Test*).

2. Deploy the SBE 16*plus* (see *Section 4: Deploying and Operating the SBE 16plus*):
   A. Install new batteries if necessary.
   B. Ensure all data has been uploaded, and then send **INITLOGGING** to make entire memory available for recording if desired.
   C. Set time and then date and establish setup and logging parameters.
   D. Set SBE 16*plus* to start logging now or in the future.
   E. Install dummy plugs and/or cable connectors, and locking sleeves.
   F. Remove protective plugs from anti-foul cups, and verify anti-foul cylinders are installed. Leave protective plugs off for deployment.
   G. Deploy SBE 16*plus*, using customer-supplied hardware.

Unpacking the SBE 16*plus*

Shown below is a typical SBE 16*plus* shipment.

SBE 16*plus* SEACAT
(shown in both plastic and titanium housing)

I/O Cable

9-pin adapter

Cell Filling and
Storage Kit

Cell cleaning solution
(Triton-X)

Spare parts kit

SBE 16*plus* Manual

Software and Software Manuals

Section 2: Description of the SBE 16*plus*

This section describes the functions and features of the SBE 16*plus* SEACAT, including specifications and dimensions.

System Description

The SBE 16*plus* SEACAT is designed to measure conductivity, temperature, and (optional) pressure in marine or fresh-water environments in moored application at depths up to 7000 meters (22,900 feet). The SBE 16*plus* operates as follows:

- The SBE 16*plus* can be programmed to acquire and record in memory time series measurements at sample rates of once every 5 seconds to once every 4 hours, adjustable in one-second increments. Between samples, the SBE 16*plus* powers down, drawing only 30 microamps of current. Simultaneous, real-time monitoring is possible using the SBE 16*plus'* three-wire RS-232C interface.
- A surface controller can request the last sample that was taken or ask the SBE 16*plus* to take a new sample. Data is transmitted over the RS-232 interface.

Self-powered and self-contained, the SBE 16*plus* features the proven Sea-Bird conductivity and temperature sensors. Nine D-size alkaline batteries provide power for approximately 400,000 samples (with no pressure sensor, pump, or auxiliary sensors). The 8 Mbyte FLASH RAM memory records 1.5 years of conductivity, temperature, and date/time data while sampling every 60 seconds (other configurations/setups vary). Setup, diagnostics, and data extraction are performed without opening the housing. The SBE 16*plus* can power external sensors and acquire their outputs.

A standard SBE 16*plus* is supplied with:

- Plastic housing for depths to 600 meters (1950 feet)
- Type XSG Bulkhead connectors:
  - one 4-pin I/O connector, and
  - two 6-pin connectors, for two differential auxiliary A/D inputs each
- 8 Mbyte FLASH RAM memory
- 9 D-size alkaline batteries
- Anti-foul attachments and expendable anti-foul devices. These are attached to each end of the conductivity cell, so that any water that enters the cell is treated. The anti-foulant is effective for approximately 2 years.

SBE 16*plus* options include:

- Titanium housing for use to 7000 meters (22,900 feet)
- Pressure sensor -
  - Strain gauge pressure sensor, or
  - Quartz pressure sensor with or without temperature compensation
- Optional type XSG bulkhead connectors:
  - 2-pin pump connector, and
  - 4-pin RS-232 connector (for SBE 38 secondary temperature sensor or up to two Pro-Oceanus Gas Tension Devices) **or**
    3-pin PAR connector
- Pump - SBE 5M or 5T submersible pump for use with pumped sensors
- Sensors for dissolved oxygen, pH, fluorescence, light (PAR), light transmission, turbidity, and gas tension
- Wet-pluggable connectors in place of type XSG connectors

- RS-485 interface in place of RS-232
- Inductive modem interface in place of RS-232 - The inductive modem uses a mooring cable as the communication link, permitting the SBE 16*plus* to be easily positioned at any depth without the use of cable connectors. Each inductive modem instrument has a programmable address, allowing up to 100 SBE 16*plus* SEACATs (or other sensors compatible with the Sea-Bird inductive modem) to be attached to a single mooring cable.
- Lithium battery pack

User-selectable output format is raw data or engineering units, in either hexadecimal or decimal form. Additionally, the SBE 16*plus* can be *factory-configured* to emulate the older SEACAT data output format, **providing compatibility with existing customer SEACAT data processing software**.

The SBE 16*plus* is supplied with a powerful Win 95/98/NT software package, SEASOFT-Win32, that includes:

- **SEATERM** – terminal program for easy communication and data retrieval.
- **SEASAVE** – program for acquiring, converting, and displaying real-time or archived raw data.
- **SBE Data Processing** - program for calculation and plotting of conductivity, temperature, pressure, auxiliary sensor data, and derived variables such as salinity and sound velocity. SBE Data Processing includes the functions in most of the post-processing modules in SEASOFT-DOS.

Notes:

- Help files provide detailed information on the use of SEATERM, SEASAVE, and SBE Data Processing.
- Separate software manuals contain detailed information on the setup and use of SEASAVE and SBE Data Processing.
- **Sea-Bird also supplies a DOS software package, SEASOFT-DOS. However, SEASOFT-DOS cannot process SBE 16*plus* data because of data output format incompatibility.**

SBE 16*plus* SEACAT Specifications

	Temperature (°C)	Conductivity (S/m)	Pressure (optional)
Measurement Range	-5 to +35	0 to 9	0 to full scale range: *Strain gauge sensor:* 20/100/350/1000/3500/7000 meters *Quartz sensor:* 60/130/200/270/680/1400/2000/ 4200/7000 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 (per month)	0.0002	0.0003	*Strain gauge sensor:* 0.004% of full scale range *Quartz sensor:* 0.002% of full scale range
Resolution	0.0001	0.00005 (most oceanic waters; resolves 0.4 ppm in salinity) 0.00007 (high salinity waters; resolves 0.4 ppm in salinity) 0.00001 (fresh waters; resolves 0.1 ppm in salinity)	*Strain gauge sensor:* 0.002% of full scale range *Quartz sensor:* Depends on sample integration time; consult factory *
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 range 1.4 to 6 S/m, plus zero conductivity (air)	Ambient pressure to full scale range in 5 steps

Memory	8 Mbyte non-volatile FLASH memory
Data Storage	**Recorded Parameter** — **Bytes/sample** temperature + conductivity — 6 (3 each) strain gauge pressure — 5 Quartz pressure without temperature compensation — 3 Quartz pressure with temperature compensation — 5 each external voltage — 2 SBE 38 secondary temperature — 3 each Pro-Oceanus GTD — 4 (pressure) + 3 (temperature) date and time — 4
Real-Time Clock	32,768 Hz TCXO accurate to ±1 minute/year.
Internal Batteries	Nine alkaline D-cells record 400,000 samples of C and T. Optional lithium batteries.
External Power Supply	9 - 28 VDC
Power Requirements	*Sampling*: no pressure sensor 50 mA; with pressure sensor 65 mA *SBE 5M pump* 95 mA; *Quiescent* 30 µA Configured with no pressure and no delays, actual sampling time 2.2 seconds/sample (no pump) or 2.7 seconds/sample (with pump). Add 0.3 seconds with pressure. Power Endurance [1]: CT only: 400,000 samples CTD only: 270,000 samples CTD & 5M pump [2]: 200,000 samples [1] With Duracell MN 1300 cells. Quiescent current (30 µA) accounts for only 2% of battery capacity/year. [2] Pump running 0.5 second to flush cell only.
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	600 meter (1950 ft): acetal copolymer (plastic); 7000 meter (22,900 ft): 3AL-2.5V titanium
Weight	With plastic housing: 7.3 kg (16 lbs); With titanium housing: 13.7 kg (30 lbs)

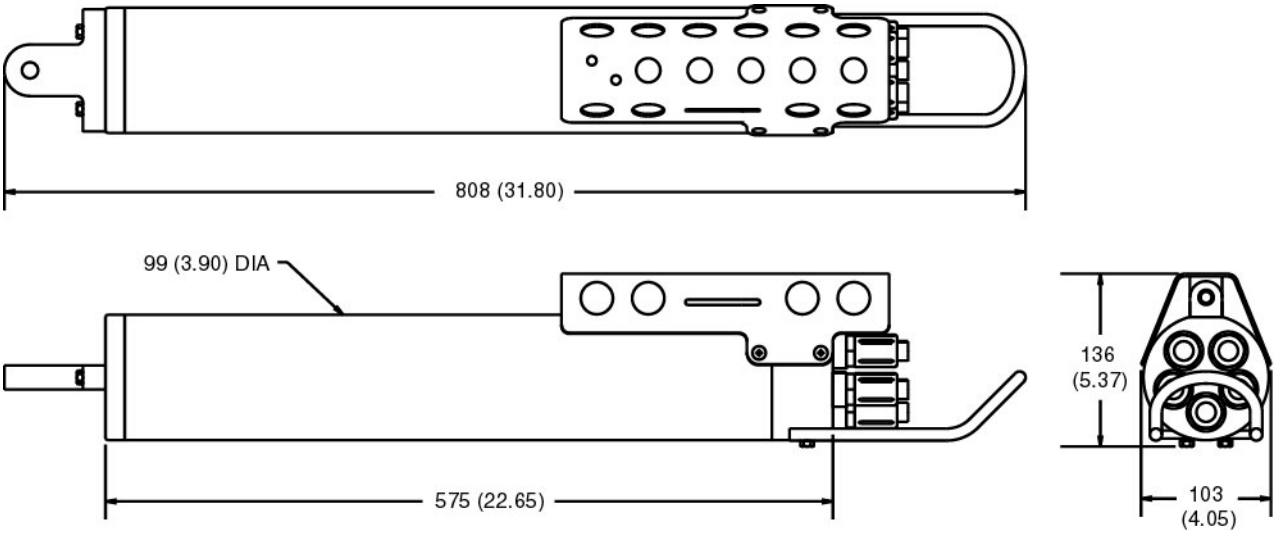
*Note on Quartz Pressure Sensor Resolution:
For each sample, the SBE 16*plus* averages 1 (factory default) or an even number of user-programmable frequency acquisition cycles (**NCYCLES**), each 0.25 seconds long. Resolution (T, C, & P) depends on **NCYCLES**. If **NCYCLES** = 4, the 16*plus* averages 4 samples in 1 second. Half of each acquisition cycle is used to integrate the Quartz pressure sensor frequency (other half for conductivity). Consequently, if **NCYCLES** = 8, the Quartz frequency is a 1 second average (Integration Period = 0.25 sec * **NCYCLES** / 2).

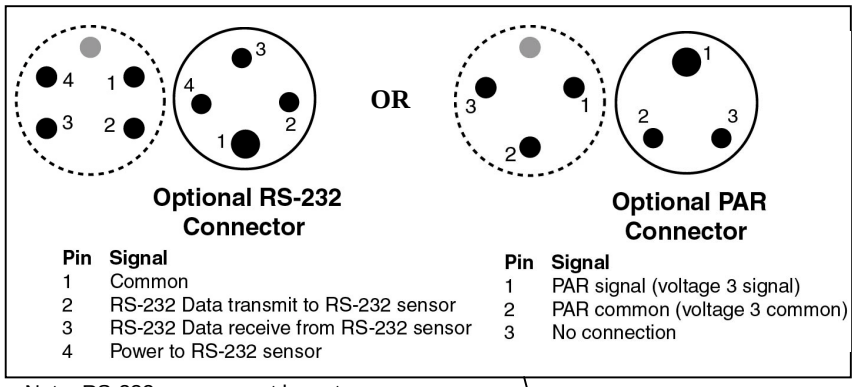
Quartz resolution (Hz) = Integration Period * Quartz Frequency / 1,228,800

To convert from frequency to pressure, see the formula on your SBE 16*plus* calibration sheet. The sensor's sensitivity (in Hz/dbar) changes by approximately 20% over the frequency span (roughly 4000 Hz), which in turn is dependent on the sensor range. This makes a perfectly accurate determination of resolution tedious. A conservative approximation for any Quartz sensor in a 16*plus* is:
Resolution is better than 0.001% when **NCYCLES** = 4 (resolution increases as **NCYCLES** increases, but the relationship is not linear).

SBE 16*plus* SEACAT Dimensions and End Cap Connectors

Dimensions in millimeters (inches)





Pin	Signal
1	Common
2	RS-232 Data transmit to RS-232 sensor
3	RS-232 Data receive from RS-232 sensor
4	Power to RS-232 sensor

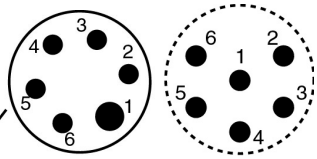
Pin	Signal
1	PAR signal (voltage 3 signal)
2	PAR common (voltage 3 common)
3	No connection

Note: RS-232 sensor must be set to same baud rate as 16*plus*.

= standard XSG connector

= optional MCBH connector

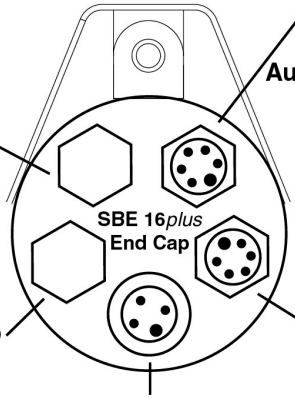
Conductivity cell and guard shown for reference

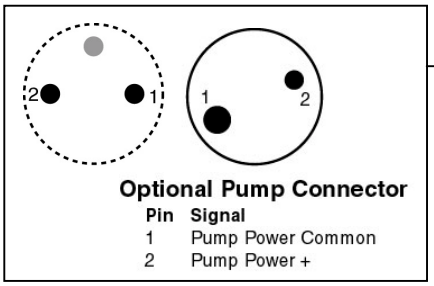


Auxiliary Differential Input 0,1

Pin	Signal
1	Common
2	Voltage 0 Signal
3	Voltage 0 Common
4	Voltage 1 Signal
5	Voltage 1 Common
6	Auxiliary Power Out

Optional Auxiliary Input Connector

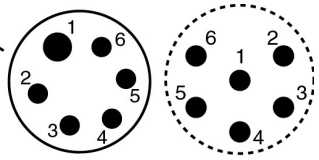




Optional Pump Connector

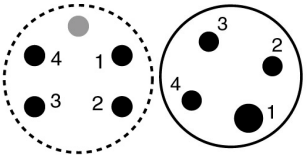
Pin	Signal
1	Pump Power Common
2	Pump Power +

Optional Pump Connector



Auxiliary Differential Input 2,3

Pin	Signal
1	Common
2	Voltage 2 Signal
3	Voltage 2 Common
4	Voltage 3 Signal *
5	Voltage 3 Common *
6	Auxiliary Power Out



Data I/O Connector

Pin	Signal
1	Common
2	Data receive
3	Data transmit
4	Auxiliary power in

* Not connected if log amp installed for PAR sensor

Data I/O

The SBE 16*plus* receives set-up instructions and outputs diagnostic information or previously recorded data via a three-wire RS-232C link, and is factory-configured for 9600 baud, 8 data bits, 1 stop bit, and no parity. SBE 16*plus* RS-232 levels are directly compatible with standard serial interface cards (IBM Asynchronous Communications Adapter or equal). The communications baud rate can be changed using the **BAUD=** command (see *Section 4:Deploying and Operating the SBE 16plus* for details).

Batteries

The SBE 16*plus* uses nine D-cell alkaline batteries or lithium batteries. If necessary, 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. An auxiliary power source (9 - 28 volts DC) may be connected to the I/O bulkhead connector on the sensor end cap to permit testing and data retrieval without affecting battery capacity. The main batteries may be replaced without affecting either the real-time clock or memory.

Data Storage

The SBE 16*plus* has an 8 Mbyte memory. Shown below are examples of available data storage for several configurations. (See *SBE 16plus SEACAT Specifications* in this section for storage space required for each parameter.)

Example 1: 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 ≈ 8,000,000 / (6 + 5 + 4) ≈ 533,000 samples

Example 2: Quartz pressure with temperature compensation, 4 external voltages, and SBE 38 secondary temperature sensor
T & C = 6 bytes/sample
Quartz P with T compensation = 5 bytes/sample
External voltages = 2 bytes/sample x 4 voltages = 8 bytes/sample
SBE 38 = 3 bytes/sample
Date/Time = 4 bytes/sample
Storage space ≈ 8,000,000 /(6 + 5 + 8 + 3 + 4) ≈ 307,000 samples

Power Endurance

Shown below is an example of a power endurance calculation.
(See *SBE 16plus SEACAT Specifications* in this section for power requirements.)

9 alkaline batteries provide nominal 14 amp-hours.

Example: no pressure sensor, pump, or auxiliary sensors
Operating current without pressure sensor = 50 mA
Nominal sampling time = 2.2 seconds
Amp-hours/sample = $0.050 \times 2.2 / 3600 = 3.06 \times 10^{-5}$
Maximum samples ≈ $14 / 3.06 \times 10^{-5} \approx 450{,}000$ samples;
Say 400,000 samples

Configuration Options

The SBE 16*plus* is available with an optional, externally mounted, submersible pump. The pump is required for an SBE 16*plus* 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-foul protection - Water does not freely flow through the conductivity cell between samples, allowing the anti-foul concentration inside the cell to build up.

Two pump models are available:

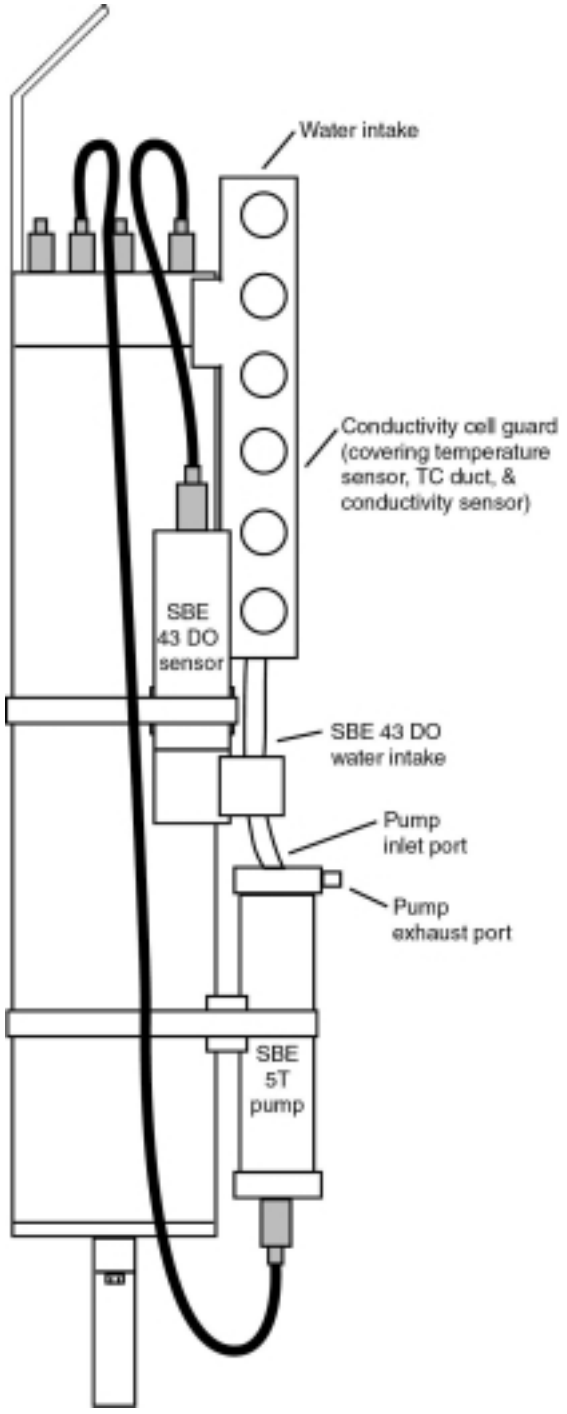
- SBE 5M miniature pump - for pumped conductivity

- SBE 5T pump - a more powerful pump for use if the SBE 16*plus* is configured with a dissolved oxygen sensor and/or pumped fluorometer

In either case, the pump is powered via a cable connected to the optional 2-pin Pump bulkhead connector on the sensor end cap.

The SBE 16*plus* can be configured with a wide range of auxiliary sensors. Two 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, an optional connector can be provided for interfacing with an RS-232 sensor, such as an SBE 38 secondary temperature sensor or Pro-Oceanus Gas Tension Devices (up to two GTDs can be integrated with the 16*plus*), or an optional connector can be provided for interfacing with a PAR sensor.

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



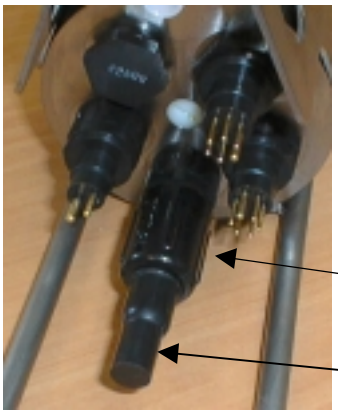
Section 3:
Power and Communications Test

This section describes the pre-check procedure for preparing the SBE 16*plus* for deployment. The power and communications test will verify that the system works, prior to deployment.

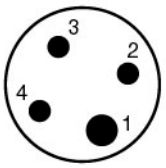
Test Setup

Note:
It is possible to use the SBE 16*plus* without SEATERM by sending direct commands from a dumb terminal or terminal emulator, such as Windows HyperTerminal.

1. If not already installed, install SEATERM and other Sea-Bird software programs on your computer using the supplied software CD:
   A. Insert the CD in your CD drive.
   B. Double click on **Seasoft-Win32.exe**.
   C. Follow the dialog box directions to install the software.
   The default location for the software is c:/Program Files/Sea-Bird. Within that folder is a sub-directory for each program.



2. Remove the dummy plug and install the I/O cable:
   A. By hand, unscrew the locking sleeve from the SBE 16*plus*' I/O (4-pin) connector. If you must use a wrench or pliers, be careful not to loosen the I/O connector instead of the locking sleeve.
   B. Remove the dummy plug from the SBE 16*plus*' I/O connector by pulling the plug firmly away from the connector.
   C. Install the Sea-Bird I/O cable connector, aligning the raised bump on the side of the connector with the large pin (pin 1 - ground) on the SBE 16*plus*.



Data I/O Connector

Pin	Signal
1	Common
2	Data receive
3	Data transmit
4	Auxiliary power in

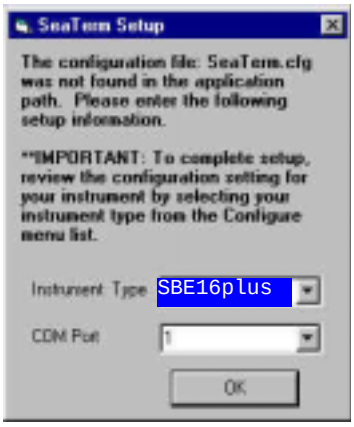
3. Connect the I/O cable connector to your computer's serial port.
   A 25-to-9 pin adapter is supplied for use if your computer has a 9-pin serial port.

Test

Note:
See SEATERM's help files for detailed information on the use of the program.

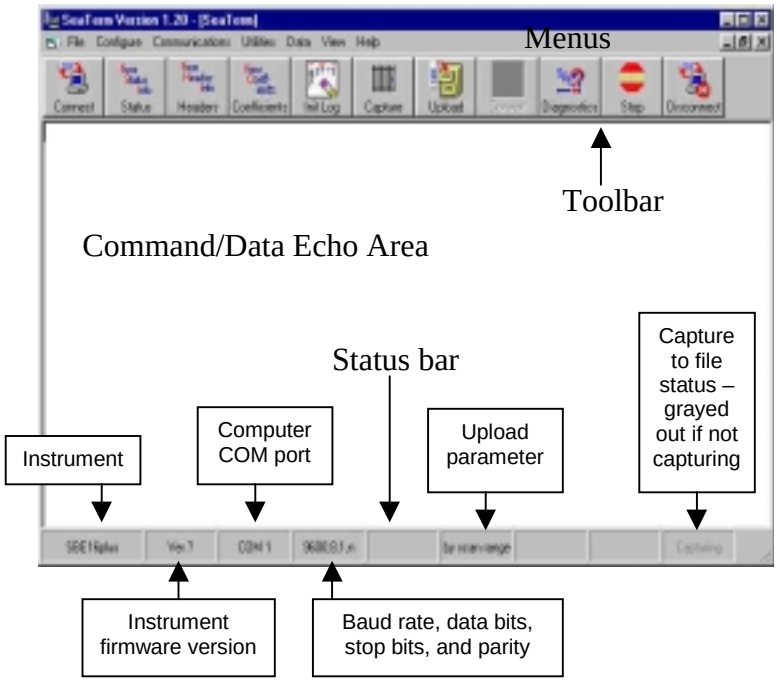
Proceed as follows:

1. Double click on SeaTerm.exe. If this is the first time the program is used, the setup dialog box appears:



   Select the instrument type (*SBE 16plus*) and the computer COM port for communication with the SBE 16*plus*. Click OK.

2. The main screen looks like this:



   - Menus – Contains tasks and frequently executed instrument commands.
   - Toolbar – Contains buttons for frequently executed tasks and instrument commands. All tasks and commands accessed through the Toolbar are also available in the Menus. To display or hide the Toolbar, select View Toolbar in the View menu. Grayed out Toolbar buttons are not applicable.
   - Command/Data Echo Area – Echoes a command executed using a Menu or Toolbar button, as well as the instrument's response. Additionally, a command can be manually typed in this area, from the available commands for the instrument. Note that the instrument must be *awake* for it to respond to a command (use the Connect button on the Toolbar to wake up the instrument).
   - Status bar – Provides status information. To display or hide the Status bar, select View Status bar in the View menu.

Note:
There is at least one way, and as many as three ways, to enter a command:
- Manually type a command in Command/Data Echo Area
- Use a menu to automatically generate a command
- Use a Toolbar button to automatically generate a command

Note:
Once the system is configured and connected (Steps 3 and 4 below), to update the Status bar:
- on the Toolbar, click Status; or
- from the Utilities menu, select Instrument Status.

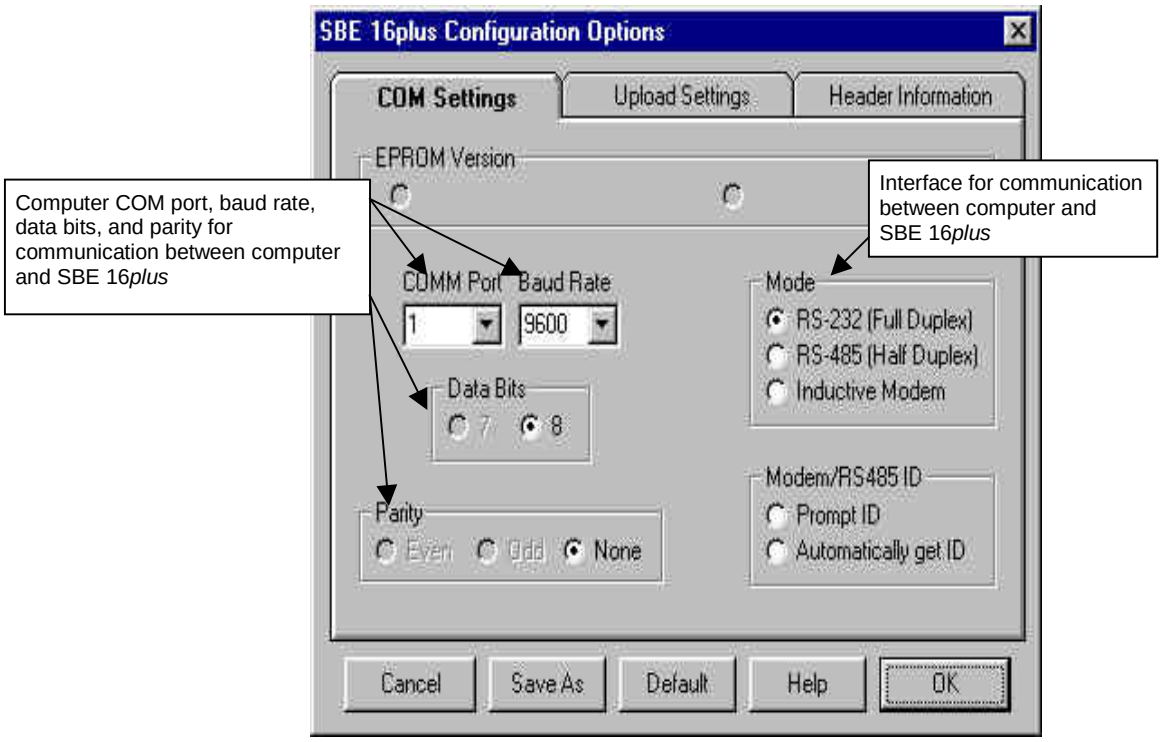
SEATERM sends the status command, which displays in the Command/Data Echo Area, and updates the Status bar.

Following are the Toolbar buttons applicable to the SBE 16*plus*:

Toolbar Buttons	Description	Equivalent Command*
Connect	Re-establish communications with SBE 16*plus*. Computer responds with **S>** prompt. SBE 16*plus goes to sleep* after 2 minutes without communication from computer have elapsed.	(press Enter key)
Status	Display instrument setup and status (logging, samples in memory, etc.).	**DS**
Headers	View data headers (header number, date and time, first and last sample, and sample interval). A new header is generated at the start of logging and every subsequent 1000 scans.	**DH**
Coefficients	Display calibration coefficients.	**DCAL**
Init Log	Reset data pointers and header numbers. This should be performed **after existing data has been uploaded from SBE 16*plus*** and prior to recording new data.	**INITLOGGING**
Capture	Capture instrument responses on screen to file; may be useful for diagnostics. File has .cap extension. Press Capture again to turn off capture. Capture status displays in Status bar.	**—**
Upload	Upload data stored in memory, in format Sea-Bird's data processing software can use (raw hex). Uploaded data has .hex extension. Before using Upload: • Configure upload and header parameters in Configure menu • **Stop logging** by using **STOP** button or sending **STOP** command	**DDb,e** (use Upload button if you will be processing data with SBE Data Processing)
Diagnostics	Perform one or more diagnostic tests on SBE 16*plus*. Diagnostic test(s) accessed in this manner are non-destructive – they do not write over any existing instrument settings.	**DS, DCAL, TS, and TSR**
Stop	Interrupt and end current activity, such as logging, uploading, or diagnostic test.	(press Esc key or Ctrl C)
Disconnect	Free computer COM port used to communicate with SBE 16*plus*. COM port can then be used by another program.	**—**

*See *Command Descriptions* in *Section 4: Deploying and Operating the SBE 16plus*.

3. In the Configure menu, select *SBE 16plus*. The dialog box looks like this:



Make the selections in the Configuration Options dialog box:

- **COMM Port**: COM 1 through COM 10, as applicable
- **Baud Rate**: 9600 (documented on instrument Configuration Sheet)
- **Data Bits**: 8
- **Parity**: None
- **Mode**: RS-232 (Full Duplex)

Click OK to overwrite an existing COM/Upload/Header Settings (.ini) file, or click Save As to save the settings as a new filename.

4. Click the Connect button on the Toolbar. The display looks like this:

   S>

   This shows that correct communications between the computer and the SBE 16*plus* has been established.
   If the system does not respond with the **S>** prompt:

   - Click the Connect button again.
   - Verify the correct instrument was selected in the Configure menu and the settings were entered correctly in the Configuration Options dialog box. Note that the baud rate is documented on the instrument Configuration Sheet.
   - Check cabling between the computer and SBE 16*plus*.

Note:
The SBE 16*plus* automatically enters quiescent (sleep) state after 2 minutes without receiving a command. This timeout algorithm is designed to conserve battery energy if the user does not send the **QS** command to put the SBE 16*plus* to sleep.
If the system does not appear to respond, click Connect on the Toolbar to reestablish communications.

5. Display SBE 16*plus* status information by clicking the Status button on the Toolbar. The display looks like this:

```
SeacatPlus V 1.3  SERIAL NO. 4000    25 Jun 2001  14:02:13
vbatt = 9.6, vlith = 0.0, ioper = 61.2 ma, ipump = 25.5 ma,
iext01 = 76.2 ma, iext23 =  73.6 ma,
status = not logging
sample interval = 15 seconds, number of measurements per
sample = 1
samples = 0, free = 364722
mode = moored, run pump for 0.5 sec, delay before sampling =
0.0 seconds
transmit real-time = yes
battery type = ALKALINE, battery cutoff = 7.5 volts
pressure sensor = strain gauge, range = 1000.0
SBE 38=no, Gas Tension Device = no
Ext Volt 0=no, Ext Volt 1=no, Ext Volt 2=no, Ext Volt 3=no
output format = converted decimal
output salinity = no, output sound velocity = no
```

6. Command the SBE 16*plus* to take a sample by typing **TS** and pressing the Enter key. The display looks like this (if converted decimal output format, no output salinity or sound velocity, and no auxiliary sensors):

```
23.7658,0.00019, 0.062, 07 Dec 2000, 08:49:10
```

   where 23.7658 = temperature in degrees Celsius
   0.00019 = conductivity in S/m
   0.062 = pressure in dbars
   07 Dec 2000 = date
   08:49:10 = time

   These numbers should be reasonable; i.e., room temperature, zero conductivity, barometric pressure (gauge pressure), current date and time (Pacific Daylight or Standard Time).

7. Command the SBE 16*plus* to go to sleep (quiescent state) by typing **QS** and pressing the Enter key.

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

Section 4: Deploying and Operating the SBE 16*plus*

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

This section includes discussions of:

- Logging operation, including an example set of commands
- Pump operation
- Timeout description
- Command descriptions
- Data output formats
- Set-up for deployment
- Deployment
- Recovery - physical handling and uploading data

Logging Operation

The SBE 16*plus* samples data at pre-programmed intervals and stores the data in its FLASH memory. Logging is started with **STARTNOW** or **STARTLATER**, and is stopped with **STOP**.

An example of the setup for the logging operation follows. Note that the SBE 16*plus'* response to each command is not shown in the example. Review the logging operation example and the commands described in *Command Descriptions* before setting up your system.

Notes:
1. The SBE 16*plus* automatically enters quiescent state after 2 minutes without receiving a command.
2. Set **OUTPUTFORMAT=0** if you will be using Sea-Bird's real-time data acquisition software (SEASAVE).

Example: Logging operation of SBE 16plus

Wake up SBE 16*plus*. Initialize logging to overwrite previous data in memory. Set up with strain gauge pressure sensor and 1 voltage sensor, take a sample every 120 seconds, take and average 4 measurements for each sample, do not transmit real-time data, and output data in raw hexadecimal format. Set up pump to run for 0.5 second before each sample. Set up to start logging on April 15, 2001 at 11 am. Send command to start logging at designated date and time. After all parameters are entered, verify setup with status (**DS**) command. Send power-off command.

(click Connect on Toolbar to wake up)
S>INITLOGGING
S>PTYPE=1
S>VOLT0=Y
S>SAMPLEINTERVAL=120
S>NCYCLES=4
S>MOOREDTXREALTIME=N
S>OUTPUTFORMAT=0
S>MOOREDPUMPMODE=1
S>STARTMMDDYY=041501
S>STARTHHMMSS=110000
S>STARTLATER
S>DS (to verify setup)
S>QS

Deploy SBE 16*plus*. Logging will start automatically at the designated date and time.

Upon recovering instrument, stop logging. Upload data in memory, in format Sea-Bird's post-processing software can use. Send power-of command.

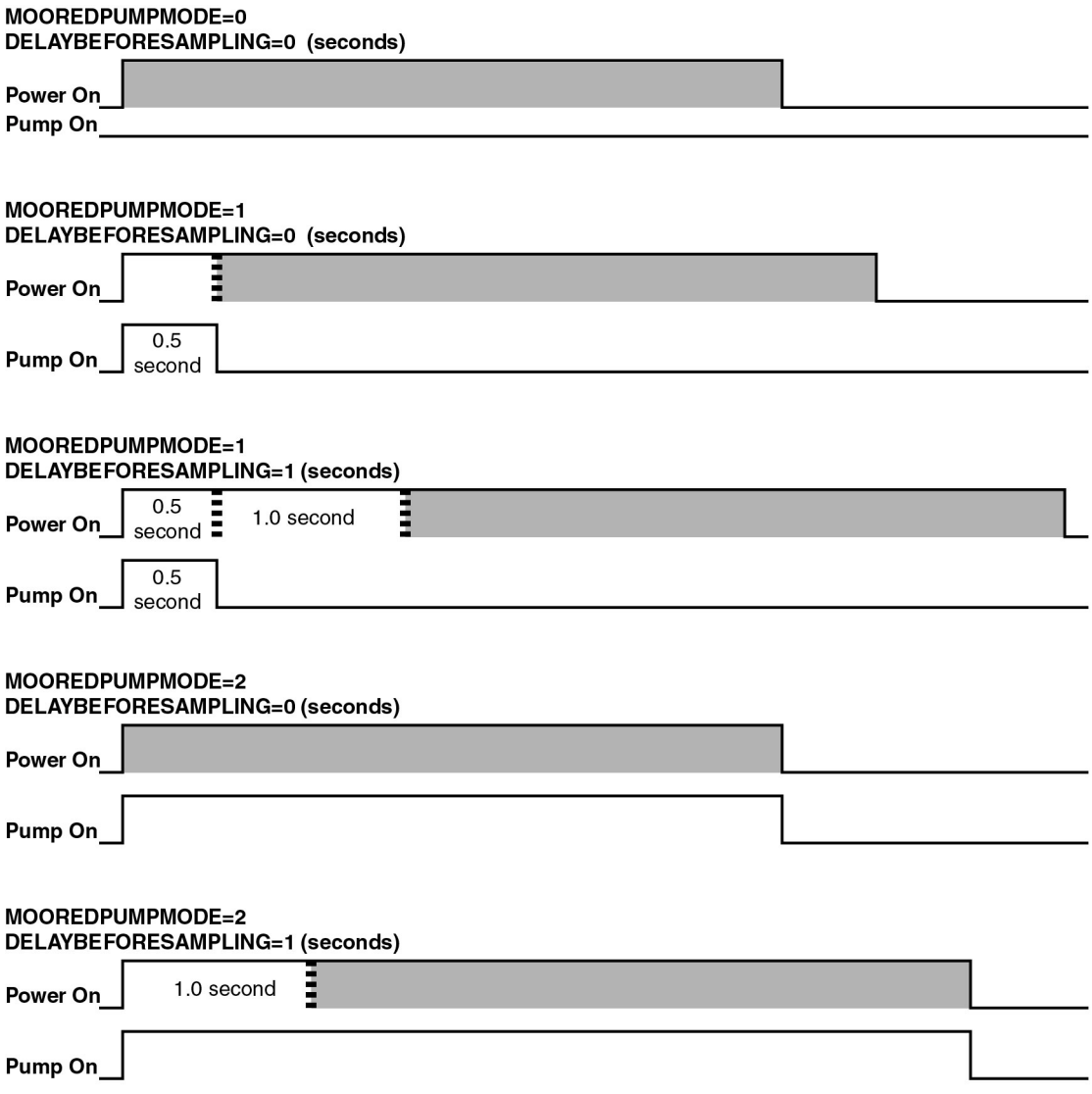
(click Connect on Toolbar to wake up)
S>STOP
(click Upload on Toolbar – program leads you through screens to define data to be uploaded and where to store it)
S>QS

Pump Operation

Note:
When using an oxygen sensor with the SBE 16*plus*, set **MOOREDPUMPMODE=2** and set **DELAYBEFORESAMPLING** as follows:
- **SBE 43** oxygen sensor - 15 seconds, to get fresh water into the plenum for the sample
- **Beckman- or YSI-type** oxygen sensor - 120 to 180 seconds, to allow instrument to polarize

Pump operation is governed by two user-programmable parameters:
- **MOOREDPUMPMODE=0**, **1**, or **2**
  The SBE 16*plus* can be set up to operate with no pump (0), with a pump running for 0.5 second before each sample (1), or the pump running during each sample (2).
- **DELAYBEFORESAMPLING=**
  The SBE 16*plus* can be set up to delay sampling after turning on external voltage sensors. Some instruments, such as a Sea Tech fluorometer or a Beckman- or YSI-type oxygen sensor, require time to stabilize after power is applied, to provide good quality data.

MOOREDPUMPMODE and **DELAYBEFORESAMPLING** interact in the operation of the pump, as shown in the diagram below.



= sampling time (2.7 - 3.0 seconds)

Note:
Sampling time includes time for the instrument to warm up as well as time to actually measure the parameters.

Timeout Description

The SBE 16*plus* has a timeout algorithm. If the SBE 16*plus* does not receive a command or sample data for two minutes, it powers down its main digital circuits. This places the SBE 16*plus* in quiescent state, drawing minimal current. **To re-establish control (wake up), press Connect on the Toolbar or the Enter key.** The system responds with the **S>** prompt.

Command Descriptions

Notes:
- Sea-Bird provides a custom EPROM to accommodate customers with an older SBE 16 (not *plus*) who need to replace the electronics but want to maintain the original instrument command set and output format. Instruments with this custom EPROM operate in Compatible State; see *Appendix IV: Compatible State* for command details.
- The firmware for the SBE 16*plus* is identical to the SBE 19*plus* Profiler, allowing the SBE 16*plus* to operate like a profiling instrument if desired. However, since the SBE 16*plus* is intended for use as a moored instrument, commands related to profiling are not documented in this manual (see the SBE 19*plus* manual on our website - www.seabird.com - for profiling details).

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

When entering commands:

- Input commands to the SBE 16*plus* in upper or lower case letters and register commands by pressing the Enter key.
- The SBE 16*plus* sends ***? CMD*** if an invalid command is entered.
- If the system does not return an **S>** prompt after executing a command, press the Enter key to get the **S>** prompt.
- If a new command is not received within two minutes after the completion of a command, the SBE 16*plus* returns to the quiescent (sleep) state.
- If in quiescent state, re-establish communications by pressing Connect on the Toolbar or the Enter key to get an **S>** prompt.
- If the SBE 16*plus* is transmitting data and you want to stop it, press the Esc key or Stop on the Toolbar (or type ^C). Press the Enter key to get the **S>** prompt.
- The SBE 16*plus* 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 SBE 16*plus* 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, commands that change the scan length (**PTYPE=**, **VOLT0=**, **VOLT1=**, **VOLT2=**, **VOLT3=**, **SBE38=**, **GTD=**, and **DUALGTD=**) prompt the user for verification before executing, to prevent accidental overwriting of existing data.

Entries made with the commands are permanently stored in the SBE 16*plus* 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* for details). Upon reassembly, reset the date and time (**MMDDYY=** and **HHMMSS=**) and initialize logging (**INITLOGGING**).

Note:
If the battery voltage is below the battery cut-off voltage (7.5 volts), the following displays in response to the status command:
WARNING: LOW BATTERY VOLTAGE!! Replace the batteries before continuing.

Note:
If the SBE 16*plus* is set up with dual GTDs, the status command shows:
Dual Gas Tension Device = Yes

Status Command	
DS	Display operating status and setup parameters. Equivalent to Status button on Toolbar. List below includes, where applicable, command used to modify parameter. • Firmware version, serial number, date and time [**MMDDYY=** and **HHMMSS=**] • Voltages and currents (main and lithium battery voltages, operating and pump current, and external voltage currents) • Logging status (not logging, logging, waiting to start at . . ., or unknown status) • Sample interval [**SAMPLEINTERVAL=**] and number of measurements to take and average per sample [**NCYCLES=**] • Number of samples and available sample space in memory • Moored mode, pump turn-on parameter [**MOOREDPUMPMODE=**], and turn-on delay [**DELAYBEFORESAMPLING=**] • Transmit data real-time? [**MOOREDTXREALTIME=**] • Battery type [**BATTERYTYPE=**] and battery cut-off voltage • Pressure sensor type [**PTYPE=**] and range [**PRANGE=**] • Sample SBE 38 secondary temperature sensor [**SBE38=**]? Sample Gas Tension Device or Dual Gas Tension Devices [**GTD=** or **DUALGTD=**]? • Sample external voltages 0, 1, 2, and 3? [**VOLT0=** through **VOLT3=** commands] • Output format [**OUTPUTFORMAT=**] • Output salinity [**OUTPUTSAL=**] and sound velocity [**OUTPUTSV=**]? (only if output format = converted decimal)

Example: Status (DS) command

```
S>DS
SeacatPlus V 1.3  SERIAL NO. 4000    25 Jun 2001  12:48:48
vbatt = 9.4, vlith = 0.0, ioper = 61.3 ma, ipump = 26.8 ma,
iext01 = 76.2 ma, iext23 =  73.6 ma,
status = not logging
sample interval = 15 seconds, number of measurements per sample = 1
samples = 0, free = 364722
mode = moored, run pump for 0.5 sec, delay before sampling = 0.0 seconds
transmit real-time = yes
battery type = ALKALINE, battery cutoff =  7.5 volts
pressure sensor = strain gauge, range = 2000.0
SBE 38 = no, Gas Tension Device = no
Ext Volt 0=yes, Ext Volt 1=yes, Ext Volt 2=yes, Ext Volt 3=yes
output format = converted decimal
output salinity = no, output sound velocity = no
```

Notes:
- **DDMMYY=** and **MMDDYY=** commands are equivalent. Either can be used to set the date.
- It is always necessary to set both date and then time. **If a new date is entered but not a new time, the new date will not be saved.**

Setup Commands

MMDDYY=mmddyy	Set real-time clock month, day, and year. This command must be followed by **HHMMSS=** command to set time.
DDMMYY=ddmmyy	Set real-time clock day, month, and year. This command must be followed by **HHMMSS=** command to set time.
HHMMSS=hhmmss	Set real-time clock hour, minute, and second.

Example: Set current date and time to 05 October 2000 12:00:00.

S>MMDDYY=100500
S>HHMMSS=120000

or

S>DDMMYY=051000
S>HHMMSS=120000

Notes:
- The SBE 16*plus'* baud rate (set with **BAUD=**) must be the same as SEATERM's baud rate (set in the Configure menu).
- An RS-232 sensor (SBE 38 or GTD) integrated with the SBE 16*plus* must use the same baud rate as used by the 16*plus*. See the RS-232 sensor's manual for details on how to set its baud rate.

BAUD=x	**x=** baud rate (600, 1200, 2400, 4800, 9600, 19200, or 38400). Default 9600.
ECHO=x	**x=** Y: Echo characters received from computer (default) - computer monitor will show entered commands as you type. **x=**N: Do not echo characters.
MOOREDTXREALTIME=x	**x**= Y: Output real-time data. **x**= N: Do not output real-time data.
BATTERYTYPE=x	**x**= 0: Alkaline batteries (or optional lithium batteries). **x**= 1: Ni-Cad batteries.

Setup Commands (continued)

REFPRESS=x

x= reference pressure (gauge) in decibars to use if SBE 16*plus* does not include a pressure sensor. SBE 16*plus* uses reference pressure in conductivity and salinity calculation. Entry ignored if SBE 16*plus* includes pressure sensor.

Notes:
- The SBE 16*plus* configuration (.con) file must match this selection of pressure sensor, external voltages, and secondary temperature sensor when viewing real-time data in SEASAVE or processing uploaded data. View and edit the .con file in SEASAVE (Windows) or SBE Data Processing. Note that these parameters are factory-set to match the ordered instrument configuration.
- The SBE 16*plus* requires verification when these commands **(PTYPE=** through **DUALGTD=**) are sent. Instrument responds:
  this command will change the scan length and initialize logging. Proceed Y/N?
  Press the Y and the Enter key to proceed. The SBE 16*plus* responds:
  Scan length has changed, initializing logging

PTYPE=x

Pressure sensor type.

x= 0: No pressure sensor.

x= 1: Strain gauge.

x= 2: Quartz without temperature compensation.

x= 3: Quartz with temperature compensation.

VOLT0=x

x= Y: Sample external voltage 0.

x= N: Do not sample external voltage 0.

VOLT1=x

x= Y: Sample external voltage 1.

x= N: Do not sample external voltage 1.

VOLT2=x

x= Y: Sample external voltage 2.

x= N: Do not sample external voltage 2.

VOLT3=x

x= Y: Sample external voltage 3.

x= N: Do not sample external voltage 3.

SBE38=x

x= Y: Sample SBE 38 secondary temperature sensor.

x= N: Do not sample SBE 38.

Note:
The baud rate for an RS-232 auxiliary sensor (SBE 38 or GTD) must be the same as the SBE 16*plus* baud rate.

GTD=x

x= Y: Sample Pro-Oceanus Gas Tension Device (GTD).

x= N: Do not sample GTD.

DUALGTD=x

x= Y: Sample dual (2) Pro-Oceanus Gas Tension Devices (GTD).
Note: If **DUALGTD=Y**, setting for **GTD=** has no effect.

x= N: Do not sample dual GTDs.

MOOREDPUMPMODE=x

x= 0: No pump.

x= 1: Run pump for 0.5 seconds before each sample.

x= 2: Run pump during each sample.

Note:
See *Pump Operation* for a detailed explanation.

DELAYBEFORESAMPLING=x

x= time (seconds) to wait after switching on external voltage before sampling (0-32,000 seconds). Default 0 seconds. Typical value if a Sea Tech Fluorometer is installed is 15 seconds.

Note:
Output format does not affect how data is stored in FLASH memory. Sea-Bird's real-time data acquisition software (SEASAVE) and data processing software (SBE DATA PROCESSING) require data to be in raw hexadecimal (**OUTPUTFORMAT=0**).

Typical use of the output format command is:
- Before beginning logging:
  - Set the output format to raw hex **if using Sea-Bird's real-time data acquisition software (SEASAVE) to view real-time data**.
  - Set the output format to converted decimal for ease in viewing real-time data **if not using SEASAVE**.
- After stopping logging, use SEATERM's Upload button to upload the data from the FLASH memory. The Upload button automatically resets the format to raw hex (**OUTPUTFORMAT=0**), so the data is compatible with SBE Data Processing.

Setup Commands (continued)

OUTPUTFORMAT=x	**x**= 0: Output raw frequencies and voltages in Hexadecimal form. Must use this format for uploading data that will be processed with Sea-Bird software. When using SEATERM's Upload button, SEATERM sends **OUTPUTFORMAT=0** command. This causes SBE 16*plus* to upload data in memory in raw hex, regardless of user-programmed **OUTPUTFORMAT**, providing data in format that Sea-Bird's data processing software can use. **x**= 1: Output converted (engineering units) data in Hexadecimal form. **x**= 2: Output raw frequencies and voltages in decimal form. **x**= 3: Output converted (engineering units) data in decimal form. Must use this format to output salinity or sound velocity.
OUTPUTSAL=x	**x**= Y: Calculate and output salinity (psu). Only applies if **OUTPUTFORMAT=3**. **x**= N: Do not calculate and output salinity.
OUTPUTSV=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 **OUTPUTFORMAT=3**. **x**= N: Do not calculate and output sound velocity.
FLASHINIT	Map bad blocks and erase FLASH memory, **which destroys all data in SBE 16*plus***. SBE 16*plus* requires you to enter this command twice, to provide verification before it proceeds. All data bits are set to 1. Sample number, header number, and data pointers are set to 0. Allow 15 minutes to initialize entire memory. Send this command (after uploading all data) if you are encountering FLASH Read errors in the Status command (**DS**) response. If not encountering these errors, use of this command is optional, as SBE 16*plus* writes over previously recorded information when **INITLOGGING** command is used before beginning logging. However, knowledge of initial memory contents (i.e., all ones) can be a useful cross-check when data is retrieved.
QS	Quit session and place SBE 16*plus* in quiescent (sleep) state. Main power is turned off. Data logging and memory retention are not affected.

Note:
GTD= and **DUALGTD=** commands were also listed above in Setup Commands.

GTD Setup/Testing Commands

You must set up the Gas Tension Device (GTD) to interface with the SBE 16*plus*, **before** you connect it to the 16*plus*. With the GTD directly connected to the computer, powered with an external power supply, and using software provided by Pro-Oceanus, set up the GTD to allow for the interface:

- **Output** to millibars
- **Baud rate** to the same baud rate as the SBE 16*plus* (the 16*plus* baud rate is set in SEATERM with the **BAUD=** command)
- **Counter integration time** so that the GTD responds to a *take pressure reading* command in 40 seconds

Set up the SBE 16*plus* to interface with the GTD(s):

- Send the **GTD=Y** or **DUALGTD=Y** command to enable the interface.
- The SBE 16*plus* with dual GTDs is shipped with a Y-cable installed for the GTDs. The GTD ends of the cable are labeled GTD #1 and #2, and the GTD IDs have been set to match by Sea-Bird. See the **SENDGTD** command to change IDs if necessary.

GTD=x

x= Y: Sample GTD.

x= N: Do not sample GTD.

DUALGTD=x

x= Y: Sample dual (2) GTDs.
Note: If **DUALGTD=Y**, setting for **GTD=** has no effect.

x= N: Do not sample dual GTDs.

TGTD

Measure GTD(s), output converted data. This command only outputs 1 sample from each GTD, and provides GTD firmware version, GTD serial number, GTD pressure, and GTD temperature.

Example: Output GTD data for system with dual GTDs:
S>TGTD
GTD#1 VR reply = *0001VR=s2.03
GTD#2 VR reply = *0002VR=s2.03
GTD#1 SN reply = *0001SN = 75524
GTD#2 SN reply = *0002SN = 81440
GTD#1 pressure reply = *00011010.04661, p = 101004661
GTD#2 pressure reply = *00021010.01580, p = 101001580
GTD#1 temperature reply = *000123.49548, t = 23.4955
GTD#2 temperature reply = *000223.0357038, t = 23.0357

SENDGTD=command

Command SBE 16*plus* to send **command** to GTD and to receive response; **command** can be any command recognized by the GTD (see GTD manual for command details).

Examples:

Send firmware version command to GTD #1:
S>SENDGTD=*0100vr
Sending GTD: **0100vr
GTD RX = *0001VR=s2.03

Send serial number command to GTD #2:
S>SENDGTD=*0200sn
Sending GTD: **0200sn
GTD RX = *0002SN=81440

Logging Commands

Notes:
- In SEATERM, to save real-time data to a file, click the Capture button on the Toolbar before beginning logging.
- If the FLASH memory is filled to capacity, data sampling and transmission of real-time data (if programmed) continue, but excess data is not saved in memory.
- If the SBE 16*plus* is sampling data and the external voltage is less than the cut-off voltage (7.5 volts) for five consecutive scans, the SBE 16*plus* halts logging and displays **WARNING: LOW BATTERY VOLTAGE** in response to the status (**DS**) command.

Logging commands direct the SBE 16*plus* to sample data at pre-programmed intervals. When commanded to start sampling with the **STARTNOW** or **STARTLATER** command, the SBE 16*plus* takes samples and stores the data in its FLASH memory. The SBE 16*plus* transmits real-time data if **MOOREDTXREALTIME=Y**. The SBE 16*plus* enters quiescent (sleep) state between samples.

To start logging, use the **STARTNOW** or **STARTLATER** command. Logging starts approximately 5 seconds after the receipt of the **STARTNOW** command. The first time logging is started after receipt of the initialize logging command (**INITLOGGING**), data recording starts at the beginning of memory and any previously recorded data is written over. When the **STOP** command is sent, recording stops. Each time the **STARTNOW** or **STARTLATER** command 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 1000 samples thereafter.

The SBE 16*plus* responds only to the **DS**, **DCAL**, **TS**, **SL**, **SLT**, **QS**, and **STOP** commands while logging. If you wake the SBE 16*plus* up while it is logging (for example, to send the **DS** command to check on the logging progress), it will temporarily stop logging. Logging will resume when it goes back to sleep again (either by sending the **QS** command or after the 2 minute timeout).

SAMPLEINTERVAL=x — **x**= interval (seconds) between samples (5 - 14,400 seconds).

Note:
If **NCYCLES** is too high, the SBE 16*plus* will not be able to take **NCYCLES** samples within **SAMPLEINTERVAL** seconds (maximum sampling rate is 4 Hz). In that case, the SBE 16*plus* internally reduces **NCYCLES** to the largest feasible number.

NCYCLES=x — **x=** number of measurements to take and average every **SAMPLEINTERVAL** seconds (default = 1). SBE 16*plus* takes and averages **NCYCLES** samples (each 0.25 seconds apart) each **SAMPLEINTERVAL** seconds; averaged data is stored in FLASH memory and (if **MOOREDTXREALTIME=Y**) transmitted real-time.

Example: If **SAMPLEINTERVAL=5** and **NCYCLES=4**, every 5 seconds the SBE 16*plus* takes 4 samples (each 0.25 seconds apart), averages the data from the 4 samples, and stores the averaged data in FLASH memory.

INITLOGGING — Initialize logging - after all previous data has been uploaded from SBE 16*plus*, initialize logging before starting to log again to make entire memory available for recording. This command sets sample number (**SAMPLENUMBER=x**) and header number (**HEADERNUMBER=x**) to 0 internally. If these are not set to 0, data will be stored after last recorded sample. **Do not send INITLOGGING until all existing data has been uploaded.**

Logging Commands (continued)

SAMPLENUMBER=x

x= sample number for first sample when logging begins. After all previous data has been uploaded from SBE 16*plus*, send **SAMPLENUMBER=0** (this sets sample and header number to 0 internally) before starting to log to make entire memory available for recording. If these are not set to 0, data will be stored after last recorded sample. **Do not send SAMPLENUMBER=0 until all existing data has been uploaded.**

Notes:
- **INITLOGGING** and **SAMPLENUMBER=0** have identical effects. Use either command to initialize logging.
- Initializing logging sets sample and header number to 0 *internally*. However, for data output, the first sample and header number is 1.
- **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 **SAMPLENUMBER=a** and **HEADERNUMBER=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.

HEADERNUMBER=x

x= header number for when logging begins. This command is typically only used to recover data if you accidentally initialize logging (using **INITLOGGING** or **SAMPLENUMBER=0**) before uploading all existing data.

STARTNOW

Start logging now.

STARTMMDDYY=mmddyy

Set delayed start month, day, and year for data logging. This command must be followed by **STARTHHMMSS=** command to set delayed start time.

Note:
STARTDDMMYY= and **STARTMMDDYY=** commands are equivalent. Either can be used to set the delayed start time.

STARTDDMMYY=ddmmyy

Set delayed start day, month, and year for data logging. This command must be followed by **STARTHHMMSS=** command to set delayed start time.

STARTHHMMSS=hhmmss

Set delayed start hour, minute, and second for data logging.

STARTLATER

Start logging at time set with delayed start date and time commands.

Notes:
- After receiving **STARTLATER**, the SBE 16*plus* displays **waiting to start at . . .** in reply to the Display Status (**DS**) command. Once logging has started, the **DS** reply displays **logging**.
- If the delayed start time has already passed when **STARTLATER** is received, the SBE 16*plus* executes **STARTNOW**.

Example: Program SBE 16*plus* to start logging on 20 January 2001 12:00:00.

```
S>STARTMMDDYY=012001
S>STARTHHMMSS=120000
S>STARTLATER
```

or

```
S>STARTDDMMYY=200101
S>STARTHHMMSS=120000
S>STARTLATER
```

STOP

Stop data logging or stop waiting to start logging (if **STARTLATER** was sent but logging has not begun yet). Press Enter key to get **S>** prompt before entering this command.

Notes:
- You may need to send the **STOP** command several times to get the SBE 16*plus* to respond.
- You must stop logging before uploading data.

Notes:
- To save data to a file, click the Capture button on the Toolbar before entering the **DD** or **DH** command.
- See *Data Output Formats* after these *Command Descriptions*.
- **Use the Upload button on the Toolbar or Upload Data in the Data menu to upload data that will be processed by SBE Data Processing**. Manually entering the data upload command does not produce data in the correct format for processing by SBE Data Processing.

Data Upload Commands

Stop logging before uploading data.

DDb,e

Upload data from scan **b** to scan **e**.
If **b** and **e** are omitted, all data is uploaded.
First sample is number 1.

Example: Upload samples 1 through 199 to a file:
(Click Capture on Toolbar and enter desired filename in dialog box.)
S>DD1,199

DHb,e

Upload headers from header **b** to header **e**.
If **b** and **e** are omitted, all headers are uploaded. First header is 1. The header includes:
- header number
- month, day, hour, minute, and second when header was written
- first and last sample for header
- interval between samples (**SAMPLEINTERVAL**)
- reason logging was halted
  (batfail = battery voltage too low;
  stop cmd = received **STOP** command or Home or Ctrl Z character;
  timeout = error condition;
  unknown = error condition;
  ?????? = error condition)

Example: Upload second header to a file:
(Click Capture on Toolbar and enter desired filename in dialog box.)
S>DH2
SBE 16*plus* responds:
```
hdr 2 30 Nov 2000 12:30:33 samples 35 to 87, int=60, stop=stop cmd
```

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

Sampling Commands

These commands request a single sample. The SBE 16*plus* always stores data for the most recent sample in its buffer. Some Sampling commands also store data in FLASH memory - the SBE 16*plus* will not execute the *store data in FLASH memory* portion of those commands while logging data.

SL	Output last sample from buffer (sample obtained with sampling command, or latest sample from logging), and leave power on.
SLT	Output last sample from buffer, then take new sample and store data in buffer. Leave power on. **Data is not stored in FLASH memory**.
TS	Take new sample, store data in buffer, output data, and leave power on. **Data is not stored in FLASH memory**.
TSS	Take new sample, **store data in buffer and FLASH memory**, output data, and turn power off.
TSSON	Take new sample, **store data in buffer and FLASH memory**, output data, and leave power on.

Testing Commands

The SBE 16*plus* takes and outputs 100 samples for each test (except as noted); data is **not** stored in FLASH memory. Press the Esc key or Stop on the Toolbar to stop a test.

TT	Measure temperature, output converted data.
TC	Measure conductivity, output converted data.
TP	Measure pressure (strain gauge or Quartz), output converted data.
TV	Measure four external voltage channels, output converted data.
TF	Measure frequency (Quartz pressure sensor), output converted data.
T38	Measure SBE 38 (secondary temperature), output converted data.
TTR	Measure temperature, output raw data.
TCR	Measure conductivity, output raw data.
TPR	Measure pressure (strain gauge or Quartz), output raw data.
TVR	Measure four external voltage channels, output raw data.
TFR	Measure frequency (Quartz pressure sensor), output raw data.
PUMPON	Turn pump on for testing purposes.
PUMPOFF	Turn pump off for testing purposes.

Notes:
- Dates shown are when calibrations were performed. Calibration coefficients are initially factory-set and should agree with Calibration Certificate shipped with SBE 16*plus*.
- See individual Coefficient Commands below for definitions of the data in the example.

Coefficients Commands

DCAL	Display calibration coefficients. Equivalent to Coefficients button on Toolbar.

Example: Display coefficients for SBE 16*plus* with a Quartz pressure sensor.

```
S>dcal
SeacatPlus V 1.3  SERIAL NO. 4000  25 Jun 2001  14:46:05
temperature:  26-jul-00
    TA0 = -3.178124e-06
    TA1 = 2.751603e-04
    TA2 = -2.215606e-06
    TA3 = 1.549719e-07
    TOFFSET = 0.000000e+00
conductivity:  01-aug-00
    G = -9.855242e-01
    H = 1.458421e-01
    I = -3.290801e-04
    J = 4.784952e-05
    CF0 = 2.584100e+03
    CPCOR = -9.570000e-08
    CTCOR = 3.250000e-06
    CSLOPE = 1.000000e+00
pressure S/N , range = 2000 psia:  14-jul-00
    PC1 = 0.000000e+00
    PC2 = 0.000000e+00
    PC3 = 0.000000e+00
    PD1 = 0.000000e+00
    PD2 = 0.000000e+00
    PT1 = 0.000000e+00
    PT2 = 0.000000e+00
    PT3 = 0.000000e+00
    PT4 = 0.000000e+00
    PSLOPE = 1.000000e+00
    POFFSET = 0.000000e+00
volt 0: offset = 0.000000e+00, slope = 1.000000e+00
volt 1: offset = 0.000000e+00, slope = 1.000000e+00
volt 2: offset = 0.000000e+00, slope = 1.000000e+00
volt 3: offset = 0.000000e+00, slope = 1.000000e+00
    EXTFREQSF = 1.000000e+00
```

Notes:
- F = floating point number
  S = string with no spaces
- If using an SBE 38 (secondary temperature sensor), its calibration coefficients are not stored in the SBE 16*plus'* EEPROM. View and/or modify the SBE 38's calibration coefficients by connecting the SBE 38 to the computer directly and using SEATERM.
- If using auxiliary A/D sensors (**VOLT0** through **VOLT3**), their calibration coefficients are not stored in the SBE 16*plus*' EEPROM, but are stored in the SBE 16*plus*' configuration (.con) file. View and/or modify the calibration coefficients using the Configure menu in SBE Data Processing or SEASAVE.

Coefficients Commands (continued)

The individual Coefficient Commands listed below are used to modify a particular coefficient or date:

Temperature

TCALDATE=S	**S=**calibration date
TA0=F	**F=**A0
TA1=F	**F=**A1
TA2=F	**F=**A2
TA3=F	**F=**A3
TOFFSET=F	**F=**offset correction

Conductivity

CCALDATE=S	**S=**calibration date
CG=F	**F=**G
CH=F	**F=**H
CI=F	**F=**I
CJ=F	**F=**J
CPCOR=F	**F=**pcor
CTCOR=F	**F=**tcor
CSLOPE=F	**F=**slope correction
CF0=F	**F=**0 value (compatible state only)

Pressure - General

PCALDATE=S	**S=**calibration date
PRANGE=F	**F=**sensor full scale range (psi)
POFFSET=F	**F=**offset correction

Strain Gauge Pressure

PA0=F	**F=**A0
PA1=F	**F=**A1
PA2=F	**F=**A2
PTEMPA0=F	**F=**pressure temperature A0
PTEMPA1=F	**F=**pressure temperature A1
PTEMPA2=F	**F=**pressure temperature A2
PTCA0=F	**F=**pressure temperature compensation ptca0
PTCA1=F	**F=**pressure temperature compensation ptca1
PTCA2=F	**F=**pressure temperature compensation ptca2
PTCB0=F	**F=**pressure temperature compensation ptcb0
PTCB1=F	**F=**pressure temperature compensation ptcb1
PTCB2=F	**F=**pressure temperature compensation ptcb2

Quartz Pressure

PC1=F	**F=**C1
PC2=F	**F=**C2
PC3=F	**F=**C3
PD1=F	**F=**D1
PD2=F	**F=**D2
PT1=F	**F=**T1
PT2=F	**F=**T2
PT3=F	**F=**T3
PT4=F	**F=**T4
PSLOPE=F	**F=**slope correction

External Frequency

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

Data Output Formats

The SBE 16*plus* stores data in a compact machine code. Data is converted and output in the user-selected format when uploading, 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.

Note:
See *Appendix IV: Compatible State* for information on commands and output format for Compatible State custom applications.

Output format is dependent on the **OUTPUTFORMAT (=0, 1, 2, or 3)** parameter, as detailed in the following sections. The inclusion of some output parameters is dependent on the system configuration - if the system does not include the specified sensor, the corresponding data is not included in the output data stream, shortening the data string.

Notes:
- When using SEATERM's Upload button, SEATERM sends the **OUTPUTFORMAT=0** command. This causes the SBE 16*plus* to upload data in memory in raw hex, regardless of the user-programmed **OUTPUTFORMAT**, providing the data in a format that Sea-Bird's data processing software can use.
- Sea-Bird's data processing software (SBE Data Processing) uses the equations shown to perform these calculations; alternatively, you can use the equations to develop your own processing software.
- The SBE 16*plus*' 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* outputs pressure relative to the ocean surface (i.e., at the surface the output pressure is 0 decibars).
  The SBE 16*plus* uses the following equation to convert psia to decibars:
  pressure (db) =
  [pressure (psia) - 14.7] * 0.689476
- Although **OUTPUTFORMAT=0** outputs *raw* data for temperature, conductivity, etc., it outputs engineering units for SBE 38 and GTD data.

OUTPUTFORMAT=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).

1. Temperature
   A/D counts = ttttt
2. Conductivity
   conductivity frequency (Hz) = cccccc / 256
3. Strain gauge pressure sensor pressure (if **PTYPE=1**)
   A/D counts = pppppp
4. Strain gauge pressure sensor pressure temperature compensation (if **PTYPE=1**)
   pressure temperature compensation voltage = vvvv / 13,107
5. Quartz pressure sensor pressure (if **PTYPE=2** or **3**)
   Quartz pressure frequency (Hz) = pppppp / 256
6. Quartz pressure sensor temperature compensation (if **PTYPE=3**)
   Quartz temperature compensation voltage = vvvv / 13,107
7. External voltage 0 (if **VOLT0=Y**)
   external voltage 0= vvvv / 13,107
8. External voltage 1 (if **VOLT1=Y**)
   external voltage 1 = vvvv / 13,107
9. External voltage 2 (if **VOLT2=Y**)
   external voltage 2 = vvvv / 13,107
10. External voltage 3 (if **VOLT3=Y**)
    external voltage 3 = vvvv / 13,107
11. SBE 38 secondary temperature (if **SBE38=Y**)
    SBE 38 temperature (°C, ITS-90) = (ttttt / 100,000) - 10
12. GTD #1 pressure (if **GTD=Y** or **DUALGTD=Y**)
    GTD #1 pressure (millibars) = pppppppp / 100,000
13. GTD #1 temperature (if **GTD=Y** or **DUALGTD=Y**)
    GTD #1 temperature (°C, ITS-90) = (ttttt / 100,000) - 10
14. GTD #2 pressure (if **DUALGTD=Y**)
    GTD #2 pressure (millibars) = pppppppp / 100,000
15. GTD #2 temperature (if **DUALGTD=Y**)
    GTD #2 temperature (°C, ITS-90) = (ttttt / 100,000) - 10
16. Time
    seconds since January 1, 1980 = ssssssss

Example: SBE 16*plus* with strain gauge pressure sensor and two external voltages sampled,
example scan = ttttttccccccppppppvvvvvvvvvvvvssssssss
= 0A53711BC7220C14C17D820305059425980600

- 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 = 25980600 (630,720,000 decimal)
  seconds since January 1, 1980 = 630,720,000

OUTPUTFORMAT=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).

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 - **PTYPE=1**, **2**, or **3**)
   pressure (decibars) = (pppppp / 1,000) - 100
4. External voltage 0 (if **VOLT0=Y**)
   external voltage 0= vvvv / 13,107
5. External voltage 1 (if **VOLT1=Y**)
   external voltage 1 = vvvv / 13,107
6. External voltage 2 (if **VOLT2=Y**)
   external voltage 2 = vvvv / 13,107
7. External voltage 3 (if **VOLT3=Y**)
   external voltage 3 = vvvv / 13,107
8. SBE 38 secondary temperature (if **SBE38=Y**)
   SBE 38 temperature (°C, ITS-90) = (ttttt / 100,000) - 10
9. GTD #1 pressure (if **GTD=Y** or **DUALGTD=Y**)
   GTD #1 pressure (millibars) = pppppppp / 100,000
10. GTD #1 temperature (if **GTD=Y** or **DUALGTD=Y**)
    GTD #1 temperature (°C, ITS-90) = (ttttt / 100,000) - 10
11. GTD #2 pressure (if **DUALGTD=Y**)
    GTD #2 pressure (millibars) = pppppppp / 100,000
12. GTD #2 temperature (if **DUALGTD=Y**)
    GTD #2 temperature (°C, ITS-90) = (ttttt / 100,000) - 10
13. Time
    seconds since January 1, 1980 = ssssssss

Example: SBE 16*plus* with strain gauge pressure sensor and two external voltages sampled,
example scan = ttttttccccccppppppvvvvvvvvssssssss
= 3385C40F42FE0186DE0305059425980600

- 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 = 25980600 (630,720,000 decimal)
  seconds since January 1, 1980 = 630,720,000

OUTPUTFORMAT=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.

1. Temperature
   A/D counts = ttttt
2. Conductivity
   conductivity frequency (Hz) = cccc.ccc
3. Strain gauge pressure sensor pressure (if **PTYPE=1**)
   A/D counts = pppppp
4. Strain gauge pressure sensor pressure temperature compensation (if **PTYPE=1**)
   pressure temperature compensation voltage = v.vvvv
5. Quartz pressure sensor pressure (if **PTYPE=2** or **3**)
   Quartz pressure frequency (Hz) = pppp.ppp
6. Quartz pressure sensor temperature compensation (if **PTYPE=3**)
   Quartz temperature compensation voltage = v.vvvv
7. External voltage 0 (if **VOLT0=Y**)
   external voltage 0= v.vvvv
8. External voltage 1 (if **VOLT1=Y**)
   external voltage 1 = v.vvvv
9. External voltage 2 (if **VOLT2=Y**)
   external voltage 2 = v.vvvv
10. External voltage 3 (if **VOLT3=Y**)
    external voltage 3 = v.vvvv
11. SBE 38 secondary temperature (if **SBE38=Y**)
    SBE 38 temperature (°C, ITS-90) = ttt.tttt
12. GTD #1 pressure (if **GTD=Y** or **DUALGTD=Y**)
    GTD #1 pressure (millibars) = pppppppppp / 100,000
13. GTD #1 temperature (if **GTD=Y** or **DUALGTD=Y**)
    GTD #1 temperature (°C, ITS-90) = ttt.tt
14. GTD #2 pressure (if **DUALGTD=Y**)
    GTD #2 pressure (millibars) = pppppppppp / 100,000
15. GTD #2 temperature (if **DUALGTD=Y**)
    GTD #2 temperature (°C, ITS-90) = ttt.tt
16. Time
    date, time = dd mmm yyyy, hh:mm:ss (day month year hour:minute:second)

Note:
Although **OUTPUTFORMAT=2** outputs *raw* data for temperature, conductivity, etc., it outputs engineering units for SBE 38 and GTD data.

Example: SBE 16*plus* with strain gauge pressure sensor and two external voltages sampled,
example scan =
ttttt, 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, 12 nov 2000, 12:23:05

- Temperature = ttttttt = 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 = 12 nov 2000, 12:23:05
  Date, time = 12 November 2000, 12:23:05

OUTPUTFORMAT=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.

1. Temperature
   temperature (°C, ITS-90) = ttt.tttt
2. Conductivity
   Conductivity (S/m) = cc.ccccc
3. Pressure (Quartz or strain gauge - **PTYPE=1**, **2**, or **3**)
   pressure (decibars) = pppp.ppp
4. External voltage 0 (if **VOLT0=Y**)
   external voltage 0= v.vvvv
5. External voltage 1 (if **VOLT1=Y**)
   external voltage 1 = v.vvvv
6. External voltage 2 (if **VOLT2=Y**)
   external voltage 2 = v.vvvv
7. External voltage 3 (if **VOLT3=Y**)
   external voltage 3 = v.vvvv
8. SBE 38 secondary temperature (if **SBE38=Y**)
   SBE 38 temperature (°C, ITS-90) = ttt.tttt
9. GTD #1 pressure (if **GTD=Y** or **DUALGTD=Y**)
   GTD #1 pressure (millibars) = pppppppppp / 100,000
10. GTD #1 temperature (if **GTD=Y** or **DUALGTD=Y**)
    GTD #1 temperature (°C, ITS-90) = ttt.tt
11. GTD #2 pressure (if **DUALGTD=Y**)
    GTD #2 pressure (millibars) = pppppppppp / 100,000
12. GTD #2 temperature (if **DUALGTD=Y**)
    GTD #2 temperature (°C, ITS-90) = ttt.tt
13. Salinity (if **OUTPUTSAL=Y**)
    salinity (psu) = sss.ssss
14. Sound velocity (if **OUTPUTSV=Y**)
    sound velocity (meters/second) = vvvv.vvv
15. Time
    date, time = dd mmm yyyy, hh:mm:ss (day month year hour:minute:second)

Example: SBE 16*plus* with strain gauge pressure sensor and two 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, 12 nov 2000, 12:23:05

- 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 = 12 nov 2000, 12:23:05
  Date, time = 12 November 2000, 12:23:05

Set-Up for Deployment

1. Install new batteries or ensure the existing batteries have enough capacity to cover the intended deployment. See *Section 5: Routine Maintenance and Calibration* for details on installing new batteries.

Note:
It is always necessary to set both date and time. **If a new date is entered but not a new time, the new date will not be saved.**

2. Program the SBE 16*plus* for the intended deployment using SEATERM (see *Section 3: Power and Communications Test* for connection information; see information in this section on commands):

   A. Set the date and then time (if not already done).

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

   C. Establish the setup and logging parameters. If desired, use **STARTMMDDYY=**, **STARTHHMMSS=**, and **STARTLATER** commands to establish delayed start date and time.

3. If you will be using SEATERM to view real-time data, press the Capture button on the Toolbar to save the data to a file.

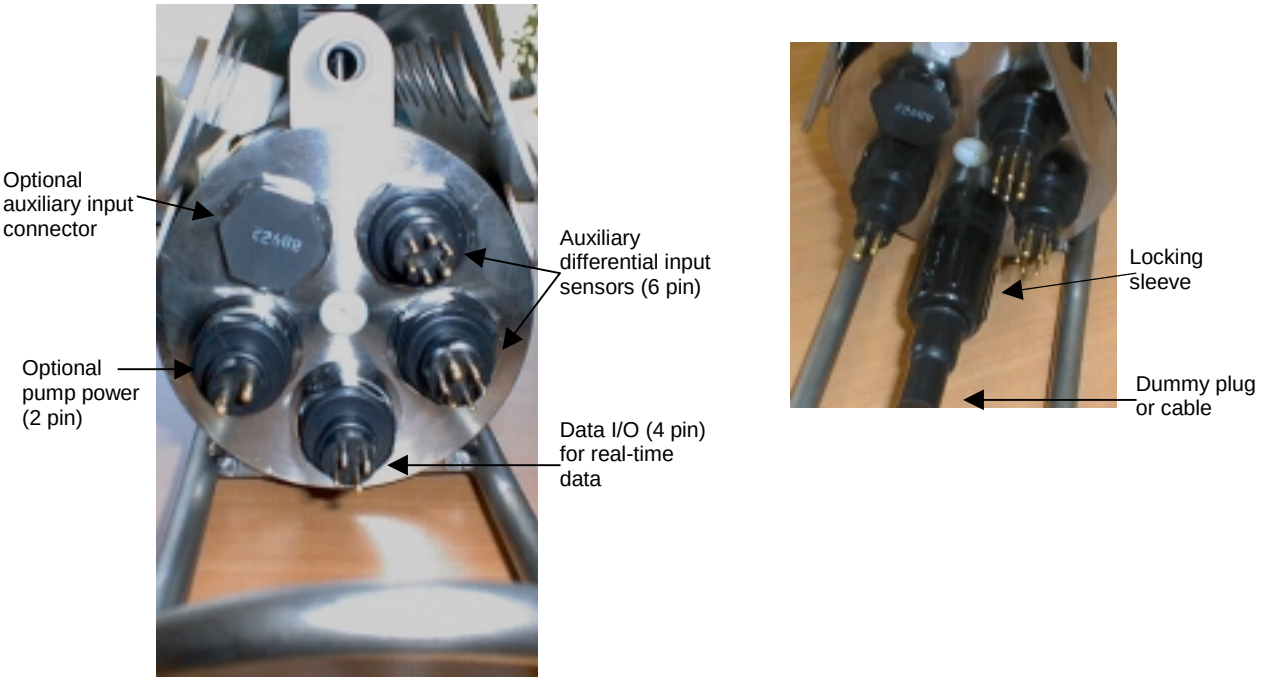
4. If you will be using SEASAVE to acquire and view real-time data:

   A. Verify that the configuration (.con) file matches the instrument configuration. Sea-Bird supplies a .con file to match the factory configuration and calibrations. If the instrument is recalibrated or the configuration is changed (such as by adding external sensors), the .con file must be updated to reflect the current condition.

   B. See SEASAVE's Help files for detailed information.

Deployment

1. Install a cable or dummy plug for each connector on the SBE 16*plus* sensor end cap:
   A. Lightly lubricate the inside of the dummy plug/cable connector with silicone grease (DC-4 or equivalent).
   B. 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 SBE 16*plus*. Remove any trapped air by *burping* or gently squeezing the plug/connector near the top and moving your fingers toward the end cap.
   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. Verify that the hardware and external fittings are secure.

4. As applicable, remove the plug(s) from the anti-foul cap(s), or remove the Tygon tubing (and associated barbed anti-foul caps) that is looped end-to-end around the conductivity cell. See *Conductivity Cell Maintenance* in *Section 5: Routine Maintenance and Calibration* for details.

5. If not already done, send the **STARTNOW** or **STARTMMDDYY**, **STARTHHMMSS**, and **STARTLATER** commands.

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

Recovery

WARNING!
Pressure housings may flood under pressure due to dirty or damaged o-rings, or other failed seals, causing highly compressed air to be trapped inside. If this happens, a potentially life-threatening explosion can occur when the instrument is brought to the surface.
If the SBE 16*plus* is unresponsive to commands or shows other signs of flooding or damage, carefully secure the instrument in a location away from people until it has been determined that abnormal internal pressure does not exist.
Contact Sea-Bird for assistance with procedures for safely relieving internal pressure.

Physical Handling

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-foul 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.)

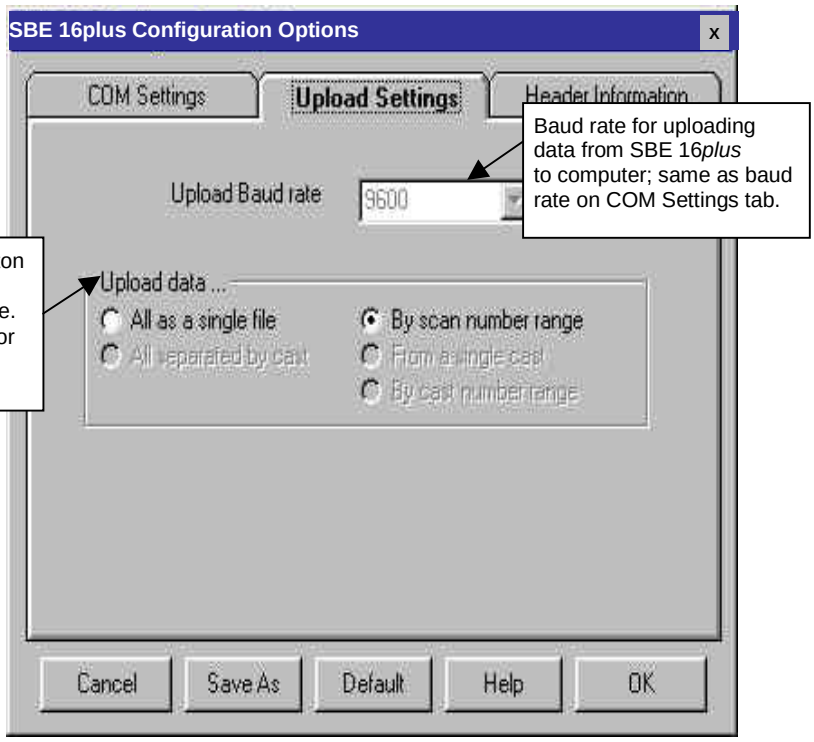
4. If immediate redeployment is not required, it is best to leave the SBE 16*plus* with batteries in place and in a quiescent state (**QS**). Because the quiescent current required is only 30 microamps, the batteries can be left in place without significant loss of capacity.

Note:
Data may be uploaded during deployment or after recovery. If uploading after recovery, connect the I/O cable as described in *Section 3: Power and Communications Test*.

Uploading Data

1. Double click on SeaTerm.exe. The display shows the main screen.

2. In the Configure menu, select *SBE 16plus*. Click on the Upload Settings tab. The dialog box looks like this:



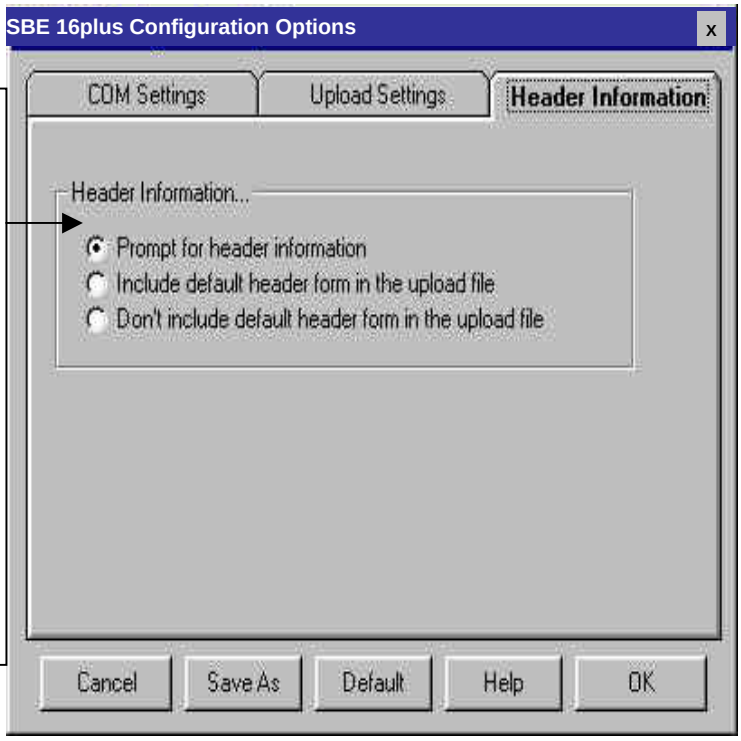
Baud rate for uploading data from SBE 16*plus* to computer; same as baud rate on COM Settings tab.

Defines data upload type when using Upload button on Toolbar or Upload Data in Data menu:
- All as single file – All data uploaded into one file.
- By scan number range – SEATERM prompts for beginning and ending scan (sample) numbers, and uploads all data within range into one file.

Note:
Set up **Upload Settings**, **Header Information**, and/or **Header Form** (Steps 2 through 4):
- The first time you upload data, and
- If you want to change upload or header parameters.

Make the selection for Upload Settings.

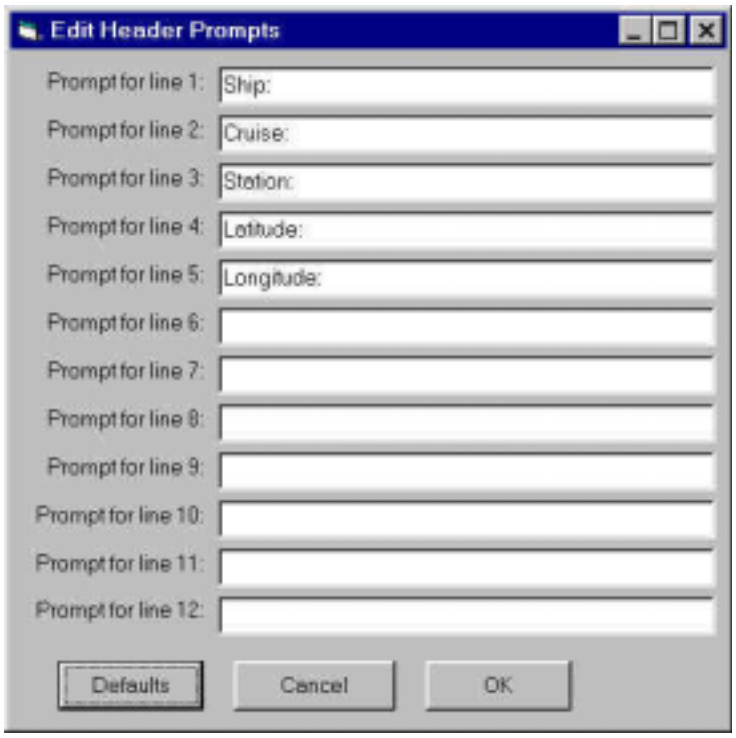
3. Click on the Header Information tab. The dialog box looks like this:



Defines header information included with uploaded data:
- Prompt for header information – Each time 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.

Select the desired header information option. Click OK to overwrite an existing COM/Upload/Header Settings file, or click Save As to save the settings as a new filename.

4. In the Configure menu, select Header Form to customize the header. The dialog box looks like this (default prompts are shown):



   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 in the Configuration Options dialog box (Step 3)
   - the header included with the uploaded data, if *Include default header form in upload file* was selected in the Configuration Options dialog box (Step 3)

   Enter the desired header/header prompts. Click OK.

5. Click Connect on the Toolbar to begin communications with the SBE 16*plus*. The display looks like this:

   S>

   This shows that correct communications between the computer and the SBE 16*plus* has been established.
   If the system does not respond as shown above:
   - Click Connect again.
   - Check cabling between the computer and the SBE 16*plus*.
   - Verify the correct instrument was selected and the COM settings were entered correctly in the Configure menu.

6. Command the SBE 16*plus* to stop data logging by pressing the Enter key and sending the **STOP** command.

7. Display SBE 16*plus* status information by clicking Status on the Toolbar. The display looks like this:

```
SeacatPlus V 1.3  SERIAL NO. 4000    25 Jun 2001  14:02:13
vbatt = 9.6, vlith = 0.0, ioper = 61.2 ma, ipump = 25.5 ma,
iext01 = 76.2 ma, iext23 =  73.6 ma,
status = not logging
sample interval = 15 seconds, number of measurements per
sample = 1
samples = 5000, free = 376300
mode = moored, run pump for 0.5 sec, delay before sampling
=0.0 seconds
transmit real-time = no
battery type = ALKALINE, battery cutoff = 7.5 volts
pressure sensor = strain gauge, range = 1000.0
SBE 38 = no, Gas Tension Device = no
Ext Volt 0 = no, Ext Volt 1 = no, Ext Volt 2=no, Ext Volt 3=no
output format = converted decimal
output salinity = no, output sound velocity = no
```

8. Click the Upload button on the Toolbar to upload stored data in a form that Sea-Bird's data processing software can use. SEATERM responds as follows before uploading the data:
   A. SEATERM sends the **OUTPUTFORMAT=0** command to set the output format to raw hexadecimal.
   B. SEATERM sends the status (**DS**) command, displays the response, and writes the command and response to the upload file. This command provides you with information regarding the number of samples in memory, sample interval, etc.
   C. **If you selected *By scan number range* in the Configuration Options dialog box (Configure menu)** – a dialog box requests the range. Enter the desired values, and click OK.
   D. **If you selected *Prompt for header information* in the Configuration Options dialog box (Configure menu)** – a dialog box with the header form appears. Enter the desired header information, and click OK.
   E. In the Open dialog box, enter the desired upload file name and click OK. The upload file has a .hex extension.
   F. SEATERM sends the data upload command (**DDb,e**).
   G. When the data has been uploaded, SEATERM shows the **S>** prompt.

9. Ensure all data has been uploaded from the SBE 16*plus* by reviewing and processing the data:
   A. Use **SEASAVE** to display the *raw* hexadecimal data from the SBE 16*plus* in engineering units (see SEASAVE's Help files for details).
   B. Use **SBE Data Processing** to process the data (see SBE Data Processing manual/Help files for details).
   C. Use the **SeaPlot** module in SBE Data Processing to plot the processed data if desired.

Note:
To prepare the SBE 16*plus* for re-deployment:
1. After all data has been uploaded, send the **INITLOGGING** command. 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 the **QS** command to put the SBE 16*plus* in quiescent (sleep) state until ready to redeploy. The quiescent current is only 30 microamps, so the batteries can be left in place without significant loss of capacity.

Section 5: Routine Maintenance and Calibration

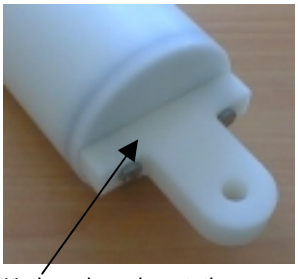
This section reviews corrosion precautions, replacement of batteries, conductivity cell storage and cleaning, replacement of anti-foul cylinders, and sensor calibration. The accuracy of the SBE 16*plus* is sustained by the care and calibration of the sensors and by establishing proper handling practices.

Corrosion Precautions

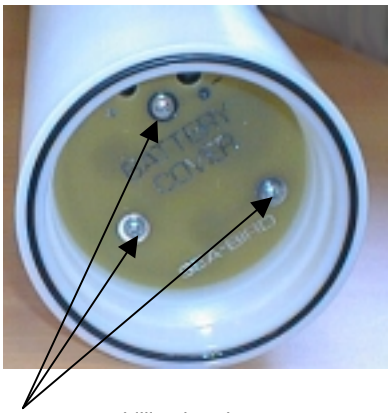
Rinse the SBE 16*plus* with fresh water after use and prior to storage.

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.

Replacing Batteries



Unthread cap by rotating counter-clockwise



Remove Phillips-head screws and washers

Leave the batteries in place when storing the SBE 16*plus* to prevent depletion of the back-up lithium batteries by the real-time clock. Even *exhausted* main batteries will power the clock (30 microamperes) almost indefinitely. If the SBE 16*plus* is to be stored for long periods, leave the batteries in place and replace them yearly.

1. Remove the battery 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. Unthread the end cap by rotating counter-clockwise (use a wrench on the white plastic bar if necessary).
   C. Remove any water from the O-ring mating surfaces inside the housing with a lint-free cloth or tissue.
   D. Put the end cap aside, being careful to protect the O-ring 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 SBE 16*plus* 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**.

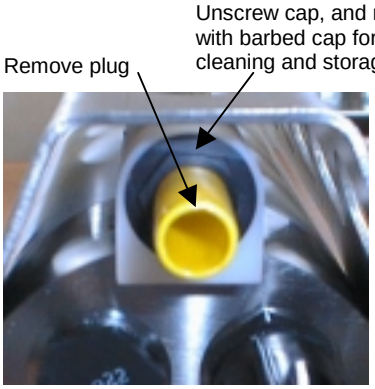
6. Check the battery voltage at BAT + and BAT - on the battery cover plate. It should be approximately 13.5 volts.

7. Reinstall the battery 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. Carefully fit the end cap into the housing and rethread the end cap into place. Use a wrench on the white plastic bar to ensure the end cap is tightly secured.

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 SBE 16*plus* 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'* conductivity cell is shipped dry to prevent freezing in shipping. Sea-Bird recommendations follow for three situations:
- Active use - storing for one day or less between uses
- Storage - storing for longer than one day
- Cleaning



The SBE 16*plus* is shipped with a kit for cell filling and storage. The kit includes a syringe and tubing assembly, and two anti-foul caps with hose barbs. The tubing cannot attach to an anti-foul cap that is not barbed.
- If your SBE 16*plus* does not include a pump - the installed anti-foul caps at both ends of the conductivity cell are not barbed.
- If your SBE 16*plus* includes a pump - the installed anti-foul cap at the pump end of the cell is barbed; the installed anti-foul 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-foul cap(s) and replace them with the anti-foul cap(s) with hose barbs **for cleaning and storage only**. Remember to reinstall the original anti-foul cap(s) before deployment. **Deploying an SBE 16*plus* with barbed anti-foul cap(s) in place of the installed caps is likely to produce undesirable results in your data.** See *Replacing Anti-Foul Cylinders* in this section for safety precautions when handling the anti-foul cylinders, which contain TBTO.

Active Use (storing for one day or less)

1. After each recovery, rinse the cell with clean, de-ionized water and drain.
   - If the cell is not rinsed between uses, salt crystals may form on the platinized electrode surfaces. When the instrument is used next, sensor accuracy may be temporarily affected until these crystals dissolve.
2. Fill the cell with a **0.1%** solution of Triton X-100 (included with shipment), using a length of Tygon tubing attached to each end of the cell to close the cell ends.
   - The Triton X-100 solution is a mild, non-ionic detergent that keeps contamination from ocean surface film, aerosols, and spray/wash on the ship deck from harming the cell calibration.

Storage (storing for longer than one day)

1. Rinse the cell with clean, de-ionized water and drain. Remove larger droplets of water by blowing through the cell. **Do not use compressed air**, which typically contains oil vapor.
2. Insert the anti-foul plugs in the anti-foul cups, to prevent dust and aerosols from entering the cell during storage.
3. When ready to deploy again - Fill the cell with a **0.1%** solution of Triton X-100 for 1 hour before deployment.

Cleaning

The rinse and soak procedure recommended for Active Use is generally sufficient. However, occasionally the cell becomes contaminated and requires more intensive cleaning. We recommend two procedures, depending on the type of contamination:

Triton Cleaning for Ocean Surface Films or Oily Contamination

1. Heat a stronger (**1%-2%**) solution of Triton X-100 to less than 60 °C.
2. Agitate the warm solution through the cell many times in a washing action. This can be accomplished with Tygon tubing and a syringe kit.
3. Fill the cell with the solution and let it soak for 1 hour.
4. Drain and flush with clean, de-ionized water for 1 minute. Then:
   - Prepare for deployment, **or**
   - Follow recommendations above for storage.

Acid Cleaning for Biological or Mineral Contamination

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 SBE 16*plus* 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 **muriatic acid** (**37% HCl**) 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.
   C. Rinse the exterior of the SBE 16*plus* to remove any spilled acid from the surface.
   D. Flush the cell for 5 minutes with warm (not hot), clean, de-ionized water.
   E. Fill the cell with a **1%** solution of Triton X-100 and let it stand for 5 minutes.
   F. Drain and flush with warm, clean, de-ionized water for 1 minute.
3. Prepare for deployment, **or**
   Follow recommendations above for storage.

WARNING!
Observe all precautions for working with strong acid. Avoid breathing the acid fumes. Work in a well-ventilated area.

Repeat this procedure a few times for reluctant contamination. Return to Sea-Bird for cleaning if three acid rinses do not restore the cell's calibration. We recommend that you do not clean with acid more than once per week.

Replacing Anti-Foul Cylinders

Anti-foul cylinder

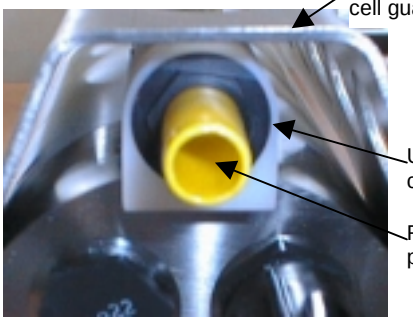
The SBE 16*plus* has an anti-foul cup and cap on each end of the conductivity cell. A new SBE 16*plus* is shipped with an anti-foul cylinder and a protective plug pre-installed in each cup.

Anti-foul cylinders have a useful deployment life of approximately 2 years. Sea-Bird recommends that you keep track of how long the cylinders have been deployed, to allow you to purchase and replace the cylinders when needed.

WARNING!

1. **Anti-foul cylinders contain tri-butyl tin oxide (TBTO). Handle the cylinders with gloves. If the cylinders come in contact with skin, wash with soap and water immediately. Dispose of gloves properly. Refer to the Material Safety Data Sheet, enclosed with the shipment, for details.**
2. Anti-foul cylinders are **not** classified by the U.S. DOT or the IATA as hazardous material, in the quantities used by Sea-Bird.

Handling the cylinders with gloves, follow this procedure to replace each anti-foul cylinder (two):



1. Remove the protective plug.
2. Unscrew the cap with a 5/8-inch socket wrench.
3. Remove the old anti-foul cylinder. If the old cylinder is difficult to remove:
   - Use needle-nose pliers and carefully break up material.
   - If necessary, remove the conductivity cell guard to provide easier access.

CAUTION:
One of the anti-foul 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-foul 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.

3. Place the new anti-foul cylinder in the cup.
4. Rethread the cap onto the cup. Do not over tighten.
5. Replace the protective plug if not ready to redeploy.

Note:

1. Please remove anti-foul cylinders from the anti-foul cups before returning an SBE 16*plus* to Sea-Bird.
2. Store removed anti-foul cylinders in a plastic bag, and keep them in a cool place.

Sensor Calibration

Note
After recalibration, Sea-Bird enters the new calibration coefficients in the SBE 16*plus*' 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 the Configure menu in SEASAVE or SBE Data Processing.

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* are supplied fully calibrated, with coefficients stored in EEPROM in the SBE 16*plus* and printed on their respective Calibration Certificates (see back of manual).

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

Conductivity Sensor Calibration

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 Calibration

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.

Pressure Sensor Calibration

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

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 face seal, such as Swagelok-200-1-OR.

Section 6: Troubleshooting

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

Each SBE 16*plus* 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.

Problem 1: Unable to Communicate with SBE 16*plus*

The **S>** prompt indicates that communications between the SBE 16*plus* and computer have been established. Before proceeding with troubleshooting, attempt to establish communications again by clicking the Connect button on SEATERM's toolbar or hitting the Enter key several times.

Cause/Solution 1: The I/O cable connection may be loose. Check the cabling between the SBE 16*plus* and computer for a loose connection.

Cause/Solution 2: The instrument type and/or its communication settings may not have been entered correctly in SEATERM. Select the SBE 16*plus* in the Configure menu and verify the settings in the Configuration Options dialog box. The settings should match those on the instrument Configuration Sheet.

Cause/Solution 3: The I/O cable may not be the correct one. The I/O cable supplied with the SBE 16*plus* permits connection to the DB-25P input connectors used on IBM Asynchronous Adapter Cards, i.e., standard RS-232 interfaces. (Sea-Bird also supplies a 25-to-9 pin adapter, for use if your computer has a 9-pin serial port.)

- SBE 16*plus* Pin 1 (large pin) goes to DB-25 pin 7 (ground)
- SBE 16*plus* pin 2 (counter-clockwise from large pin) goes to DB-25 pin 2
- SBE 16*plus* pin 3 (opposite the large pin) goes to DB-25 pin 3

Problem 2: No Data Recorded

Cause/Solution 1: The SBE 16*plus'* memory may be full; once the memory is full, no further data will be recorded. Verify that the memory is not full using the **DS** command (*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, use the **INITLOGGING** command to reset the memory. After the memory is reset, the **DS** command 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 in the .con file. Verify the settings in the instrument .con file match the instrument Configuration Sheet.

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 in the instrument .con file. Verify the calibration coefficients in the instrument .con file match the instrument Calibration Certificates.

Problem 4: Program Corrupted

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

Cause/Solution 1: In rare cases, the program that controls the SBE 16*plus'* microprocessor can be corrupted by a severe static shock or other problem. 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 Batteries* in *Section 5: Routine Maintenance and Calibration* for details).
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 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 SBE 16*plus* (see *Section 3: Power and Communications Test* for details). Use the **DS** command to verify that the date and time and sample number are correct.

Glossary

Battery pack – Nine alkaline D-cells standard. Available with optional lithium batteries.

Fouling – Biological growth in the conductivity cell during deployment.

PCB – Printed Circuit Board.

SBE Data Processing – Sea-Bird's WIN 95/98/NT data processing software, which calculates and plots temperature, conductivity, and optional pressure, data from auxiliary sensors, and derived variables such as salinity and sound velocity.

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

SEACAT*plus* – High-accuracy conductivity, temperature, and pressure recorder. The SEACAT*plus* is available as the SBE 16*plus* (moored applications) and SBE 19*plus* (moored or profiling applications). A *plus* version of the SBE 21 (thermosalinograph) is under development.

SEASAVE – Sea-Bird's WIN 95/98/NT software used to acquire, convert, and display real-time or archived raw data.

SEASOFT-DOS – Sea-Bird's complete DOS software package, which includes software for communication, real-time data acquisition, and data analysis and display. SEASOFT-DOS' modules for real-time data acquisition and data analysis are not compatible with the SBE 16*plus*' data output formats (except for an SBE 16*plus* operating in Compatible State).

SEASOFT-Win32– Sea-Bird's complete Win 95/98/NT software package, which includes software for communication, real-time data acquisition, and data analysis and display. SEASOFT-Win32 includes SEATERM, SeatermAF, SEASAVE, SBE Data Processing, and PLOT39.

SEATERM – Sea-Bird's WIN 95/98/NT terminal program used to communicate with the SBE 16*plus*.

TCXO – Temperature Compensated Crystal Oscillator.

Triton X-100 – Concentrated liquid non-ionic detergent, used for cleaning the conductivity cell.

Appendix I: Functional Description and Circuitry

Sensors

The SBE16*plus* 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 SBE16*plus* 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 pressure sensor is a Druck strain-gauge sensor or a Quartz pressure 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 four 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

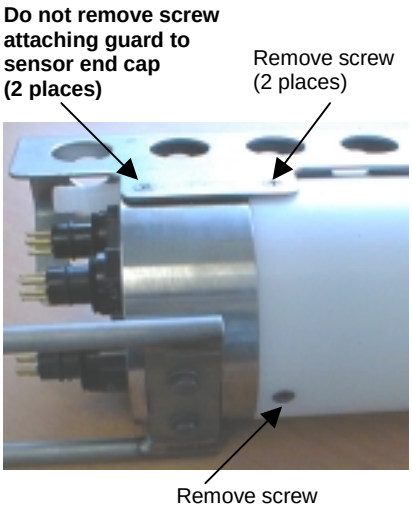
SBE 16*plus'* main battery is a series connection of D-cells that drop into the battery compartment as a cluster of end-to-end stacks, three batteries each (standard 9-cell battery pack has three stacks). The positive battery connections are contact areas on double-thick printed circuit disks that form 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 lithium cells (1/2 AA non-hazardous) which are diode OR'd with the main battery (and external power source, if used). The lithium supply is capable of supporting all SBE 16*plus* functions and serves to permit orderly shutdown in the event of failed or exhausted main batteries. The main batteries can be changed without disturbing memory or the real-time clock.

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.

Reassembly

Note:
Before delivery, desiccant packages are attached to the PCBs with string, and the electronics chamber is filled with dry Argon. These measures help prevent condensation.
If the electronics are exposed to the atmosphere, dry gas backfill with Argon. If the exposure is for more than 12 hours, also replace the desiccant package.
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 (**MMDDYY=** and **HHMMSS=**) and initialize logging (**INITLOGGING**) before redeploying. No other parameters should have been affected by the electronics disassembly (send the **DS** command to verify).

Appendix III: Command Summary

CATEGORY	COMMAND	DESCRIPTION
Status	**DS**	Display status and setup parameters.
Setup	**MMDDYY=mmddyy**	Set real-time clock month, day, year. Follow with **HHMMSS=** or it will not set date.
	DDMMYY=ddmmyy	Set real-time clock day, month, year. Follow with **HHMMSS=** or it will not set date.
	HHMMSS=hhmmss	Set real-time clock hour, minute, second.
	BAUD=x	**x=** baud rate (1200, 2400, 4800, 9600, 19200, or 38400). Default 9600.
	ECHO=x	**x=Y**: Echo characters as you type. **x=N**: Do not echo characters.
	MOOREDTXREALTIME =x	**x=Y**: Output real-time data. **x=N**: Do not output real-time data.
	BATTERYTYPE=x	**x=0**: Alkaline batteries. **x=1**: Ni-Cad batteries.
	PTYPE=x	**Pressure sensor type -** **x=0**: No pressure sensor. **x=1**: Strain gauge. **x=2**: Quartz without temperature compensation. **x=3**: Quartz with temperature compensation.
	REFPRESS=x	**x=** reference pressure (gauge) in db to use if SBE 16*plus* does not include pressure sensor.
	VOLT0=x	**x=Y**: Sample external voltage 0. **x=N**: Do not.
	VOLT1=x	**x=Y**: Sample external voltage 1. **x=N**: Do not.
	VOLT2=x	**x=Y**: Sample external voltage 2. **x=N**: Do not.
	VOLT3=x	**x=Y**: Sample external voltage 3. **x=N**: Do not.
	SBE38=x	**x=Y**: Sample SBE 38 secondary temperature sensor. **x=N**: Do not.
	GTD=x	**x=Y**: Sample Gas Tension Device. **x=N**: Do not.
	DUALGTD=x	**x=Y**: Sample dual (2) Gas Tension Devices. **x=N**: Do not.
	MOOREDPUMPMODE =x	**x=0**: No pump. **x=1**: Run pump for 0.5 seconds before each sample. **x=2**: Run pump during each sample.
	DELAYBEFORESAMPLING =x	**x=** time (seconds) to wait after switching on external voltage before sampling (0-32,000 seconds). Default 0 seconds.
	OUTPUTFORMAT=x	**x=0**: output raw frequencies and voltages in Hex. **x=1**: output converted data in Hex. **x=2**: output raw frequencies and voltages in decimal. **x=3**: output converted data in decimal.
	OUTPUTSAL=x	**x=Y**: Calculate and output salinity (psu). Only applies if **OUTPUTFORMAT=3**. **x=N**: Do not calculate and output salinity.
	OUTPUTSV=x	**x=Y**: Calculate and output sound velocity (m/sec). Only applies if **OUTPUTFORMAT=3**. **x=N**: Do not calculate and output sound velocity.
	FLASHINIT	Map bad blocks and erase FLASH memory, **which destroys all data in SBE 16*plus***.
	QS	Enter quiescent (sleep) state. Main power turned off, but data logging and memory retention unaffected.

CATEGORY	COMMAND	DESCRIPTION
GTD Setup/Testing	**GTD=x**	**x=Y**: Sample Gas Tension Device. **x=N**: Do not.
	DUALGTD=x	**x=Y**: Sample dual (2) Gas Tension Devices. **x=N**: Do not.
	TGTD	Measure Gas Tension Device(s), output 1 converted data sample for each GTD.
	SENDGTD=command	Command SBE 16*plus* to send **command** to GTD and to receive response (**command** can be any command recognized by GTD).
Logging	**SAMPLEINTERVAL=x**	**x=** interval (seconds) between samples (5 - 14,400).
	NCYCLES=x	**x=** number of measurements to take and average every **SAMPLEINTERVAL** seconds. Default = 1.
	INITLOGGING	After all previous data has been uploaded, send this command before starting to log to make entire memory available for recording. If not sent, data stored after last sample. Equivalent to **SAMPLENUMBER=0** command.
	SAMPLENUMBER=x	**x=** sample number for first sample when logging begins. After all previous data has been uploaded, set to 0 before starting to log to make entire memory available for recording. If not reset to 0, data stored after last sample. Equivalent to **INITLOGGING** command.
	HEADERNUMBER=x	**x=** header number for first header when logging begins.
	STARTNOW	Start logging now.
	STARTMMDDYY =mmddyy	Delayed logging start: month, day, year. Must follow with **STARTHHMMSS=**.
	STARTDDMMYY =ddmmyy	Delayed logging start: day, month, year. Must follow with **STARTHHMMSS=.**
	STARTHHMMSS =hhmmss	Delayed logging start: hour, minute, second.
	STARTLATER	Start logging at delayed logging start time.
	STOP	Stop logging or stop waiting to start logging. Press Enter key to get **S>** prompt before entering command. Must stop logging before uploading data.
Data Upload	**DDb,e**	Upload data beginning with scan b, ending with scan e. Stop logging before sending this command.
	DHb,e	Upload headers from header b to header e.
Sampling	**SL**	Output last sample from buffer and leave power on.
	SLT	Output last sample from buffer, then take new sample and store data in buffer. Leave power on.
	TS	Take sample, store data in buffer, output data, and leave power on.
	TSS	Take sample, **store in buffer and FLASH memory**, output data, and turn power off.
	TSSON	Take sample, **store in buffer and FLASH memory**, output data, and leave power on.
Testing Takes and outputs 100 samples for each test (except as noted). Press Esc key or Stop on Toolbar to stop test.	**TT**	Measure temperature, output converted data.
	TC	Measure conductivity, output converted data.
	TP	Measure pressure, output converted data.
	TV	Measure 4 external voltage channels, output converted data.
	TF	Measure frequency (Quartz pressure sensor), output converted data.
	T38	Measure SBE 38 (secondary temperature), output converted data.
	TTR	Measure temperature, output raw data
	TCR	Measure conductivity, output raw data.
	TPR	Measure pressure, output raw data.
	TVR	Measure 4 external voltage channels, output raw data.
	TFR	Measure frequency (Quartz pressure sensor), output raw data.
	PUMPON	Turn pump on for testing purposes.
	PUMPOFF	Turn pump off for testing purposes.

Note:
Use the Upload button on the Toolbar or Upload Data in the Data menu to upload data that will be processed by SBE Data Processing. Manually entering the data upload command does not produce data in the correct format for processing by SBE Data Processing.

CATEGORY	COMMAND	DESCRIPTION
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 SBE 16*plus*.	**DCAL**	Display calibration coefficients; all coefficients and dates listed below are included in display (as applicable). Use individual commands below to modify a particular coefficient or date.
	TCALDATE=S	**S**=Temperature calibration date.
	TAO=F	**F**=Temperature A0.
	TA1=F	**F**=Temperature A1.
	TA2=F	**F**=Temperature A2.
	TA3=F	**F**=Temperature A3.
	TOFFSET=F	**F**=Temperature offset correction.
	CCALDATE=S	**S**=Conductivity calibration date.
	CG=F	**F**=Conductivity G.
	CH=F	**F**=Conductivity H.
	CI=F	**F**=Conductivity I.
	CJ=F	**F**=Conductivity J.
	CPCOR=F	**F**=Conductivity pcor.
	CTCOR=F	**F**=Conductivity tcor.
	CSLOPE=F	**F**=Conductivity slope correction.
	CF0=F	**F**=Conductivity 0 value (Compatible State only).
	PCALDATE=S	**S**=Pressure calibration date.
	PRANGE=F	**F**=Pressure sensor full scale range (psi).
	POFFSET=F	**F**=Pressure offset correction.
	PA0=F	**F**=Strain gauge pressure A0.
	PA1=F	**F**=Strain gauge pressure A1.
	PA2=F	**F**=Strain gauge pressure A2.
	PTEMPA0=F	**F**=Strain gauge pressure temperature A0.
	PTEMPA1=F	**F**=Strain gauge pressure temperature A1.
	PTEMPA2=F	**F**=Strain gauge pressure temperature A2.
	PTCA0=F	**F**=Strain gauge pressure temperature compensation ptca0.
	PTCA1=F	**F**=Strain gauge pressure temperature compensation ptca1.
	PTCA2=F	**F**=Strain gauge pressure temperature compensation ptca2.
	PTCB0=F	**F**=Strain gauge pressure temperature compensation ptcb0.
	PTCB1=F	**F**=Strain gauge pressure temperature compensation ptcb1.
	PTCB2=F	**F**=Strain gauge pressure temperature compensation ptcb2.
	PC1=F	**F**=Quartz pressure C1.
	PC2=F	**F**=Quartz pressure C2.
	PC3=F	**F**=Quartz pressure C3.
	PD1=F	**F**=Quartz pressure D1.
	PD2=F	**F**=Quartz pressure D2.
	PT1=F	**F**=Quartz pressure T1.
	PT2=F	**F**=Quartz pressure T2.
	PT3=F	**F**=Quartz pressure T3.
	PT4=F	**F**=Quartz pressure T4.
	PSLOPE=F	**F**=Quartz pressure slope correction.
	EXTFREQSF=F	**F**=External frequency (Quartz pressure sensor) scale factor.

Appendix IV: Compatible State

Sea-Bird can provide a custom EEPROM for the SBE 16*plus* to accommodate customers with older SBE 16s who need to replace the electronics but want to maintain the command set and output format of the original instrument. Instruments with this custom EEPROM operate in Compatible State.

Compatible State Commands

Notes:
The following Compatible State commands have equivalent commands in the SBE 16*plus* command set:
- **IL** = **INITLOGGING**
- **GL** = **INITLOGGING** followed by **STARTNOW**
- **RL** = **STARTNOW**
- **QL** = **STOP**

- Commands marked with ***** (***** is not part of the command) alter the SBE 16*plus'* memory and require verification before executing, to prevent accidental modifications.
  After the command entry, the SBE 16*plus* responds:
  'message' Y/N Type **Y** and press the Enter key.

  The SBE 16*plus* then responds:
  Are you sure ^Y/N Hold down the Ctrl key and type **Y** (any other response aborts command).
- Braces [ ] indicate optional command parameters. Items enclosed in braces need not be entered.

NRC

x=Y: Set conductivity channel to narrow range (fresh water, 0 - 0.6 S/m). If set to narrow range, the **DS** command indicates Narrow Range Conductivity.

x=N: Set conductivity channel to standard range (salt water, 0 - 6.5 S/m).

IL *****

Initialize logging - after all previous data has been uploaded from SBE 16*plus*, initialize logging before starting to log again to make entire memory available for recording. This command resets the sample number and header number to 0. If **IL** is not sent, data will be stored after the last recorded sample. **Do not send this command until all existing data has been uploaded.**

GL *****

Start logging now, overwriting existing data. First scan is set to 0, so any previously recorded data will be over-written, regardless of whether memory has been initialized or not.

RL *****

Resume logging now; do not overwrite existing data. Data is stored after last previously stored sample.

QL *****

Quit logging. Press Enter key to get **S>** prompt before entering this command.

Note:
You must quit logging before uploading data.

Notes:
- To save data to a file, click the Capture button on the Toolbar before entering the **DD**, **DC**, or **DH** command.
- In all upload commands, **B** is upload baud rate (1= 600 baud, 2 = 1200 baud, 3 = 9600 baud, 4 = 19200 baud, 5 = 38400 baud).
- See *Data Output Formats* after these *Command Descriptions*.
- **Use the Upload button on the Toolbar or Upload Data in the Data menu to upload data that will be processed by SEASOFT**. Manually entering the data upload command does not produce data in the correct format for processing by SEASOFT.

DD[Bb,e]

Upload raw data from scan **b** to scan **e,** at baud rate **B**. If **B** is omitted, baud rate that you are currently communicating with is used. If **b** and **e** are omitted, all data is uploaded. First sample is number 0.

Example: Upload samples 0 through 199 at 38400 baud to a file: (Click Capture on Toolbar and enter desired filename in dialog box.)
S>DD50,199

DH[b,e]

Upload headers from **b** to **e**. Baud rate is baud rate that you are communicating with currently. If **b** and **e** are omitted, all headers are uploaded. First header is 0. The header includes:
- header number
- month, day, hour, minute, and second when header was written
- first and last sample in header
- sample interval
- reason logging was halted
  (batfail = battery voltage too low;
  switch off = switch turned off;
  recv cmd = received **QL** command;
  timeout = error condition;
  unknown = error condition;
  ?????? = error condition)

Compatible State Output Format

Note:
Sea-Bird's data processing software (SEASOFT-DOS) uses the equations shown to perform these calculations; alternatively, you can use the equations to develop your own processing software.

In Compatible State, data is always output in Hexadecimal form. The parameters are output in the order listed below, with no spaces or commas between the parameters. Shown with each parameter are the number of digits in the data, and how to calculate the parameter from the data (use the decimal equivalent of the hex data in the equations).

The parameters are defined as follows:

- tttt = 2 bytes of temperature frequency
- cccc = 2 bytes of conductivity frequency
- pppp = 2 bytes of pressure data for Paine strain gauge pressure sensor
- pppppp = 3 bytes of pressure data for Quartz pressure sensor
- dddd = 2 bytes of pressure temperature data for Quartz pressure sensor
- uuu = 12 bits representing first stored voltage
- vvv = 12 bits representing second stored voltage
- xxx = 12 bits representing third stored voltage
- yyy = 12 bits representing fourth stored voltage

Shown below are the data formats:

- No external voltages sampled:
  With Paine pressure sensor - ttttccccpppp
  With Quartz pressure sensor - ttttccccpppppppdddd
- Two external voltages sampled:
  With Paine pressure sensor - ttttccccuuuvvvpppp
  With Quartz pressure sensor - ttttccccpppppppuuuvvvdddd
- Four external voltages sampled:
  With Paine pressure sensor - ttttccccuuuvvvxxxyyypppp
  With Quartz pressure sensor - ttttccccpppppppuuuvvvxxxyyydddd

The following equations define the calculation of the parameters from the data (use the decimal equivalent of the hex data in the equations):

- Raw temperature frequency = (tttt / 19) + 2100
- Raw standard conductivity frequency =
  square root [(cccc * 2100) + 6,250,000]
- Raw narrow range conductivity frequency (older models) =
  square root [(cccc * 303) + 6,250,000]
- Voltage = voltage number (such as uuu) / 819
- Paine pressure = decimal equivalent of bits 0 - 13 of pppp.
  Bit 14 is sign bit: + if bit 14 = 0; - if bit 14 = 1.
- Quartz pressure = pppppp / 256
- Quartz pressure temperature =
  {[(dddd / 819) + 9.7917] * 23.6967} - 273.15

Example: SBE 16*plus* with Quartz pressure sensor and two external voltages sampled, example scan = 69CC43228D1B8003005908AA

- tttt = 69CC (27084 decimal);
  temperature frequency = (27084 / 19) + 2100 = 3525.474Hz
- cccc = 4322 (17186 decimal); conductivity frequency =
  square root [(17186 * 2100) + 6250000] = 6059.340 Hz
- pppppp = 8D1B80 (9247616 decimal);
  Quartz pressure = 9247616 / 256 = 36123.5
- uuu = 030 (48 decimal); voltage = 48 / 819 = 0.059 volts
- vvv = 059 (89 decimal); voltage = 89 / 819 = 0.109 volts
- dddd = 08AA (2218 decimal); Quartz pressure temperature =
  {[(2218 / 819) + 9.7917] * 23.6967} - 273.15 = 23.0

Appendix V: Replacement Parts

Part Number	Part	Application Description	Quantity in SBE 16*plus*
30816	Parker 2-234E603-70	Battery end cap to housing piston seal (1), sensor end cap to housing seals (2)	3
30090	Parker 2-153N674-70	Battery end cap to housing face seal	1
31090	Screw, 10-32 x 5/8 flat Phillips-head, titanium	Secures conductivity cell guard to housing	2
31089	Screw, 10-32 x 1/2 flat Phillips-head, titanium	Secures sensor end cap to housing (side opposite conductivity cell guard)	1
30145	Screw, 6-32 x 1/2 Phillips-head, stainless steel	Secures battery cover plate to battery posts	3
30242	Washer, #6 flat, stainless steel	For screw 30145 (secure battery cover plate to battery posts)	3
80076.1	Battery cover plate	Retains batteries	1
22018	Batteries	Power SBE 16*plus*	9
17394	2-pin cable	From SBE 16*plus* to pump	1
80087	4-pin I/O cable	From SBE 16*plus* to computer	1
17130	25-pin to 9-pin adapter	Connects I/O cable to 9-pin COM port on computer	1
17043	Locking sleeve	Locks cable/dummy plug in place	4
17044	2-pin dummy plug	For when pump not used	1
17046	4-pin dummy plug	For when I/O cable not used	1
17047	6-pin dummy plug	For when auxiliary differential input sensors not used	2
24173	Anti-foul cylinder	Anti-foul poison tubes inserted into anti-foul cups	2
231505	Anti-foul cap	Secures anti-foul cylinder in cup	2
30984	Anti-foul plug	Seals end of anti-foul assembly when not deployed	2
50091	Triton X-100	Conductivity cell cleaning solution	1
60021	Spare battery end cap parts	Assorted o-rings and hardware	-
50273	Spare hardware kit	Assorted hardware	-
50274	Spare o-ring kit	Assorted o-rings	-
50276	Seaspares kit	Includes 50273 and 50274, as well as bulkhead connectors, dummy plugs, and other parts	-

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