SEA·BIRD
SCIENTIFIC

User manual

Shallow SeaFET™ V2 pH sensor

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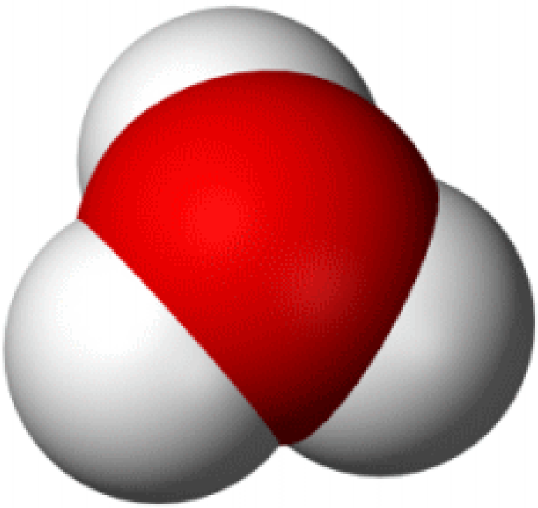

425-643-9866
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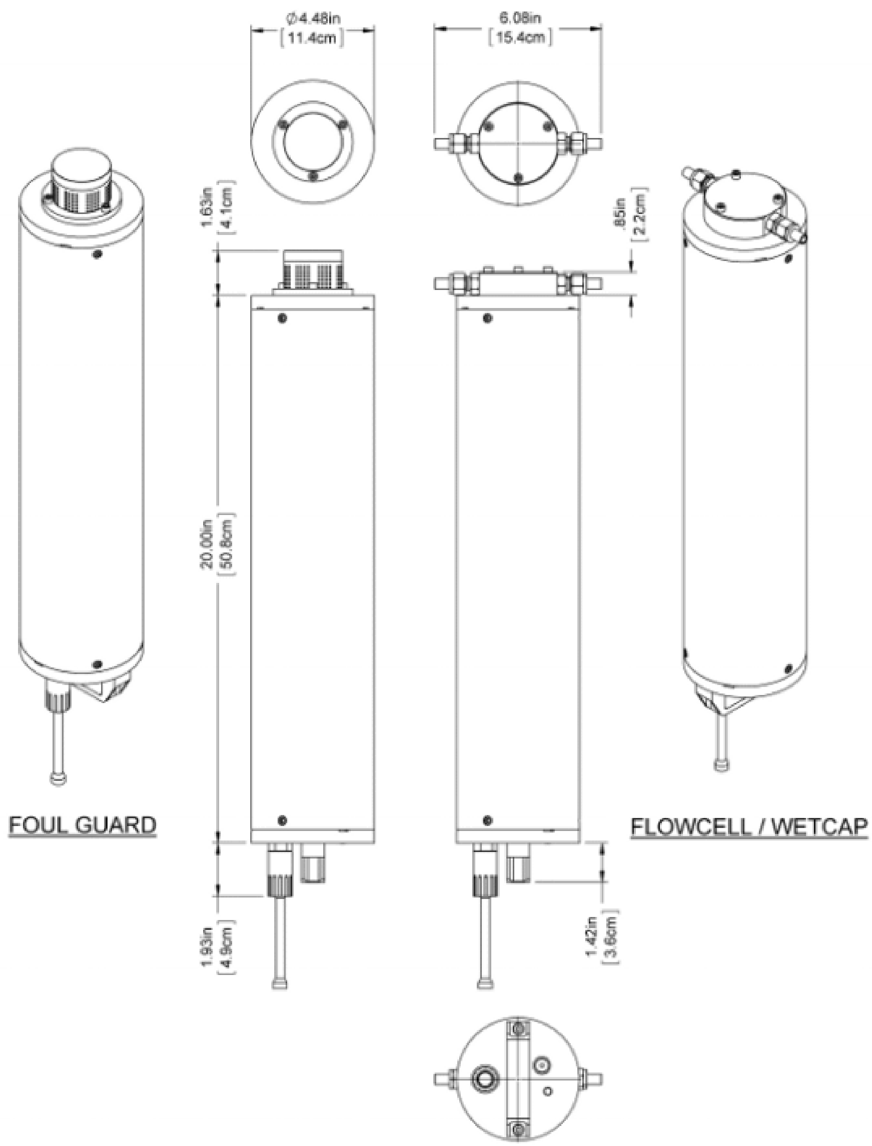
Table of Contents

Section 1 Specifications

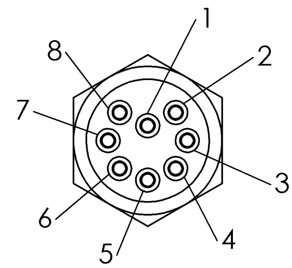
1.1 Mechanical

Rated depth	50 m
Weight in air, water	5.4 kg, 0.1 kg
Length	50.8 cm 4.1 cm (anti-fouling guard) 2.2 cm (flow cell)
Diameter	11.4 cm
Temperature range, operation	0–50 °C
Temperature range, storage	2–55 °C

SeaFET™ V2 dimensions



1.1.1 Bulkhead connector

Contact	Function	MCBH-8-MP
1	Voltage in	
2	Power supply return-signal ground	
3	No connect	
4	CTD/pump V in (12 V, 650 mA, optional)	
5	TXD/D+	
6	RXD/D-	
7	CTD TXD (optional)	
8	CTD RXD (optional)	

1.2 Electrical

Input	6–18 VDC
Current draw, operation	main battery: 340–400 mW, isolated battery pack: 10 µA
Current draw, low power	main battery: 70 µA, isolated battery pack: 1.1 mA
Real-time clock drift	2 ppm (0–40 °C)
Communication interface	RS232: 9600–115200 baud 19200 baud (default)
Data storage	32 Mb (over 1240000 samples)

1.3 Analytical

Measurement range	6.5–9.0 pH
Salinity range	2–40 psu
Accuracy	±0.05 pH
Precision	better than 0.004 pH
Resolution	0.0001 pH
Stability	0.005 pH/mo

Section 2 Product overview

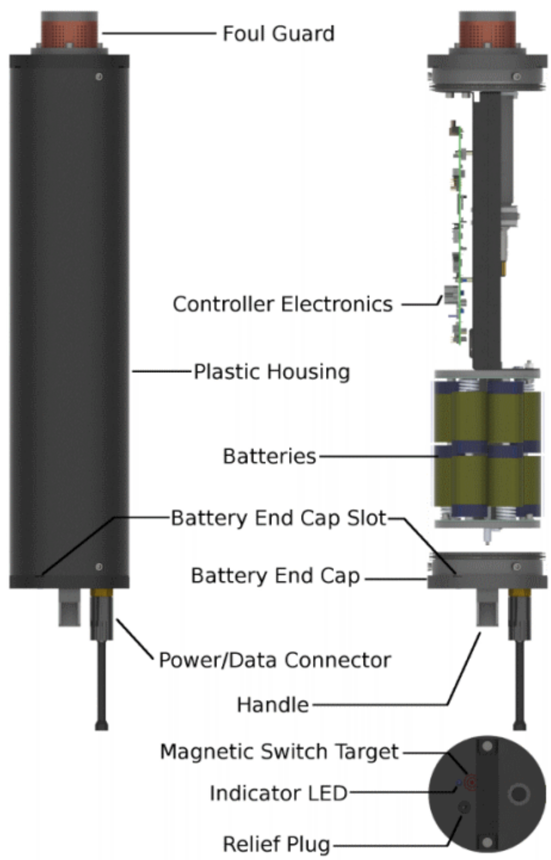
⚠ CAUTION

When sensor is not in use, make sure that the wet cap is in place and is filled with clean seawater. Do not put the sensing elements in fresh water: it may cause data to be unstable and damage to the sensor.

⚠ CAUTION

Do not let the DuraFET potassium chloride (KCl) gel or the wet cap filling solution freeze. This will damage the DuraFET and void the warranty.

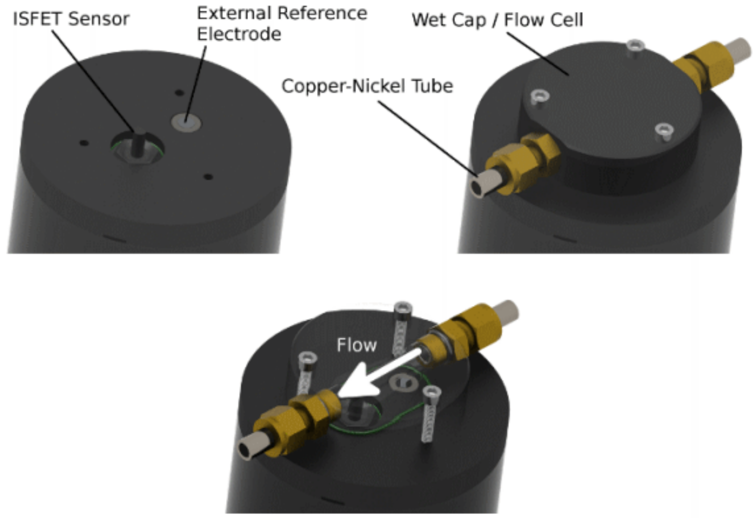
The sensor uses ion-sensitive field effect transistor (ISFET) technology to measure pH in marine environments at depths to 50 meters. The sensor stores data and has an internal battery pack so that it can operate autonomously for a long-term deployment.



The SeaFET™ can attach to an external pump or a Sea-Bird SBE37 CTD. When attached to the CTD, the system operates in SeapHOx™ mode, which also measures temperature, salinity, oxygen and depth.

The manufacturer-supplied software lets the user set up the sensor, monitor graphical data in real time, upload stored data, and process that data.

The end flange with the ISFET sensor and the external reference electrode must be covered with a seawater-filled cap during storage. This cap is also used as a flow cell when the SeaFET™ is connected to a pump. If the sensor will be completely underwater, attach the copper anti-fouling guard instead.



2.1 Ion-sensitive field effect transistor (ISFET)

The primary sensor element of the SeaFET™ is the ISFET, a solid-state sensor that senses pH in marine environments. The ISFET has two reference electrodes: an internal reference and an external reference, that give separate reference potentials to the ISFET and show separate pH values (pH internal and pH External). After the corrections for temperature and salinity are applied, the values from the internal and external are similar, and let the user verify the validity of the sensor's measurements.

Internal reference

The internal reference is part of the DuraFET® sensor and has a silver/silver chloride (Ag/AgCl) electrode bathed in a saturated potassium chloride (KCl) solution. Ions in seawater diffuse across a frit on the DuraFET® and propagate the charge to the internal reference electrode. The electrode stays isolated from the sensed medium, which allows the pH Internal measurements to remain relatively stable at the expense of some uncertainty. If accurate salinity and temperature data are not available to correct the external cell, the internal cell is generally more accurate.

External cell

The external reference has and Ag/Ag/Cl reference electrode in direct contact with seawater. The potential of this electrode varies with pH and chloride concentration, so unless chloride concentration is known, the external reference is not stable. To correct this, salinity can act as an approximation of chloride concentration. If accurate salinity data is available, it can be applied to the pH external data and significantly reduce measurement errors, and give the most accurate and stable pH data.

Section 3 Set up sensor and verify operation

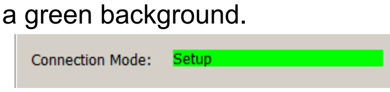
Make sure that the sensor has new batteries installed or is connected to a power supply (optional) and PC through the RS232 connector on the supplied cable, and is on.

Most PCs no longer have RS232 "COM" ports so an RS232-to-USB converter is necessary. Make sure that the USB driver software is installed on the PC so that there is communication between the sensor and the PC.

3.1 Install and start software

The manufacturer-supplied software communicates with a number of sensors. The sensors that are supported are listed in the **Sensor** menu of the software.

1. Get the software from manufacturer's website or the manufacturer-supplied CD.
2. Install the appropriate software.
    a. For Windows™: Double-click on the file with ".exe" appended to the name.
    b. For Mac OS X: Double-click on the file with ".pkg" appended to the name. Make sure that the default "Install for all users on this computer" is selected as the destination for the installed software.
3. Push **Run** in the new window.
   The setup wizard starts.
4. Follow the on-screen instructions to install the software.
5. Connect the cable to the bulkhead connector on the sensor and to the PC.
6. If necessary, start the software.
7. Push **Connect** in the Dashboard area.
8. If necessary, change the "Instrument Type" to the connected sensor.
9. Put a check in the "Try All Baud Rates" box.
   The software automatically finds the correct baud rate.
10. If necessary, select the communication port.
11. Push **Connect**.
    The "Connection Mode" shows "Transition" on a yellow background, and then shows "Setup" on a green background.



12. Verify that the "Deployable Status" shows "Ready to Deploy."
13. Make sure that the "Clock Time" is correct.

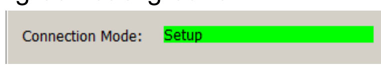
3.1.1 Set clock

The sensor uses an internal clock to apply date- and time-stamps to collected data and to schedule sensor activity. Set the internal clock of the sensor so that it is aligned with the PC. Note that the sensor clock is always set to Coordinated Universal Time (UTC). To change this, go to the **Preferences** menu, then *Display*, and remove the check in the box next to "Use UTC Time."

1. Make sure that the sensor is connected to a PC and has power supplied to it.
2. If necessary, start the software.
3. Select **Sensor**, *SeaFET*, *Advanced*, *Set Clock* from the main menu.
4. Push **Synch Time** to align the sensor clock with the clock of the PC.

3.2 Verify sensor operation

Do the steps below to make sure that the sensor operates, collects, and transfers data with the settings selected by the user before further setup and deployment.

1. Connect the cable to the bulkhead connector on the sensor and to the PC.
2. If necessary, start the software.
3. Push **Connect** in the Dashboard area.
4. If necessary, change the "Instrument Type" to the connected sensor.
5. Put a check in the "Try All Baud Rates" box.
   The software automatically finds the correct baud rate.
6. If necessary, select the communication port.
7. Push **Connect**.
   The "Connection Mode" shows "Transition" on a yellow background, and then shows "Setup" on a green background.
   

8. Go to the *General* tab and push **Browse** to find or make the *Default Data Directory* on the PC.
   Data from the sensor is saved here. Note that the UCI software can be started by a double-click on a ".sbsdat" filetype.
9. Push **OK**.

3.2.1 Components

The SeaFET™ V2 has 12 manufacturer-installed D-cell batteries to supply power to the sensor. The LED near the magnetic switch shows the status of various sensor operations.

The LED shows the status of the sensor. It no longer lets the user change data settings or power settings.

Table 1 LED status flashes

No flash	Sensor batteries or memory not ready for deployment	• RTC battery is below 2.5V • Isolated battery is below 4.0V • Main battery or external power supply is below 7.0V • Memory is full
Red flash	Sensor has not received a command to collect data	• The sensor is in standby for a command to begin data collection • Push "Start" to start data collection. ("startnow" or "startlater" in a terminal program.)
Green flash	Sensor is in operation	Logger-controlled (polled) data collection occurs. The sensor has received a "Start," "startnow," or "startlater" command.

The internal batteries are divided into a 12 V main battery pack and a 6 V isolated battery pack. The main battery pack supplies power to the sensor and the isolated battery pack supplies power to the sensing element when the sensor is in a low power "standby" mode.

Power can be supplied to the sensor from either the internal batteries or an external power source. The sensor will use an external source when the voltage is at or above 9 volts, but the internal batteries must be installed so that the sensing element has permanent, uninterrupted power. A loss of power to the sensing element (complete removal of the internal batteries and any external power) requires that the sensor be "re-conditioned," which can take up to 24 hours.

3.2.2 General

Go to the **UCI** menu, then *Preferences*, to select the *General* settings for the sensor.

1. Set the Connection Settings:
   - Enter the "Maximum Wakeup Attempts" for the number of times the software will try to connect to a sensor. Range: 5–15.
   - Enter the "Response Timeout" for the interval of time of communication between the sensor and the software. Range: 5–10.
2. Enter the Default Data Directory:
   - Enter the file path or push **Browse** to find the directory in which to save data from the sensor.
   - If the "Prompt at startup" box has a check in it, the user can change the directory that the data is stored in every time the software starts.
3. Push **Apply**.
4. Push **OK** to save the settings.

3.2.3 Display

Go to the **UCI** menu, then *Preferences*, to select *Display* settings for the sensor.

1. Put a check in the box for the sensor to show time in UTC.
2. Put a check in the "Open Instrument Console" box to see this window when the software starts.
3. Put a check in the "Open Application Console" box to see this window when the software starts.
4. In the Performance Optimization Settings area:
   - Enable or disable the "Real Time Display" in the software.
   - Enable or disable the "Time Series Graph."
   - SUNA only: Enable or disable the "Spectra Graph."
   - SUNA only: Enable or disable the "Total Absorbance Graph."
5. In the Time Series Settings area:
   - Put a check in the box at "Time Axis Range Unbounded" to include all data over time.
   - Enter a value between 1 and 1440 to limit the time range of the data shown.
   - Select either "Single Plot" or "Multiple Plots" as the type of chart.
6. SUNA only—Spectra Graph Settings:
   - Put a check in the box at "Graph History Unbounded" to include all data over time.
   - Enter a value between 1 and 2147483647 to limit the time range of the data shown.
7. SUNA only—Total Absorbance Graph Settings:
   - Enter a value between 150 and 400 nm for the "Minimum Wavelength Cutoff."
   - Put a check in the box at "Graph History Unbounded" to include all data over time.
   - Enter a value between 1 and 2147483647 to limit the time range of the data shown.
8. Push **Apply**.
9. Push **OK** to save the settings.

3.2.4 Message logging

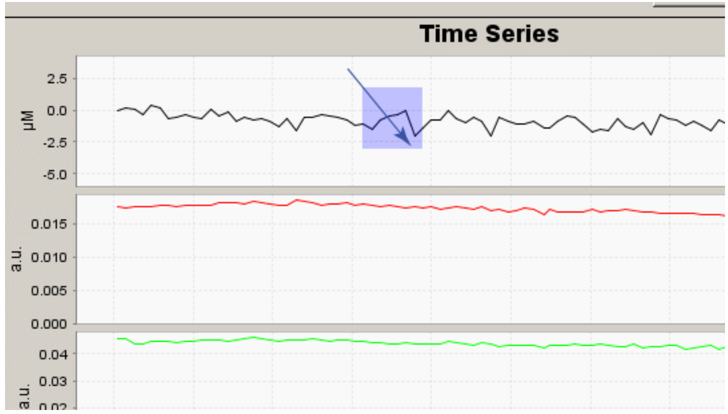
The software automatically saves files that have information about the sensor use, data collection, and software operation over time. This information helps the user and Customer Support find any problems and do troubleshooting.

Go to the **UCI** menu, then *Preferences*, to select *Message Logging* settings for the sensor.

1. In the Message Logging area, select the level of message to see.
    - INFO: Typical level of detail for a deployment. Keeps a log of all high-level operations.
    - ERROR: Keeps only errors that typically need to be examined.
    - WARN: Keeps only warnings within the system. Good for long deployments.
    - DEBUG: A moderate level of detail, used mainly by support staff at the manufacturer. Both DEBUG and TRACE files are very large.
    - TRACE: The most detailed level, used mainly by the manufacturer for troubleshooting.
2. Put a check in the box at "Display Dialog for Error Level Messages" to see an alert when an ERROR message is saved.
3. Select "Daily Log Files" to make a new file each day.
4. Select "Rolling Log Files" to store a user-specified "Maximum Number" that is no larger than the "Maximum Size" log files.
5. Put a check in the box at "Enable Logging Lost Bytes" to save extra bytes or incomplete data frames (which are typically discarded) to help with troubleshooting.
6. Push **Apply**
7. Push **OK** to save the settings.

3.3 Verify sensor collects data

1. Push **Start** in the Dashboard area.
   The "Connection Mode" shows "Acquisition."
    - Push **OK** so that the software is "Temporarily enabling Transmit Real Time Setting..." The software shows the data as it is collected in the *Time Series* tab.
    - The **Expected Data Start** window shows "You will see data in approximately *xxx* seconds" and shows an indication of time left. This lets the sensor become stable before it starts to collect data.
2. Put a check in the box next to any additional parameters, so that they will show in the *Time Series* graph.
3. Optional: save data directly to the PC.
    a. Go to the **View** menu and select Data Logging.
    b. Push **Logging Options** to see details in this tab.
    c. Push **Browse** to change the directory to which data is saved on the PC.
    d. Push **Start Logging to File**.
4. Look at the data in the *Time Series* graph. The user can look at data in real-time for each sensor that has power supplied, is connected and is in communication with the software.
    - Put a check in the box next to "Time Axis" to push **Zoom In** and **Zoom Out** to change the scale of time.
    - Put a check in the box next to "Range Axis" to push **Zoom In** and **Zoom Out** to change the scale of the data.
    - To move the data in any direction, push the "Ctrl" key on the PC keyboard and the left button of the mouse pointer at the same time.
    - To select a specific part of the data to zoom in on, pull the mouse pointer diagonally (refer to the arrow in the graph below).



- Push **Auto Range** to see the data for each selected parameter. The software adjusts the scale so that the data will always show.
- Push **Default Ranges** to go back to the manufacturer-set default scale for each parameter.
- Put a check in the box next to "Show Data Points" to see the value of the collected data when the mouse moves over each point.
- Push **Select Sensors To Display** to change the parameters to look at in the *Time Series* graph.

5. Let the sensor collect data for approximately 5 minutes.

6. Push **Stop** in the Dashboard.
The "Connection Mode" mode shows "Setup."

3.4 Transfer data

⚠ CAUTION

Use only the batteries recommended by the manufacturer as replacements. Do not mix new and used cells or chemistries.

1. Push **Transfer Data** in the Dashboard area.
The **Transfer Data** window shows.

- The Memory Summary lets the user estimate the available data storage in the sensor. The "Sample Length" is sensor-specific and shows the length of each data record that the sensor stores. "Free Samples" shows how many more samples the sensor can store.

2. In the "Transfer Type" drop-down menu in the Data Transfer Options area, select either "All Data" or "Block size (bytes)."

- "All Data": all data stored in the sensor is transferred to the PC in both .csv and .sbsdat file types.
- "Sample Number Range": a user-specified range of samples. Select the specific samples in the Sample Number Range area.

3. In the Data Transfer area, select the baud rate for data transfers from the sensor to the PC.
The software temporarily increases the sensor's baud rate to upload data more quickly. After the transfer is complete, the software changes the baud rate to the default for the connected sensor.

4. In the CSV Format Options area, specify either the "UTC' or "Local" time stamp.

5. In the Output CSV Data File area, type a new filename or use the automatically generated file name.

6. Push **Transfer**.

- The data is copied to the PC.
- The software uploads a raw **.sbsdat** file and automatically converts the data to a readable **.csv** file type.
- The Transfer Progress window shows the status of the file transfer and conversion.
- The default is a check in the boxes for "Display Data when Conversion Completed" and "Close this Dialog when Conversion Completed."

Section 4 Deployment and recovery

Remove any bubbles from the wet cap on the sensor before deployment. Bubbles may collect on the sensing elements and compromise the data quality. The manufacturer recommends that the user submerge the sensor and use a syringe and tubing to flush the wet cap or the anti-fouling guard. The sensor can be deployed either vertically or horizontally. Make sure that the sensing elements face up, with the battery endcap down, to help prevent the collection of bubbles.

The sensing elements are sensitive to light. If the sensor is deployed near the surface, make sure the exposure to light is limited. It can help to deploy the sensor vertically with the sensing elements point downward.

To prepare the sensor for deployment—

1. Engage the magnetic switch and LED to verify that the LED blinks red or green.
2. Install the anti-fouling guard if it is available, or remove the plastic plugs from the wet cap to deploy without the anti-fouling guard.
3. Connect the deployment cable to the sensor and a PC.
4. Make sure that settings are correct in the *Settings*.
5. Push **Start** in the software. In a terminal emulator, send "startnow" or "startlater."
6. Engage the magnetic switch. Make sure that the LED blinks green. This shows that the sensor is in operation or will be in operation at the specified start date and time.

4.1 Deployment wizard

The deployment wizard makes it easy to set up the sensor for a specific deployment.
Autonomous operation mode

1. Preset data collection times.
2. Push **Synchronize SeaFET clock to computer**. The sensor and the PC show the same time.
3. Set the date and time for the sensor to start data collection.
4. Put a check in the box to send collected data in real time to a connected controller. Data is still stored in the sensor if this box does not have a check in it.
5. **Pump Settings**: put a check in the box to enable operation of an external pump. Values can be between 0–255. If set to 0, the pump will operate continuously.
6. Battery Endurance: enter the temperature of the water in which the sensor will be deployed.
   Enter the data collection interval. Minimum = 10 seconds.
7. Make a deployment report to see sensor statistics, calibration values, and settings.

Polled (controlled) operation mode

1. Commanded data collection.
2. Push **Synchronize SeaFET clock to computer**. The sensor and the PC show the same time.
3. Output format shows the order of the data values from the sensor.
4. **Pump Settings**: put a check in the box to enable operation of an external pump. Values can be between 0–255. If set to 0, the pump will operate continuously.
5. Battery Endurance: enter the temperature of the water in which the sensor will be deployed. Enter the data collection interval. Minimum = 10 seconds.
6. Make a deployment report to see sensor statistics, calibration values, and settings.

4.2 Remove wet cap

1. If necessary, unplug the cable from the sensor.
2. Remove the two plastic plugs from the wet cap. Keep them for future use.

3. Put the sensor over a sink or bucket and empty the solution of filtered seawater from the wet cap.
4. Put the sensor upright again.
5. Use a 5/32" hex key to remove the three 10-32 x 5/8" socket head cap screws from the wet cap. Keep the screws to use with the anti-fouling guard.
6. Remove the wet cap. Keep the O-ring for future use.
7. Use a clean dry cloth to clean the sensor and the wet cap of any artificial seawater.
8. Make sure to keep the wet cap, O-rings and plastic plugs for future use.

4.3 Attach anti-fouling guard and deployment cable

1. Put the sensor on a flat surface with the external reference electrode end flange face up.
2. Put the anti-fouling guard over the ISFET and external reference electrode.
3. Use a 5/32" hex key to install the three 10-32 x 5/8" socket head cap screws that secured the wet cap. Make sure to tighten completely.
4. If necessary, disconnect the test cable from the sensor and connect the deployment cable. If the sensor is to be deployed autonomously, attach the dummy plug and lock collar onto the connector.

4.4 Real-time data collection

Real-time data collection is only possible when the sensor is configured to output data with every sample collected. Go to **Sensor**, *SeaFET*, *SeaFET Settings* to change this setting to real-time data transfer under the *Data* tab.

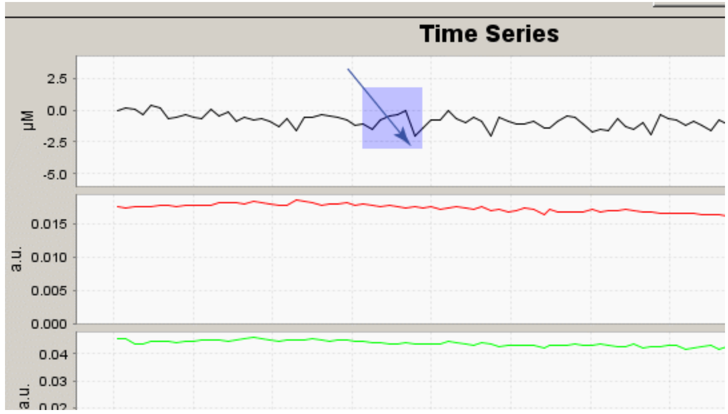
4.4.1 Start data collection

1. Make sure that the sensor has power supplied and is connected to the software.
2. Make sure that there is a check in the box at "Transmit Data in Real Time."
3. Make sure that the "Output Format" is as selected.
4. Push **Start**.

4.4.2 Look at collected data

The user can monitor data in the *Real Time Data* or the *Time Series* graph. Information about the data, such error statistics, shows in the *Acquisition Monitor*, and the collected data is saved to a file on the sensor.

1. The *Real Time* display is continuously updated to show the most recent data collected by the sensor.
2. Look at the data in the *Time Series* graph. The user can look at data in real-time for each sensor that has power supplied, is connected and is in communication with the software.
    - Put a check in the box next to "Time Axis" to push **Zoom In** and **Zoom Out** to change the scale of time.
    - Put a check in the box next to "Range Axis" to push **Zoom In** and **Zoom Out** to change the scale of the data.
    - To move the data in any direction, push the "Ctrl" key on the PC keyboard and the left button of the mouse pointer at the same time.
    - To select a specific part of the data to zoom in on, pull the mouse pointer diagonally (refer to the arrow in the graph below).



- Push **Auto Range** to see the data for each selected parameter. The software adjusts the scale so that the data will always show.
- Push **Default Ranges** to go back to the manufacturer-set default scale for each parameter.
- Put a check in the box next to "Show Data Points" to see the value of the collected data when the mouse moves over each point.
- Push **Select Sensors To Display** to change the parameters to look at in the *Time Series* graph.

3. Select the **View** menu, then *Acquisition Monitor* (or push **Error Details** on the *Real Time Data* window.
   Use this window to see when and why there are errors in the data.

4.4.3 Save real-time data

The sensor has sufficient internal memory to save months or even years of data. For tethered operation such as profiling or a pre-deployment test, the user can set up the software to save data as it is transmitted from the sensor.

1. Make sure that the sensor is connected to the software.
2. In the *Settings* window, set the mode of operation to *Continuous*.
3. Push **Start**.
4. From the main menu, select **View**, then *Data Logging*.
5. Push **Start Log**.
   The PC starts to save the data collected by the sensor.
   - To enable "Auto Log Duration," put a check in the box and specify a time to stop the data from being saved.
   - To enable "Repeat Auto Log after Interval," put a check in the box and specify a time interval after which the data will be saved.
6. To stop data from being saved to the PC, push **Stop Log**.

4.4.4 Configure data file headers

The user can add custom headers to data files in addition to the default OPERATOR, EXPERIMENT, and COMMENT static headers.

1. Select the **Sensor** menu, then *Advanced*, then *Data Log Header*.
2. Push **Add**
3. Double-click the HEADER_ID row to enter a custom header.
4. Push **OK**.
5. To remove a custom header, select the row to remove and push **Remove**.
6. Put a check in the "Prompt" box so that the software will ask for input of the header record values whenever data collection is started.

4.5 Logger-controlled data collection

In this mode the sensor is controlled by a system controller such as a buoy controller, CTD with a serial port, or STOR-X.

4.6 Recover sensor from deployment

⚠ CAUTION

Do not let the sensing elements get dry. If the sensor will not be deployed immediately, put the wet cap in place and fill with artificial seawater.

Examine the sensor

Make sure that the sensing elements are protected at all times. When the sensor is not submerged, the wet cap must be installed on the sensor and filled with filtered seawater.

Look at the sensing elements. Clean them if there are any particulates near them or the ISFET. Look at the ceramic frit at the base of the ISFET: it should be white or off-white. Refer to Clean electrode and sensing element on page 22 for procedures to clean the sensing elements.

Section 5 Data retrieval and analysis

The sensor can save and send data at the same time, and the manufacturer-supplied software can transfer files from the sensor to the connected PC. Refer to Transfer data on page 11 for details.

5.1 Data format

Data from the sensor is output in ASCII, in "frames." Each frame has a row of data values. The values and the order of values in each frame is OutputFormat=1. Data is separated by a comma and a space. Every frame ends with a carriage return <CR> and line feed <LF>.

OutputFormat=1 is data converted to engineering units, in decimal format. The order of output:

- FrameSync
- Timestamp
- Sample number
- Data error flag
- pH external
- pH internal
- Vrs_ext
- Vrs_int (DuraFET only)
- pH temperature (DuraFET only)
- Internal temperature

Example output:

```
SEAFET00281,2018-05-01T08:24:28, 10, 0000,6.9227,6.8275,-0.936386,-0.993090, 23.1636, 42.2,23.7
```

Note that values for salinity, sound velocity, specific conductivity, and sample number are not sent, even if the settings shows these as "on."

5.1.1 Diagnostic data format

OutputFormat=0 is data in decimal format used by the manufacturer for diagnostics. The order of output:

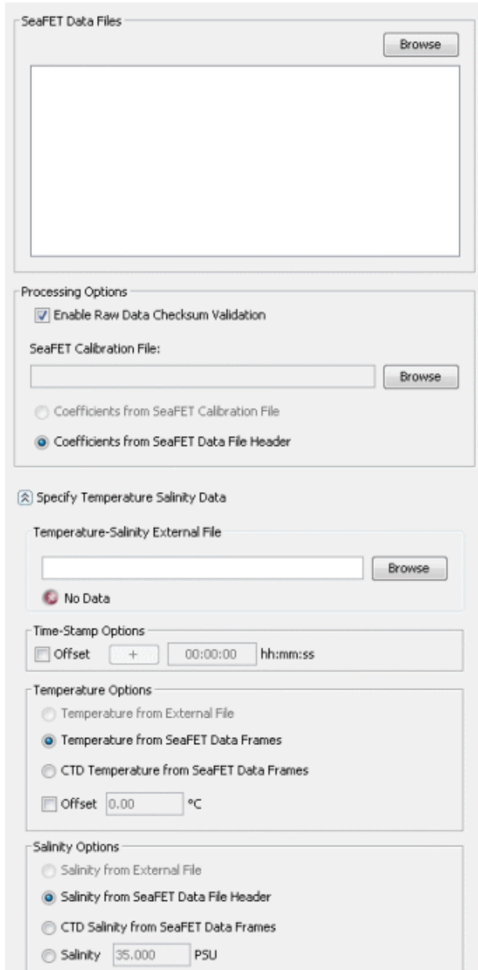
- FrameSync
- Timestamp
- Data error flags
- Temperature
- Vrs_ext
- Vrs_int
- pH temperature
- Vk
- Ib
- Ik
- Internal relative humidity
- Internal temperature

Example output:

```
SEAFET00201, 2018-05-01T08:20:33, 0000, 5189166, 4989334, 972849, 6043289, 8379635, 8384892, 26208, 28824
```

5.2 Process data

Use the *Data Processing Panel* in the software to process the .sbsdat data files that have already been transferred to the PC. The user can add temperature and salinity measurements to calculate a more accurate pH value than that from the SeaFET™ V2 sensor, which uses an internal thermistor and a fixed salinity value.



<u>SeaFET Data Files</u>

1. Select **Data**, *SeaFET*, then *SeaFET Data Processing* from the main menu.
2. Push **Browse** to find and select one or more raw files to put in the <u>SeaFET Data Files</u> list. There are several ways to change which files are selected:
   - Select one file. All others are de-selected.
   - Hold **Ctrl** and select a file to change whether it is selected or de-selected. The other files that are already selected will not change.
   - Hold **Shift** and select a file to select a range of files.
   - Hold **Ctrl** and **Shift** to select a range of files. The other files that are already selected will not change.
   - Use the "up" and "down" arrow keys instead of a mouse.

<u>Specify Temperature Salinity Data</u>

Select the up-arrows to the left of "Specify Temperature Salinity Data" to open the menu.

Push **Browse** to find the file with the temperature and salinity data from an external sensor. The software uses this data in one of two formats:

A generic .csv format, YYYY-MM-DD hh:mm:ss, <temperature>, <salinity><CR><LF>, where:

- date and time is UTC when the data was collected
- temperature is in C°, floating point format
- <salinity is in PSU, in floating point format

- <CR><LF> is the carriage return and line feed that is the end of the line, or row, of data.

For example—

- 2013-04-25 15:22:48, 10.8326,34.8974

Sea-Bird Electronics .CNV format as made from the *SBE Data Processing* software application. Convert CTD data so that the software can read it:

1. Copy the .hex and .xmlcon files from the CTD to the SBE Data Processing directory.
2. Select **Run** from the main menu, then *Data Conversion*.
3. In the *File Setup* tab, select the .hex and .xmlcon files to convert.
4. Go to the *Data Setup* tab. Push **Select Output Variables**.
5. In the Select Output Variables area, add the fields below in order:
   a. Time, sensor (seconds)
   b. Temperature (degrees C)
   c. Salinity, practical (PSU)
6. Push **Start Process**. The software makes a .cnv file.

The data looks similar to the example below:

388682568 10.8326 34.8974 0.000e+00

388682574 10.8547 34.8950 0.000e+00

Time-stamp Options

Put a check in the "Offset" option to specify a positive or negative time offset for the external temperature and salinity data. This will adjust for clock or time zone differences between the two sensors.

Temperature Options

Select one of the options for the source of temperature data for the SeaFET™ to process:

- "Temperature from External File"—values from an external sensor.
- "Temperature from internal Durfet"—values from the DuraFET internal thermistor.
- "CTD Temperature form SeaFET Data Frames"—values from the data frames of the SeaFET from an attached CTD.
- Put a check in the "Offset" box and enter a value to apply to the temperature. The value can be from an external file, from the SeaFET™, or from a CTD.

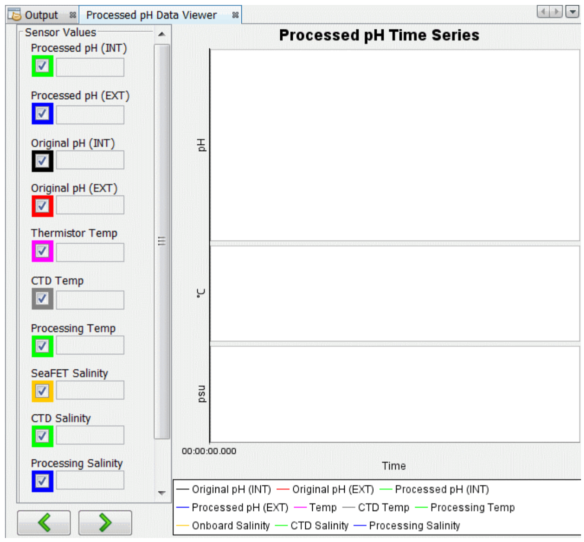
Salinity Options

Select one of the options for the source of salinity data for the SeaFET™ to process:

- "Salinity from External File"—values from an external sensor.
- "Reference Salinity"—value stored in the sensor.
- "Salinity"—specify a salinity value used to process all pH data.

5.3 Show processed data

The processed data shows in *Time Series* graph of the software.



Click on the graph to get a marker to see the data from all plots. These show in the "Sensor Values" on the left side of the tab and change as the user moves the marker.

5.4 Export logged data

Export the data stored in the sensor to either a comma-separated file or a Microsoft® Excel file with a local or UTC time stamp.

1. From the **Data** menu, select *Export Logged Data*.
2. Push **Browse** to find the file to export.
3. Select a file from the list.
    - Select "SUNA Logged Data File" in the "Files of Type" to see the **.csv** and **.bin** files that show for SUNA, **or**
    - Select "Instrument Logged Data File" in the "Files of Type" to see the **.sbsdat** file that shows for all other supported sensors.
4. Push **Open**
5. Push **Next**.
   The output format shows (all sensors but SUNA).
6. Push **Next**.
7. Select the Export Options, the Format Options, and the Exported Data Output File location.
   The data is stored in the directory selected in "Exported Data Output File" area.
8. Push **Finish**.

5.5 Replay data from multiple sensors

The software lets the user replay data that has been saved on the PC from each supported sensor. The user can select up to 12 parameters to replay.

1. Go to the **Data** menu, then *Replay Logged Data*.
2. Go to the area of the first supported sensor and push **Browse** to go to the .csv file-type.
3. Select the file, then push **Open**.
4. Push **Select Sensors for Display**.
5. Put a check in the box of each parameter to look at in the *Time Series* graph.
6. Push **OK**.

Section 6 Maintenance

⚠ CAUTION

When sensor is not in use, make sure that the wet cap is in place and is filled with clean seawater. Do not put the sensing elements in fresh water: it may cause data to be unstable and damage to the sensor.

⚠ CAUTION

Do not use high-purity water such as Milli-Q on the sensor. The manufacturer recommends clean tap water over DI water.

⚠ CAUTION

Do not leave the sensor in direct sun. Heat over 35 °C can cause damage to the sensor.

⚠ CAUTION

Do not touch the sensing elements. They are sensitive to electrostatic discharge (ESD).

⚠ CAUTION

Do not let the sensor come in contact with solutions that do not contain bromide (and NIST-type buffers). This can void the calibration.

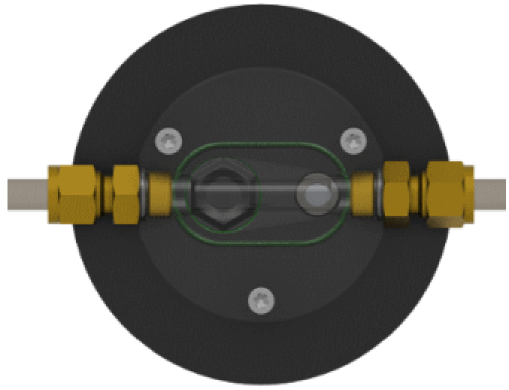
⚠ CAUTION

Use only the batteries recommended by the manufacturer as replacements. Do not mix new and used cells or chemistries.

6.1 Install wet cap

The wet cap is filled with filtered natural seawater that has a salinity equivalent to 35 ppt. The sensing element and reference electrodes **must** be kept wet with either the anti-fouling guard or the wet cap, even if the sensor is out of service for a few minutes.

1. Put the sensor on a flat surface.
2. Remove the anti-fouling guard:
   a. Use a 5/32" hex key to remove the three 10-32 x 5/8" socket head cap screws. Keep the screws to use with the wet cap.
   b. Remove the anti-fouling guard from the sensor.
3. Put the wet cap O-ring into the groove at the bottom of the cap. Make sure that the O-ring is not twisted or pinched. Do not use O-ring grease near the sensing element and reference electrode.
4. Put the wet cap over the element and electrode. Make sure that the O-ring touches the face of the end flange.
5. If the wet cap will be used as a flow cell, make sure it is installed in the orientation below so that sufficient water flows through the sensing elements.



6. Use the three 10-32 x 5/8" socket head cap screws to secure the wet cap to the end flange.
7. If necessary, remove the plugs and fill the wet cap with sterilized artificial seawater.
8. Insert the plugs again.
    a. Make sure they are sealed.
    b. If necessary, empty a small amount of water to insert the last plug.
9. Clean the sensor housing and wet cap with a clean lint-free wipe.

6.2 Clean electrode and sensing element

Clean the sensing surfaces after a deployment and before the sensor is put in storage.

1. Remove the wet cap or anti-fouling guard that is attached to the sensor.
2. Flush the electrodes with warm tap water to remove particulates.
3. To remove other types of fouling:
    a. Use a household cleaner such as Joy® or Windex® or a laboratory soap such as Sparkleen® or Detergent 8® to remove oily deposits.
    b. Use diluted hydrochloric acid to remove mineral deposits. Rinse thoroughly with artificial seawater or tap water.
    c. Rinse with high-purity isopropyl alcohol (90% or higher). Do not submerge in alcohol.
4. Use lint-free wipes or cotton swabs to gently dry the sensing elements.

6.3 Remove and replace batteries

Replace the batteries in the sensor when necessary. Use the sensor *Dashboard* in the software or use the magnetic switch to make sure that the batteries have sufficient power for a deployment.

Table 2 Required tools and supplies

8/32" thumb screw	flat head screwdriver
5/32" hex wrench	2 new desiccant packs or sealable plastic bag to store the packs removed from the sensor
1/4" socket driver	12 new alkaline D-cell batteries

1. Make sure that the wet cap or anti-fouling guard is attached to the sensing elements.
2. Remove the vent plug:
    a. Put the sensor on its side on a flat surface.
    b. Put the 8/32" thumb screw into the center thread of the vent plug.
    c. Pull on the thumb screw until it does not come out any further.

3. Use a 5/32" hex wrench to remove the three 10-31 x 3/8" screws from the battery end flange.

4. Insert a flat head screwdriver into the slot between the pressure housing and the end flange.

5. Loosen the end flange with the screwdriver until the end flange can be pulled from the pressure housing with one hand.
   A safety line attaches the end flange to the battery plate to keep the battery connector wires attached.

6. Press the locking tab on the white end flange connector to disconnect and gently pull it out.
7. Remove the desiccant packs and put them in a sealed bag.
8. Remove the two ¼" nuts that hold the battery plate:

- When batteries are installed, the battery plate compresses six springs that hold the batteries. Make sure to loosen the nuts equally—loosen one a few turns, then the other—so that the battery plate does not lock.

9. Remove the batteries.
10. Follow the polarity labels and put in new batteries.

- Change all of the batteries. Do not mix used and new cells.
- Do not mix battery chemistries. The manufacturer recommends industrial 1.5V alkaline D-cells.

11. Examine, clean, and if necessary, lubricate the O-rings on the end flange.

12. Examine and clean the surface on the inside of the battery compartment where the O-rings sit.

13. Replace the desiccant packs.

The old ones can be used again, but the manufacturer recommends that the user install new packs.

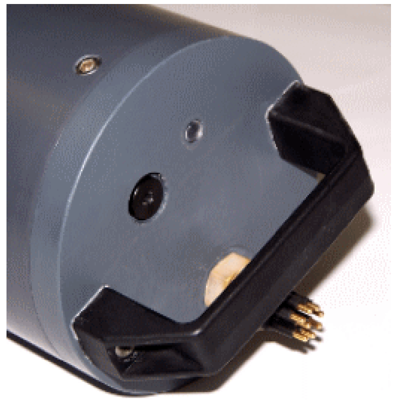
14. Put the battery plate into position and tighten the two nuts equally until the battery plate is flush with the white connector.

15. Connect the battery connector. Make sure that it "locks" in the receptacle.

16. Install the end flange. Make sure that the wiring is not pinched.

17. Use a hex wrench to install the three 10-31 x 3/8" screws.

18. Fully insert the vent plug.



19. Connect the sensor to the software and turn on the internal batteries.
    The voltages in the sensor *Dashboard* are 12V and 6V. If they are not, open the sensor and correct the problem.

6.4 Maintain bulkhead connector

CAUTION

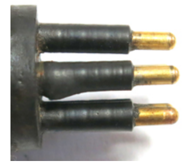
Do not use WD-40® or petroleum-based lubricants on bulkhead connectors. It will cause damage to the rubber.
Damaged connectors can cause a loss of data and additional costs for service.

Damaged connectors can cause damage to the sensor and make it unserviceable.

Examine, clean, and lubricate bulkhead connectors at regular intervals. Connectors that are not lubricated increase the damage to the rubber that seals the connector contacts. The incorrect lubricant will cause the bulkhead connector to fail.

1. Apply isopropyl alcohol (IPA) as a spray or with a nylon brush or lint-free swab or wipes to clean the contacts.
2. Flush with additional IPA.
3. Shake the socket ends and wipe the pins of the connectors to remove the IPA.
4. Blow air into the sockets and on the pins to make sure they are dry.
5. Use a flashlight and a magnifying glass to look for:

Cracks, scratches, or other damage on the rubber pins or in the sockets.		
Any corrosion.		

Separation of the rubber from the pins.	
Swelled or bulging rubber pins.	

6. Apply a small quantity of 3M™ Spray Silicone Lubricant (3M ID# 62-4678-4930-3) to the pin end of the connector. Make sure to let it dry.
7. Connect the connectors.
8. Use a lint-free wipe to clean any unwanted lubricant from the sides of the connectors.

6.5 Calibration

6.5.1 Manufacturer calibration

NOTICE

The manufacturer recommends that the user return the sensor annually for calibration to make sure it gives the highest level of accuracy for both pH calculation and re-processed data. Note that the DuraFET gel is a consumable component and is usually replaced annually as well. The external reference electrode is replaced as needed.

Calibration coefficients are stored in the sensor and are used with an on-board temperature measurement and the user-selectable salinity constant to calculate pH from the cell voltage potentials. The calculated pH value shows in each data frame sent from the sensor.

Calibration coefficients are written to the header section of every raw .sbsdat data file that uploaded from the sensor. The software uses these coefficients to re-process data.

Because the ISFET sensor is sensitive to pressure, the manufacturer's calibration is only valid for near-surface deployments. To get accurate measurements for deeper deployments, the manufacturer recommends that the user collect independent pH data in situ just before and after a deployment so that an offset correction can be applied.

6.5.2 Verify calibration

⚠ CAUTION

Do not use NIST-type buffers with the sensor to check accuracy. The chemistry of those buffers is not appropriate for marine pH measurements and can damage the external reference electrode.

The manufacturer recommends that the user monitor the accuracy of the calibration at regular intervals. Compare the calculated pH values with independent pH data that is collected just before and after a deployment, either in situ or from direct measurements of a primary standard under temperature-controlled conditions.

One procedure for pre- and post-deployment checks is to start with a sample of known pH and salinity (TRIS or other Certified Reference Material).

1. Fill the wet cap with the sample. Close the opening and update the stored salinity value with the sample salinity value: in the software, go to **Sensor**, *SeaFET*, *SeaFET Settings*, then *Processing* to enter the updated sample salinity value.
2. Make sure the sensor and a bottle of the additional sample is at a constant temperature in a bath (e.g. overnight).
3. Flush the wet cap with the sample and then fill the wet cap. Return the sensor to the bath. Record data until the values are stable and similar to the expected values. Do not leave the standard TRIS recipe (it has no bromine) in the wet cap for extended periods of time because it will start to change the chemistry of the external reference electrode and void the calibration.

Section 7 Reference

7.1 Acquisition monitor

The software has an *Acquisition Monitor* window that shows the results of a data collection event. The user can look at it to see any problems with the data. In most cases, the number of frames with bad data are minimal, but the information in this window can help the user see why and when errors occur.

7.2 Terminal commands

This is a reference for advanced users. The values of these commands are stored in the sensor until the user changes them. Notes about terminal commands are listed below.

- Commands are not case-sensitive. Use "Enter" to store a command.
- The sensor sends an error message if a command is invalid.
- The argument Y and 1 are both "Yes" and N and 0 are both "No." For example, OutputSal=y and OutputSal=1 are equivalent.
- If there is no communication with the sensor for 2 minutes, it goes into a low power mode. Use "Enter" to start communication again.
- Use the "Esc" key or type ^C, then "Enter" to stop the sensor as it sends data.
- If the user sent StartNow (autonomous mode) and the sensor is in operation or in standby, the user can use the Status commands, TS, TPS, SL, QS, and Stop. For example, if the user sends a DS to see status data, the sensor completes the current measurement and then responds to the command. If OutputExecuted=Y, the sensor will send "executing" messages until the measurement is complete.
- If the user sent StartLater (autonomous mode) and the sensor is operation or in standby, the user can use the Status commands, TS, TPS, SL, QS, and Stop. To send other commands, enter the Stop command, then enter any other commands, and send StartLater again.

Status

GetCD	show configuration
GetSD	show status
GetCC	show calibration coefficients
GetEC	show event counter
Reset EC	reset event counter
GetHD	show hardware
Help	shows list of available commands
DS	show status and configuration
DC	show calibration coefficients
pHCalHist	show pH sensor calibration history related to stored data

General setup

DateTime=x	set clock. format is mmddyyyyhhmmss
BaudRate=x	RS232 rates. Default is 19200. 600*, 1200*, 2400*, 4800, 9600, 19200, 38400, 57600, 115200. *available only if no oxygen sensor is not installed.
OutputExecutedTagx	x=Y: show XML executing and executed tags. x=N: do not show
TxRealTime=x	x=Y: send real-time data during autonomous operation or in serial line sync mode. x=N: do not send

QS	puts sensor in low power ("quiescent") state. Sensor continues to take measurements and store data.
OutputFormat=x	x=0: send raw decimal data. x=1: send converted decimal data.
Initlogging	resets the memory pointer to sample number 0. Makes all memory available for storage. Send command twice to confirm.
*Default	reset user settings back to the defaults as shipped from the manufacturer
SampleInterval=x	x=interval in seconds between samples (6–21600) when command is sent with StartNow or StartLater.

Data collection

StartNow	start data collection now.
StartLater	start data collection at a specified time in the future
StartDateTime=	mmddyyyhhmmss is format for delayed data collection start time
Stop	stop data collection, or wait to start data collection if StartLater was sent
SL	sends as output the last sample stored in the buffer
TS	take sample, store data in buffer, send data, leave power on
TPS	operate pump, collect data once, send data in the current specified format
TSS	take sample, store in buffer and in flash memory, send as output. Valid only if usepump=Y or in SeapHOx™ mode.
PSS	operate pump, collect a sample, store in buffer and in flash memory, send as output. Valid only if usepump=Y or in SeapHOx™ mode.
Getsamples:b,e	upload converted data, where b=start sample number, and e=end sample number. Total must be less than 5000.
Recoversamples	restore the stored sample number. Use to restore the sample number after the "initlogging" command is sent but before any new data is collected.
ReferenceSalinity=x	sets the salinity value in psu that is used in calculations

Pump setup

MinCondFreq=x	minimum conductivity frequency for pump to operate, Hz
PreFlush=x	time, in seconds, for pump to operate before the first measurement. Default is 300. Range 300–600. If autonomous operation starts with StartNow, the pre-flush starts immediately. If autonomous operation starts with StartLater, the pre-flush starts *x* seconds before scheduled start time.
PreFlushStartTIme=x	set mmddyyyyhhmmss for controlled ("polled") data collection set 0 to disable the pre-flush for controlled data collection
OxNTau=x	pump operation time multiplier. Default is 7.0. Range 0–100.0.
PumpTime=x	time the pump operates for each measurement, when oxygen sensor is installed. Range 0–550.
PumpOn	start pump. Pump will stop after 2 minutes without communication or when PumpOff is sent.
PumpOff	stop pump, if started with PumpOn.

SeaFET™ calibration coefficients

phcaldate=	sensor sends command to DO sensor and gets response.
K0=	set K0 coefficient
K2=	set K2 coefficient

ReferenceSalinity=	set the salinity value to be used in calculations
tdfcaldate=	DuraFET temperature calibration date, dd-mm-yy
tdfa0=	set DuraFET thermistor temperature coefficient, A0
tdfa1=	set DuraFET thermistor temperature coefficient, A1
tdfa2=	set DuraFET thermistor temperature coefficient, A2
tdfa3=	set DuraFET thermistor temperature coefficient, A3

SeapHOx™-specific

Resync	re-sync host SeaFET™ to SBE-37-SMP-ODO. Communicates with the 37 to configure the CTD and download coefficients and serial numbers from the attached SBE37 and SBE63
Send37=x	x = command for SBE37
Ctdpower=	configures the SeapHOx™ to provide power to the attached SBE37. Power can come from internal batteries or external source. x=0: do not power the SBE37. x=1: power the SBE37.
Setoxunits=x	x=0: show oxygen units in ml/L. x=1: show oxygen units in mg/L
Usectdt=	use CTD temperature value for calculations

7.3 Terminal program setup and use

If necessary, use a terminal program to set up and operate the sensor.

1. Use the test cable to connect the sensor to the PC and a 12V power supply.
2. Start a terminal emulator program such as HyperTerminal® or Tera Term.
3. Select "Serial" for the type of connection.
4. Set up the connection at 19200, 8 bits, no parity, 1 stop bit, flow control: none.

7.4 Polled data collection

The sensor collects data at user-specified intervals when it receives an RS232 polled sample command from an external controller. To operate the sensor manually, send any character and wait for 3 seconds for the sensor to go into Standby mode. The user has 2 minutes to send a polled sample command before the sensor returns to a low power mode. Refer to Terminal commands on page 29 for the description of the four polled sample commands.

The output from the sensor is a single frame of data. Send a polled sample command, then send the "qs" command to return the sensor to a low power mode. Otherwise the sensor will stay in Standby mode for 2 minutes and drain the batteries more quickly.

7.5 Calculate pH from raw data

Refer to the equations below for calculations that derive pH from the "shallow" SeaFET™ components:

- internal electrolyte gel ($V_{INT\ FET/REF}$)
- external solid-state electrochemical cell voltage readings ($V_{EXT\ FET/REF}$)
- sample pressure (P)
- sample temperature (T)
- sample salinity (S)

Refer to the cited references for more details.

The internal electrochemical cell shows a Nernstian response to pH and have a negligible response to the chloride activity (Martz et al. 2010). Then:

$$pH_{INT\ Cell} = \frac{V_{INT\ FET/REF} - k_{0\ INT} - k_{2\ INT} * t}{S_{nernst}}$$

The solid-state electrochemical cell shows a Nernstian response to pH but is also sensitive to the chloride activity. (Johnson et al. 2016). Then:

$$pH_{EXT\ Cell} = \frac{V_{EXT\ FET/REF} - k_{0\ EXT} - k_{2\ EXT} * t}{S_{nernst}} + \log(Cl_T) + 2 * \log(\gamma_{HCl}) - \log\left(1 + \frac{S_T}{K_S}\right) - \log\left(\frac{1000 - 1.005 * S}{1000}\right)$$

where

$$S_{nernst} = \frac{R * T * \ln(10)}{F}$$

R = universal gas constant (8.3144621 J/[K mol])

t = temperature in °C

T = temperature in K

S = salinity in psu

P = pressure in dbar

F = Faraday constant (96485.365 C/mol)

The constants k_0 and k_2 are the cell standard potential offset and temperature slope respectively.

Note that $k_{0\ \text{INT and EXT}}$ and $k_{2\ \text{INT and EXT}}$ are given as part of the sensor calibration remaining derivation of pH involves salinity, temperature, and pressure to derive:

Cl_T is Total Chloride

Y_{HCl} is the HCl activity coefficient

S_T is Total Sulfate

K_S is the Acid Dissociation Constant of $HSO_4^-{}_{\text{T and P}}$

Total chloride in seawater

$$Cl_T = \frac{0.99889}{35.453} * \frac{S}{1.80655} * \frac{1000}{1000 - 1.005 * S}$$

where S is salinity in psu.

Sample ionic strength

$$I = \frac{19.924 * S}{1000 - 1.005 * S}$$

where S is salinity in psu.

Debye-Huckel constant for activity of HCl

$$A_{DH} = 0.0000034286 * t^2 + 0.00067524 * t + 0.49172143$$

where t is temperature in °C.

Logarithm of HCl activity coefficient

$$\log(\gamma_{HCl}) = \frac{-A_{DH} * \sqrt{I}}{1 + 1.394 * \sqrt{I}} + (0.08885 - 0.000111 * t) * I$$

where A_{DH} is the Debye-Huckel constant for activity of HCl, I is the ionic strength, and t is the temperature in °C.

Total sulfate in seawater

$$S_T = \frac{0.1400}{96.062} * \frac{S}{1.80655}$$

where S is salinity in psu.

Acid dissociation constant of HSO_4^-

$$K_S = (1 - 0.001005 * S) * e^{\frac{-4276.1}{T} + 141.328 - 23.093 * \ln(T) + \left(\frac{-13856}{T} + 324.57 - 47.986 * \ln(T)\right) * \sqrt{I} + \left(\frac{35474}{T} - 771.54 + 114.723 * \ln(T)\right) * I - \left(\frac{2698}{T}\right) * I^{1.5} + \left(\frac{1776}{T}\right) * I^2}$$

where S is salinity in psu, T is temperature in K, and I is the ionic strength.

Section 8 General information

Revised editions of this user manual are on the manufacturer's website.

8.1 Warranty

This sensor is warranted against defects in materials and workmanship for one year from the date of purchase. The warranty is void if the manufacturer finds the sensor was abused or neglected beyond the normal wear and tear of deployment.

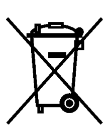
8.2 Service and support

The manufacturer recommends that sensors be sent back to the manufacturer annually to be cleaned, calibrated, and for standard maintenance.
Refer to the website for FAQs and technical notes, or contact the manufacturer for support at support@seabird.com.

Do the steps below to send a sensor back to the manufacturer.

1. Complete the online Return Merchandise Authorization (RMA) form or contact the manufacturer.
   ***Note:** The manufacturer is not responsible for damage to the sensor during return shipment.*
2. Remove all batteries from the sensor, if so equipped.
3. Remove all anti-fouling treatments and devices.
   ***Note:** The manufacturer will not accept sensors that have been treated with anti-fouling compounds for service or repair. This includes AF 24173 devices, tri-butyl tin, marine anti-fouling paint, ablative coatings, etc.*
4. Use the sensor's original ruggedized shipping case to send the sensor back to the manufacturer.
5. Write the RMA number on the outside of the shipping case and on the packing list.
6. Use 3rd-day air to ship the sensor back to the manufacturer. Do not use ground shipping.
7. The manufacturer will supply all replacement parts and labor and pay to send the sensor back to the user via 3rd-day air shipping.

8.3 Waste electrical and electronic equipment



Electrical equipment that is marked with this symbol may not be disposed of in European public disposal systems. In conformity with EU Directive 2002/96/EC, European electrical equipment users must return old or end-of-life equipment to the manufacturer for disposal at no charge to the user. To recycle, please contact the manufacturer for instructions on how to return end-of-life equipment, manufacturer-supplied electrical accessories, and auxiliary items for proper disposal.

Sea-Bird Electronics
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