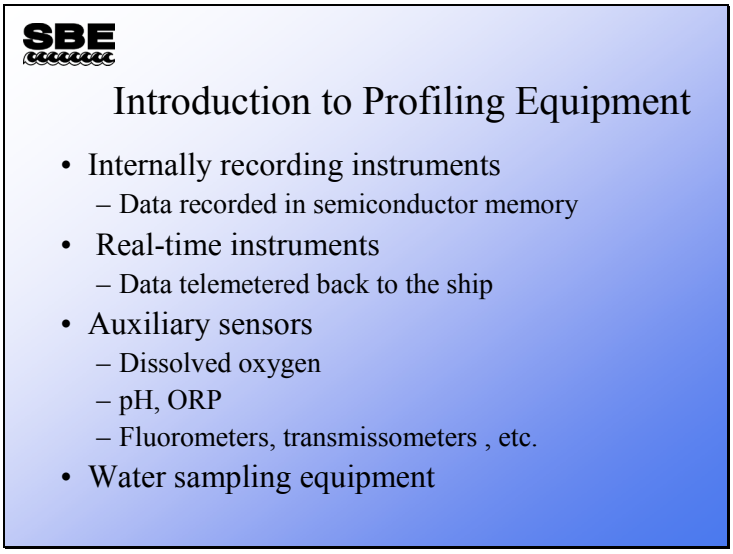
Module 1

Introduction to Profiling Equipment

Overview

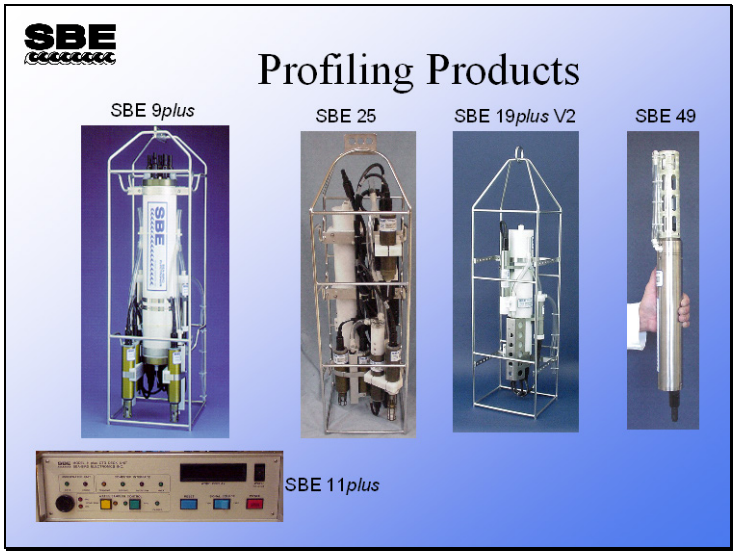


In this module we are going to present Sea-Bird's equipment offerings for profiling. We will present internally recording instruments first, followed by real-time instruments and then water sampling equipment.

At the end of this module you should be:

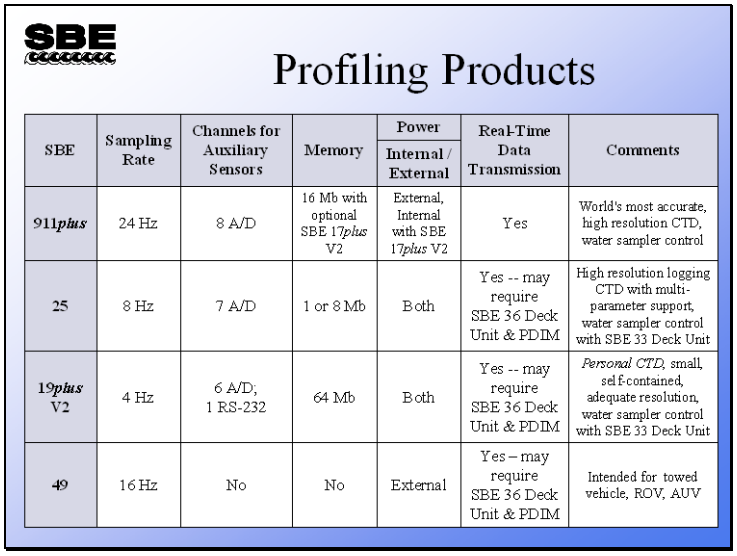
- Familiar with Sea-Bird's profiling product line.
- Aware of the difference between real-time and internally recording instruments.
- Familiar with the water sampling options available.
- Able to install Seasoft.

Profiling Products



Sea-Bird offers 4 profiling instruments: the real-time SBE 9*plus*/11*plus* system, the internally recording SBE 25 and SBE 19*plus* V2, and the real-time SBE 49. The capabilities of these instruments are contrasted in the following pages.

Profiling Products (*continued*)



SBE	Sampling Rate	Channels for Auxiliary Sensors	Memory	Power Internal / External	Real-Time Data Transmission	Comments
911*plus*	24 Hz	8 A/D	16 Mb with optional SBE 17*plus* V2	External, Internal with SBE 17*plus* V2	Yes	World's most accurate, high resolution CTD, water sampler control
25	8 Hz	7 A/D	1 or 8 Mb	Both	Yes -- may require SBE 36 Deck Unit & PDIM	High resolution logging CTD with multi-parameter support, water sampler control with SBE 33 Deck Unit
19*plus* V2	4 Hz	6 A/D; 1 RS-232	64 Mb	Both	Yes -- may require SBE 36 Deck Unit & PDIM	*Personal CTD*, small, self-contained, adequate resolution, water sampler control with SBE 33 Deck Unit
49	16 Hz	No	No	External	Yes – may require SBE 36 Deck Unit & PDIM	Intended for towed vehicle, ROV, AUV

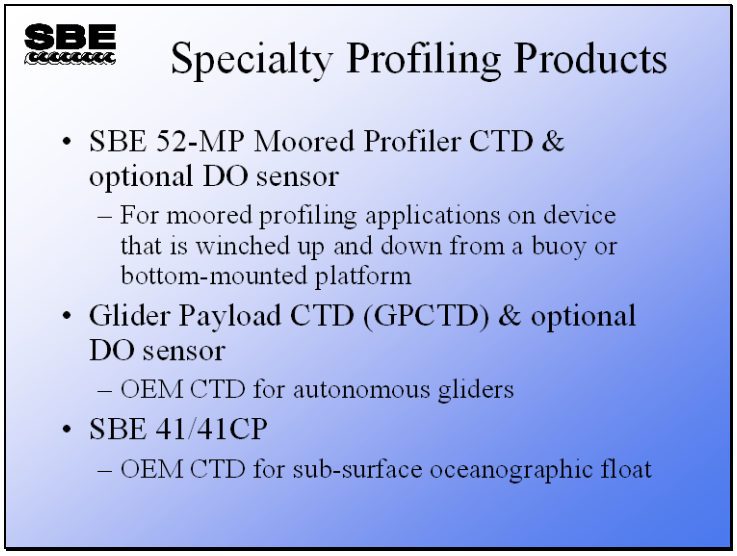
Sea-Bird's flagship CTD is the SBE 9*plus* and SBE 11*plus*. The 9*plus* is the underwater part of the system; it houses acquisition, telemetry, and power supply circuitry. The 9*plus* receives power from the 11*plus* deck unit and operates over more than 10 kilometers of sea cable. It can operate several types of water samplers and may be configured with a serial port multiplexed into the data stream, to accommodate instruments with serial output rather than the traditional voltage or frequency. It comes standard with pressure, 2 temperature and 2 conductivity channels, and 8 voltage channels.

The SBE 25 features internal recording at up to an 8 Hz sample rate. It supports temperature, conductivity, and pressure, plus 7 voltage channels. The 25 makes a smaller instrument package and is battery powered with semiconductor memory.

The SBE 19 and 19*plus* have been in the field since 1987, and there are over 2500 instruments in use at present. The SBE 19*plus* V2 is an enhancement of the 19*plus*. It is also battery powered with internal memory. It features independent temperature and conductivity channels, an integral T-C duct (hardware to improve the flow of water past the sensors), and 6 voltage channels. The 19*plus* V2 samples up to a rate of 4 Hz and averages 1 to 32767 scans (decreases the sample rate).

The SBE 49 is an integrated CTD sensor intended for use as a modular component in towed vehicles, ROVs, AUVs, or other platforms that can supply DC power and acquire serial data. The 49's pump-controlled, TC-ducted flow minimizes salinity spiking. The SBE 49 samples at 16 Hz.

Profiling Products (*continued*)



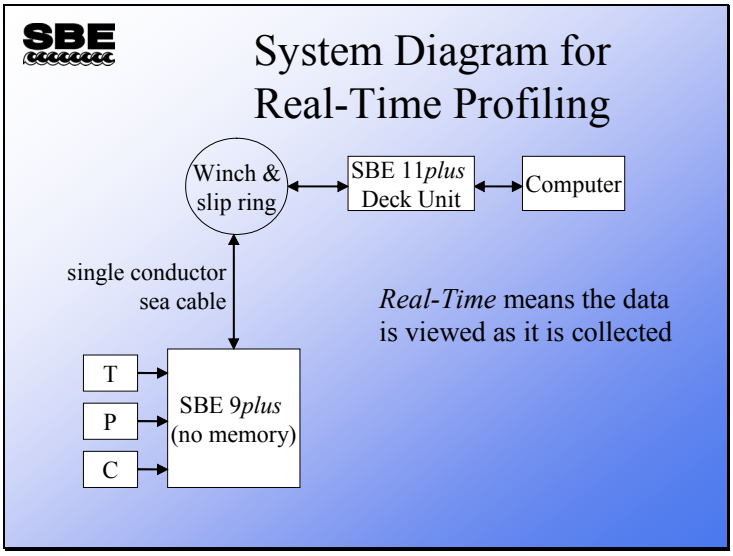
In addition to the *general purpose* profiling CTDs, Sea-Bird offers several CTDs for specific applications.

The SBE 52-MP Moored Profiler CTD that is designed for moored profiling applications in which the instrument makes vertical profile measurements from a device that travels vertically beneath a buoy, or from a buoyant sub-surface sensor package that is winched up and down from a bottom-mounted platform. The 52-MP samples at 1 Hz, is externally powered, and can store up to 28,000 samples. It can optionally be configured with an SBE 43F Dissolved Oxygen sensor.

The Glider Payload CTD (GPCTD) is a modular, low-power profiling instrument for autonomous gliders with the high accuracy necessary for research. The GPCTD samples at 1 Hz or at user-programmable sample intervals, and can store up to 559,000 samples. It can optionally be configured with an SBE 43F Dissolved Oxygen sensor.

The SBE 41 and 41CP are OEM CTDs for sub-surface oceanographic floats for the Argo program. We'll talk more about this at the end of the module.

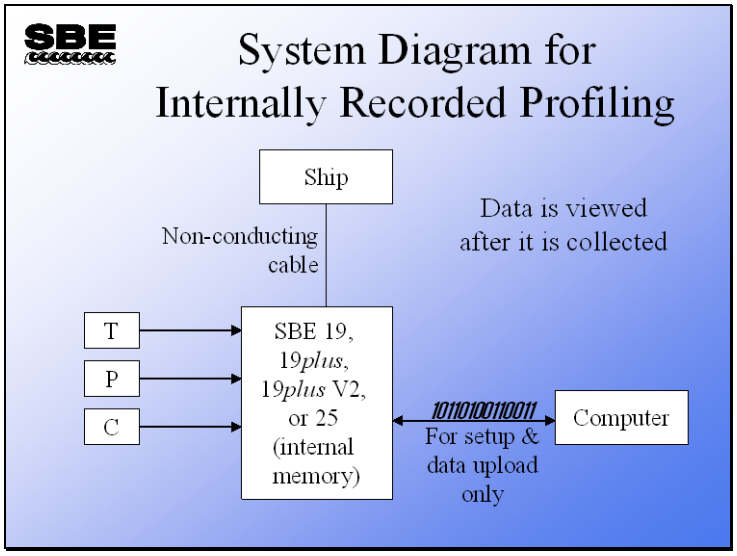
Real-Time Profiling



Real-time profiling means that you are viewing and storing data on your computer at almost the same time that the measurement is being made at the end of the winch cable. The *almost* part is because there is some time involved in packaging the bits up and sending them up the wire to the deck unit and then onto your computer.

The system consists of sensors that convert environmental parameters to electrically measurable quantities like voltage or frequency. The data acquisition component measures the sensors' outputs and telemeters them up the sea cable. The deck unit receives the telemetered data, does some minor manipulation, and transmits the data to your computer for display and storage. In the middle of all this is the winch and slip ring, which provide the mechanical means of getting the instrument package down into the ocean and the electrical data stream up to the deck unit.

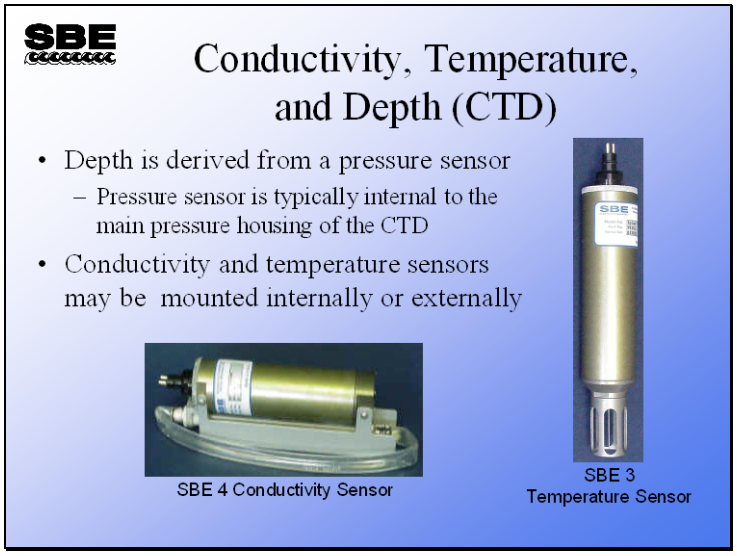
Cabling for Internally Recorded Profiling



Internally recorded profiling means that the measurements are stored in semiconductor memory inside the instrument and are downloaded to your computer and viewed *after* the equipment is on deck. The ship is not required to have a sea cable with an internal conductor.

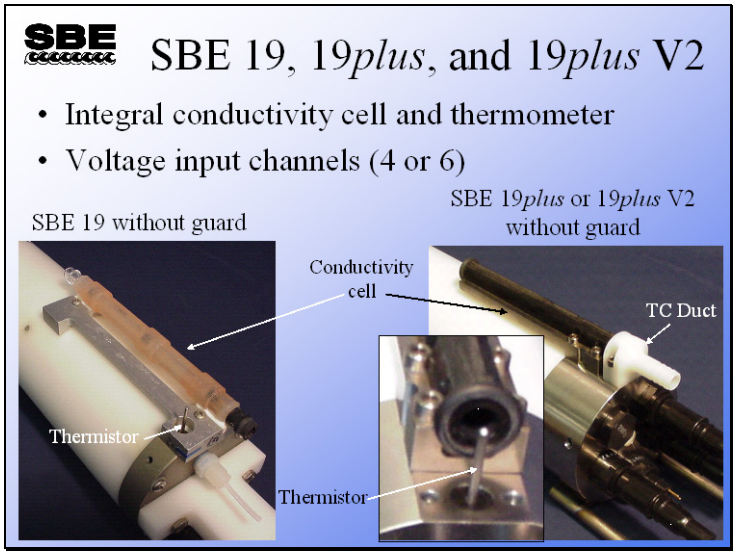
The measurement system consists of sensors that convert environmental parameters to electrically measurable quantities. The data acquisition portion of the system converts the sensor output to digital data and stores it internally.

Conductivity, Temperature, and Pressure Sensors



The pressure sensor is typically housed internally to protect it from shock and from rapid temperature change. Note however that we also measure temperature at the pressure sensor, and mathematically compensate for the temperature effect on the output.

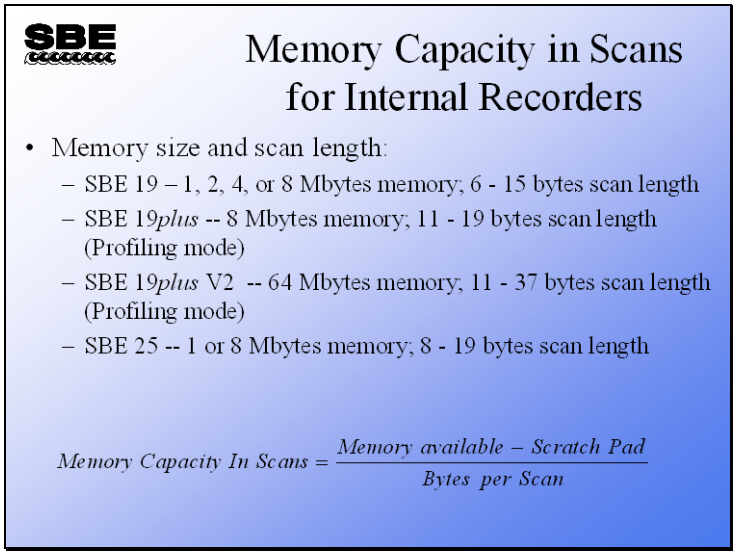
SBE 19 vs SBE 19*plus* / 19*plus* V2, Sensor Placement



The SBE 19 has side-by-side temperature and conductivity sensors. The SBE 19*plus* and 19*plus* V2 feature inline sensors and an integral ducting system, which ensures that water that passes the thermometer goes into the conductivity cell.

The SBE 19*plus* V2 has 6 voltage input channels, an improvement over the 4 channels available with the SBE 19 and 19*plus*. It also has more memory to accommodate the additional data.

Calculating Memory Capacity in Scans



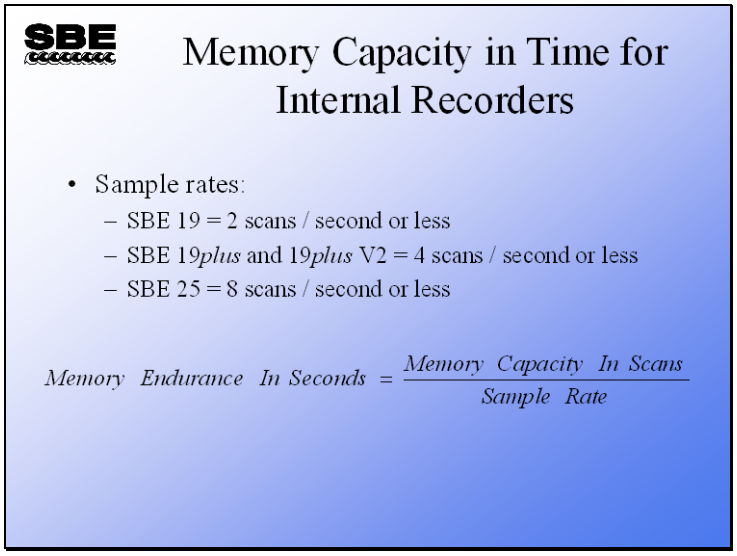
Because our profiling instruments can be set up to acquire data from auxiliary sensors, the *length* of data for each sample is dependent on the number of auxiliary sensors that are *enabled* (the CTD manual provides the commands for *enabling* the auxiliary sensor channels). The number of samples that fit in memory is dependent on the length of data for each sample, as well as the memory size in the CTD.

Examples are shown below for the SBE 19*plus* V2 and 25; see the CTD manual for details.

SBE 19*plus* V2 in Profiling mode:
No external voltages sampled: tttttcccccpppppdddd
6 external voltages sampled: tttttcccccpppppddddvvvvvvvvvvvvvvvvvvvvvvvv
where:
ttttt = 3 bytes temperature frequency
ccccc = 3 bytes conductivity frequency
ppppp = 3 bytes pressure (strain-gauge)
(note: Quartz sensor also available)
dddd = 2 bytes pressure sensor temperature compensation
vvvv = 2 bytes representing each stored voltage
Memory capacity: 5,818,000 scans (no external voltages), 2,782,000 scans (6 external voltages)

SBE 25:
No external voltages sampled: tttttcccccsppp
7 external voltages sampled: tttttcccccsppuuuvvvwwwxxxyyyzzz0aaa
where:
ttttt = 3 bytes temperature frequency
ccccc = 3 bytes conductivity frequency
s = sign character for pressure
ppp = 12 bits pressure
uuu through zzz and aaa = 12 bits stored voltages
0 = 4 bits all zero (used to make an even number of characters)
Memory capacity: 1,000,000 scans (no external voltages), 430,000 scans (7 external voltages)

Calculating Memory Capacity in Time

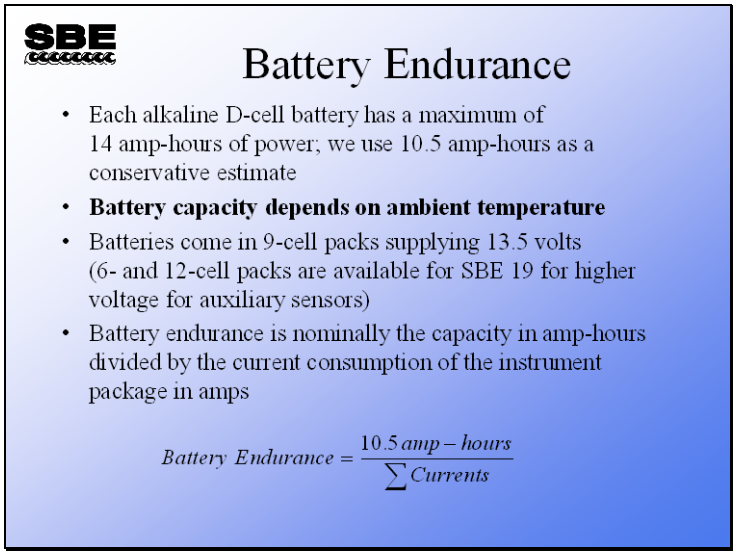


Memory endurance in time is the ratio of memory capacity in scans divided by the instrument sample rate.

- The SBE 19 sample rate can vary from 2 samples per second to 4 minutes between samples.
- The SBE 19*plus* and 19*plus* V2 sample rate is 4 Hz (4 samples per second); however, you can average between 1 and 32767 samples, for a range of 0.25 seconds to 2.3 hours between samples stored in memory.
- The SBE 25 samples at 8 Hz and can average between 1 and 8 scans, for a range of 0.125 seconds to 1 second between samples stored in memory.

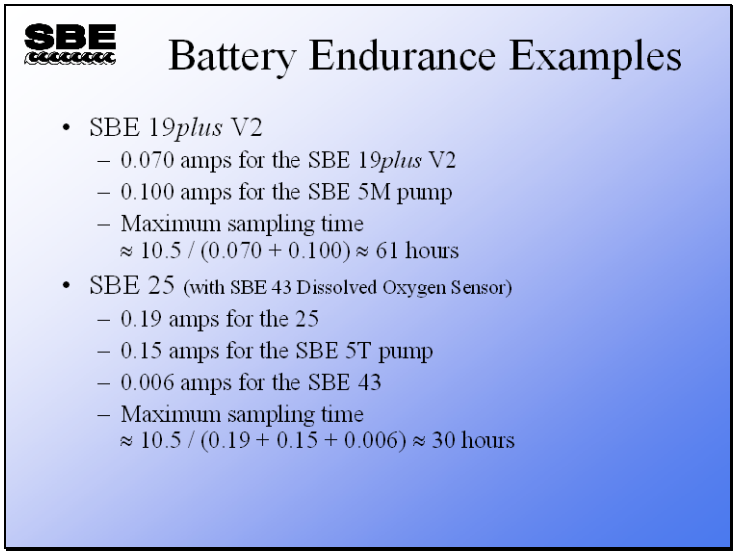
Full memory? All of these CTDs continue to take measurements, but they **will not record the new data or overwrite the data that is already in memory**. If you are transmitting real-time data, they will transmit the data.

Calculating Battery Endurance in Time



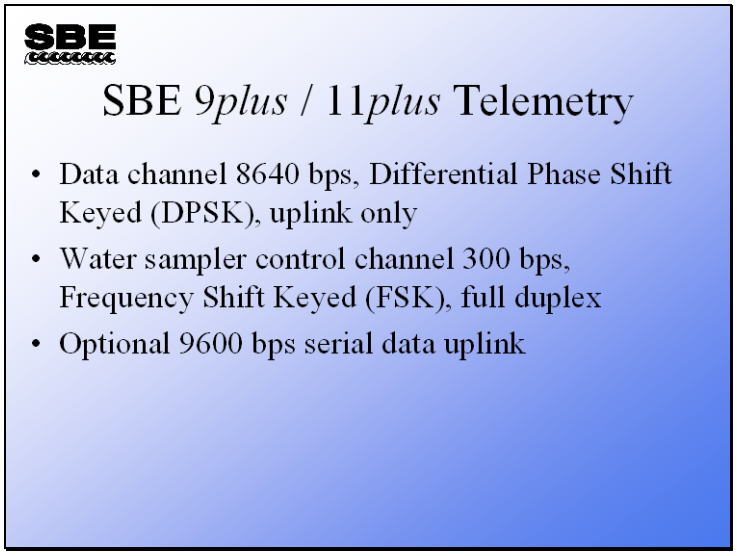
Battery endurance is difficult to estimate, because a battery's life depends on the ambient temperature. Moreover, batteries tend to lose their capacity as they age. The information on this slide is a good rule of thumb for alkaline batteries. However, for critical work, consider that batteries are cheap, so you might as well start with a new set.

Battery Endurance Examples



Where do you find the information on current draws? See the specifications in the CTD manual for the CTD and pump; see brochures / specification sheets for any auxiliary sensors (such as the SBE 43, etc.).

SBE 9*plus*/11*plus* Telemetry Channels

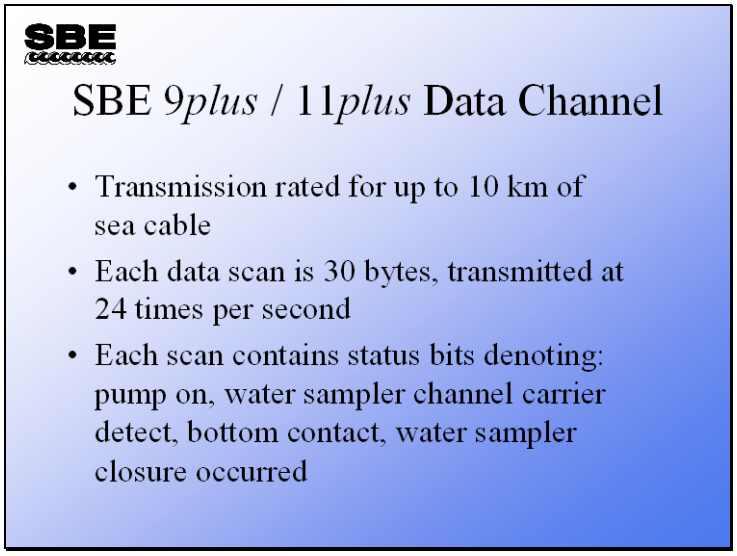


The 9*plus* / 11*plus* CTD has two standard telemetry channels, the data channel and the water sampler control channel (often referred to as the modem channel). The data channel is for uplink only; the data flows from the 9*plus* to the 11*plus*. The water sampler control channel is duplex; data flows both ways, from the 9*plus* to the 11*plus* and from the 11*plus* to the 9*plus*.

The data channel operates at 8640 bits per second (8640 baud) and transmits from the 9*plus* as a Differential Phase Shift Keyed (DPSK) signal. Binary data is packaged into standard 10-bit serial frames (8 data bits, 1 start bit, 1 stop bit, and no parity); it is modulated to 34.5 kHz and a 0 bit is represented as 0 degree phase, a 1 bit as 180 degree phase. The 11*plus* demodulates the telemetry and standard serial receivers (UART) accept the serial frame.

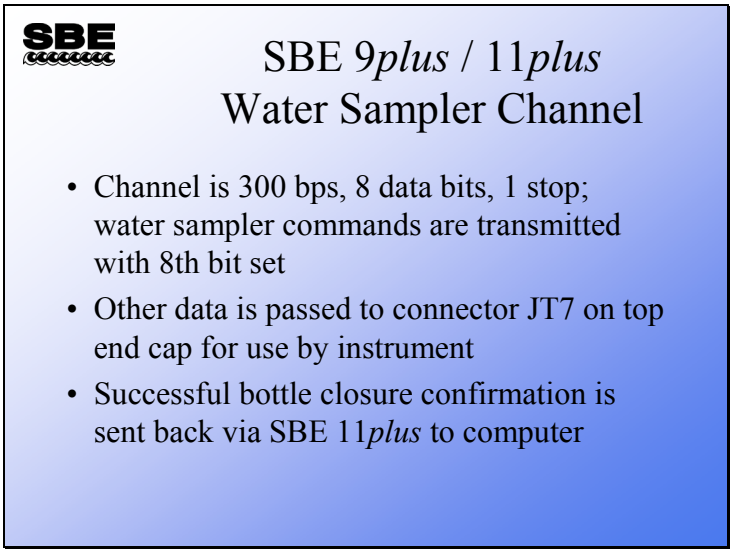
The water sampler channel is a 300 bit per second (300 baud) Frequency Shift Keyed (FSK) duplex channel, modulated to 1 kHz for the downlink and 2 kHz for the uplink. This channel is meant for water sampler control and for communications with user instrumentation. Water sampler control information has the 8th bit in a 7 bit ASCII character set. Any data without the 8th bit set is assumed to be meant for a remote instrument and is passed to the center bulkhead connector of the top end cap.

SBE 9*plus*/11*plus* Data Telemetry



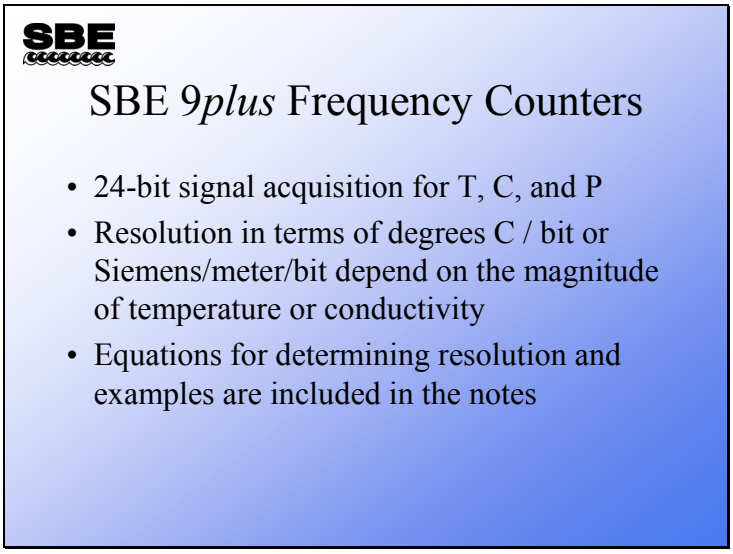
The data transmission rate of the 9*plus* is constrained by the 24 Hz scan rate. Of the 30 bytes that make up a scan, 29 of them are transmitted in standard asynchronous format, 1 start bit, 8 data bits, and 1 stop bit. The 30th byte is all zeros; it is not transmitted. This lack of a data byte is used by the 11*plus* and the 17*plus* to synchronize the data acquisition. Synchronization occurs with each data scan. As an option, the data transmission speed can be doubled and serial data at 9600 baud from a remote instrument can be time dimension multiplexed into the telemetry stream. This option requires a hardware change; it finds use with some optical instrumentation that transmits data at 9600 baud. The disadvantage to deploying this option is the data transmission is not as robust, and some lower quality sea cables will not allow transmission to occur over the whole 10 km.

SBE 9*plus*/11*plus* Water Sampler Telemetry



All water sampler communications are carried out over the 300-baud FSK modem channel. This is a separate, full-duplex communication channel that is frequency domain multiplexed onto the single conductor sea cable. You have the option of commanding water sampler closures with the buttons on the deck unit or via the computer keyboard. If you want to use the computer, you must have two serial ports installed on your computer.

SBE 9*plus* Frequency Acquisition



Frequency counters require a reference frequency to count the sample frequency against. Consider that if you want to measure frequency in Hertz (cycles/second), you need to know how long a second is. The resolution of the type of counters employed in the 9*plus* depends on the frequency of the sample, the scan rate, and the frequency of the reference.

$$Resolution\,(Hz/Bit) = Scan\,Rate \times \left(\frac{F_s}{F_r}\right)$$

Where:
F_s is the sensor frequency
F_r is the CTD reference frequency (6,912,000Hz for C & T; 27,648,000 for P)

To find resolution in scientific units, we need to divide resolution by sensitivity (Hz/scientific unit). Approximate values can be obtained from the sensor calibration sheet. Some examples follow. These are for illustration only; your computer will use higher precision math and the appropriate calibration equations for your sensors.

Temperature:

At -1°C, Fs = 2100 Hz, Sensitivity = 48 Hz/°C
Resolution = 0.00015°C per bit

At 31°C, Fs = 4000 Hz, Sensitivity = 76 Hz/°C
Resolution = 0.00018°C per bit

Conductivity:

At 1.4 Seimens/meter (S/m), Fs = 5000 Hz, Sensitivity = 1900 Hz/(S/m)
Resolution = 0.0000091 S/m per bit

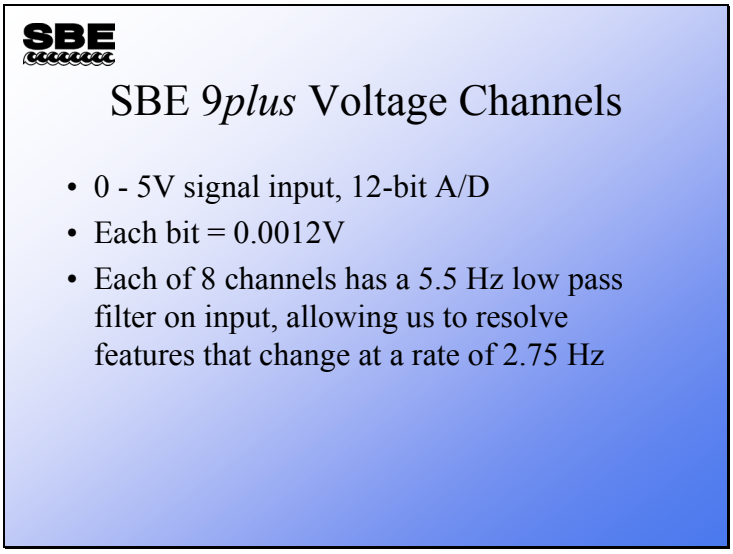
At 5.8 S/m, Fs = 11000 Hz, Sensitivity = 960 Hz/(S/m)
Resolution = 0.0000398 S/m per bit

Pressure (10,000 psi range Digiquartz sensor, with a conversion factor of 1.46 psi/dbar):

At 0 dbar, Fs = 33994 Hz, Sensitivity = 0.614 Hz/dbar
Resolution = 0.041 dbar per bit

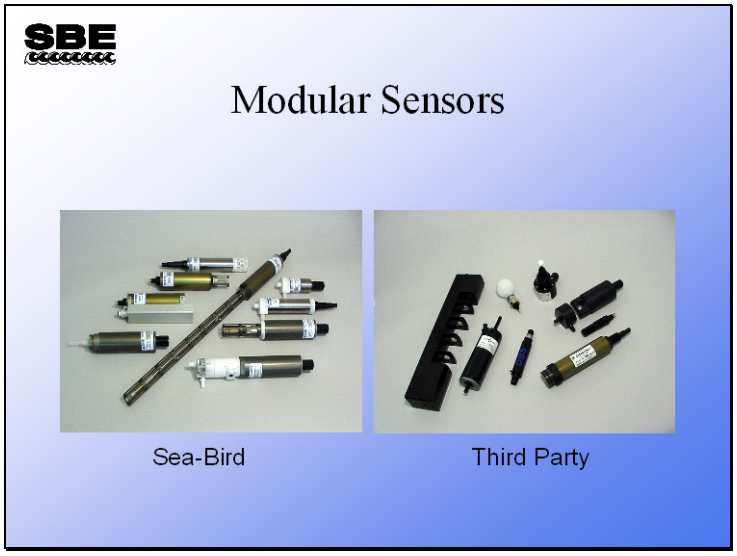
At 6800 dbar, Fs = 38,480 Hz, Sensitivity = 0.614 Hz/dbar
Resolution = 0.054 dbar per bit

SBE 9*plus* Voltage Acquisition



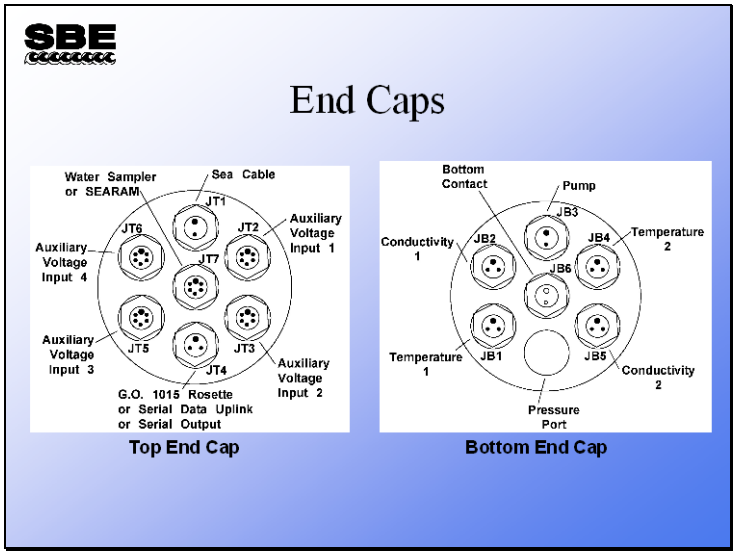
The low pass filter on the voltage channels minimizes noise, which can be more of a problem at a high sampling rate (remember, the 9*plus* samples at 24 Hz). Our other CTDs do not have this filter because of their slower sampling rates.

Modular Sensors, SBE and Others



Sea-Bird offers a variety of modular sensors of our own manufacture and also many from other manufacturers. These sensors have various outputs: voltage, frequency, or serial ASCII data. In addition to temperature and conductivity, dissolved oxygen and pH are offered, as are oxidation potential, light, transmittance, fluorescence, and turbidity.

SBE 9*plus* End Cap Connections

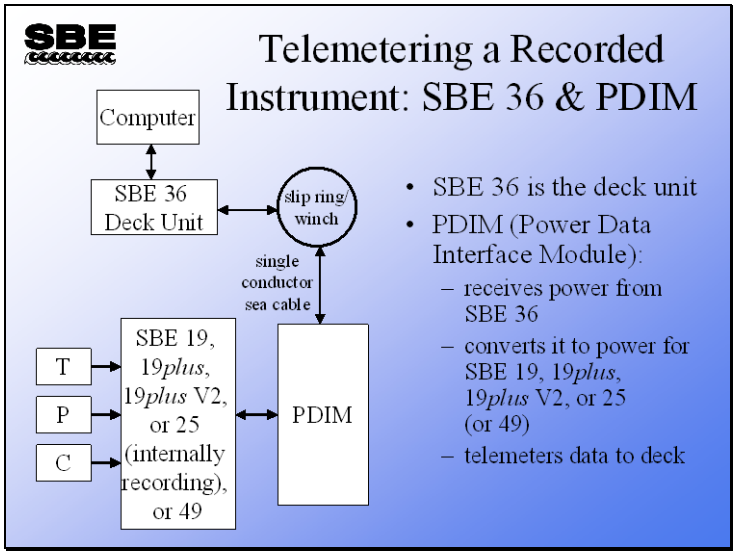


The **top end cap** of the 9*plus* has bulkhead connectors for all auxiliary sensors. Auxiliary sensors are those that are not temperature, conductivity, or pressure. Each auxiliary bulkhead has inputs for two 0 – 5V differential input channels. In addition, there is a 2-pin connector for the sea cable and a 3-pin connector for a GO 1015 rosette sampler. The center connector connects to the SBE 17*plus* (a memory module), a remote instrument, or an SBE 32 Carousel Water Sampler.

The **bottom end cap** has connectors for pairs of temperature and conductivity sensors, pump power, and a bottom contact switch. The bottom contact switch is mechanical, with a weight that hangs below the instrument package. When the weight contacts the ocean bottom, a bit is set in the data stream and an alarm in the SBE 11*plus* deck unit sounds.

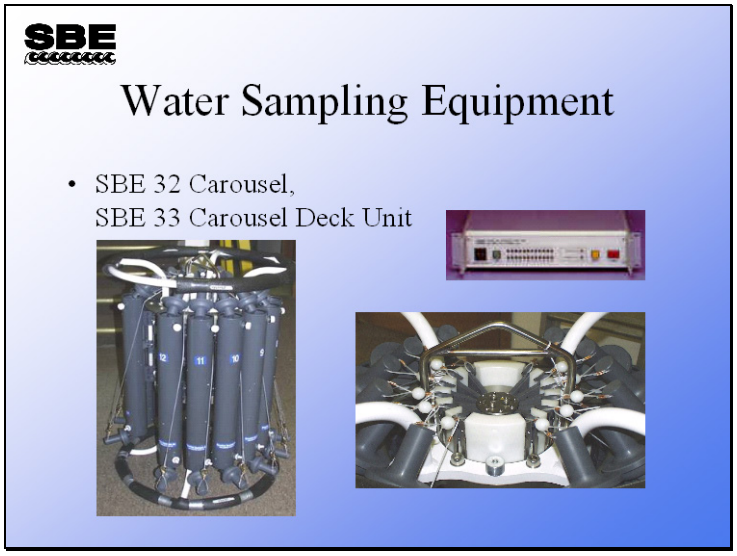
WARNING! Do not plug the sea cable into the pump or bottom contact connector; this could cause serious damage to the CTD. In 2007, Sea-Bird changed the bottom contact connector to a female connector to reduce the possibility of this error; older units can be retrofitted if desired.

Real-Time Options for Internally Recording Instruments



The SBE 36 and PDIM provide power and telemetry, but no water sampling capability.

Water Sampling Equipment



As a companion to CTD profilers, Sea-Bird supplies water sampling equipment. Sea-Bird manufactures the framework, mechanism for closing bottles, and deck power supply and sampler control. The water sample bottles themselves are not manufactured by Sea-Bird. The SBE 32 is the portion of the equipment that triggers the bottle closure.

The Carousel trigger mechanism is an electro-mechanical device. It operates by energizing a solenoid magnet that pulls a mechanical trigger, releasing the nylon lanyards that hold the top and bottom caps of the water sampler open.

For the SBE 9*plus* CTD, the 11*plus* Deck Unit provides real-time water sampler control. The SBE 33 Deck Unit shown above provides real-time water sampler control for internally recording CTDs (SBE 19, 19*plus*, 19*plus* V2, or 25) as well as for the SBE 49 FastCAT CTD.

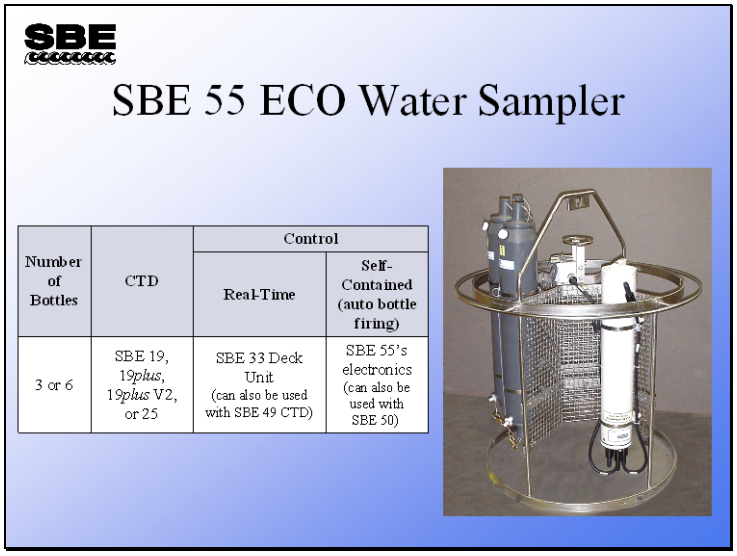
Water Sampling Equipment (*continued*)

SBE 32 Carousel Water Sampler

Carousel	Number of Bottles	Bottle Size (liters)	CTD	Control	
				Real-Time	Self-Contained (auto bottle firing)
SBE 32 (standard)	12	1.7 - 30	*9plus*	SBE 11*plus* Deck Unit	SBE 17*plus* V2
	24	1.7 - 12			
	36	Consult factory			
	12	1.7 - 30	19, 19*plus*, 19*plus* V2, or 25	SBE 33 Deck Unit (can also be used with SBE 49 CTD)	Auto Fire Module
	24	1.7 - 12			
	36	Consult factory			
SBE 32C (compact)	12	1.7 - 8	*9plus*	SBE 11*plus* Deck Unit	SBE 17*plus* V2
			19, 19*plus*, 19*plus* V2, or 25	SBE 33 Deck Unit (can also be used with SBE 49 CTD)	Auto Fire Module (can also be used with SBE 50)
SBE 32SC (sub-compact)	12	1.7 or 2.5	19, 19*plus*, 19*plus* V2, or 25	SBE 33 Deck Unit (can also be used with SBE 49 CTD)	Auto Fire Module (can also be used with SBE 50)

In autonomous (self-contained) mode, the system can be programmed to fire bottles at pre-defined pressures or times. The SBE 50 Pressure Sensor can be used in place of a CTD to provide the pressure measurements for autonomous bottle firing.

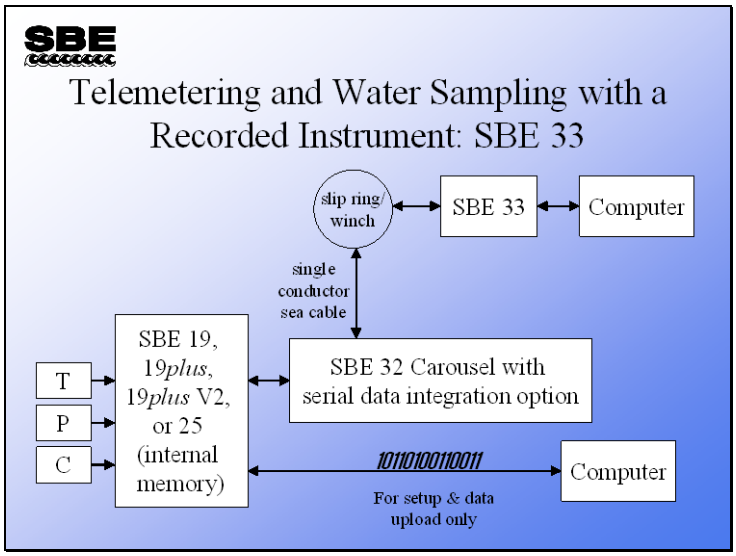
Water Sampling Equipment (*continued*)



The SBE 55 is a small, 3- or 6-bottle water sampler, intended for sampling in depths to 600 meters. Its trigger mechanism operates in the same way as the mechanism on the Carousel, and its electronics are similar.

The ECO is compatible with the SBE 33 Deck Unit for real-time applications. It has built-in auto-fire capability, so an Auto Fire Module is not required for autonomous applications. The ECO is not intended for use with the SBE 9*plus* / 11*plus* system (which is typically deployed for deeper applications).

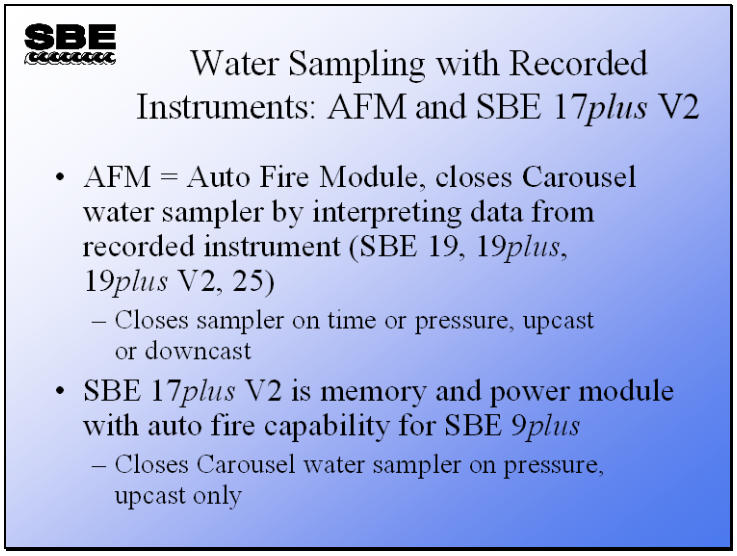
Water Sampling in Real-Time for Internally Recording Instruments



This setup can also be used with an SBE 49 FastCAT CTD, which has no internal memory.

The diagram also applies to a standard SBE 55 ECO Water Sampler (serial data integration capability is built into the standard ECO).

Water Sampling for Internally Recording Instruments

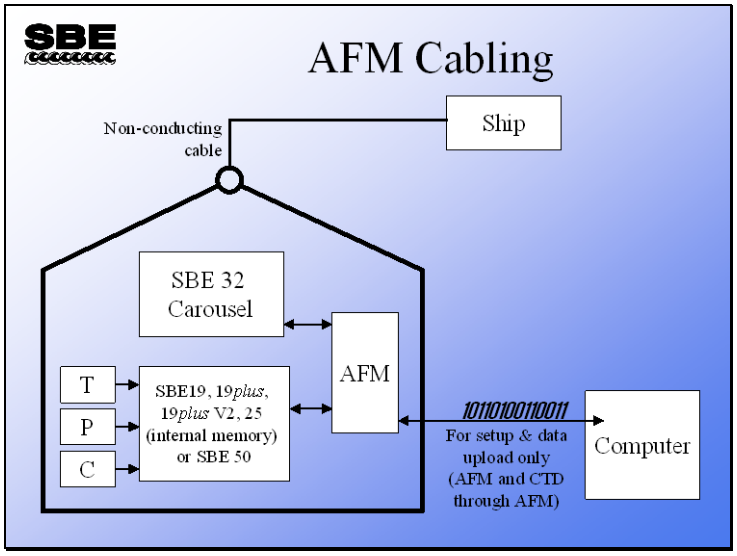


Internally recording instruments output a real-time, RS-232 serial data stream. This data stream is suitable for real-time telemetry over short cables only. The data stream is used by the AFM to monitor the depth of the sampling package for the purpose of closing water samplers.

The ECO has built-in auto-fire capability, so no auxiliary equipment is required for autonomous applications. Like the AFM, it closes bottles on time or pressure, on upcast or downcast.

Autonomous vs Real-Time Water Sampling: Autonomous sampling does not provide water sample quality that is equal to that from real-time sampling; it is a compromise intended to serve users who do not have real-time capability on their vessel. For real-time sampling, you typically stop the winch before each sample, ensuring the sample is actually taken where you think it is. Autonomous sampling usually provides some *smearing* of the sample, as the package continues to move while the bottle is closing. You can program the AFM to sample when stationary, but you are estimating the depth based on the cable payout, and do not have exact knowledge of the water features before you take the sample.

Cabling for Water Sampling with the AFM



The AFM is programmed to close water samplers at the required depths, and then it is armed. It receives pressure data from the CTD; when the closure parameter for a water sample has been met, it actuates the Carousel and records a small amount of CTD data. When the CTD is retrieved, the data in the CTD and AFM are uploaded to the computer. The data in the AFM is used in post-processing to get a table of CTD parameters to go with whatever is gleaned from the water samples.

The SBE 55 ECO Water Sampler's built-in electronics operate similarly to the AFM / SBE 32 Carousel Water Sampler combination.

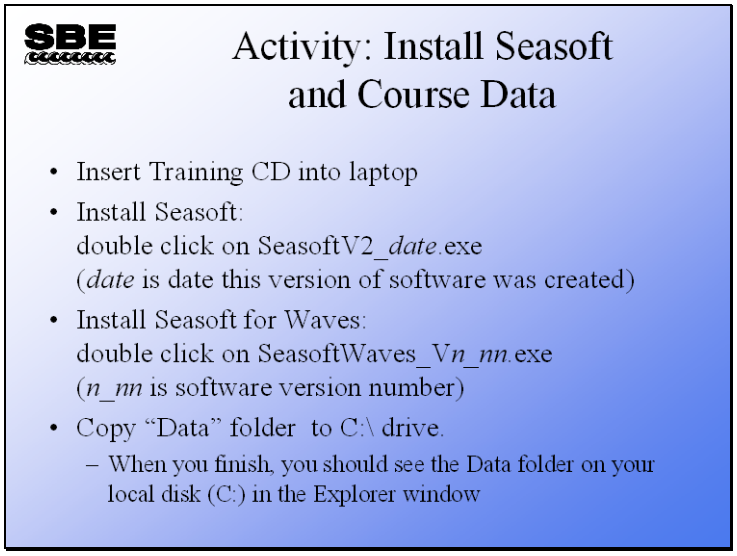
Battery Power and Internal Recording for the SBE 9*plus*

The SBE 17*plus* V2 acts as battery power and internally recording memory for the SBE 9*plus*. This device has the capability to close water samplers as well. It only closes bottles on the upcast.

Autonomous Profiling

The SBE 41 and 41cp are CTDs that are used with buoyancy engines. After deployment they become negatively buoyant, sinking to ~1000 meters, resting for 10 days, and then making themselves positively buoyant, collecting a profile as they rise through the ocean. Once on the surface, they transmit their data via a satellite back to the scientist who deployed them. Because they receive no handling after deployment and have minimal time on the surface, they provide an excellent example of conductivity sensor drift in an optimum environment.

Activity



- **SeasoftV2_*date*.exe** installs programs intended for use with CTDs, including: SeatermV2 and Seaterm (terminal programs), and SeatermAF (terminal program for auto-fire water sampling systems); Seasave V7 and Seasave-Win32 (real-time data acquisition programs); and SBE Data Processing (post-processing program).
  - The installation program contains two versions of our main terminal program. **SeatermV2** is a newer, easier-to-use terminal program intended for use with instruments that can output data in XML. **We will be using SeatermV2 in the course instead of the older Seaterm.**
  - The installation program contains two versions of our real-time data acquisition program – **SeasaveV7** is a new, easier-to-use version of Seasave. **We will be using Seasave V7 in the course instead of the older Seasave-Win32**.
- **Seasoft for Waves** is intended for use with our wave and tide gauge products, which we will not discuss during class (covered in Modules 13 and 14 in your binder).
- The **Data folder** contains data we will use in exercises for this class.

Additional setup notes:

If the Explorer window does not show file extensions (.con, .dat, .hex, etc.) and/or does not show the full path in the address bar, we suggest you change the settings to make your life easier for this course. Follow these directions (written for Windows XP Professional) to change settings:

1. Select Start / Control Panel.
2. Select Folder Options.
3. Click the View tab.
   A. **Unclick** *Hide extensions for known file types.*
   B. Click *Display the full path in the address bar.*
   C. Click Apply.
   D. Click OK.