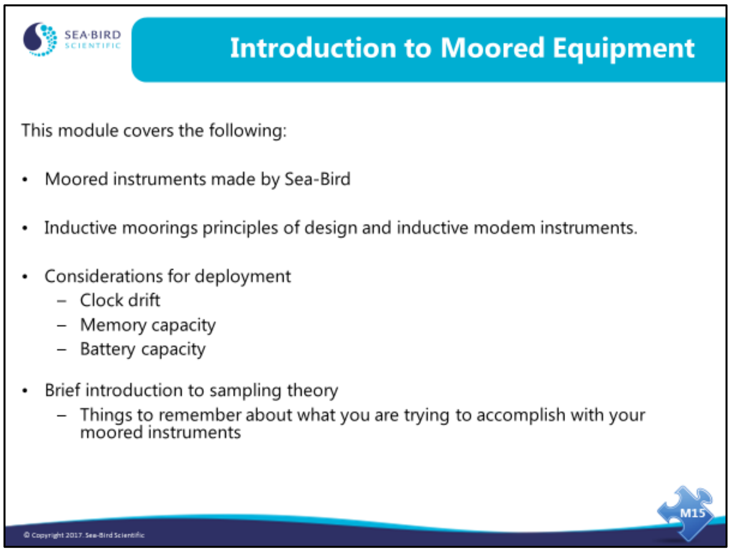
Introduction to Moored Equipment

Sea-Bird Scientific University Module 15

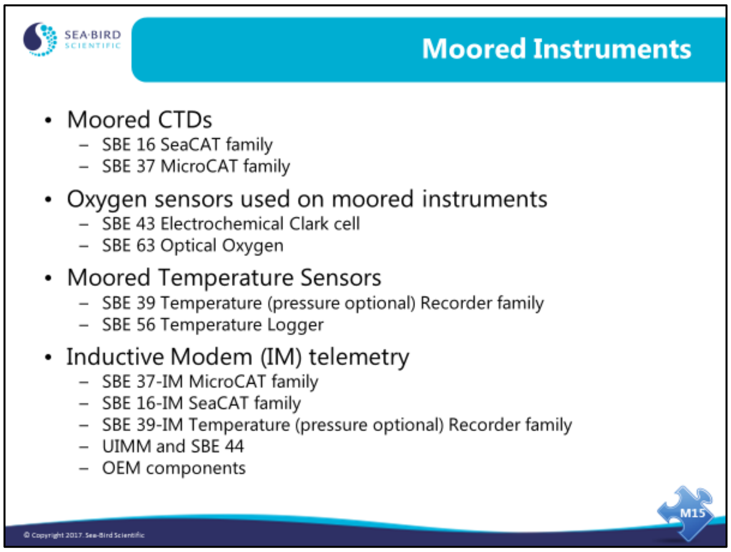
M15

Overview



In this module we will present Sea-Bird instrumentation intended for moorings.

Overview



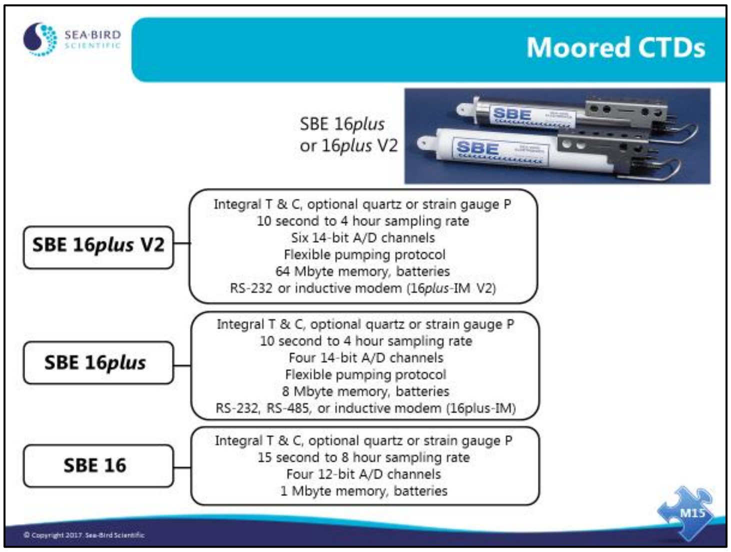
In this module we will present Sea-Bird instrumentation intended for moorings. The SBE 16 SeaCAT family provides power and A/D inputs for auxiliary sensors. The MicroCAT family is smaller and less expensive, but does not have power for external sensors or auxiliary A/D inputs (IDO and ODO MicroCATs support an integral Dissolved Oxygen sensor). The SBE 39 family has only temperature and pressure. The SBE 56 is a small, economical temperature recorder.

As an accessory to our moored instruments, Sea-Bird offers inductive telemetry for mooring. This technology allows communication with moored instruments in real-time without cable breakouts. The SBE 44 is a stand-alone modem meant for interfacing other manufacturer's instrumentation to the inductive mooring string, while the UIMM is a newer and more flexible modem without internal power.

When we complete this module you should:

- Be aware of the instrument platforms available for moored applications
- Understand the means of telemetering real-time data from the mooring to the land-based receiving station

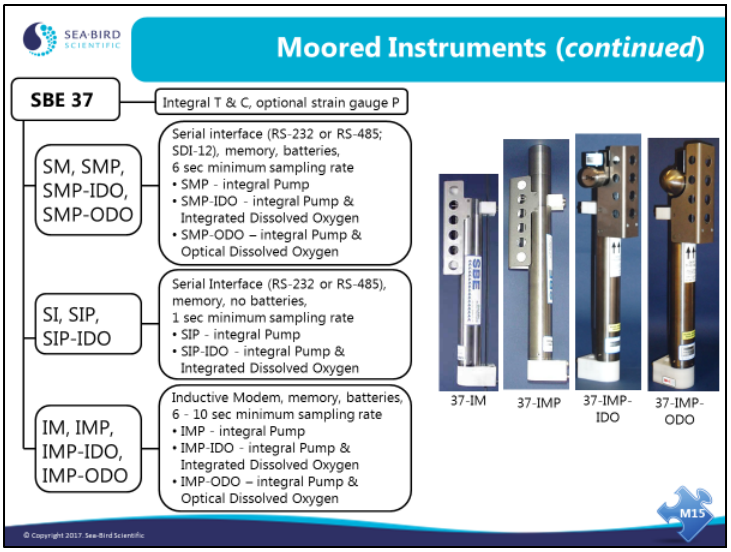
Introduction to SBE 16 SeaCAT Family



The SBE 16, 16*plus*, and 16*plus* V2 are moored versions of the SBE 19 family of SeaCATs. The 16*plus* V2 is actually a 19*plus* V2 in moored mode, with optional pressure sensor. These instruments have the capability to power external sensors and log analog A/D data from them. This is the instrument of choice if you require more data than C, T, and P.

The 16*plus* V2 (the current version as of 2008) is available with serial interface (RS-232) or inductive modem interface (16*plus*-IM V2). The SBE 16*plus* V2 and 16*plus*-IM V2 have a 600-meter plastic housing or 7000- or 10,500-meter titanium housing.

Introduction to SBE 37 MicroCAT Family



Like the SBE 16 SeaCAT family, the SBE 37 MicroCATs have integral T and C sensors, and may also be equipped with a pressure sensor. It comes in three main types:

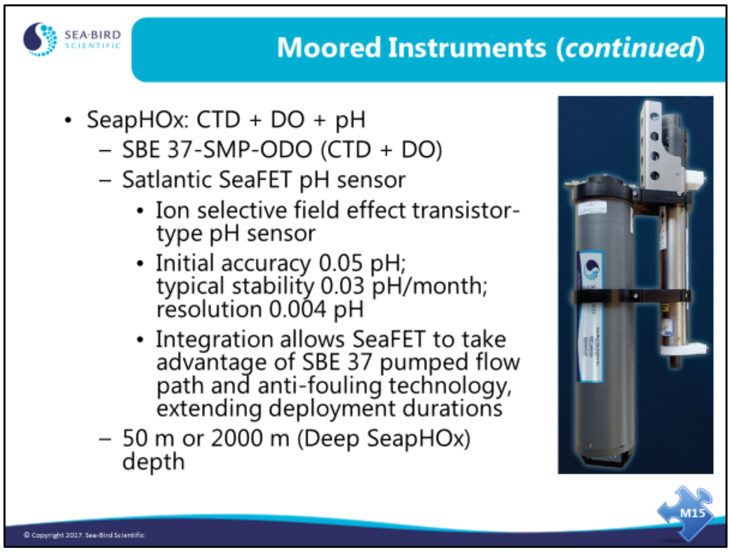
- SM has memory, batteries, and serial interface (RS-232 or RS-485). It is meant for moorings that do not require communication with the surface during deployment. SMP and SMP-ODO are available with SDI-12 interface in addition to RS-232.
- SI has memory * and serial interface (RS-232 or RS-485), but no batteries. It is intended for ROVs, submarines, etc. as a companion for instruments requiring T and C, such as acoustic Doppler profilers or optical instruments.
  * Note: Memory was added in 2008.
- IM has memory, batteries, and an inductive modem for communications in real-time with the surface.

All three types of MicroCAT are available with:

- An integral pump (SMP, SIP, and IMP), which provides improved anti-foul protection
- An integral pump and an Integrated Dissolved Oxygen sensor (SMP-IDO, SIP-IDO, and IMP-IDO) [SBE 43 DO sensor]
- An integral pump and an Optical Dissolved Oxygen sensor (SMP-ODO, SIP-ODO* , and IMP-ODO) [SBE 63 DO sensor] ** SIP-ODO coming soon*

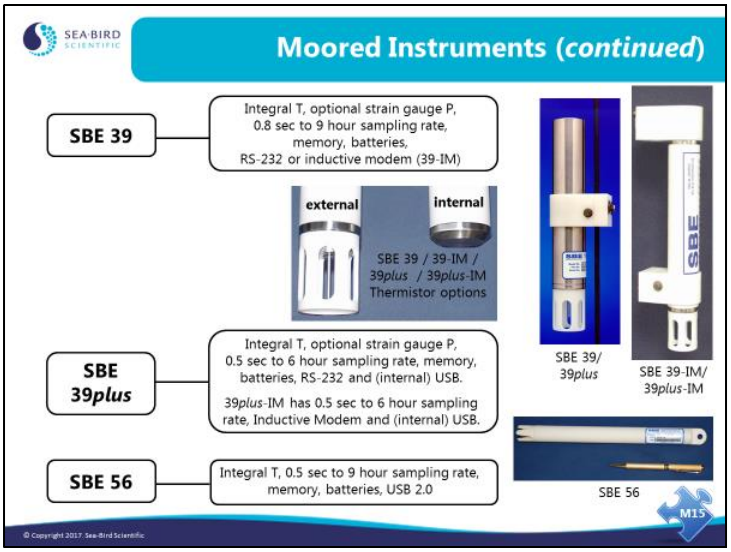
All MicroCATs have a 350-meter plastic or 7000-meter titanium housing.

Introduction to SeapHOx Family



SeapHOx combines the Satlantic SeaFET pH sensor with the Sea-Bird Electronics SBE 37-SMP-ODO MicroCAT CTD+DO sensor; depth rating to 50 m.

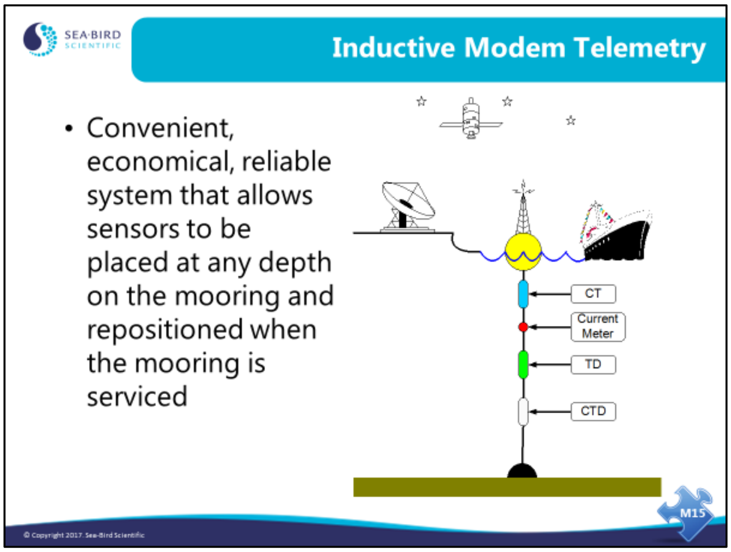
Introduction to SBE 39 and 56 Families



The SBE 39*plus* (current version) is a temperature recorder with optional pressure sensor, available with RS-232 serial interface or inductive modem interface (39*plus*-IM). An example of its use is mounted on bottom trawls to measure bottom depth, time on bottom, and temperature. The SBE 39*plus* and 39*plus*-IM have a 600 m plastic or 10,500 m titanium housing. They are available with an external thermistor in a pressure-protected sheath (0.5 sec time constant) for fast sampling, or internal thermistor embedded in the titanium end cap (25-sec time constant) for rugged conditions. Compared to the SBE 39, the 39*plus* has faster sampling (as fast as 0.5 seconds between samples for 39*plus* or 5 seconds between samples for 39*plus*-IM), improved power and memory, and an internal USB port for fast data upload.

The SBE 56 is an economical temperature logger with a USB 2.0 interface. Unlike our more broad-featured products, the SBE 56 has only a small number of user-programmable parameters (clear memory, sample interval, date and time, start now or start later). The accompanying software provides a very simple user interface for programming, uploading, plotting, and exporting the data. The SBE 56 has a plastic housing, rated to 1500 m.

Inductive Modem Telemetry

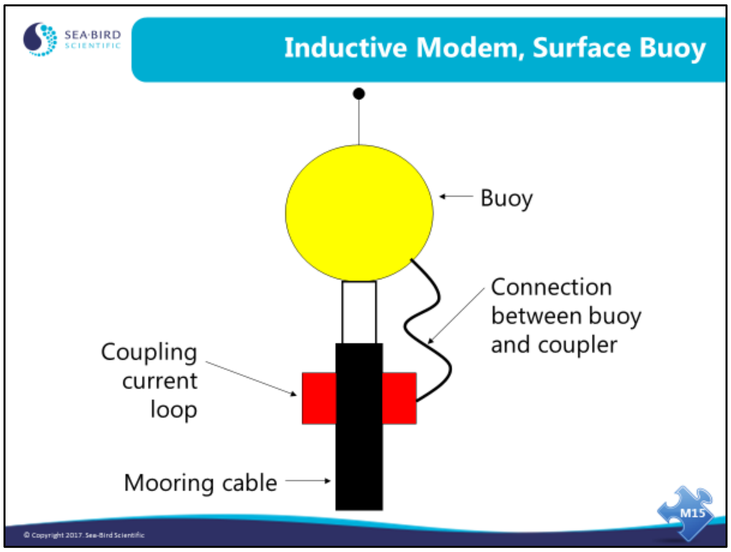


An inductive modem uses electrical current loops to transmit information. Recall from physics class, electrical current flowing in a wire loop induces current to flow in a loop that passes through it. You can think of these loops as links in a chain. The first loop is in the surface buoy. The second loop is formed by the mooring cable and the seawater. The third loop is at the instrument, underwater. Because all coupling is done in loops, no cable breakouts are required.

The communications link is one way only, meaning that if the surface modem is transmitting to the remote instruments, then the remote instruments must all be listening. Conversely, if one of the remote instruments is transmitting, then the surface modem must be listening. To achieve this, all instruments have a unique two-digit address from 00 to 99.

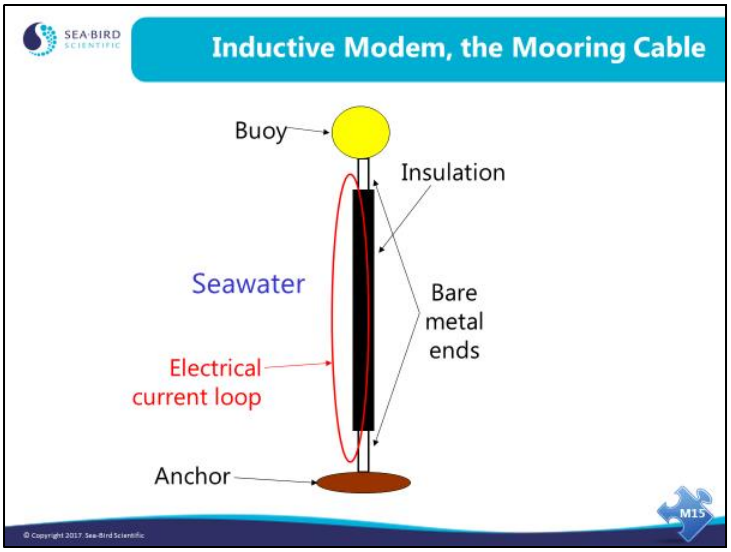
The electrical current carries an AC signal that is phase-shift-keyed. Digital data is encoded by the transmitting modem into an AC signal that is impressed on the current loop, and it is received and decoded by the remote modem’s receiver.

Inductive Modem Telemetry (*continued*)



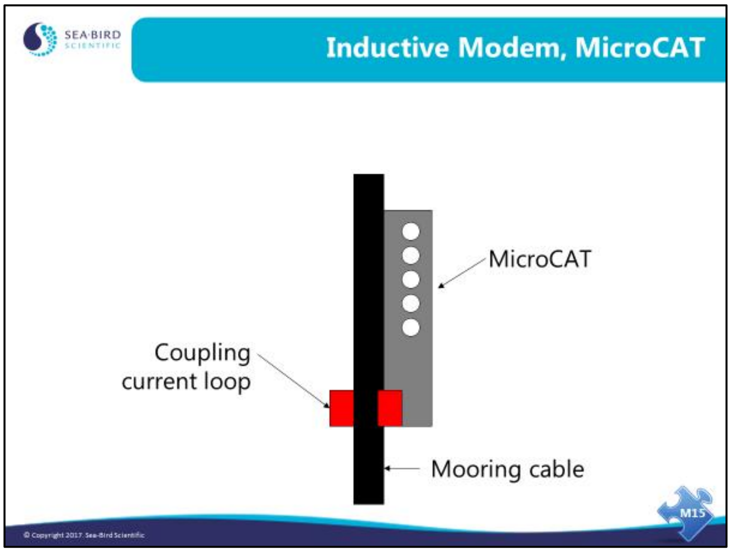
The first current loop is made around the mooring cable. The coupler is a ferrite donut. Ferrite is the stuff that magnetic tape is made from. The electrical current that flows around the coupler induces a current that flows through the mooring cable and the seawater. Thus, the modem signal is transmitted by the surface buoy into its coupler, and the coupler induces a current in the seawater and mooring cable.

Inductive Modem Telemetry (*continued*)



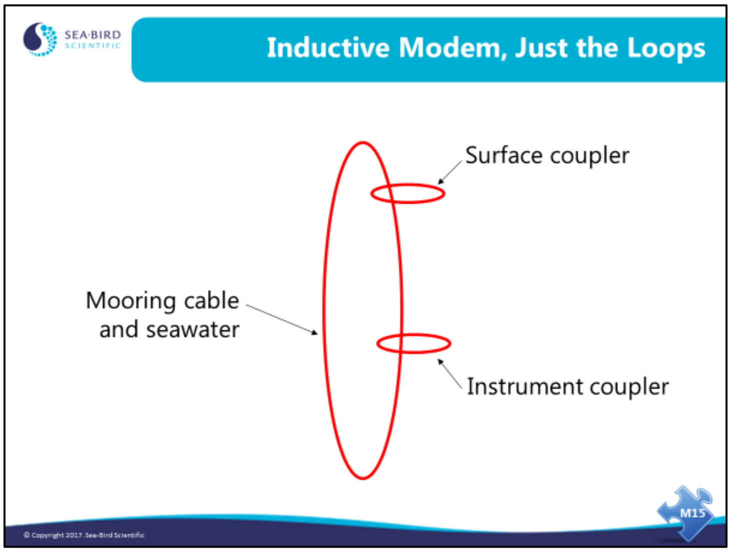
The second current loop is made by the mooring cable itself and seawater. The cable is bare metal on the top and bottom and insulated in the middle.

Inductive Modem Telemetry (*continued*)



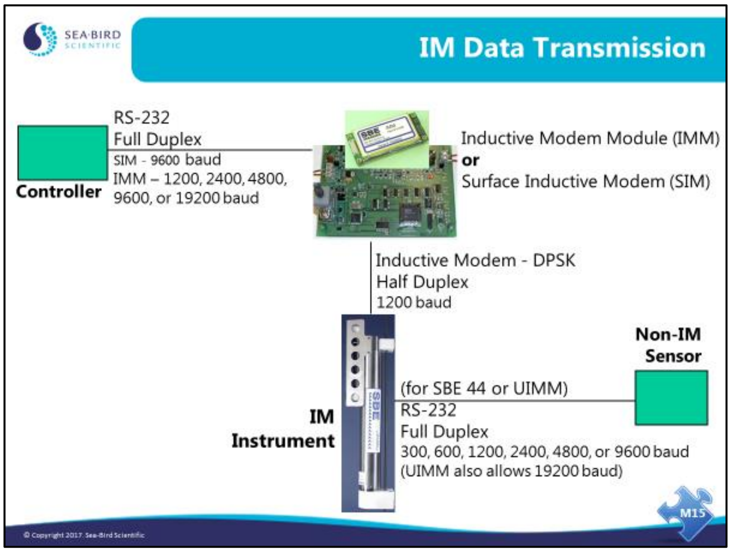
The last loop is at the remote instrument. It has a coupler just like the surface buoy. The current that the surface buoy has induced in the seawater mooring cable loop in turn induces a current in the remote instrument's coupler. The modem in the remote instrument receives and decodes the signal. If the information contained in the signal is addressed to the remote instrument it behaves accordingly, e.g., transmitting a data scan or a status report.

Inductive Modem Telemetry (*continued*)



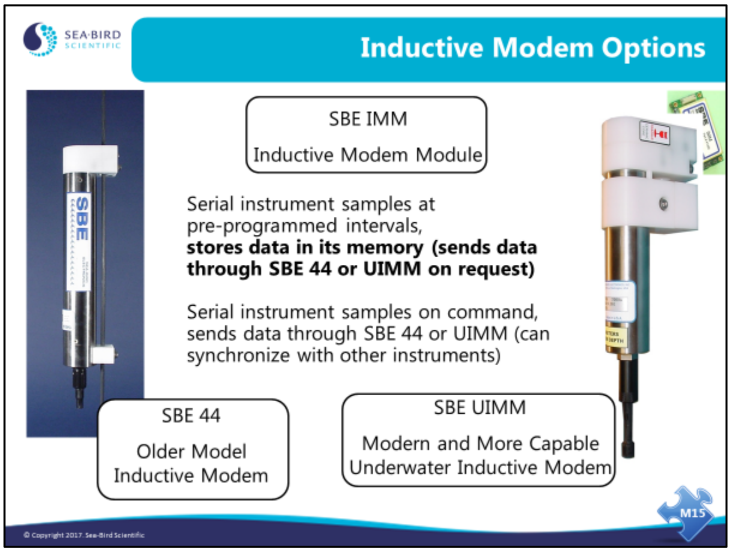
Here is a very simple view of the communication links. Note that there can be up to 100 instrument couplers on the mooring cable – seawater loop.

Inductive Modem Telemetry (*continued*)

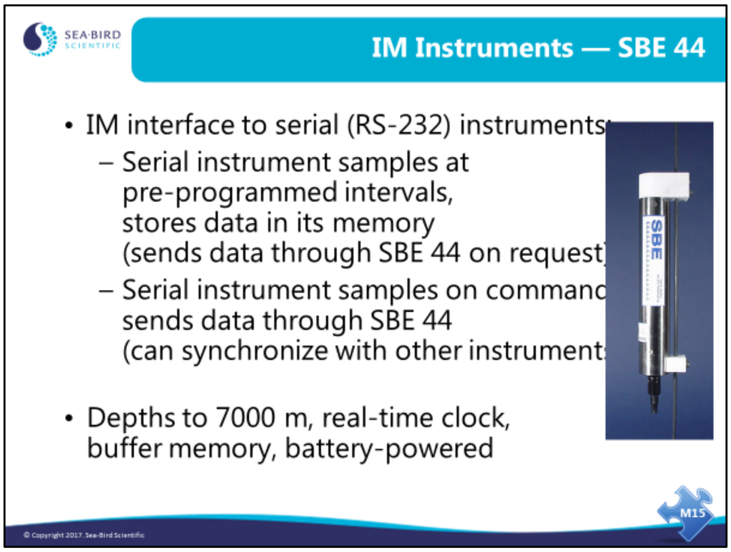


Here are all the players in inductive modem data transmission. The controller is user-supplied and should be able to switch power to the Inductive Modem Module (IMM) or Surface Inductive Modem (SIM). The inductive modem DPSK is via the mooring cable. If you want to use sensors with serial data output made by another manufacturer, there are two choices: the SBE 44 is a stand-alone inductive modem supporting common baud rates with buffering sufficient for most applications, while the UIMM provides more flexibility in programming but must be externally powered.

Inductive Modem Instruments

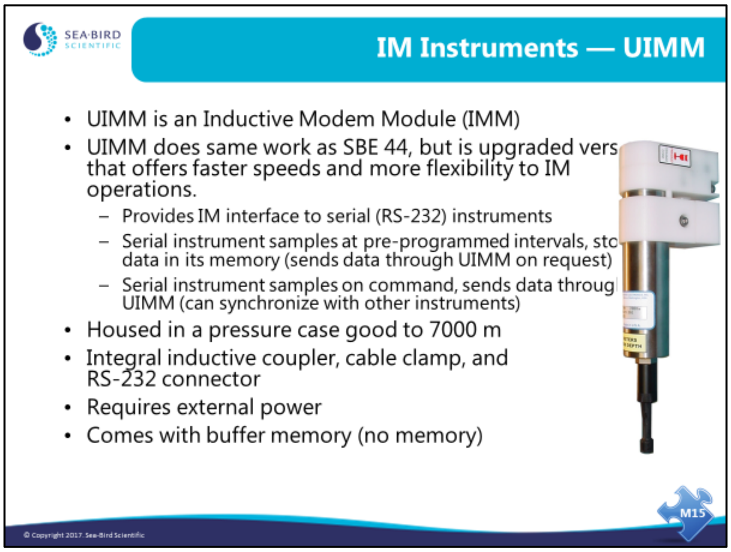


Inductive Modem Instruments (*continued*)



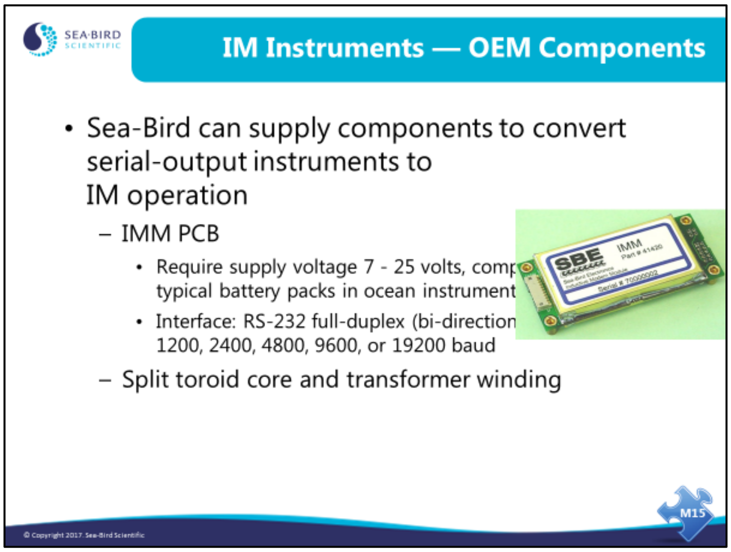
The SBE 44 is meant to allow the use of instruments that have a serial interface and the capability to sample on demand to be used with an inductive telemetry mooring. The SBE 44 has an internal 9 volt, 7.2 amp-hour battery and can provide power to the external device. Alternatively, the external device can provide power to the 44. The inductive link operates at 1200 baud. This restricts the data rate of the external instrument; however the SBE 44 has data buffers that allow the external instrument to transmit small amounts of data at a higher rate.

Inductive Modem Instruments (*continued*)

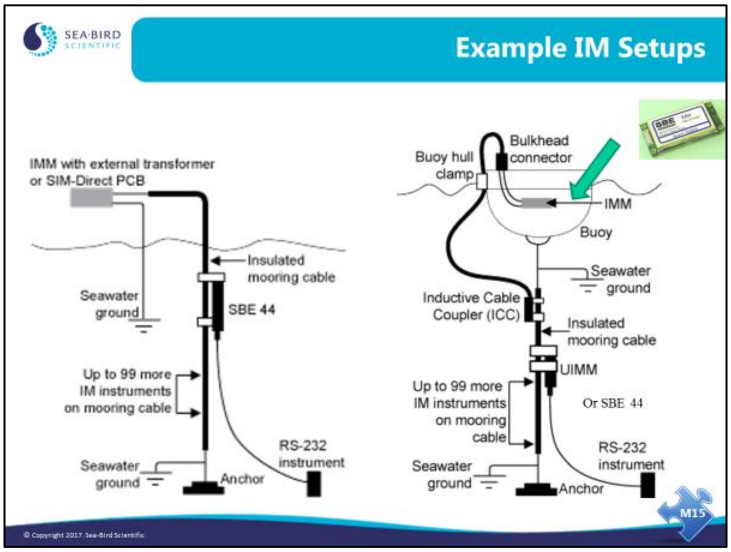


The UIMM provides more flexibility in programming than the SBE 44, allowing for connection to a wider number of RS-232 instruments. Unlike the SBE 44, the UIMM requires external power.

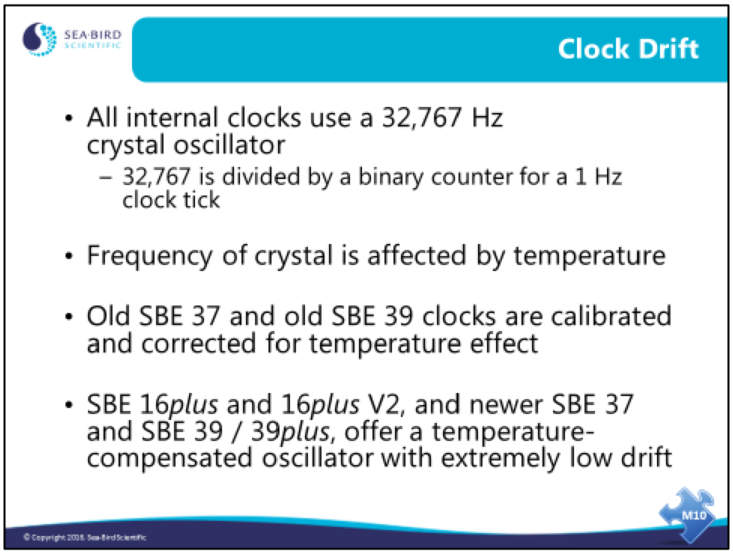
Inductive Modem Instruments (*continued*)



Inductive Modem Instruments (*continued*)



Clock Drift

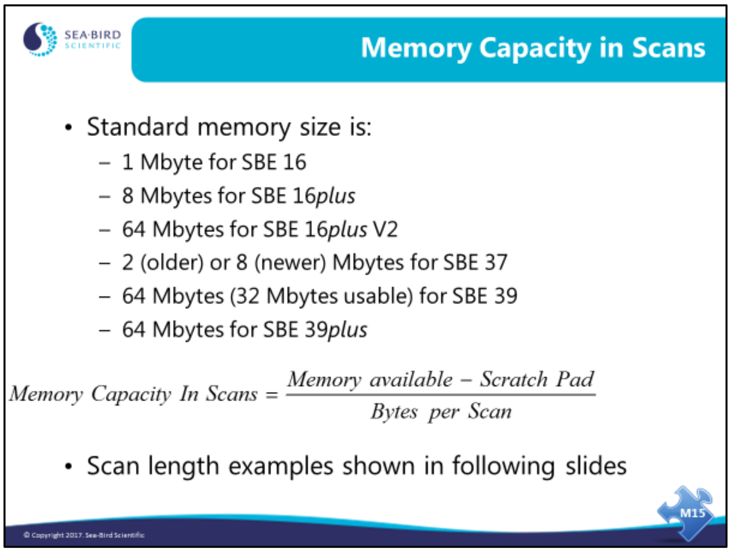


All clocks drift. If you put 10 instruments on a mooring, all set to the same time, and come back 1 year later, they will all report different times. This can lead to some difficulties when you process the data. Clocks drift because of instability of the crystal oscillator that the clocks use to keep time. A small change in oscillator frequency will translate into a clock that runs fast or slow.

For this reason, Sea-Bird calibrates the clock frequency versus temperature and corrects for drift each time an older SBE 37 or older 39 wakes to take a sample. To ensure the time between samples is consistent, each time the instrument wakes and takes a sample, the time to the next sample is set to be the calibrated time interval between samples, not the next clock time. This ensures a data series that is evenly spaced in time. Otherwise, the time between samples would vary depending on temperature's effect on the oscillator.

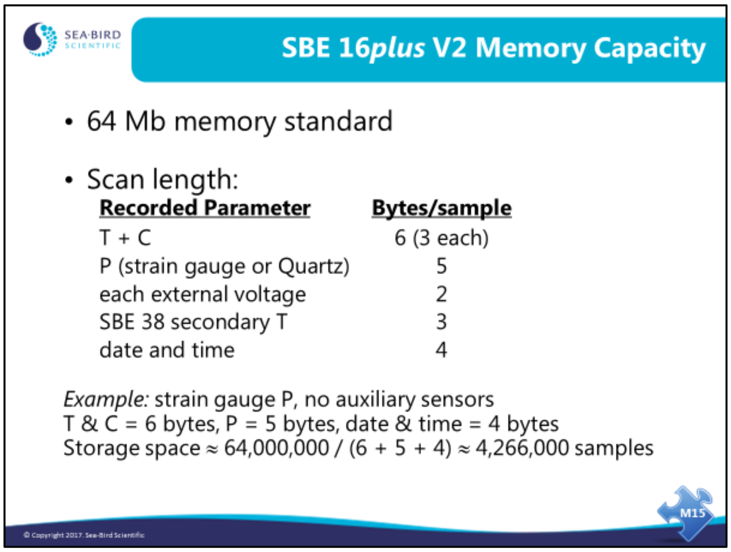
The SBE 16*plus* and 16*plus* V2, and newer SBE 37 (all IDOs and ODOs; others with firmware version ≥ 3.0) and SBE 39 and 39*plus*, use a temperature-compensated oscillator that provides a very stable time base. Previously these were not available in a small enough package to make them practical for a moored instrument.

Memory Capacity



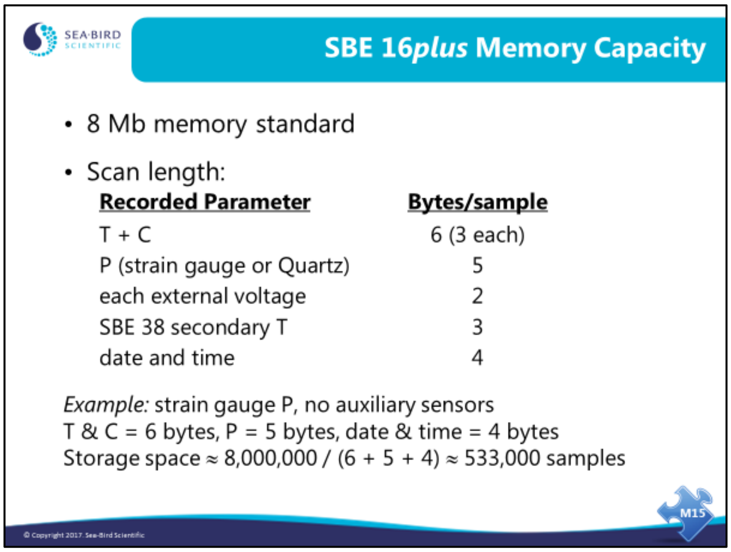
Memory capacity calculations are basically the same as seen for profiling instruments. Refer to Module 1 for an overview of this calculation; examples for specific instruments are on the following pages.

Memory Capacity: SBE 16*plus* V2



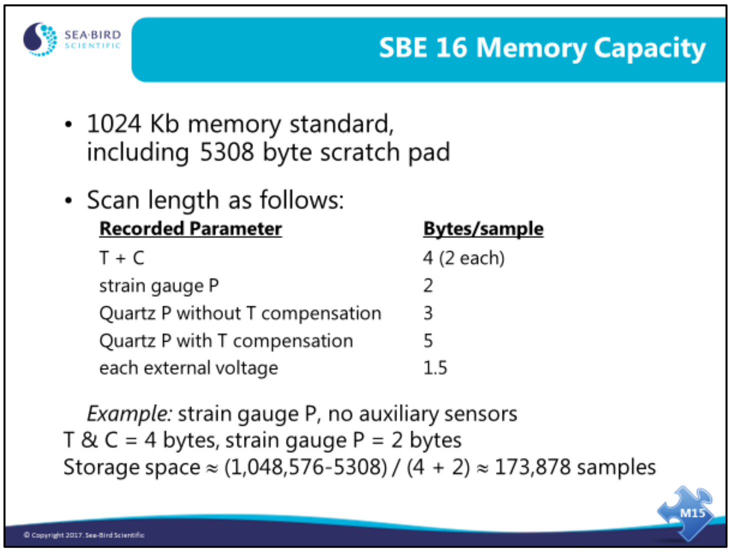
The SBE 16*plus* V2 has considerably more memory than the 16 or 16*plus*, with 64 Mbytes of non-volatile flash memory. Again, memory capacity depends on the configuration of the instrument.

Memory Capacity: SBE 16*plus*



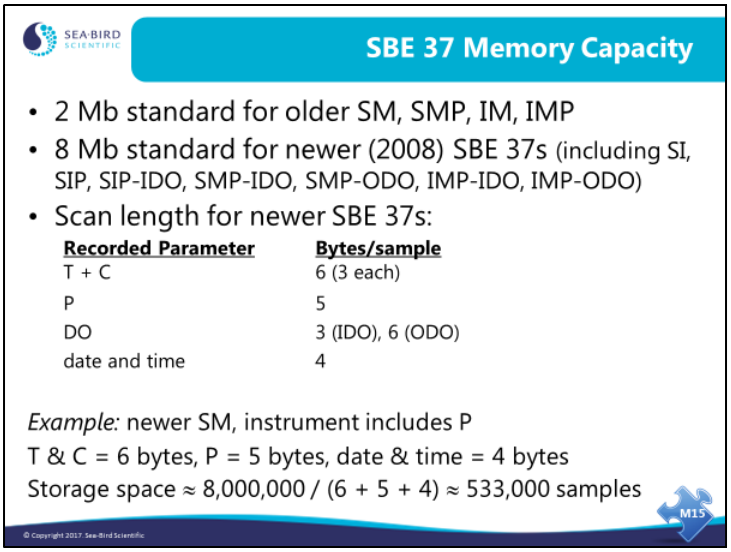
The SBE 16*plus* has considerably more memory than the 16, with 8 Mbytes of non-volatile flash memory. Again, memory capacity depends on the configuration of the instrument.

Memory Capacity: SBE 16



The SBE 16 has battery backed-up semiconductor memory of 1 Mbyte. Actual capacity in scans depends on how the instrument is configured.

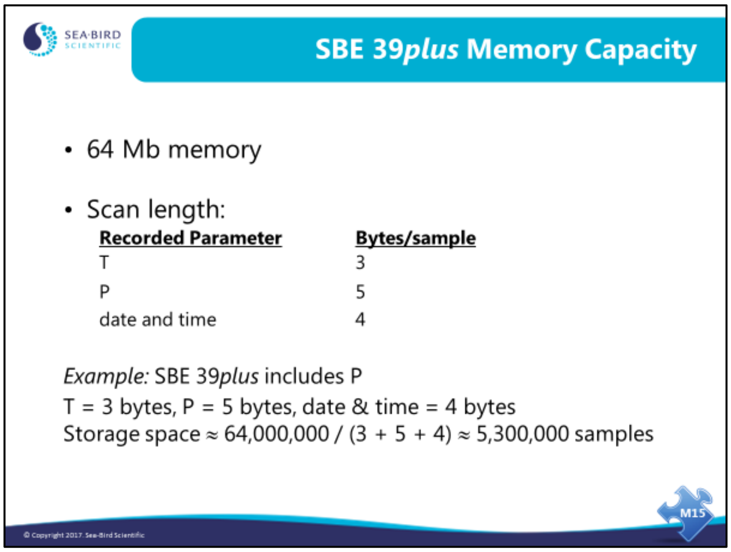
Memory Capacity: SBE 37 MicroCAT



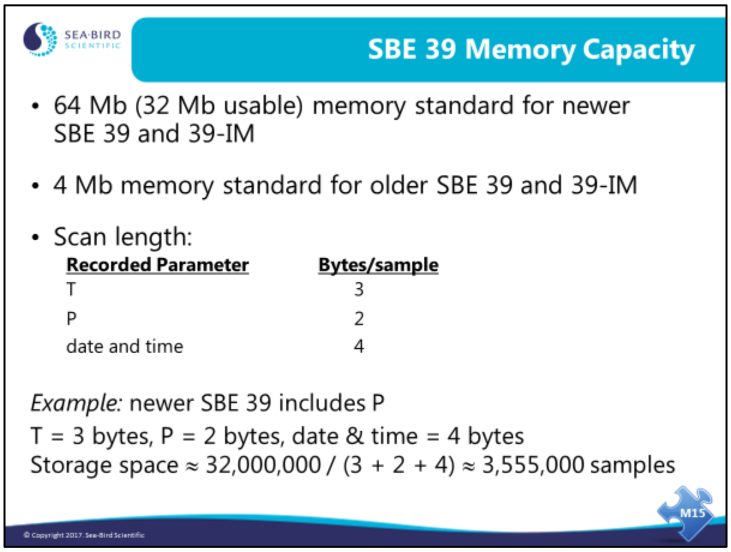
MicroCAT electronics were redesigned in 2008. For MicroCATs without dissolved oxygen, the new electronics design can be identified by the firmware version (send the **DS** or **#iiDS** command, as applicable, in the terminal program to see the firmware version) – firmware 3.0 and later. Among other changes, the revised electronics provide more memory for the 37-SM, SMP, IM, and IMP – 8 vs 2 Mbytes. And for the first time, the 37-SI and SIP have internal memory (8 Mbytes). The IDO MicroCATs (SMP-IDO, SIP-IDO, and IMP-IDO) and ODO MicroCATs (SMP-ODO, IMP-ODO) all have 8 Mbytes memory.

Note: The scan length for the older (< firmware version 3.0) electronics is different than shown on the slide. T & C is 5 bytes (2.5 bytes each) per sample, P is 2 bytes/sample. Date and time is 4 bytes/sample, but storage of date and time with each scan in memory is optional.

Memory Capacity: SBE 39*plus*

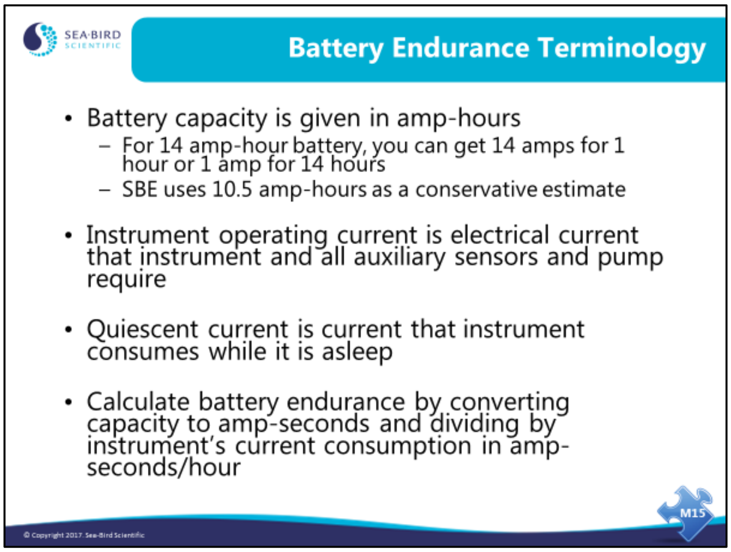


Memory Capacity: SBE 39



In 2008, the SBE 39 and 39-IM electronics were redesigned. The new electronics design can be identified by the firmware version (send the status command in the terminal program to see the firmware version) – firmware 3.1 and later for the SBE 39, digital firmware version 1.04 and later for the 39-IM. Among other changes, the revised electronics provides more memory – 32 MB of usable memory vs 4 Mbytes.

Battery Endurance

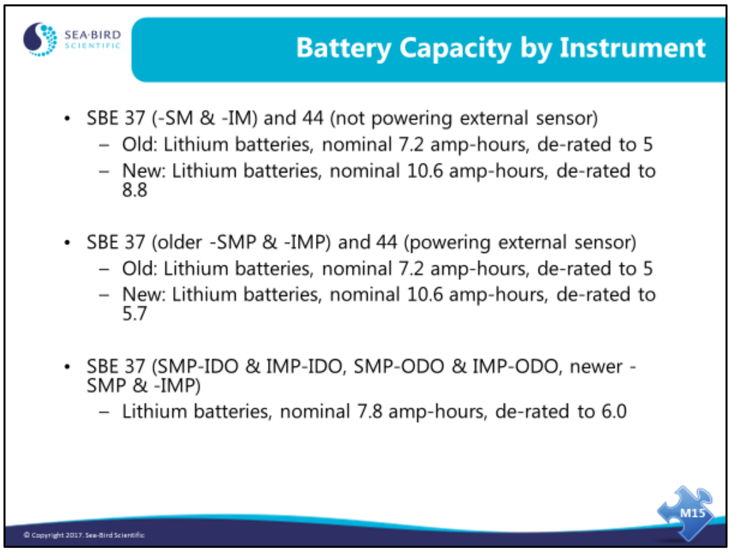


Battery endurance is a topic of great interest to those who work with moored instruments. However, estimating battery endurance is a very difficult to do accurately. Battery manufacturers specify the amount of energy contained in a battery in terms of ampere hours. This is the amount of current that the battery can supply for a given length of time. If a small amount of current, 100 milliamps for example, is drawn from the battery, it will last many hours (years). Conversely if a large current is drawn, 1 amp for example, the battery will last for few hours.

Calculating battery endurance requires summing the amount of current drawn by the instrument and its auxiliary sensors for the length of time they are operating. In addition, the quiescent current of the main instrument must be included. The quiescent current is that drawn by the instrument while it is sleeping, and is required for operation of the clock and the circuits that monitor the communications lines, so that when you attempt to communicate with the instrument it awakens and responds.

For instruments that use alkaline batteries, Sea-Bird uses Duracell brand alkaline batteries exclusively; all our examples for alkaline batteries will be based on these.

Battery Capacity by Instrument



Sea-Bird offers different types of batteries depending on the type of instrument.

- The SBE 37 (SM & IM, older SMP & IMP) and 44 come with lithium batteries. Sea-Bird began selling a new battery pack and batteries for these instruments in 2008.

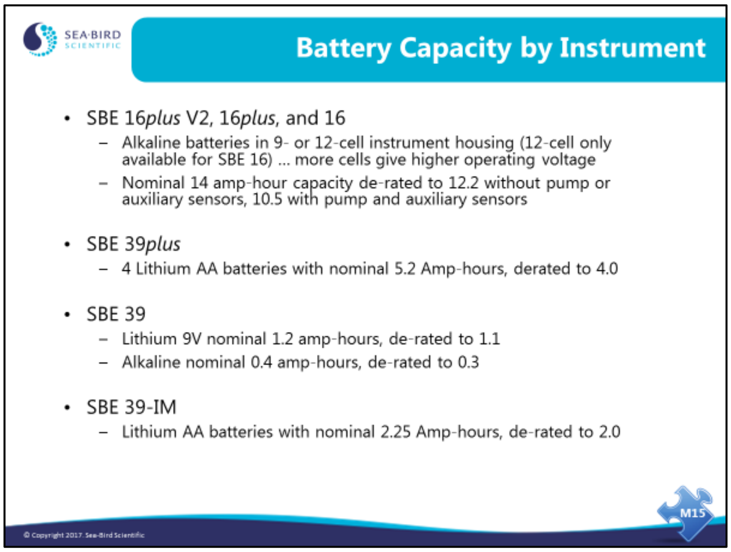
  - *Old* battery was a custom-built battery made from 3 Panasonic BR-2/3A (6 of these *sticks* were installed in a battery holder).

  - *New* battery is 12 AA lithium cells in a new battery holder. These cells are less expensive and widely available, and provide more power for longer deployments.

  NOTE: Pumped MicroCATs (SMP and IMP) and an SBE 44 that is powering the external sensor have different power consumption characteristics than unpumped MicroCATs (SM and IM) and an SBE 44 that is not powering the external sensor. Consequently, the batteries are de-rated differently.

- The 37-SMP-IDO, IMP-IDO, SMP-ODO, IMP-ODO, and newer 37-SMP and IMP (April 2011 and later), use 12 AA lithium cells in a battery holder. Although the pack looks similar to that for the older 37s, it is wired differently and is a different color; **the packs are not interchangeable**.

Battery Capacity by Instrument (*continued)*

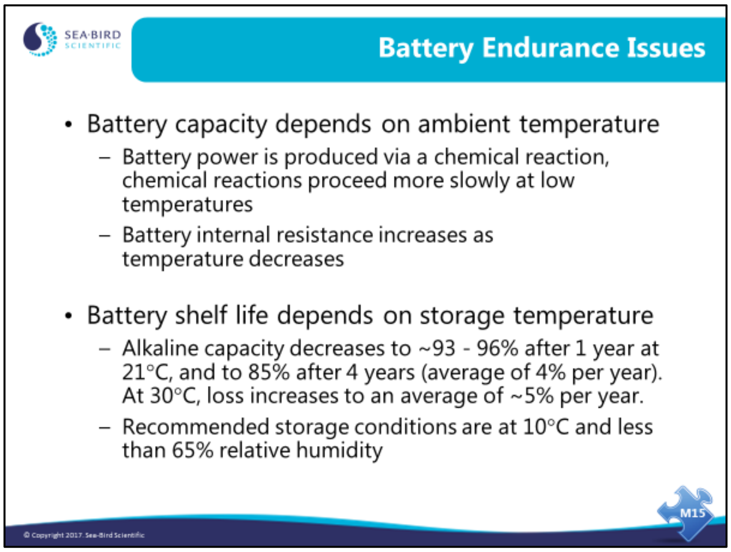


Sea-Bird offers different types of batteries depending on the type of instrument.

- The SBE 16*plus* V2 is normally supplied with alkaline batteries; however a lithium battery pack *kit* may be purchased (these lithium batteries are not supplied by Sea-Bird).
- The SBE 39*plus* comes with AA lithium batteries only.
- The SBE 39 can be powered with a lithium or alkaline battery.
- The SBE 39-IM comes with AA lithium batteries only.

  Note: A few early versions of the 39-IM used the same batteries as the SBE 39.

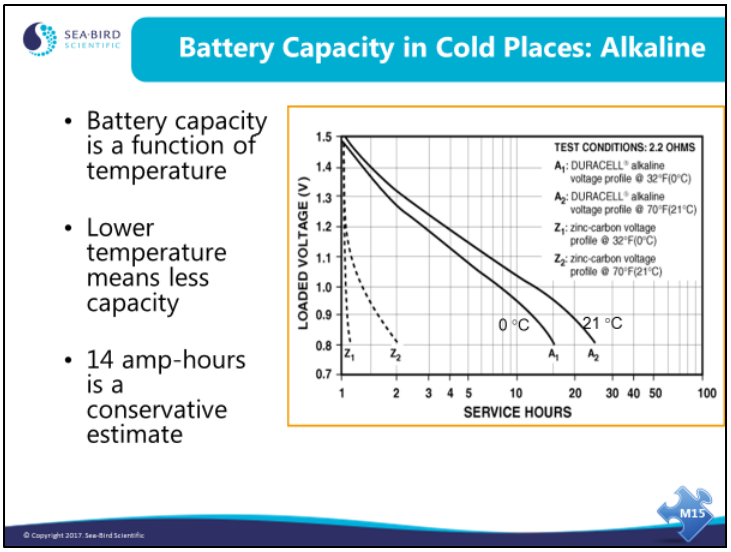
Battery Endurance Issues



As mentioned in a previous page, battery endurance is very difficult to estimate. Battery capacity depends on the temperature of their use for the reasons outlined in the slide above. In addition, batteries exhibit shelf life degradation. A battery in storage will slowly discharge at a rate that leaves about 85% capacity after 4 years in good storage conditions. Batteries stored at high temperatures will lose capacity more rapidly. Obviously, a fresh battery has the most capacity.

- A battery operated at high temperature will gain capacity due to a faster chemical reaction and lower internal resistance, but will lose capacity due to more rapid shelf life degradation.
- Conversely, a battery operated at low temperature will gain from better shelf life but lose due to less efficient chemical reaction and higher internal resistance.

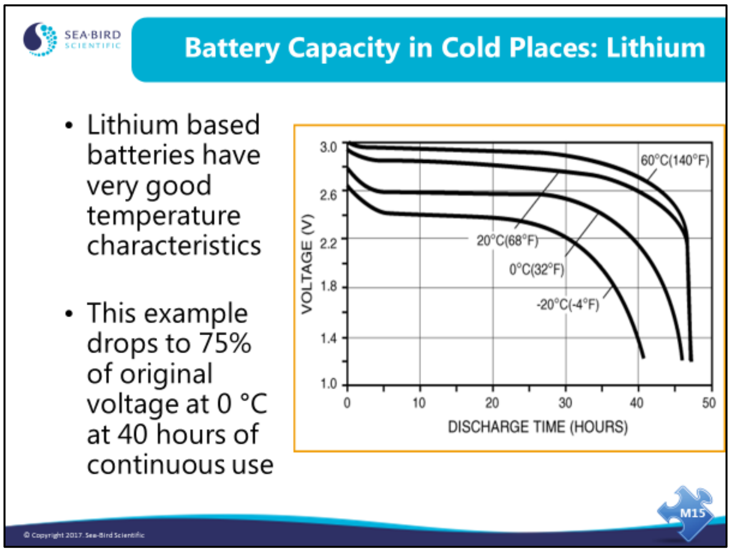
Battery Endurance: Alkaline Battery Capacity



Considering the time and money involved in making a mooring, fresh batteries are a small expense. We estimate the battery life in an SBE 16, 16*plus*, or 16*plus* V2 assuming that it begins with 14 amp-hours of power. As you see from the plot, 14 amp-hours is a conservative estimate. At 0 °C an alkaline battery is expected to supply 0.8 volts after 15 hours of continuous service (i.e., continuous sampling, not the intermittent sampling usually done with moored instruments).

A standard, 9-cell battery pack starts at 13.5 volts (1.5 volts x 9 batteries) and drops to 7.2 volts (0.8 volts x 9 batteries) after 15 hours. Sea-Bird instruments measure the battery voltage and will not sample if the voltage is below a cut-off threshold. The value of 7.2 volts is above the cut-off for an SBE 16 and just below it for a 16*plus* or 16*plus* V2.

Battery Endurance: Lithium Battery Capacity

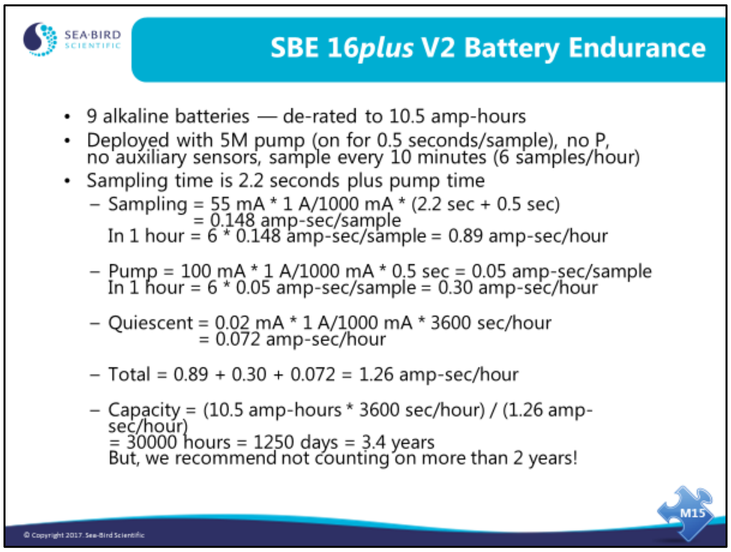


Lithium batteries offer better performance. The main drawback to using them is international shipping restrictions on lithium. For example, looking at the lithium batteries for the SBE 37 MicroCATs and SBE 44 Underwater Inductive Modem:

- The old battery pack (37-SM, SMP, IM, IMP, and 44) was made of 6 custom-built batteries. It is legal to ship them separately; however, once assembled into the battery pack they become illegal to ship, as they are too large a mass.
- The new battery pack (2008 and later) uses 12 AA lithium cells installed in a battery holder. Like the old battery pack, they cannot be shipped assembled in the battery holder.

Note: The lithium batteries used in the SBE 39*plus*, 39, 39-IM, and 56 can be shipped installed in the instrument.

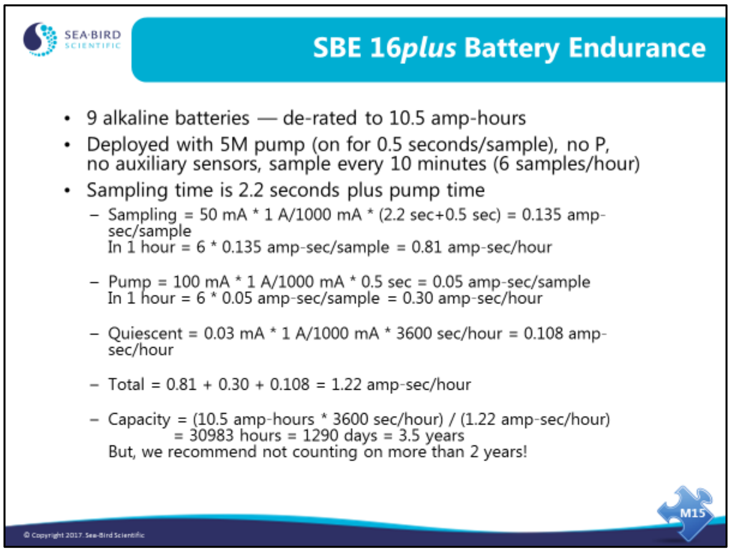
Calculating Battery Endurance: SBE 16*plus* V2



Recall the slide on memory endurance for the SBE 16*plus* V2. We can calculate that we have memory for 6,400,000 samples if measuring and storing only temperature, conductivity, date and time (6,400,000 = 64,000,000 / [6 + 4]). However, we have battery power for only 180,000 samples (≈ 30000 hours * 6 samples/hour). As with the SBE 16*plus*, we are battery-limited.

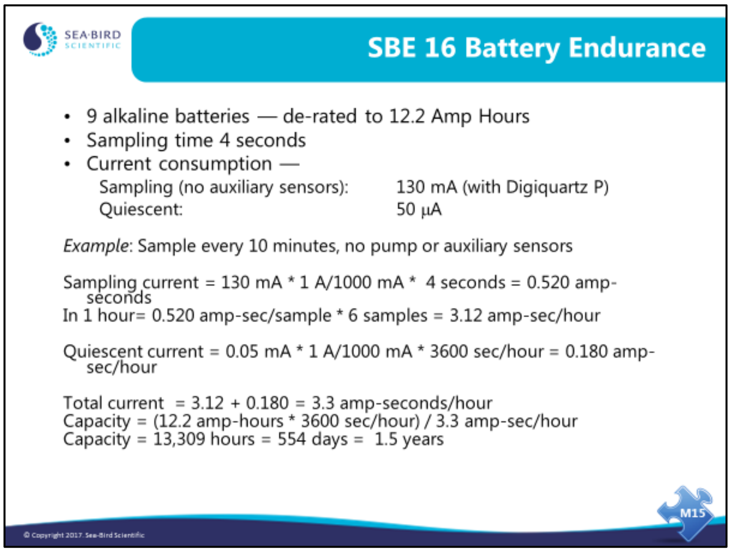
Note that battery capacity depends on operating temperature; capacity is reduced as battery temperature goes down. With profiling applications, an instrument may spend part of its time in cold water. In moored applications it is not unusual for an instrument to spend its entire deployment in cold water.

Calculating Battery Endurance: SBE 16*plus*



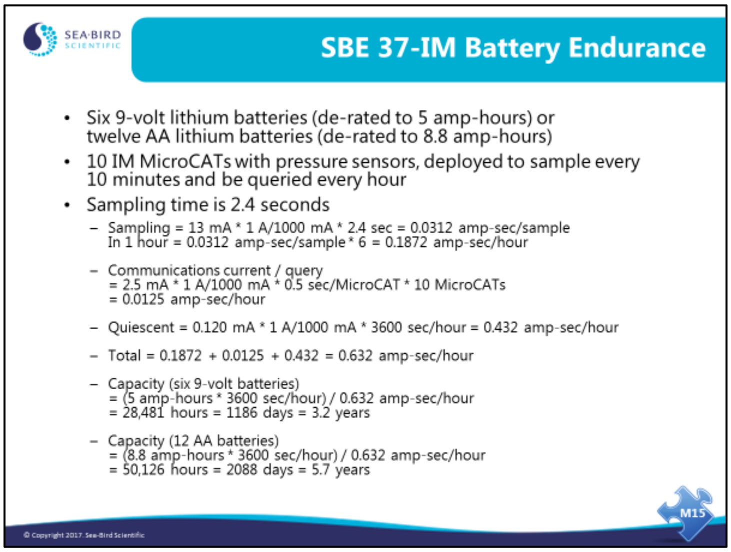
Recall the slide on memory endurance for the SBE 16*plus*. We can calculate that we have memory for 800,000 samples if measuring and storing only temperature, conductivity, date and time (800,000 = 8,000,000 / [6 + 4]). However, we have battery power for only 185,000 samples (≈ 30983 hours * 6 samples/hour). As with the SBE 16, we are battery-limited.

Calculating Battery Endurance: SBE 16



Recall the slide on memory endurance for the SBE 16. We can calculate that we have memory for 115,918 samples if measuring temperature, conductivity, and Digiquartz pressure, with no auxiliary sensors (115,918 = [1,048,576 – 5308] / [4 + 5]). This is enough memory for 19,319 hours of operation if sampling every 10 minutes. We will run out of battery power before we run out of memory.

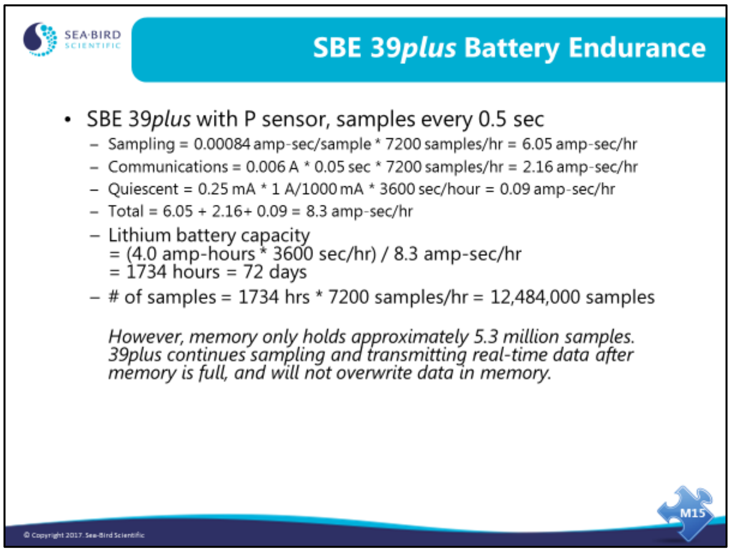
Calculating Battery Endurance: SBE 37 MicroCAT



Battery capacity is shown in this example for both the old and new battery pack.

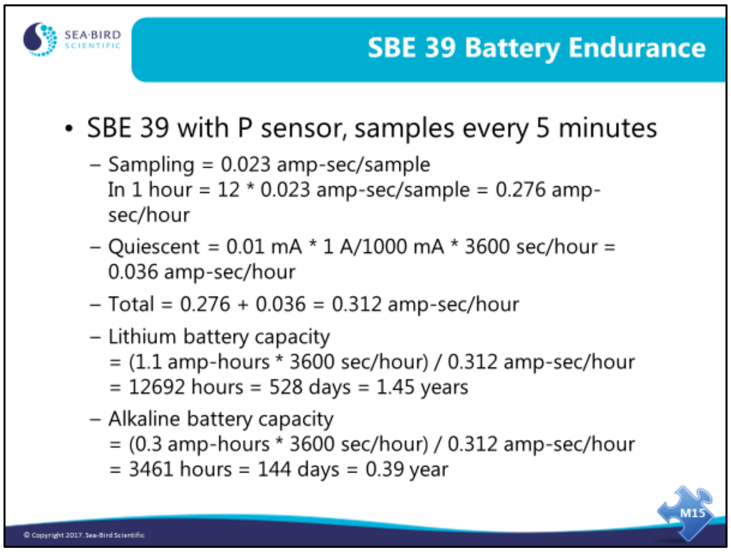
We can calculate that we have memory for 533,000 samples if measuring and storing temperature, conductivity, pressure, date and time (533,000 = 8,000,000 / [6 + 5 + 4]). However, we have battery power for 170,000 samples (≈ 28481 hours * 6 samples/hour) with the old battery pack or 300,000 (≈ 50126 hours * 6 samples/hour) with the new battery pack. If using the old battery pack, we are battery-limited. If using the new battery pack, we are memory-limited.

Calculating Battery Endurance: SBE 39*plus*



Unlike most of our instruments, the 39*plus* deployment length is limited by memory, not battery.

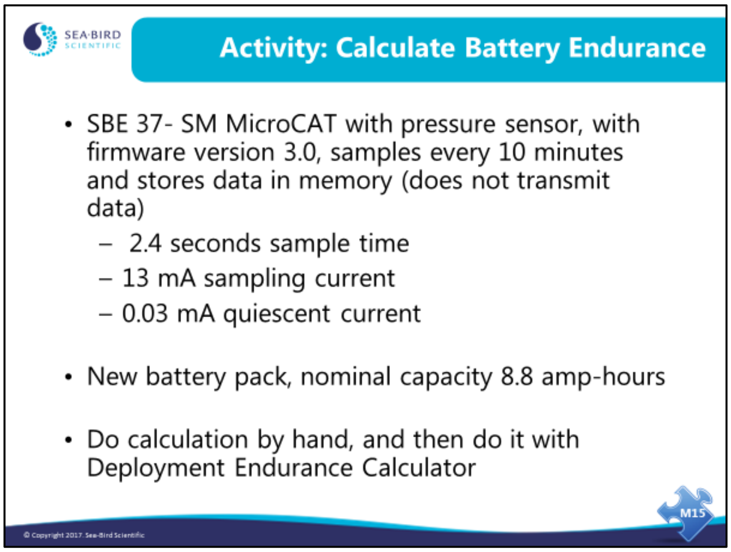
Calculating Battery Endurance: SBE 39



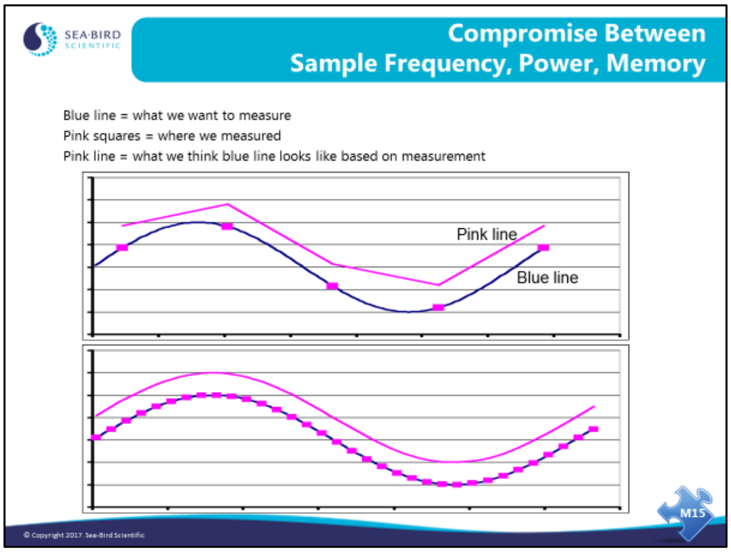
Note: Sea-Bird's easy-to-use battery endurance calculator, **Deployment Endurance Calculator**, can perform these calculations for most of our moored instruments.

The Calculator is installed as part of our Seasoft V2 software suite (which you installed on the first day of the class). See our website for details (www.seabird.com/software/deployment-endurance-calculator).

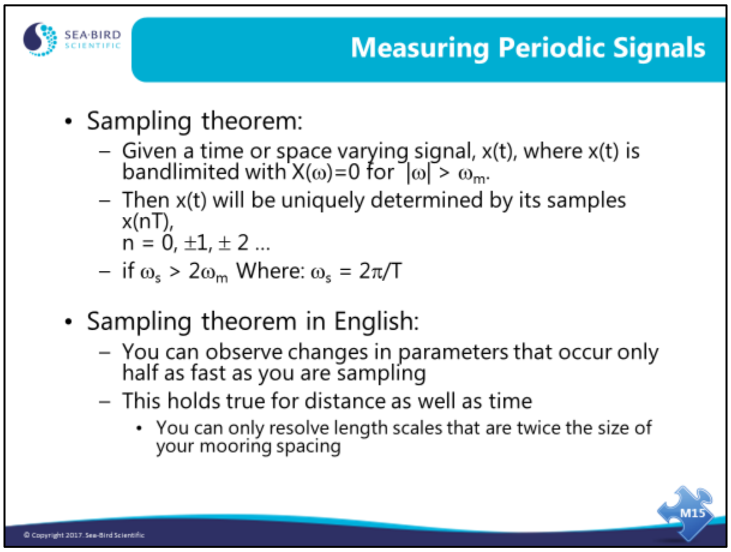
Activity: Calculate Battery Endurance



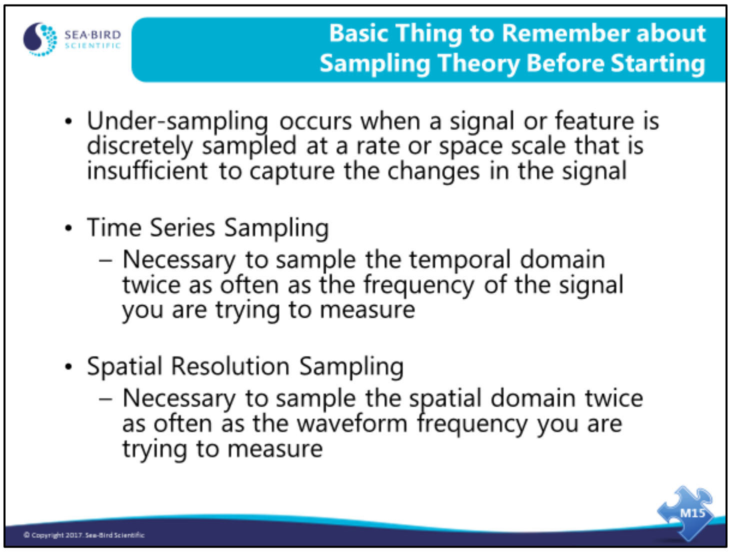
Measuring Periodic Signals



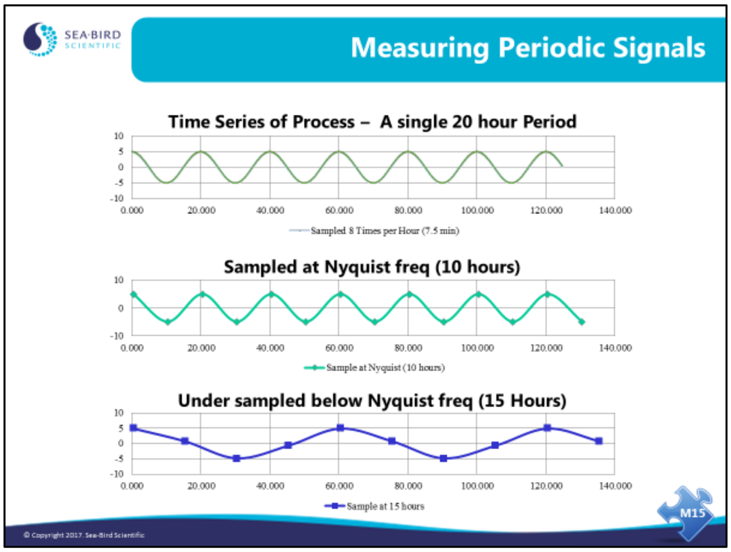
Measuring Periodic Signals *(continued)*



Measuring Periodic Signals *(continued)*



Measuring Periodic Signals *(continued)*



This is a simple example of a single 20-hour periodic signal sampled within the Nyquist frequency (every 10 hours or more often) and then undersampled (every 15 hours or less often). You can see how the wrong signal is produced when the signal we are after is not sampled fast enough.

Measuring Periodic Signals *(continued)*