OPERATING AND REPAIR MANUAL
SBE 31 MULTI-CHANNEL COUNTER

SEA-BIRD ELECTRONICS, INC.

1808 136th Place NE

Bellevue, Washington 98005 USA

Phone: (425) 643 9866 Fax: (425) 643-9954 email: seabird@seabird.com

vers. 31.003

LIMITED LIABILITY STATEMENT

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

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

TABLE OF CONTENTS

1-1 SYSTEM DESCRIPTION

The Sea-Bird SBE 31 Multichannel Counter is used to acquire frequency (and optionally voltage) information from a suite of sensors. High resolution and accuracy are offered at a fast sample rate of 24 scans per second, with capability to average the sensor data to provide slower data rates to the system computer.

Using a high-resolution hybrid counting technique, the SBE 31 digitizes frequency data (input through rear-panel connectors) at 24 scans per second from sensors such as Sea-Bird's SBE 3 Oceanographic Thermometer, SBE 4 Conductivity Meter, or SBE 12 (Paroscientific Digiquartz) pressure transducer. The hybrid method ensures that the measurement period is constant regardless of sensor frequency, and yet the high-resolution advantages of period-counting are realized.

12 volts dc (200 milliamp maximum) is also available at the red and black binding posts for powering Sea-Bird or other sensors.

A thumbwheel switch is used to select the desired input frequency or voltage for front-panel display.

The SBE 31 supplies DC power to, and aquires data from, the external sensors connected to the back panel. It formats the data under microprocessor control, and passes the data to a companion computer.
Data output is provided in both IEEE-488 and RS-232 format.
An optional interface is available for acquiring NMEA 0183 standard navigation/position data.

If desired, the SBE 31 can average the underwater unit data to reduce the processing or archiving demands placed on the accompanying computer.

See the SYSTEM CONFIGURATION SHEET at the front of this manual which describes the features of your particular SBE 31

2-1 INSTALLATION AND OPERATING INSTRUCTIONS

The SBE 31 Multichannel Counter is fully assembled and tested. The front and back panel displays and controls are described in this section. Before connecting the companion computer, apply power to the unit and run through the preliminary checkout as described in this section.

2-1.1 POWER-ON (DEFAULT) CONDITIONS

Basic functions are performed at 'power up' or after the "RESET" button has been pushed; these are the 'default' operating conditions. For example, the numeric display will show channel frequencies subsequent to 'power up', but data will not be output to the computer interface ports. Modifications to the default conditions are implemented by transmitting 'commands' from a computer to the IEEE-488 or RS-232C interface ports (see Section 3-6).

2-1.2 FRONT PANEL DISPLAYS AND CONTROLS

The 'POWER' switch is pressed to turn on the deck unit. Voltage will immediately be applied to the internal circuit cards as well as the rear panel sensor connectors.

The 'DATA' light indicates that the Deck Unit Microprocessor board is successfully receiving data from the encoder electronics (located in the internally mounted cardfile) at the expected rate and format. In general, if this light is on and the 'ERROR' light is off, it may be assumed that the SBE 31 is working properly.

The 'TRANSMIT' light will blink when the Deck Unit sends data out over the IEEE-488 or the RS-232C interface.

The 'RECEIVE' light will blink when the Deck Unit receives characters from the computer.

The 'OVERFLOW' light will come on if the output buffer has overflowed because the computer did not take the data from the deck unit quickly enough. If this light comes on it means that at least some data has been irretrievably lost.

The 'RESET' button empties the output buffer and halts input to it until instructions are received from the computer. The 'RESET' function may also be performed via software control (explained in Section 3-6). This function should always be performed before beginning a CTD cast, since otherwise the first data sent to the computer may be old data left over from the end of a previous cast. SEASOFT performs this reset function automatically.

The 'WORD DISPLAY' on the front panel may be used to view individual data words (uncorrected frequencies or voltages). No computer is required to obtain this display.

The 'WORD SELECT' thumbwheel switch on the front panel may be used to select any sensor channel, data buffer status, or other diagnostic indicators for viewing on the 'WORD DISPLAY' (see Section 3-4).

2-1.3 BACK PANEL CONNECTORS

The AC power connector is designated for either 115 VAC or 230 VAC operation via a separate power cable (supplied). The fuse holder is marked for either 1 amp fast blow (115VAC) or .5 amp fast blow (230VAC).
AVOID CONNECTING 230VAC TO AN SBE 31 MARKED FOR 115VAC AS DAMAGE WILL RESULT.
Computer I/O takes place through the 'IEEE-488' and/or 'RS-232' connectors.
Typically, the external sensor cables are attached to MS type connectors located on the back panel. The arrangement, quantity and type of sensor connector is variable. For the exact back panel layout of your unit, see the SBE 31 back panel drawing located in the 'schematics' section of this manual. The back panel sensor connectors provide power (at +12 volts DC) and receive the sensor output signal. Banana jacks also provide +12 volts DC and GROUND at the back panel.

2-1.4 PRELIMINARY CHECKOUT

Apply main power at the AC connector. **CAUTION: CONNECTING 230 VOLTS TO AN SBE 31 BUILT AND MARKED FOR 115 VOLTS WILL CAUSE DAMAGE TO THE SBE 31.** Observe that the 'Data' light comes on and the 'Error' light is off. This confirms that the encoder section is transmitting data and that the data is being correctly processed by the microprocessor logic.

Set the SBE 31 thumbwheel switch to position 0. The display should read the frequency being input to rear panel MS connector labeled "F0". If there is no frequency source connected, the display will read 0.000. Set the thumbwheel switch to look at the remaining frequency inputs in the same way. Following the last frequency word is the first A/D voltage word. The four digits to the left of the decimal point represent A/D converter channel 0; the right digits, channel 1. Channels that have no sensors attached to them will read '4095' which is the A/D converter output for 0 volts. A display reading of '0' represents +5 volts DC at the A/D channel. Check the remaining A/D inputs in the same way.

With the thumbwheel set to position A, the digits to the left of the decimal point are normally zero, but would represent pressure sensor temperature compensation if the SBE 31 is configured for a 'Digiquartz' type pressure sensor. The right hand digits will show the incrementing modulo count. Since the deck unit defaults on power up to average 8 scans together but the modulo count is transmitted for the most recent scan only, this number will increase in steps of 8. Modulo count is a scan identifier in the form of an 8 bit number which increases 0, 1, 2, 3, etc up to 255 and then rolls over to 0, 1, 2 etc. It is generated in the encoder circuitry and can be used for diagnostic purposes.

Thumbwheel position C shows the number of bytes available in the IEEE-488 buffer (initially 7000). When recording data via the IEEE-488 interface, this number will decrease as the deck unit places data in the data buffer and will increase as the computer processes and stores CTD data. It will be important to ensure that the buffer count periodically resets to 7000 otherwise the buffer will eventually fill and data loss will occur. The computer display update rate (set in SEASOFT) is used to prevent the occurrence of overflow. Thumbwheel position D performs in the same manner but relates to the RS-232 output; the buffer length for RS-232 data is 14000 bytes.

Note that these thumbwheel switch positions are specific to the system configuration - see the SBE 31 configuration sheet near the front of this manual for details.

Connect your computer to the SBE 31 using the IEEE-488 or RS-232C output ports. See Section 3.6 for a description of the computer commands needed to implement control and to process the output data. If you have an IBM or COMPAQ computer or equivalent with an 8087 coprocesser and the National Instruments GPIB interface installed, the software provided with the system will run directly.

2-2 PERFORMANCE VERIFICATION

2-2.1 CRYSTAL OSCILLATOR AGING

The frequency of the crystal oscillator in the Underwater Unit will change with time, about 1 ppm in the first year and less than 0.3 ppm in subsequent years.

2-2.2 FREQUENCY CHANNEL PERFORMANCE CERTIFICATION

To check a data channel (or the entire system) for proper operation, disconnect the sensor cable from the sensor and use a frequency generator and counter to put a sine or square wave of 0.5 to 10 volts peak-to-peak amplitude and known frequency into the sensor cable and check this frequency against that computed by the Deck Unit and sent to the computer.

2-2.3 A/D CHANNEL PERFORMANCE CERTIFICATION

Input known voltages in the range 0 to + 5 volts and confirm that the correct voltage (±0.1%) is output via the system post processing software. There are no adjustments in the A/D section, so any inconsistencies will have to be accounted for in software. Calibration of the auxiliary sensors through the entire CTD processing circuitry will automatically correct A/D errors.

2-3 CONNECTING SENSORS

The male bulkhead connectors on Sea-Bird temperature and conductivity sensors have three pin connectors (XSG-3-BCL type) which have the following pinouts:

Pin 1 (large pin)	Ground
Pin 2 (first pin CCW face view)	Signal
Pin 3	Supply (+ 10 to + 20 volts dc)

2-3.1 TEMPERATURE/CONDUCTIVITY SENSOR CONNECTION

Shielded cables with female connectors for mating to the Sea-Bird sensors can be connected to each MS connector on the back panel. Pin 1 of all MS connectors is common, pin 3 is +12v power.

3-1 COMPUTER INTERFACING TO THE SBE 31 MULTICHANNEL COUNTER

When SBE 31 power is turned on or the front panel 'RESET' button is pushed the internal EEPROM settings are read and the output buffers are reset and flushed.

Changes to the deck unit configuration may be made by specifically formatted commands to the deck unit's IEEE-488 or RS-232C interface ports. (see Sections 3-6).

If the SEASOFT CTD data acquisition software is to be used, follow the instructions furnished with the software package. It will not be necessary to separately implement the commands outlined in section 3-4, as the software does so automatically.

In order to facilitate data handling, the SBE 31, like other data processing equipment, cluster individual data bits into groups of various sizes. The following definitions apply in this manual:

- Byte — Always 8 bits. May be serial (as generated in the Underwater Unit) or parallel (the Deck Unit's IEEE-488 output).
- Character — (ASCII Character). Data Byte encoded to ASCII standard.
- Channel — Path taken by data deriving from a single sensor (for example, a temperature sensor) or other source (such as the modulo counter).
- Word — This term is used to describe a group of data bits subject to certain arithmetic and display operations by the Deck Unit. Words consist of 3 bytes. A word may comprise a single frequency channel, or two A/D channels. The Modulo Word conveys the modulo count, pump, bottom contact, modem, water sampler interface status bits, and a twelve-bit number representing pressure sensor compensation temperature.
- LSB — Least significant bit
- MSB — Most significant bit
- Scan — The set of data derived from a single sample of each of a system's sensors, typically obtained 24 times per second.
- Word Number — The sequential position of a data word in the Scan. The word number depends on the order in which the word is presented to the computer or displayed, not on the order in which a particular sensor's data was acquired. The first word in the scan is word number zero.

3-2 COMMUNICATING WITH THE SBE 31

If Sea-Bird SEASOFT software is used, the IEEE-488 address must be set to 1 and the RS-232C parameters must be set to 19200 baud, 8 data bits, no parity, and one stop bit.

See Section 3-6 for instructions on how to configure the SBE 31. All necessary communications protocols are handled by the software. Follow the menu prompts when running SEASOFT, and read the SEASOFT Installation Instructions supplied with the SEASOFT diskettes.

To verify the deck unit configuration, connect the SBE 31 interface RS-232 port to a terminal or to COM1 on an IBM PC compatible computer. If you are connected to a PC, run the program TERM11 (included with SEASOFT).

Press the reset button on the SBE 31 front panel. The deck unit configuration will be displayed.
A typical example is:

SBE 31 V 5.0
number of scans to average = 4
number of frequency words = 8
number of voltage words = 0
GPIB address = 1

TERM11 can also be configured to run on COM2 by entering:
  TERM11 -P2
on the command line.

3-3 DECK UNIT CONFIGURATION

The internal switches in previous versions of the SBE 31 have been replaced with non volatile EEPROM. Commands are sent via the SBE 11 RS-232 interface to configure the deck unit. The RS-232 interface is set to 19,200 baud, 8 data bits, no parity. **This setting can not be changed.**

3-3.1 DISPLAY DECK UNIT CONFIGURATION

Press the RESET button on the front panel or enter DS followed by the enter key to display the deck unit configuration.

A typical response is:

SBE 31 V 5.0
number of scans to average = 4
number of frequency words = 8
number of voltage words = 0
GPIB address = 1

3-3.2 IEEE-488 ADDRESS SELECTION

The Deck Unit is shipped with the IEEE-488 address set at 1. The address can be changed the command:

gpib=N

where N is the new GPIB address. The GPIB address must be set to 1 in order for the deck unit to work with SEASOFT.

3-4 DATA FORMATS

The formats in this section are those associated with the deck unit's output ports and display and are not to be confused with the (different) format of the internal cardfile electronics.

These outputs are user configurable with regard to the number of frequency channels and A/D channels sent to and stored by the host computer. The standard SBE 31 is internally defined as a 12 word system. For applications that do not require all of the frequency channels and/or all of the A/D channels, the unused channels may be suppressed. This can result in a substantial saving in the disk space required to store CTD data. Channel suppression is selected via the program SEACON, refer to the SEASOFT manual for a discussion of this procedure. The following paragraphs consider an SBE 31 set to utilize 5 frequency channels and 8 A/D channels.

The configuration shown below is a typical example which may not represent your system. For the specific configuration of your unit, see the SBE 31 configuration sheet near the front of this manual.

3-4.1 DATA WORD DESIGNATION

The Deck Unit data words (each containing three bytes) are assigned as follows:

Word 0:	Frequency 0
Word 1:	Frequency 1
Word 2:	Frequency 2
Word 3:	Frequency 3
Word 4:	Frequency 4
Word 5:	A/D channels 0-1
Word 6:	A/D channels 2-3
Word 7:	A/D channels 4-5
Word 8:	A/D channels 6-7
Word 9:	unused
Word 10:	unused and marker byte (thumbwheel switch position A)
Word 11:	Modulo Count, Underwater Unit status bits, and Pressure Temperature Compensation (thumbwheel switch position B)

These word numbers indicate the order of the data scan sent to a computer via the IEEE-488 or RS-232 port, they are used with some of the special commands described in Section 3-7. Words 0 through 11 correspond to the settings (0,1,2,3,4,5,6,7,8,9,A,B) of the thumbwheel switch. The next section discusses available data on the deck unit front panel. Suppressed channels will be set to zero on the front panel display.

3-4.2 FRONT PANEL DISPLAY

Any data word may be selected for display by the thumbwheel switch on the SBE 31 front panel. However, if the SBE 31 is configured with more than 15 data words, it will be necessary to run TERM11 and enter the 'LX' command to allow selection and viewing of the higher words, modulo count, IEEE-488 and RS-232 buffers on the display. See section 3-7.7 for a description of the LX command.

This display is updated approximately every second if the number of scans to average in the deck unit has been set to one. For other averaging rates the display is updated each time a set of scans is averaged.

Data words for each frequency channel are displayed directly in Hz. Each data word for auxiliary A/D channels contains information from 2 A/D voltage channels (voltages 0-7, representing dissolved oxygen, fluorometer, etc.). The first 4 digits (reading left to right) correspond to the lower numbered voltage present (e.g V0) in the selected data word, the second 4 digits correspond to the next numbered voltage (e.g. V1). These voltages are displayed as the decimal values of the 12 bit numbers associated with each channel. These are binary representations of analog voltages, with zero volts input giving a readout of 4095, and 5 volts input giving a readout of 0. The explicit interpretation of displayed values is described in Section 3-5.

Switch position 9 is unused, and position A displays 255 (a marker byte). The modulo count and (optional) pressure sensor temperature compensation information are observed by selecting position B for display. The four digits left of the decimal point show the (optional) temperature compensation value (a reading of 2500 corresponding to about 22 degrees would be typical). The right four digits show the incrementing modulo count.

The SBE 31 places data to be transmitted to the companion computer into a buffer, this allows the deck unit and the computer to operate with some independence. If the thumbwheel switch is set to C, the number of bytes available in the IEEE-488 buffer is displayed. If the thumbwheel switch is set D, the number of bytes in the RS-232C buffer is displayed.

When transferring data to a computer, the deck unit places data in the buffer at the rate it is acquired. The data is removed (transferred to the computer) as it is requested by the computer. If the computer spends too much time calculating and displaying the data it may start to fall behind and the number of available bytes will decrease. When the number of available bytes is less than an entire scan the buffer overflow light will be latched on and will stay on until a reset command is received or the deck unit is reset.

Thumbwheel switch position E displays the status bits. Status bits are used by the SBE 11*plus*, with an SBE 9*plus*, to monitor pump on/off, bottom contact switch, water sampler, and modem carrier detect. These status bit functions are not applicable to the SBE 31.

3-4.3 IEEE-488 OUTPUT DATA FORMAT

The listing which follows is standard and will represent normal conditions subsequent to turn-on or reset of the Deck Unit. As a means of reducing disk storage space requirements, the SBE 31 provides the option of suppressing unused data channels from the data stream. For instance, if only primary temperature and conductivity channels are being used then the secondary channels may be stripped from the data stream. Similarly, if all A/D channels are not being used, the unused channels may be stripped out as well. If data channels are suppressed, the listing below will be shortened. Channel numbers are suppressed from the last to the first. Section 3-6 discuss the pertinent SBE 31 commands, the instrument configuration program SEACON may be set so that SEASAVE automatically programs the SBE 31 to delete unused data channels.

The specific data output sequence provided with this CTD system is provided on the SYSTEM CONFIGURATION SHEET at the front of this manual.

The last word ALWAYS contains the (optional) Digiquartz temperature compensation data, a byte of zeros, and the modulo N count, and the end or identify (EOI) line is ALWAYS asserted with the last byte. The data are output in the following order for a system supporting 5 frequency inputs and 8 A/D channels (note: MSB = most significant bit, LSB = least significant bit)

BYTE 0	Word 0	Frequency Channel 0
BYTE 1	Word 0	Frequency Channel 0
BYTE 2	Word 0	Frequency Channel 0
BYTE 3	Word 1	Frequency Channel 1
BYTE 4	Word 1	Frequency Channel 1
BYTE 5	Word 1	Frequency Channel 1
BYTE 6	Word 2	Frequency Channel 2
BYTE 7	Word 2	Frequency Channel 2
BYTE 8	Word 2	Frequency Channel 2
BYTE 9	Word 3	Frequency Channel 3
BYTE 10	Word 3	Frequency Channel 3
BYTE 11	Word 3	Frequency Channel 3
BYTE 13	Word 4	Frequency Channel 4
BYTE 13	Word 4	Frequency Channel 4
BYTE 14	Word 4	Frequency Channel 4
BYTE 15	Word 5	A/D Channel 0 (8 MSBs)
BYTE 16	Word 5	A/D Channel 0 (4 LSBs 4-7) A/D Channel 1 (4 MSBs 0-3)
BYTE 17	Word 5	A/D Channel 1 (8 LSBs)
BYTE 18	Word 6	A/D Channel 2 (8 MSBs)
BYTE 19	Word 6	A/D Channel 2 (4 LSBs 4-7) A/D Channel 3 (4 MSBs 0-3)
BYTE 20	Word 6	A/D Channel 3 (8 LSBs)
BYTE 21	Word 7	A/D Channel 4 (8 MSBs)
BYTE 22	Word 7	A/D Channel 4 (4 LSBs 4-7) A/D Channel 5 (4 MSBs 0-3)
BYTE 23	Word 7	A/D Channel 5 (8 LSBs)
BYTE 24	Word 8	A/D Channel 6 (8 MSBs)
BYTE 25	Word 8	A/D Channel 6 (4 LSBs 4-7) A/D Channel 7 (4 MSBs 0-3)
BYTE 26	Word 8	A/D Channel 7 (8 LSBs)
BYTE 27	Word 9	unused
BYTE 28	Word 9	unused
BYTE 29	Word 9	unused
BYTE 30	Word 10	unused
BYTE 31	Word 10	unused
BYTE 32	Word 10	Marker byte (all ones)
BYTE 33	Word 11	Pressure Sensor Temperature MSBs (optional)
BYTE 34	Word 11	4 LSB = CTD status, 4 MSB = pressure sensor temp LSBs (optional)
BYTE 35	Word 11	Modulo count (EOI line asserted)

Thus there are 12 words per scan * 3 bytes per word = 36 bytes per scan. Note that selection of 3 active frequency inputs (frequency 3, frequency 4 and analog channels suppressed) would result in the following 18 byte format:

BYTE 0	Word 0	Frequency Channel 0
BYTE 1	Word 0	Frequency Channel 0
BYTE 2	Word 0	Frequency Channel 0
BYTE 3	Word 1	Frequency Channel 1
BYTE 4	Word 1	Frequency Channel 1
BYTE 5	Word 1	Frequency Channel 1
BYTE 6	Word 2	Frequency Channel 2
BYTE 7	Word 2	Frequency Channel 2
BYTE 8	Word 2	Frequency Channel 2
BYTE 9	Word 3	unused
BYTE 10	Word 3	unused
BYTE 11	Word 3	unused
BYTE 12	Word 4	unused
BYTE 13	Word 4	unused
BYTE 14	Word 4	Marker byte (all ones)
BYTE 15	Word 5	Pressure Sensor Temperature MSBs (optional)
BYTE 16	Word 5	4 LSB = CTD status, 4 MSB = pressure sensor temp LSBs (optional)
BYTE 17	Word 5	Modulo count (EOI line asserted)

3-4.4 RS-232C OUTPUT DATA FORMAT

The format is the same as described in Section 3-4.3 except:

A. Each byte is sent as two ASCII encoded characters. The first character is the hexadecimal representation of the most significant 4 bits; the second character is the hexadecimal representation of the least significant 4 bits.

For example, the byte with a value of 42 (base 10) or 2A (hexidecimal) would be sent as:

first character:	32	[ASCII for 2]
second character:	41	[ASCII for A]

B. The two characters representing the modulo N count will be preceded by 2 pressure sensor temperature characters and 2 'zero' characters. The modulo characters will be followed by a carriage return character (0D , base 16), and then a line feed character (0A , base 16). Thus there are (NWORDS * 3 * 2 + 2) ASCII characters per scan. For a 12-Word system there are 74 characters per scan.

3-4.5 NMEA LAT/LON DATA

For IEEE-488 data, seven bytes are appended to each scan of CTD data.

For RS-232C data 14 ASCII characters followed by a carriage return and line feed are sent once per second.

The format is:

Latitude (deg) = (byte 1 * 65536 + byte 2 * 256 + byte 3) / 50000
Longitude (deg) = (byte 4 * 65536 + byte 5 * 256 + byte 6) / 50000
If bit 1 in byte 7 is 1 this is a new position.
If bit 8 in byte 7 is 1 Latitude is negative.
If bit 7 in byte 7 is 1 Longitude is negative.

North latitudes are positive, south latitudes are negative.
East longitudes are positive, west longitudes are negative.

Example:

APPENDED DATA = 2455FC5D32B141

byte 1 = 24 hex = 36 decimal
byte 2 = 55 hex = 85 decimal
byte 3 = FC hex = 252 decimal
byte 4 = 5D hex = 93 decimal
byte 5 = 32 hex = 50 decimal
byte 6 = B1 hex = 177 decimal
byte 7 = 41 hex = 01000001 binary

Latitude = (36 * 65536 + 85 * 256 + 252) / 50000 = 47.62616 degrees
Longitude = (93 * 65536 + 50 * 256 + 177) / 50000 = -122.1565 degrees
Longitude is negative (bit 7 in byte 7 is 1).
This is a new position (bit 1 in byte 7 is 1).

3-4.6 FREQUENCY DATA CONVERSION

The primary frequencies representing Temperature (F_t) Conductivity (F_c) and Pressure (F_p) may be derived as follows:

$$F_T = BYTE(0) \times 256 + BYTE(1) + BYTE(2)/256$$

$$F_C = BYTE(3) \times 256 + BYTE(4) + BYTE(5)/256$$

$$F_P = BYTE(6) \times 256 + BYTE(7) + BYTE(8)/256$$

Conversion of frequency and A/D voltage information to engineering units is described in Section 3-5 below.

3-5 CONVERSION OF DATA TO ENGINEERING UNITS

The relationships listed below must be evaluated by the computer used to acquire, display, and store CTD data. They are as used within SEASOFT.

3-5.1 TEMPERATURE

Determine the sensor frequency per 3-4.8. Then

$$T = \frac{1}{g + h\ln(f_0/F) + i\ln^2(f_0/F) + j\ln^3(f_0/F)} - 273.15 \qquad ^\circ\mathrm{C}$$

Where:

g, h, i, j, & f_0 are coefficients listed on the sensor calibration data sheet. F is the sensor frequency in Hz.

3-5.2 CONDUCTIVITY

Determine the sensor frequency per 3-4.8. Then

$$C = \frac{g + hf^2 + if^3 + jf^4}{[10(1 + \delta t + \varepsilon p)]} \qquad \text{Siemens/meter}$$

Where:

g, h, i, & j are coefficients listed on the sensor calibration data sheet, t is ambient temperature as derived in 3-5.1, and p is pressure in decibars (dBar). δ (CTcor = 3.25e-6) and ε (CPcor = -9.57e-8) are the nominal conductivity cell coefficients of thermal expansion and pressure compressibility. **Note that for reasons of computation efficiency, F is the sensor frequency in kHz**.

3-5.3 PRESSURE

Determine the sensor frequency per 3-4.8. Then

$$P = 6894.759C\{1 - (T_0F/10^6)^2\} \times \{1 - D[1 - (T_0F/10^6)^2]\} \qquad \text{pascals}$$

Where:

C, D, & T_0 are coefficients listed on the pressure sensor calibration data sheet. F is the sensor frequency in Hz. T_0 is in µs. Note that C & T_0 are functions of the temperature within the Digiquartz sensor, T_D (see Section 3-5.4), and are determined by the equations below:

$$C(T_D) = C_1 + C_2T_D + C_3T_D^2$$

$$T_0(T_D) = T_{01} + T_{02}T_D + T_{03}T_D^2 + T_{04}T_D^3$$

Where:

C_1, C_2, C_3 and T_{01}, T_{02}, T_{03}, T_{04} are coefficients listed on the pressure sensor calibration sheet and T_D is determined via the equations below.

3-5.4 PRESSURE TEMPERATURE COMPENSATION

$T_D = M \times (\text{12 bit pressure temperature compensation word}) - B$ ºC

The pressure temperature compensation word (12 MSBs of Modulo Word) will have a decimal value between 0 and 4095. For example, if the pressure temperature compensation word has a binary value of 101010000001, the decimal equivalent is 2689. For this value and assuming the nominal values of M and B (0.01258 and -9.844; see SBE 9plus Configuration Sheet for exact values),

BYTE 33 (8 MSBs) 10101000 & BYTE 34 (4 MSBs) 0001XXXX (X=don't care) is
101010000001 binary or 2689 decimal.

$T_D = 0.01258 \times 2689 - 9.844 = 23.98$ ºC

It is recommended that pressure temperature be computed using a backward-looking 30 second running average in order to prevent bit transitions in pressure temperature from causing small jumps in computed pressure. Because the heavily insulated pressure sensor has a thermal time constant on the order of one hour, the 30 second average does not significantly alter the computed pressure temperature.

3-5.5 MODULO COUNT

The Modulo Count is an 8 bit number generated by the underwater unit which increments one count for each scan. If the deck unit averages data, the modulo count output from the deck unit will increment by the number of scans averaged. It is used to provide a check on system data integrity.

3-5.6 CTD STATUS BITS

The 4 least significant bits of byte 34 are CTD status bits. These bits are displayed with the deck unit thumbwheel switch set to E. Status bits are used by the SBE 11*plus*, with an SBE 9*plus*, to monitor pump on/off, bottom contact switch, water sampler, and modem carrier detect. These status bit functions are not applicable to the SBE 31.

3-5.7 A/D VOLTAGES

Each A/D data channel is stored as a 12 bit binary number. To compute the voltage for a particular channel, convert the 12 bit number to its decimal equivalent, N. (see section 3-4.3 for the location of the bits within the data stream)

Then for a 0 to 5 volt input range:

$V = 5 \{1 - (N/4095)\}$ Volts

As an example, consider the data format in Section 3-4.3. Determination of voltages measured in channel 0 would be as follows (the binary values assigned to the bytes are entirely arbitrary and are for purpose of example only):

Byte 15: 00110111 Byte 16: 01001111 Byte 17: 10101010

Byte 15 comprises the most significant digits of N, and the four most significant bits of Byte 16 are the LSBs of N. Accordingly, N may be written in binary as:

$$N_{\text{base 2}} = 001101110100$$

in decimal form:

$$N_{\text{base 10}} = 884, \qquad V = 5\,\{1 - (884/4095)\} = 3.9221 \text{ Volts}$$

3-5.8 DISSOLVED OXYGEN

Voltages proportional to dissolved oxygen sensor current (I) and membrane temperature (T) are digitized by the A/D converter and may be derived per Section 3-5.7 above.

$$I = mV_0 + b \qquad \mu\text{A}$$

Where:

V_0 is the voltage in A/D channel 0 per Word 5 and m and b are constants given on the Dissolved Oxygen Sensor Calibration Sheet. Typical values for m and b are 4 x 10^{-7} and 10^{-9} respectively with I taking values between 0 and 2 µA for V_0 in the range 0 to +5 volts.

$$T = kV_1 + c \qquad ^{\circ}\text{C}$$

Where:

V_1 is the voltage in A/D channel 1 per Word 5 and k and c are constants given on the Dissolved Oxygen Sensor Calibration Sheet. Typical values for k and c are 4 and 15 respectively with T taking values between -5 and +35 °C or V_1 in the range 0 to +5 volts.

3-6 COMPUTER COMMANDS AND COMMAND FORMAT

Commands necessary for routine use of this system are described in the sections immediately following. Other commands, which may be useful in special cases, are described in Section 3-7.

WHEN USING SEA-BIRD SOFTWARE, ALL NECESSARY COMMANDS ARE AUTOMATICALLY SENT TO THE SBE 31. SEE SOFTWARE MANUAL FOR COMPLETE INFORMATION.

The following commands are sent automatically by SEASAVE to configure the deck unit. With the exception of the 'A' (number of scans to average) command, these setting are not stored in EEPROM.

Upon receipt of the commands listed below, the Deck Unit will execute the functions indicated. All commands remain in effect until the 'RESET' button is pushed or new commands are sent.

All commands and data sent to the deck unit must be sent as ASCII characters. The general format is:

CDRL

C is a one line character identifier

D is an ASCII string corresponding to the integer number required for the command.

R Carriage Return (not required)

L is the ASCII character for LINE FEED. The value is 10 decimal or 0A hexadecimal. This character terminates all commands. The command string must be less than 30 characters long.

3-6.1 SET FREQUENCY CHANNELS: NFREQ = X

Set the number of frequency channels in the deck unit where X equals the number of channels.

Example: nfreq=8 sets the number of frequency channels to 8

3-6.2 SET A/D VOLTAGE CHANNELS: NVOLTS = X

Set the number of A/D voltage channels in the deck unit where X equals the number of channels.

Example: nvolts=4 sets the number of A/D voltage channels to 4

3-6.3 RESET DATA BUFFERS: R

Reset and flush buffers; do not put data into buffers; leave all other parameters the same. Any command except 'START COLLECTING DATA', 'OVERRIDE DATA WORD DISPLAY', SET THUMBWHEEL SWITCH' and 'STOP' will cause an automatic execution of 'RESET BUFFERS', since otherwise the first output data after the command would not reflect the new format. Thus, every command sequence must be ended with the command 'START COLLECTING DATA' to resume the data output stream.

3-6.4 START COLLECTING DATA: GX

Deck Unit begins putting data into its output buffers at a rate determined by how many scans are averaged. X designates which buffer(s) are used.

If X = 'I' data is put into the IEEE-488 buffer.

If X = 'R' data is put into the RS-232C buffer.

If X = 'B' data is put into both buffers.

The user's computer obtains this data by exercising the appropriate bus protocol.

3-6.5 CHANGE THE NUMBER OF SCANS TO AVERAGE: AXX

XX is the number of scans averaged by the Deck Unit; XX must be between 1 and 50:

3-6.6 STOP PLACING DATA INTO BUFFERS: S

Deck Unit stops putting data into buffers.

3-6.7 NMEA Standard 0183 INTERFACE COMMANDS

NY	add 7 bytes of Lat/Lon to the CTD data
NN	do not add Lat/Lon data (default)
NSR	send Lat/Lon/Time ASCII data (RS-232)
NSI	send Lat/Lon/Time ASCII data (IEEE-488)

3-7 SPECIAL COMPUTER COMMANDS

The commands listed in this section are not required for routine use of the CTD system, but may be useful in certain diagnostic or maintenance modes, or where the unit has been adapted to other operating configurations. See Section 3-6 for a description of command formats.

3-7.1 ADJUST THE REFERENCE FREQUENCY: FX

X = reference frequency in Hz.

Example: 'F6912002' will set reference frequency to 6,912,002 Hz

Note: The reference frequency is determined by the crystal oscillator in the encoding unit, and is initially adjusted to 6,912,000 Hz. The SBE 31 defaults to this value on power-up or if the RESET button is pressed. If the crystal frequency changes because of aging (or for any other reason), this command may be used to compensate the change. In the case of the example, the command has been used because the crystal frequency has been determined to have changed to 6,912,002 Hz.

3-7.2 DIVIDE THE REFERENCE FREQUENCY: CNX

N = word number 0 to 9

X = the integer value by which the regular frequency is to be divided for use in this channel.

Example: 'C24' will set reference frequency for channel 2 as the regular reference frequency (per FX command or default) divided by 4.

This command may be used more than once to place different reference frequencies in the word assignments associated with several channels. Note that the command must be compatible with the hard-wired configuration of the encoding unit.

The CNX command would be used to acquire information from sensors generating low-frequency outputs where the normal reference frequency would cause overflow in the hybrid counting process.

3-7.3 MULTIPLY THE REFERENCE FREQUENCY: MNX

This command works analogously to the CNX command. It should be used if a high-resolution channel has been installed in the Underwater Unit, e.g., a 27,648,000 Hz crystal oscillator for improved pressure resolution, and is automatically implemented if the pressure sensor type has been set to Paroscientific Digiquartz, high resolution by DIP switch S3 or if the high-resolution pressure entry has been chosen when running SEACON.

3-7.4 SELECT DATA CHANNEL TYPE: DNX

The data channel type default settings are determined by switch S5 and are automatically loaded on power-up. These default settings can be temporarily changed with the DNX command. N = word number. X = data type.

If X = 0, data type is 'frequency'. Data in word N will be converted to frequency per the description in Section 3-4.8. If averaging is employed, the frequencies will be averaged.

If X = 2, data type is 'A/D'. Data in word N will be treated as two 12 bit channels. If averaging is employed, the individual 12 bit numbers will be separately averaged.

If X = 3, data type is 'BINARY BIT'. Data in word N will be passed directly from the Underwater Unit in 24 bits. If averaging is employed in the deck unit, words with data channel type set to BINARY BIT are subsampled, not averaged by the deck unit (even if the SBE 31 is set to average scans).

3-7.5 SUPPRESS DATA WORD: XN

N = word number to be suppressed (in hexadecimal).

Data channels may be deleted from the data stream that is transferred to the host computer with the suppress data word command. Note that in the case of frequency channels a word corresponds to one channel, for A/D channels a word contains 2 channels. This command is useful in reducing the size of a data scan and hence the amount of disk space required to store CTD data. When using SEASOFT programs, data words are suppressed through settings in software (SEACON) and the proper XN command is sent automatically.

3-7.6 UNSUPPRESS ALL DATA WORDS: U

All data words are restored to the data stream with the U command. Send this command once before sending any XN commands.

3-7.7 CHANGE CHANNEL LEVEL FOR THUMBWHEEL SWITCHES: LX

The LX command is only needed for multi-channel counters having more than 15 data words.

For example, a 35 channel counter (36 words, 0 - 35) would use the LX command as indicated.
Enter 0, 1, or 2 in place of X to select the appropriate level.
Level 0 allows thumbwheel switch access to words 0 - 15. Level 1 allows access to words 16 - 31. Level 2 allows access to words 32 - 34, modulo, IEEE-488 and RS232 buffer displays.

4-1 FUNCTIONAL DESCRIPTION OF THE SBE 31 MULTICHANNEL COUNTER

The SBE 31 supplies power to and digitizes signals from frequency output sensors such as Sea-Bird temperature and conductivity sensors, or Paroscientific Digiquartz pressure sensors. To obtain the high encoding speed and resolution required by profiling applications, a 'hybrid' period counting technique is used. Each sensor has its own counting electronics circuit, so that all sensors are sampled simultaneously. Two 12-bit counters are used for each sensor - one counter accumulates the integral number of sensor counts during the sample interval (1/24) second, and the other counter measures the time from the beginning of the measurement period until the first positive-going zero crossing of the sensor frequency, i.e., determines the 'fractional' sensor count.

As an option, signals from voltage output sensors are acquired using a conventional voltage-input multiplexed A/D converter. The A/D output is a binary number between 4095 and 0 corresponding to voltages in the range of 0 to +5 volts. The A/D binary values are incorporated into the CTD serial data stream and are available in unconverted form for display or transfer to the system computer.

Data is transferred from the SBE 31 to a computer via IEEE-488 and/or RS-232C ports.
Front panel LED's indicate system status and proper operation, and an 8-digit numeric display (under control of a thumbwheel switch) permits readout of any data channel. Various control functions may be implemented by means of commands sent over the data I/O busses.

4-1.1 SENSOR FREQUENCY RANGES ALLOWED

Each counter can handle 4096 counts. The maximum time that the N_r counter will be gated "on" will be $1/F_s$. Since the N_r counter runs at 6,912,000 Hz, the minimum allowable F_s is given by 6,912,000/4096, or 1687.5 Hz. The maximum allowable sensor frequency is determined by the size of the N_s counter - no more than 4096 counts may be accumulated during the measurement interval. Thus F_s max = 4096/(1/24) = 98,304 Hz for 24Hz systems.
F_s max can be calculated in the same way for systems with alternate scan rates.

4-1.2 RESOLUTION (FREQUENCY CHANNELS)

CTD resolution degrades as the scan rate increases. In the discussion which follows, a scan rate of 24 per second is assumed. For systems with other sampling rates, ratio the given resolution accordingly.

$$Resolution = Scan\ Rate \times F_s/F_r \qquad \text{Hz/Bit}$$

where:

F_s is the sensor frequency, and
F_r is the CTD reference frequency (6,912,000 Hz).

At 2 kHz and 24 scans per second, the resolution is 0.0069 Hz/bit, and at 98 kHz the resolution is 0.34 Hz/bit. To get resolution in engineering units, we need to divide by "sensitivity", for example, Hz/(Degree Celsius). To compute nominal values of resolution in engineering units, we use the approximate values for sensitivity (Sen) from the sensor specification sheets. The values given here are for illustrative purposes only - the user's computer must use the more exact equations and the specific calibration constants for each sensor installed in order to make the conversions to engineering units (see section 3-5).

Temperature: At -1 °C, F_s = 2.1 kHz, and Sensitivity = 48 Hz/°C)
Resolution = 0.00015 °C per bit

At 31 °C, F_s = 4 kHz, and Sensitivity = 76 Hz/°C
Resolution = 0.00018 °C per bit

Conductivity: At 1.4 Siemens/meter (S/m), F_s = 5kHz, and Sensitivity = 1900 Hz/(S/m)
Resolution = 0.0000091 S/m per bit

At 5.8 S/m, F_s = 11 kHz, and Sensitivity = 960 Hz/(S/m)
Resolution = 0.0000398 S/m per bit

Pressure:(10,000 psi range Digiquartz sensor, assuming a conversion factor of 1.46 psi/dbar;
resolution with other sensor ranges changes proportionately):

At 0 dbar F_s = 33,994 Hz and Sensitivity = 0.726 Hz/dbar
Resolution = 0.041 dbar/bit

At 6800 dbar, F_s = 38,480 Hz and Sensitivity = 0.614 Hz/dbar
Resolution = 0.054 dbar/bit

4-1.3 ACCURACY (FREQUENCY CHANNELS)

The accuracy of the system is determined by the accuracy of the sensors used and by the accuracy of the crystal oscillator ("master clock") that generates the reference frequency F_r. F_r is stable to within 1 ppm over the temperature range of -20 to 70 deg C -- the time drift will be less than 1ppm for the first year and less than 0.3 ppm per year thereafter. A five-year worst case master clock error budget of 3.2 ppm total yields temperature error of 0.00016 deg C, conductivity error of 0.00005 S/m and presure error of 0.3 dBar.

4-1.4 A/D CHANNELS (AUXILIARY INPUTS)

Eight voltages in the range of 0 to +5 volts are optionally available. The voltages are selected sequentially by a CMOS multiplexer and digitized to 12 bits by successive approximation. The first A/D channel voltage is acquired during an interval of about 50 µs at the beginning of each scan (the same time at which counting of frequency channels begins); the second channel is processed during the next 50 µs, etc. Differential input amplifiers followed by 2-pole Butterworth anti-aliasing filters are used in each A/D channel. Input channels are selected for A/D conversion by a CMOS multiplexer and then passed through a buffer amplifier with a gain of 2 to the A/D converter.

4-1.5 RESOLUTION (MULTIPLEXED A/D CHANNELS)

The analog voltage input range of 0 to +5 volts is multiplied by a gain of 2 by the buffer amplifier preceding the A/D converter. The A/D converter input range of 0 to 10 volts is converted to digital values between 4095 and 0. The resolution at the SBE 31 A/D input ports is therefore 5 volts/4096 = 0.0012 volts/bit.

4-1.6 ACCURACY (MULTIPLEXED A/D CHANNELS)

The Micro Networks series MN5206 A/D converter chip provides true 12-bit accuracy without adjustment. The low-pass filters and differential amplifiers have been designed to maintain an overall accuracy of about 0.1% over the range of temperature encountered in ocean profiling.

4-1.7 AVERAGING

While the encoder electronics scan rate is typically fixed at 24 scans per second, the SBE 31 can "average-together" the data from multiple scans. The effective scan rate (ESR) is set by a command from the computer, and can be any number from 1 through 50.

Effective Scan Rate = (nominal scan rate)/N (scans per second)

for example:

2 scans per second = (24 scans per second)/12
1 scans per second = (24 scans per second)/24
.5 scans per second = (24 scans per second)/48

where N is any integer up to a limit imposed by register overflow; this upper limit occurs when

Minimum ESR = maximum sensor frequency/65535

There are two advantages to operating at a lower ESR: (1) If the scan rate is reduced by increasing N, the system resolution improves in proportion to N. (2) Operating at a lower scan rate results in fewer bytes per second of data at the output port, which may be useful when a less capable computer is being used to process and log the data, or simply to reduce the quantity of data for subsequent storage and analysis. The disadvantage is that the rapidly changing values will be obscured by the averaging.

Note that SEASOFT software limits the average number to: 1.5 * (scan rate).
Therefore, in a standard SBE 31 with the encoder electronics running at a fixed 24 scans per second, SEASOFT will accept an average number between 1 and 36 resulting in an 'effective scan rate' of between 24 scans per second and .67 scans per second (or one scan every 1.5 seconds) respectively.

4-1.8 DATA INTERFACES

The SBE 31 is supplied with both IEEE-488 (parallel) and RS-232C (serial) interfaces. Data output and control commands can be sent via either interface. To successfully transmit full rate (24 Hz) data will all channels active, the RS-232C interface must be set to 19200 baud or the parallel interface must be used. With minimum data channels active (4 words) and a reasonably fast computer (i.e. 80386 processor), 24 Hz data acquisition may be accomplished at lower baud rates. Memory buffers at the output ports prevent loss of data when the computer is temporarily occupied by other tasks (Buffer size = 7000 bytes for IEEE-488, 14000 bytes for RS-232C).

4-1.9 RECEIVER

The Receiver board accepts logic level output of data from the encoder electronics, where it is then sent to a UART and to a micro-controller, which checks the decoded bits and activates a 'valid character' line to indicate successful reception of each 8-bit character. The absence of the valid character signal, at times when it is expected, lights the Deck Unit 'ERROR' LED.

4-1.10 MICROPROCESSOR

The primary computational function of the microprocessor (8085) is to compute (with supporting 9511 math chip) sensor frequencies from the 12 bit counts Ns and Nr which originate in the encoding unit. Other microprocessor duties are manipulative and involve the distribution of data to the output ports and the front panel numeric display. Program control of microprocessor function is provided by a 256K EPROM.

Deck unit microprocessor power-on default functions may be modified by commands sent over the IEEE-488 or RS-232C interfaces (Section 3-6)

4-1.11 ENCODED DATA FORMAT

The following is the sequence of the data as output by the encoder electronics. This represents a typical configuration and may not accurately represent your unit. See the SBE 31 configuration sheet near the front of this manual for specific information regarding your unit.

For the (different) output sequence from the SBE 31 IEEE-488 or RS-232 ports, see section 3-4.3. The first data byte contains 8 bits of (optional) pressure temperature compensation information. The second byte contains 4 remaining bits of (optional) pressure temperature data, and status 'flags' for various conditions. The third byte is a count which increments on successive data scans. Information from the frequency input channels ('frequency 0' through 'frequency 4' in this case) make up the next 15 data bytes which would be used for temperature, conductivity, and pressure sensors in a system set up to measure 'CTD'.

The next data are generated by the 12 bit A/D converter, with each channel pair allocated 3 bytes.

The data sequence from the Encoder Unit is:

Byte 1:	8 MSB of (optional) Pressure sensor temperature compensation
Byte 2:	4 LSBs of (optional) Pressure sensor temperature compensation, status bits
Byte 3:	Modulo count
Byte 4-6:	Frequency 0 (Temperature, primary)
Byte 7-9:	Frequency 1 (Conductivity, primary)
Byte 10-12:	Frequency 2 (optional Pressure)
Byte 13-15:	Frequency 3 (Temperature, secondary)
Byte 16-18:	Frequency 4 (Conductivity, secondary)
Byte 19-30:	12-Bit A/D Channels 0 to 7
Byte 31-36:	expansion (all zeros)

A total of 36 bytes of data are generated for each scan. In its presentation of data to the IEEE-488 port, the Deck Unit outputs the Modulo byte at the end of the scan rather than at the beginning.

4-1.12 POWER

The SBE 31 operates on 105 - 125 VAC, (optionally 210 - 250 VAC) 50 to 400 Hz. A Power One HTAA-16W-A power supply generates +5, +12, and -12 volts DC for use by the Microprocessor and Receiver boards, cardfile and back panel banana jacks (for powering external sensors). The input power line is fused at 1 Amp (0.5 Amp for 230 VAC models). The line fuse is accessible at the back panel. The Power-One supply has foldback current limiting, and is not separately fused.
An Acopian DB15-20 power supply (DB15-20-230 for 230 VAC models) may also be installed to supply optional boards required for support A/D voltage inputs.

4-1.13 COOLING

A 115 VAC (optional 230 VAC) fan is installed in the back panel. Slots at the rear panel top and bottom allow air interchange.

4-2 DESCRIPTION OF THE SBE 31 CIRCUITRY

The SBE 31 Multichannel Counter electronics are constructed in a rack-mount cabinet housing two main PC boards, a card file containing the encoding circuitry, one (or two) modular power supply(s), a cooling fan, and a series of front panel displays and rear panel connectors. Multichannel Counter electronics are powered from 115 or 230 VAC: **REMOVE THE AC POWER CORD FROM THE REAR PANEL BEFORE ATTEMPTING TO SERVICE THE DECK UNIT.**

4-2.1 CHASSIS WIRING

The chassis wiring diagram shows the SBE 31 modules and the wiring which interconnects them. Operation of these modules is described in subsequent sections. The AC power input fuse is 1 Amp in 115 VAC units and 0.5 Amp in 230 VAC models.

4-2.2 POWER SUPPLIES

Power for SBE 31 circuitry is supplied by a conventional open-frame linear supply (Power One, Model HTAA-16W-A; Power-One, Inc., Camarillo, California) generating +/- 12 and +5 volts from the main AC supply and located at the top left front of the SBE 31 chassis. Its input jumpers permit operation from either 115 or 230 VAC. Screw-driver adjustment of the output voltage levels is possible, but not ordinarily required. The Power-One supply uses fold-back current limiting for complete short-circuit protection. Detailed specifications and a schematic diagram are included at the end of this manual.

Power for the AD/CS and DIFF AMP / LOW PASS FILTER cards is supplied by an Acopian DB15-20 power supply (DB15-20-230 for 230 VAC models) located on the right panel near the back of the SBE 31 chassis.
This power supply may not be installed if the SBE 31 is not configured with A/D inputs.

4-2.3 NMEA INTERFACE

CONNECTION TO A NMEA TRANSMITTER

The 2 pin MS connector is used to connect the NMEA interface to a NMEA transmitter. The connections are as follows:

Pin	Function
A	NMEA 'A' (signal)
B	NMEA 'B' (signal return)

The NMEA interface is configured for 4800 baud, 8 data bits, one stop bit, no parity.

Refer to Section 3-3.8 for instructions on selecting the NMEA message to decode. The green LED on the NMEA interface board or front panel will flash each time a valid NMEA message is decoded.

5-1 TROUBLE DIAGNOSIS AND REPAIR

Servicing of the Sea-Bird CTD equipment should only be performed by experienced technicians who have been trained to work with complex mechanical/electrical equipment. **LIFE-THREATENING HIGH VOLTAGES ARE PRESENT WHEN POWER IS ON. THESE HAZARDOUS VOLTAGES MAY PERSIST FOR UP TO ONE MINUTE AFTER REMOVAL OF POWER.**

THE BEST WAY TO PROTECT AGAINST ELECTRICAL SHOCK IS TO DISCONNECT THE AC POWER CORD FROM THE REAR PANEL OF THE MULTICHANNEL COUNTER, THEN WAIT A FULL MINUTE BEFORE ATTEMPTING SERVICE.

ALWAYS DISCONNECT THE AC MAINS CABLE BEFORE CHECKING FUSES!!!

For protection of the circuitry, we also recommend that AC power be removed and a 1 minute period for supply capacitor discharge be allowed before opening housings, changing connections, removing or inserting circuit cards, or otherwise working on the equipment.

5-1.1 MULTICOUNTER COMPLETELY INOPERATIVE

If the panel lights are out, the power switch pilot light is dark, and the fan is not running, probably either the AC power has been disconnected or the main fuse blown. Check the AC power source. Remove the power cable, and check the main fuse. Replace if necessary.

If the main fuse blows again, there is probably a short in the main chassis AC wiring (the separate fuses and short circuit protection circuitry associated with the internal power supplies will prevent the main fuse blowing even if internal circuitry is malfunctioning). See chassis wiring diagram - it may be necessary to disconnect one section after another to locate the problem. **USE EXTREME CAUTION WHILE MAKING THESE TESTS! THE VOLTAGE LEVELS ARE LIFE-THREATENING!**

All voltages are measured relative Microprocessor board ground terminal or to pin 2 of any plug-in card; this is main signal/power ground for the SBE 31.

Measure +5, +12, and -12v supply levels at the Microprocessor board terminals.
Measure +5v at the cardfile on pin 1 of any card
Measure +15, and -15v supply levels at cardfile AD/CS board pins 5 and 3 respectively (the AD/CS board and ±15v power supply are optional).

If the +5, +15, or -15 volt levels are absent or in error by more than about 0.5 volts, remove all the underwater unit plug in printed circuit boards. Check the power supply levels again - if these are now ok, the problem is probably in one of the plug-in boards. Start plugging boards in, beginning with the Logic board. (Turn off power and wait one minute for supply discharge before plugging in each board). If a board is found which appears to cause the drop in supply voltage, refer to the circuit description in Section 4-2 and the board's schematic diagram.

Check the board for dead shorts at the power input pins - an IC or one of the power supply bypass capacitors may be shorted. Also, carefully examine the board for any metallic material (solder, wire clippings, shavings) which may have inadvertently shorted the printed circuit traces or component pins. With the board in the underwater unit chassis, look at the board outputs and inputs for signal irregularities. The logic levels are 5 volt CMOS and should swing the full 0 to +5 volts.

If the **power supply levels are not ok with the plug-in boards removed**, check the backplane wiring for broken connections or wires, and for any shorted connections.

The +5v supply is also used by the Microprocessor board and Receiver board. If the +5v supply is still faulty after checking the cardfile as detailed above, disconnect the ribbon cable at Microprocessor JP2. If +5v is now OK then the problem is on the Receiver board, if +5v is still not OK then the problem is on the Microprocessor board.

If the +12, or -12 volt levels are absent or in error by more than about 0.5 volts, then the problem is on the Microprocessor board or Receiver board. Disconnect the ribbon cable at Mircoprocessor board JP2 as described above to determine which of the two boards is causing the problem. The cardfile electronics does not use the +12 or -12v supplies.

5-1.2 POWER SUPPLIES OK BUT NO DATA

Check Logic Board pin 3 for the NRZ logic level. If this signal is present, the encoder electronics are probably working correctly.

Check for proper output signals from the Logic Board. The following should be observed:

Pin 5 FR	27,648 kHz (square wave)
Pin 4 FR/4	6,912 kHz (square wave)
Pin H	69120 Hz (square wave)
Pin 6	8640 (square wave)
Pin 9 SE	24 Hz (square wave)

If any of the signals described above are **missing or of improper shape or frequency**, disconnect power from the CTD and remove all the plug-in cards except the Logic Board. If any of the tabulated signals remain faulty, the trouble is on the Logic Board, or is the result of a short in the backplane wiring.

If the signals described above are ok on the Logic Board alone, reinstall the remaining circuit boards one-by-one, checking the suspect signal after each card is installed until the faulty card is located.

5-1.3 ONE OR MORE NON-FUNCTIONING CHANNELS

If a frequency channel is giving improper readings, check that the sensor signal is present on AP counter board (pins 7 and H on the backplane. These are 2 volt p-p sine waves in the frequency range of 2800 - 12000 Hz for temperature and conductivity and a 4 volt square wave in the range 35000 to 40000 Hz for the pressure sensor.

If one of the sensor outputs is faulty, remove that channel's AP Counter Board - if this restores the signal, the AP Board has a defective input. Try one of the other AP Counters (all of the AP Counter boards are identical) in the offending channel position.

If the AP Counter inputs are ok, try swapping AP Counter Boards to locate the faulty one. If the problem stays with the same channel, check that the FR, SE, SC, and RESET, inputs are active.

If the problem is a faulty A/D channel, check that the inputs to the A/D Board multiplexer (pins D, F, H, J, L, 10, 8, 7) are as assumed. Check for +15 and -15 volts at the A/D Board. Look for the SE scan clock at pin 9; this starts the (rapid ~ 50 μs/channel) acquisition of A/D channel data. Check that the SC shift clock is present at pin 6, and that serial data is present at pin 4.

5-1.4 DATA OVERFLOW LIGHT ON

Data from the SBE 31 is made available to the companion computer by placing it in RAM buffer. The companion computer then requests the data, emptying the buffer. If the computer is too slow in making these requests the buffer will overflow and light the overflow LED. The rate at which the computer requests data from the deck unit depends on the other activities it must also perform. Users of SEASOFT will find that the most common cause of buffer overflow is that an older (8088 or 80286) computer is updating the screen too often.

The rate of screen update may be changed in the SEASAVE "miscellaneous run time parameters" menu. Set the thumbwheel switch to C if using the IEEE-488 interface or D if using the RS-232 interface. Begin logging data and observe the number displayed, the number should periodically reset to 7000 for the IEEE-488 interface or 14000 for the RS-232. If the display does not reset it will eventually overflow. Set the screen update parameter to a value that allows the buffers to reset. If a suitable rate of screen update can not be found then the deck unit will have to average more data scans (or suppress data channels) to reduce the data output to the computer.

5-1.5 NO DATA COLLECTED, GPIB ERRORS NOTED WHEN SEASAVE EXITED

This condition is possible when the ".CON" file does not match the instrument. Check the ".CON" file with SEACON. Refer to the SEASOFT manual for details on how to use SEACON.

5-1.6 DATA LIGHT NOT ON

The number of data words per scan (12), and the system scan rate (24/second) are hardwired within the design of the encoder Logic board.
Check all Microprocessor board switches to see that they are set according to the tables listed in Section 3-3 of this manual.

If the data light is not on but the SBE 31 is passing data to the companion computer, the wiring to the light or the light driver circuitry (Microprocessor board U23, U24, U25 and U27) may be defective.

If the data light is out because the data is not being decoded, check the power supplies as in section 5-1.1
If power supplies are correct, check the 'valid word' signal at J4 on the receiver board. If 'valid word' is present, the problem is likely in the Microprocessor board. Examine the printed circuit board carefully for metal particles that may have inadvertently entered the SBE 31 housing and shorted narrowly-spaced tracks.

5-1.7 IEEE-488 INTERFACE NOT WORKING

Check that the IEEE-488 Address is properly selected to match the external interface. As shipped, the IEEE-488 address is set to 1; this is also the default address used by the National Instruments GPIB-PC2A interface as supplied for use in IBM PC/XT/AT computers. If your interface requires a different address, see Section 3-3.2 to change the GPIB address.

If software other than that supplied by Sea-Bird is used, make sure that the proper commands are sent to the SBE 31, for example, the command 'GI' must be used to begin the transfer of data to the IEEE-488 interface bus. See Section 3-6.

Check that ribbon connector JP3 (Microprocessor board) is properly mated. ICs 5, 6, and 17 perform the IEEE-488 interface functions and may be defective.

5-1.8 RS-232 INTERFACE NOT WORKING

The settings for baud rate, number of data bits, number of stop bits, and parity must conform to the requirements of the external RS-232 device. The SBE 31 is shipped with baud rate = 19200, 8 data bits, 1 stop bit, and disabled parity. These settings cannot be changed.

Make sure that the RS-232 device is sending the proper commands, for example, the command 'GR' must be used to begin transferring data to the RS-232 interface; see Section 3-6.

Check to see that the connection to Microprocessor board JP6 (RS-232 I/O connector) is properly secured. This connector may be installed 180 degrees to normal position in order to reverse the Receive/Transmit connections.

Check the circuitry associated with U17, and U15 if the trouble persists.

5-1.9 SBE 31 DISASSEMBLY

DISCONNECT THE AC POWER CABLE FROM THE REAR OF THE DECK UNIT!!! WAIT 1 MINUTE BEFORE BEGINNING DECK UNIT DISASSEMBLY.

Remove the four rear-most screws from the corners of the top cover. The cover will slide directly back permitting access to the upper part of the Deck Unit interior. Four similarly placed screws retain the bottom cover in the same fashion.

5-2 SENSOR PROBLEMS

Apparent sensor problems may be the result of trouble with the cables or the acquisition circuitry in the underwater unit, or the trouble may be nothing more than an incorrect entry of the sensor calibration coefficients. The conductivity and temperature sensors have identical power and output characteristics, and may be freely interchanged to help localize the fault.

Although repair of these sensors is certainly possible, it is not likely that repairs can be made without affecting the sensor's calibration. The Sea-Bird sensors are small and easily replaced in the field; as they are supplied with calibration coefficients, a spare sensor can get a failed unit into fully operating and calibrated condition with a minimum of trouble. Sea-Bird is also always ready to send replacement sensors by air courier immediately upon notification of a failure.

5-2.1 CONDUCTIVITY AND TEMPERATURE SENSORS

If a sensor is generating conductivity, temperature, or pressure-dependent frequency but the indicated value is significantly erroneous, **check that the coefficients used in the processing software are as stated on the calibration certificates** supplied with the sensor. **CAUTION - The environment inside the sensor housing was completely desiccated and backfilled with pure argon prior to factory calibration. Opening the housing will introduce humidity (atmospheric water vapor) which will cause an immediate offset to the calibration and temporary drift instability.**

Swap the cable connections to the temperature and conductivity sensors to verify the operation of the acquisition circuit (SEASOFT permits the reversal of the channel assignments to permit the proper display of temperature or conductivity when this is done - use the SEACON program to do this).

If no output frequency is being generated, the SBE 31 will display 0.000 in the defective channel. If a sensor is defective, swapping sensors will put a sensible frequency into the previously 0.000 reading display.

If no frequency indication occurs with the sensors swapped, disconnect the rubber molded plug from the sensor connector. +12 volts should be measured between the large pin and one of the small pins (if the large pin is up when looking into the plug, the +12 should be found on the left side small pin).

The proper functioning of a frequency channel may be confirmed by connecting a frequency source (square or sine wave, 2 - 5 volts p-p) to right side small pin (as defined above) and the large (ground) pin of the sensor cable. The SBE 31 should read the frequency of the generator.

The sensors may also be checked separately from the SBE 31 by connecting a power source of 10 to 20 volts and observing the frequency output with an oscilloscope.

Application Bulletin No. 3 explains temperature/conductivity sensor disassembly instructions. Look for broken leads or evidence of water leakage.

5-2.2 PRESSURE SENSOR (DIGIQUARTZ)

The standard SBE 31 is not configured to accept pressure sensor temperature compensation.
The sensor's red lead should be at +12 volts, the black lead at power common. The blue lead should be connected to a frequency channel input. A properly operating sensor will exhibit a square wave frequency in the range 35 to 40 kHz at this point.

It is not possible to perform field repairs on a defective pressure sensor; any repair work must be done at the factory.

Systems using temperature compensation of the pressure channel employ a solid-state (bandgap) temperature sensor imbedded in the pressure sensor. This element (Analog Devices type AD590) is a 2-terminal device which generates a current proportional to absolute temperature (1 microampere per °K). The current is input to an op amp on the (optional) Modulo 12P board; a current of opposite polarity is derived from the REF02/Op215 reference and used as an offset source. The current difference is scaled through the 95K ohm precision fixed resistor R19 to create an input to the 12 bit A/D converter, U8. The A/D converter parallel output is strobed into the CD4021 shift registers in preparation for transmission to the Microprocessor board.

Resistors (1K and 2.2K) are inserted in series with the leads from the temperature sensor for noise suppression. Check that these are intact. The white lead (from the pressure sensor) should go through the 2.2 K ohm resistor to a source of -15 volts. The orange lead should connect to pin 10 of the Modulo P board. Disconnect this lead and connect through a microammeter to power common. If the sensor is working correctly, the current should be approximately equal (in microamperes) to the ambient temperature in ^{o}K.

If the temperature sensor appears to be ok, check the voltage levels associated with Modulo 12P board U3.

5-2.3 DISSOLVED OXYGEN SENSOR

The dissolved oxygen sensor should show a sensor current channel output of approximately +5 volts when the system is powered up. This 'saturation' condition will continue for up to a minute or two, after which the output will steadily decline until a stable reading (typically 2 volts) representative of atmospheric oxygen level is maintained.

If the oxygen current channel voltage is zero upon power up, the sensor is defective. This condition can be caused by the sensor module proper (the small brown plastic element at the top of the DO sensor) breaking contact. See the Disassembly instructions in the 'dissolved oxygen' section which describe how the sense module's electrical contact is made.

The electrical cable connecting the DO probe to the SBE 31 back panel should be checked. Disconnect the cable from the probe and check for +12 volts between the large pin (common) and the left-hand pin (viewed from face with large pin up). Put a voltage source of approximately 5 volts between the large pin and the bottom small pin: the deck unit should read about 1024 (thumbwheel typically set to 5, left 4 digits of display). Connect to the right small pin: read 1024 on the right hand 4 digits.

The DO probe housing may be disassembled to allow checking for broken wires, water leakage, etc.

5-3 SENSOR MAINTENANCE

Sea-Bird sensors have annular zinc anodes at their connector ends. Check these from time to time and replace if substantially worn.

5-3.1 CONDUCTIVITY CELL STORAGE

When possible, keep the conductivity cell in distilled water during periods of non-use by looping a length of water-filled Tygon tubing end to end. It is normally not necessary to do any cleaning of the conductivity cells during a cruise, unless you have evidence that the sensors have been fouled by passing through a pool of oil on the water, for example. Even this type of abuse is not likely to have much affect on sensor calibration if the cells were wet as they passed through the oil, since oil does not stick well to wet surfaces.

If it is not practical to leave the conductivity cell stored with distilled water in it (due to the danger of freezing, for example) merely rinse the cell with distilled water after each use (to remove salt water), then blow lightly through the cell to insure that no water is trapped inside. This is easily done using the Tygon tubes supplied. Loop the tubing end to end of the cell to keep out airborne contaminants. If the cell has been stored dry, wet with a 1% solution of Triton X100 (or other non-ionic detergent) before use.

APPENDIX A NMEA MESSAGE FORMATS

Field Definitions:

Field Type	Symbol	Definition
Status	A	Single character field: A = Yes, data valid, warning flag clear V = NO, data invalid, warning flag set
Latitude	llll.ll	Fixed/Variable length field: degrees|minutes.decimal - 2 fixed digits of degrees, 2 fixed digits of minutes and a variable number of digits for decimal - fraction of minutes. Leading zeros always included for degrees and minutes to maintain fixed length. The decimal point and associated decimal - fraction are optional if full resolution is not required.
	a	N or S
Longitude	yyyyy.yy	Fixed/Variable length field: degrees|minutes.decimal - 3 fixed digits of degrees, 2 fixed digits of minutes and a variable number of digits for decimal - fraction of minutes. Leading zeros always included for degrees and minutes to maintain fixed length. The decimal point and associated decimal - fraction are optional if full resolution is not required.
	b	E or W
Time	hhmmss.ss	Fixed/variable length field: hours|minutes|seconds.decimal - 2 fixed digits of hours, 2 fixed digits of seconds and a variable number of digits for decimal fraction of seconds. Leading zeros are always included for hours, minutes, and seconds to maintain fixed length. The decimal point and associated decimal-fraction are optional if full resolution is not required.
Checksum	*	Optional Checksum Delimiter.
	hh	Optional Checksum Field. The absolute value calculated by exclusive OR'ing the 8 data bits (no start or stop bits) of each character in the message, between, but excluding "$" and "*".

NMEA message formats:

GGA - Global Positioning System Fix Data

Time, position, and fix related data for a GPS receiver.

$--GGA,hhmmss.ss,llll.ll,a,yyyyy.yy,b,x,xx,x.x,x.x,M,x.x,M,x.x,xxxx*hh<CR><LF>

GLL - Geographic Position - Latitude/Longitude

Latitude and Longitude of present vessel position, time of position fix, and status.

$--GLL,llll.ll,a,yyyyy.yy,b,hhmmss.ss,A*hh<CR><LF>

RMA - Recommended Minimum Specific Loran-C Data

Position, course, and speed data provided by a LORAN-C receiver.

$--RMA,A,llll.ll,a,yyyyy.yy,b,x.x,x.x,x.x,x.x,x.x,a*hh<CR><LF>

RMC - Recommended Minimum Specific GPS/TRANSIT Data

Time, date, position, course, and speed data provided by a GPS or TRANSIT navigation receiver.

$--RMC,hhmmss.ss,A,llll.ll,a,yyyyy.yy,b,x.x,x.x,ddmmyy,x.x,a*hh<CR><LF>

TRF - TRANSIT Fix Data

Time, date, position, and information related to a TRANSIT fix.

$--TRF,hhmmss.ss,ddmmyy,llll.ll,a,yyyyy.yy,b,x.x,x.x,x.x,x.x,xxx,A*hh<CR><LF>