SBE 38

Digital Oceanographic Thermometer

User's Manual

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Table of Contents

Section 1: Introduction

This section includes contact information and photos of a standard shipment.

About this manual

This manual is to be used with the SBE 38 Digital Oceanographic Thermometer. It is organized to inform the user of operation and data collection. We've included detailed specifications, command descriptions, maintenance and calibration information, and helpful notes throughout the manual.

Located at the end of this manual is a feedback questionnaire. Please take a few moments after you have used the manual to let us know how you like the contents and format. Either use the form or e-mail comments to eroy@seabird.com. Tell us what sections helped you and what sections left you with questions. Your feedback will help *us* provide you with a complete and comprehensive User's Manual.

Manual Version # 005

How to contact Sea-Bird

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Our business hours are:
Monday-Friday, 0800 to 1800 Pacific Standard Time
(1600 to 0200 Universal Time)
Except from April to October, when we will be on "summer time"
(1500 to 0100 Universal Time)

Unpacking the SBE 38

Inside the packing crate, you will find your SBE 38 and its accessories. The photos below show a typical shipment.

Software, TERM37

User Manual

Data I/O cable with battery connector and battery #801093

9-pin adapter #17130

Section 2: Description of the SBE 38

This section describes the function and features of the SBE 38 including specifications and dimensions.

System Description

The SBE 38 Digital Oceanographic Thermometer is a highly accurate and stable instrument. It is not affected by shock and vibration, has a rugged corrosion-proof 10,000 meter titanium pressure housing, and is easy to use.

Real-time temperature data is transmitted in ASCII characters (in units of degrees Celsius) via RS-232 or 485 standard serial interface for display or logging by PC or data logger.

Applications include calibration baths, oceanographic/aquatic research, and environmental monitoring.

The SBE 38 operates in one of three modes:

1) RS-232 with one SBE 38 connected to the interface.
2) RS-485 with one SBE 38 connected to the interface.
3) RS-485 with several RS-485 sensors sharing one pair of wires (half duplex).

On power up, the SBE 38 will read its EEPROM. According to its programming, the SBE 38 will sample and transmit temperature at the set data rate, or wait for a command. In mode 3, it will only sample on command.

Instrument Specifications

SBE 38	
Measurement Range	-5 to +35 °C (Optional: -5 to +50°C)
Initial Accuracy[1]	0.001 °C (1mK)
Typical Stability (in 6 months)	0.001 °C (1 mK) certified
Resolution	0.00025 °C (0.25 mK)
Sensor Calibration	-1 to +35 °C
Self-Heating Error	Less than 200 µK
Response Time[2]	500 milliseconds

1 NIST-traceable calibration applying over the entire range.
2 Time to reach 63% of final value following a step change in temperature.

Weights

Air 2.0 lbs (0.90 kg)
Water 1.2 lbs (0.54 kg)

Materials Titanium pressure case rated at 10,500 meters

Interface

RS-232 standard
Power Required: 8-15 VDC @ 10 milliamps average

RS-485 half duplex (optional)
Power Required: 8-15 VDC @ 6 milliamps average

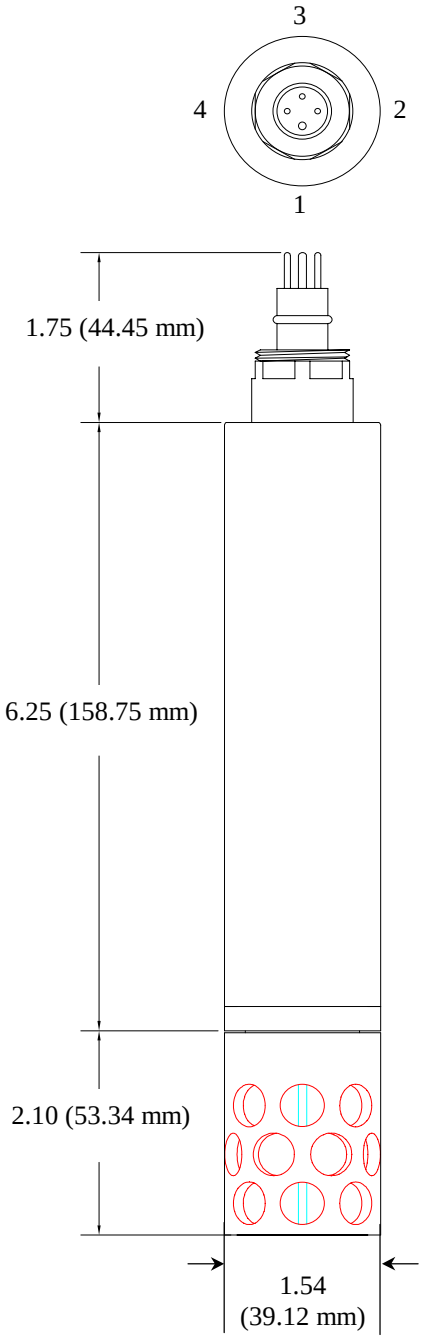
Communication
Baud Rate: 9600
Data Bits: 8
Stop Bits: 1
Parity: None

RMS Noise at temperature equivalent of 8.5 °C:

NAVG	Noise [°C]
1	0.000673
2	0.000408
4	0.000191
8	0.000133
16	0.000081
32	0.000052

SBE 38 Dimensions (in inches)

PIN	SIGNAL
(1)	Common, white
(2)	Receive, black or RS-485 A
(3)	Transmit, green or RS-485 B
(4)	Power, red



Sample Interval calculation

Interval between samples (seconds) = NAVG * 0.133 + 0.34

(NAVG = A/D cycles. See page 16)

Section 3: Operating the SBE 38

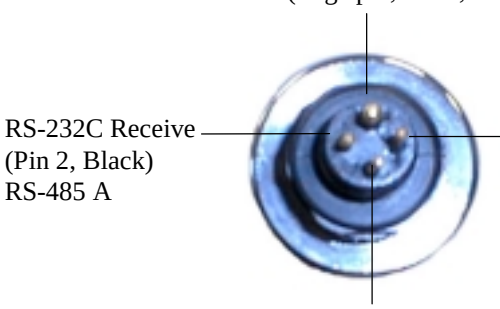
This section will provide instructions for establishing communications with the SBE 38 and converting from RS-232 interface to RS-485. It also includes command descriptions.

Establishing Communications

Once the SBE 38 is powered up and connected to the computer, a terminal program will communicate with the SBE 38. Follow these step-by-step instructions for establishing communications by setting up the serial port and baud rate. You will then check instrument status and command the SBE 38 to sample.

Note:
For convenience of initial testing, a 9 volt battery is included.
Plug the battery into the battery connector and establish communications (page 10).
The SBE 38 will operate approximately 50 hours on the 9 volt Duracell battery (or equivalent).
If the battery is not needed, simply cut the battery connector wire off.

Electrical Interface



Power: 8-15 Volts DC

Transmit: RS-232C Transmit from SBE 38 to computer
(Computer DB-25, pin 3 or DB-9, pin 2)
RS-485 B

Receive: RS-232C Receive data transmitted from computer
(Computer DB-25, pin 2 or DB-9, pin 3)
RS-485 A

Ground: System ground, power and computer
(Computer DB-25, pin 7 or DB-9, pin 5)

Changing the SBE 38 Interface *(Board layout below)*

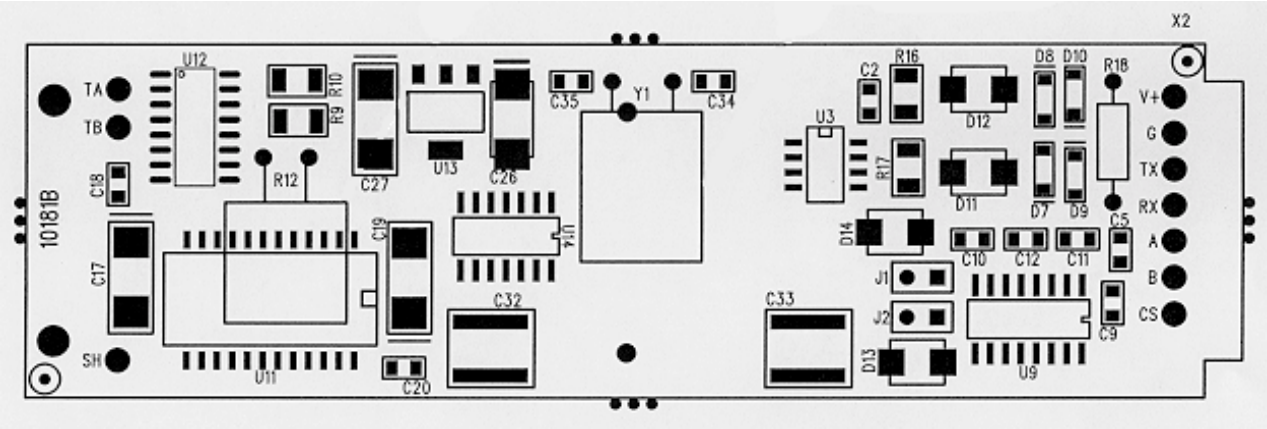
Note:
For more information about RS-485 applications, see Appendix III, page 23.

Switching from RS-232 to RS-485:

Connect SBE 38 Pin 2 (Black) to Pad A, instead of Pad RX.
Connect SBE 38 Pin 3 (Green) to Pad B, instead of Pad TX.

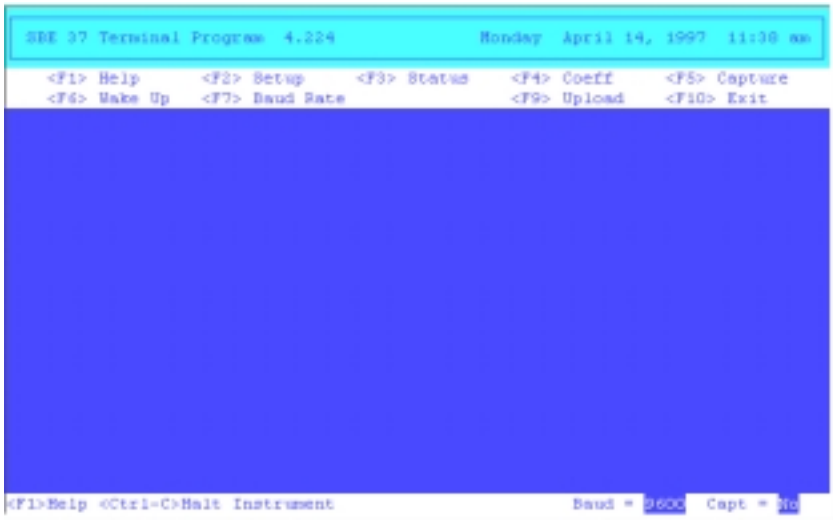
Switching from RS-485 to RS-232:

Connect SBE 38 Pin 2 (Black) to Pad RX, instead of Pad A.
Connect SBE 38 Pin 3 (Green) to Pad TX, instead of Pad B.



Begin Communications

1. Once connected to a computer and power supply, * type “TERM37” .
2. The main terminal screen should be as shown below.



*** Note:**
TERM37 is currently being used to communicate with the SBE 38. A universal terminal program is being developed and will be available by year end 1998.

3. Note the function keys...

The function keys are used to control different features of the terminal programs and to send commands to the instruments for initialization and status information.

(*See next page for function key chart*.)

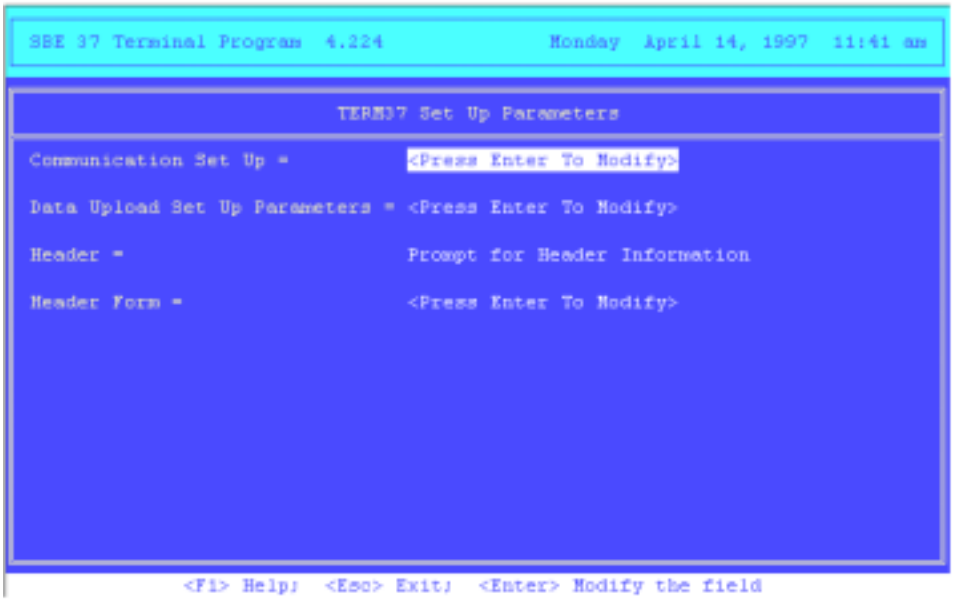
Active Function Keys:

F1	Display help screens
F2	Display the terminal setup form
F3	Display instrument status
F4	Display instrument headers
F5	Capture instrument responses to a file
F6	Establish communications with the instrument.
F7	Change the baud rate of the terminal program
F9	Upload, *Not Applicable*
F10	Exit to DOS
CTRL-C	Halt display voltages and display frequency diagnostic

The bottom status line contains:

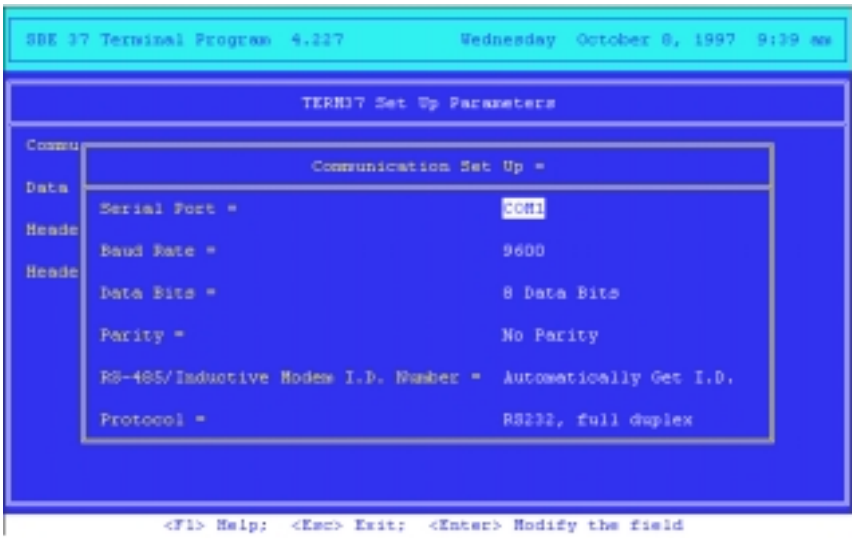
BAUD	Displays the current baud rate.
Capt	Displays the 'capture to disk' status. If YES, all replies from the instrument are being written to a file on disk.

4. Press <F2> for the Set Up Parameters Form. This screen will allow you to set up Communication Parameters, Data Upload Parameters and Header Information.



5. Communication Set Up <Press Enter To Modify> is already highlighted. Press Enter and select the appropriate COMM port and protocol.

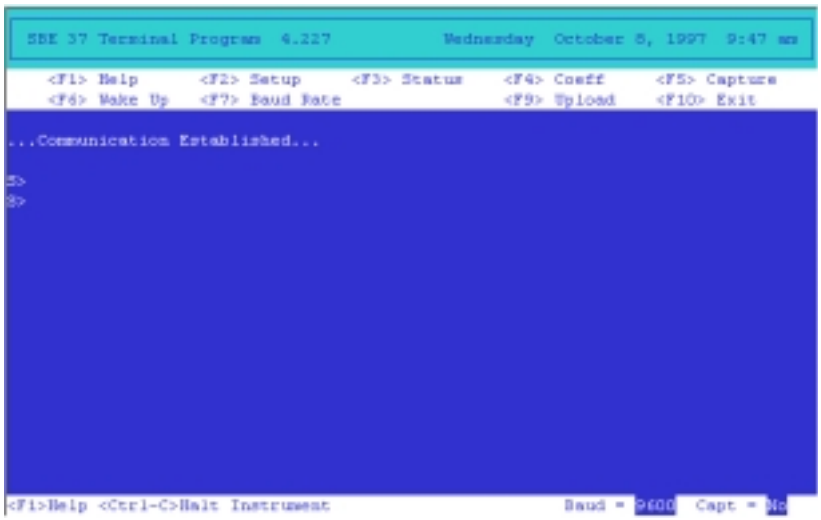
   The SBE 38 communicates at 9600 baud (default), 8 data bits, 1 stop bit and no parity.



6. Exit the Communications Set Up Form by pressing <Esc>.

7. Press <ESC> to return to Set Up Form. You are then prompted to save the Set Up file. Select Yes or No.

8. Press <F6> to establish communications with the SBE 38.

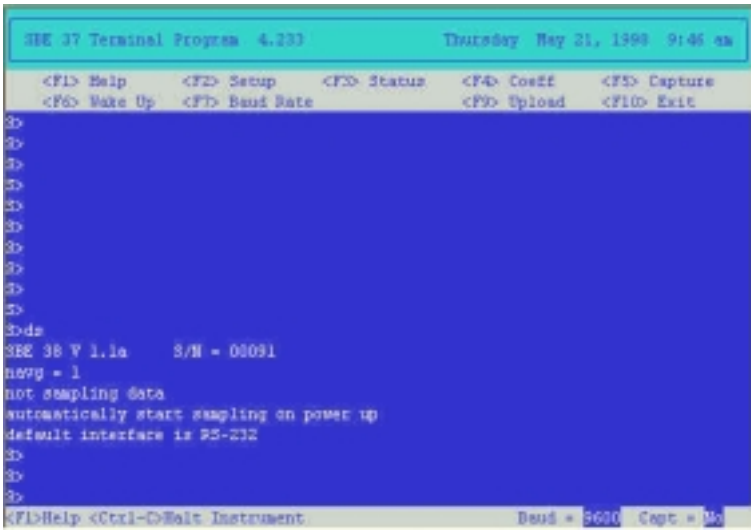


9. TERM37 has now established communications with the SBE 38 (see screen on previous page).
10. If the terminal program is not able to establish communications with the instrument by cycling through the baud rates, try the following :
    a. The baud rate (as documented on the front cover of this manual) should be set with the <F7> function key.
    b. The set up parameters accessed through the <F2> function key should also be verified.

Note:	*Subsequent attempts at communicating with the instrument can be made by pressing the <enter> key or the <F6> function key.*

    c. Check the cable to the PC.
    d. Verify your COM port. Make sure the COM port is the same as the information in the Set Up form.
    e. Check the power supply.
    f. Call Sea-Bird for assistance.

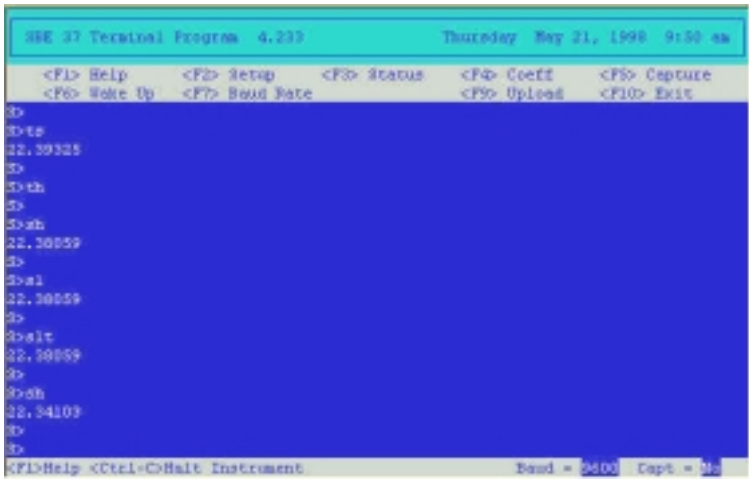
11. Once communication has been established, check the instrument status by typing "DS". The following information may appear on the screen below.
    (See the DS Command Description section for more information on this command, page 15.)



12. Take a sample by typing "TS". (See Operating Mode Command Descriptions for more information) The screen will display something like this:

    21.32305

13. Try some other commands to confirm operation. Type TH (take sample and hold), then SH (send held sample) or SL (send last sample) or SLT (send last, take a new and hold). See the screen below and refer to command descriptions, page 16.



Command Formats and Descriptions

These sections will describe commands that can be used with both RS-232 and RS-485 interfaces.

[*See Appendix II for Command Summary Tables*]

Commands to the SBE 38 may be entered in upper or lower case letters and are terminated with a carriage return. The SBE 38 will send "**? CMD"** whenever an invalid command is entered.
Communications can be re-established by using the <F6> key or typing the <enter> key twice while in the terminal program, e.g. **TERM37**.

STATUS Command Description

DS Display operating status; firmware version, serial number, sample interval, number of A/D cycles to average for each sample, and the default interface.

Example:

S> DS
SBE38 V 1.1a S/ N 0090
NAVG=1
Not sampling data
Automatically start sampling on power up
Default interface is RS-232
S>

Note:
If the voltage supply is below 6.5 volts, the following message will be displayed:
WARNING: LOW BATTERY VOLTAGE!!

SETUP Command Descriptions

INTERFACE=232	Set wake up data output interface to RS-232
INTERFACE=485	Set wake up data output interface to RS-485
BAUD=1200	Set the baud rate to 1200
BAUD=2400	Set the baud rate to 2400
BAUD=4800	Set the baud rate to 4800
BAUD=9600	Set the baud rate to 9600 (default)
FORMAT=C	Output Converted Data
FORMAT=R	Output Raw Data

Note:
When setting the baud rate with 'baud=' command, remember to use <F7> to change the terminal program baud rate also. Observe the rate at the bottom right of the screen.

(SETUP continued)

DIGITS=n	Set number significant digits to n (0-6)
NAVG=n	Set A/D cycles to average to n (Range is 1-300, default is 4)
AUTORUN=Y	Start sampling when powered on (Note: When using RS-485 interface, NAVG must be greater than 30 to enable AUTORUN)
AUTORUN=N	Wait for a command when powered on

OPERATING Command Descriptions

GO	Start sampling data at a rate determined by the number of A/D cycles
STOP	Stop sampling data
TS	Take sample and output data
TH	Take sample, hold results
SH	Send held data
SL	Send last sample
SLT	Send last sample, take a new sample, and hold results

CALIBRATION Command Description

DC Display calibration coefficients

Note:
The dates shown are when calibrations were performed. The calibration coefficients are entered into the SBE 38 at the factory and should agree with the calibration data sheets shipped with the SBE 38.

Example:

S> DC *<CR><LF>*
SBE38 V 1.0 0091
calibration: 08-apr-96
A0 = -9.420702e-05
A1 = 2.937924e-04
A2 = -3.739471e-06
A3 = 1.909551e-07

CALDATE=*S*	where S is a character string without spaces reflecting the calibration date i.e. 24June1998
A0=F	where F is a floating point number reflecting temperature i.e. 24.15
A1=F	Definition same as A0
A2=F	Definition same as A0
A3=F	Definition same as A0

RS-485 Command Descriptions

IDREQ=Y Commands received via the RS-485 interface must be preceded with #NN where NN is the RS-485 ID (multiple RS-485 devices sharing one pair of wires)

IDREQ=N Commands received via the RS-485 interface are not preceded with #NN where NN is the RS-485 ID (Only one SBE 38 is connected)

TXDELAY=n Set the delay after transmitting a reply until the transmitter is disabled to n msec (range is 1-500 msec, default is 25 msec)

RXDELAY=n Set the delay after receiving a command until enabling the transmitter to n msec (range is 1-500 msec, default is 25 msec)

Notes:
(a) If the ID required flag is set (IDREQ=Y) then commands received via the RS-485 port must be prefaced with: #NN, NN=RS-485 ID

(b) When multiple RS-485 sensors are on the line,send the '@' character before a command to clear the receive buffers.

Note:
The SBE 38 can be programmed to either require or not require an ID as part of the command when using the RS-485 interface.
An ID is never required when using the RS-232 interface.
The command IDREQ=Y sets the SBE 38 to require an ID as part of a command used in Mode 3 (see page 6 for Modes).
In Mode 2, the command IDREQ=N sets the SBE 38 to not require an ID as part of the command to simplify communications when only one SBE 38 is used.

Global Commands

These commands never require the #NN preface.

ID? Display RS-485 ID and state of ID required flag

***ID=NN** Set RS-485 ID to N, N=0-99. Only one RS-485 device can be on the line when this command is sent!

GDATA Take a sample and hold the results

ADATA Take a sample and hold results. GDATA and ADATA perform the same function. Both are included to provide compatibility with the RS-485 MicroCATs.

One exception…

DATANN Command ID NN to send held sample. This command is the same as the SH command but does not require the #NN preface and is included for compatibility with the RS-485 MicroCATs.

Examples:

ID required, ID=5, multiple sensors on the line. To display status, type:
@#05DS
ID required, ID=5, multiple sensors on the line. To set txdelay, type:
@#05TXDELAY=25
ID not required, ID=5, one SBE 38 on the line. To display status, type:
DS
ID not required, ID=5, one SBE 38 on the line. To set txdelay, type:
TXDELAY=25

Data Output Formats

Converted Temperature Data Format

RS-232 and Continuous sampling

Temperature is output in ITS-90 units (degrees Celsius) with the following format:

ttt.ttt<CR><LF>

where: t is temperature and the number of digits following the decimal point is user programmable, 0-6. <CR> is carriage return, <LF> is line feed.

RS-485 DATANN, TS, SH, SL, and SLT response

Temperature is output in ITS-90 units (degrees Celsius) with the following format:

ii, sssss, ttt.ttt<CR><LF>

where: ii is RS-485 ID, sssss is the SBE 38 serial number, and ttt.ttt is temperature (the number of digits following the decimal point is user programmable, 0-6.

Raw Temperature Data Format

The SBE 38 can be programmed to output raw data. See 'FORMAT=' on page 16.

The format is:

NNNNNN.N<CR><LF>

Section 4: Routine Maintenance and Calibration

This section reviews corrosion precautions and sensor calibration information.

WARNING!!!

Pressure housings may flood under pressure due to dirty or damaged o-rings, or other failed seals, causing highly compressed air to be trapped inside. If this happens, a potentially life-threatening explosion can occur when the instrument is brought to the surface.

If the SBE 38 is unresponsive to I/O commands or shows other signs of flooding or damage, the instrument should be carefully secured in a location away from people until it has been determined that abnormal internal pressure does not exist.

Contact Sea-Bird for assistance with procedures for safely relieving internal pressure.

Overall Care

The accuracy of the SBE 38 can be sustained by the care and calibration of the instrument and by establishing proper handling practices.

Corrosion Precautions

All exposed metal is titanium; other materials are plastic. No corrosion precautions are required, however direct electrical connection of the SBE 38 housing to mooring or other dissimilar metal hardware should be avoided. The SBE 38 should be rinsed with fresh water after use and prior to storage.

Calibration

The SBE 38 is calibrated in Sea-Bird's state of the art calibration laboratory which maintains primary temperature standards (water triple point (TPW) and gallium melting point (GaMP) cells), ITS-90 certified and standards-grade platinum resistance thermometers, and a low-gradient temperature bath.

The calibration of the SBE 38 is accomplished using the following equation to characterize the non-linear temperature versus resistance response of the sensor. Temperature is computed using the Steinhart-Hart polynomial for thermistors (Steinhart and Hart, 1968; Bennett, 1972) which is based on thermistor physics. Thermistors require individualized coefficients to the Steinhart-Hart equation because the thermistor material is an individualized mix of dopants. (n is the SBE 38 output):

(A) $t_{90L} = \dfrac{1.0}{(a0 + a1[\ln(n)] + a2[\ln^2(n)] + a3[\ln^3(n)])} - 273.15$ [°C]

(B) $t_{90} = slope * t_{90L} + offset$ [°C, *ITS*-90

Appendix I: Measurement Method

Temperature is determined by applying an AC excitation to reference resistances and an ultra-stable aged thermistor with a drift rate of less than 0.002 BC per year. Each of the resulting outputs is digitized by a 24 bit A/D converter. The reference resistor is a hermetically sealed VISHAY. AC excitation and ratiometric comparison using a common processing channel removes measurement errors due to parasitic thermocouples, offset voltages, leakage currents, and gain errors. Maximum power dissipated in the thermistor is 0.5 microwatts, and contributes less than 200 µK of overheat error.

A raw count (ratio) is related to resistance measurements as:

1048576 * (NT) / (NR);
where NR is the output from the reference resistor and NT is thermistor output.

The number of acquisition cycles (raw counts) averaged per measurement is user programmable. Increasing the number of cycles per measurement increases the time to acquire the measurement and the interval between measurements, while reducing the RMS temperature noise from the sensor. The interval between measurements is determined as follows:

interval [sec.] = 0.133 * Ncycles + 0.339

The thermometer's output is computed from the raw count and calibration coefficients stored in EEPROM.

Appendix II: Command Summary Tables

FUNCTION	COMMAND	DESCRIPTION
STATUS	DS	Display status
SETUP	INTERFACE=232	Set wake up data output interface to RS-232
	INTERFACE=485	Set wake up data output interface to RS-485
	BAUD=B	Set baud rate to B; 1200,2400,4800,9600
	FORMAT=C	Output converted raw data
	FORMAT=R	Output raw data
	DIGITS=n	Set number of significant digits for converted data to n (range is 0-6)
	NAVG=n	Set A/D cycles to average to n (range is 1-300, default is 4)
	AUTORUN=Y	Start sampling when powered on (Note: When using RS-485 interface, NAVG must be greater than 30 to enable AUTORUN.)
	AUTORUN=N	Wait for a command when powered on
OPERATING	GO	Start sampling data at a rate determined by the number of A/D cycles to average (NAVG command)
	STOP	Stop sampling data
	TS	Take sample and output data
	TH	Take sample, hold results
	SH	Send held data
	SL	Send last sample
	SLT	Send last sample and then take a new sample, holding results
TESTING	*EETEST	Test EEPROM
COEFFICIENTS	DC	Display calibration coefficients
	CALDATE=S	Inputs calibration data
	A0=F	Temperature A0
	A1=F	Temperature A1
	A2=F	Temperature A2
	A3=F	Temperature A3
	Where: F = floating point number S = string, no spaces	

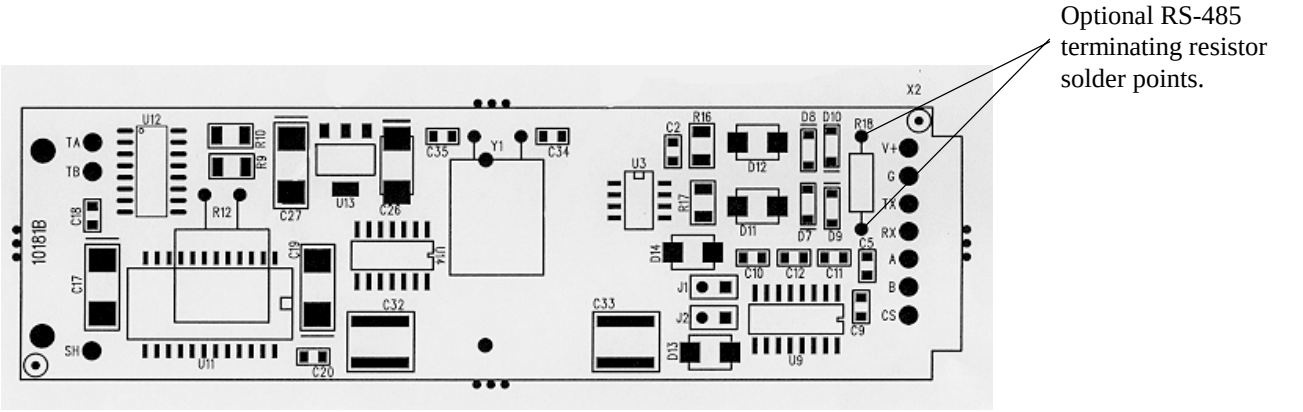
Appendix II: Command Summary Tables continued…

FUNCTION	COMMAND	DESCRIPTION
RS-485 Specific	IDREQ=Y	Commands received via the RS-485 interface must be preceded with #NN where NN is the RS-485 ID (multiple RS-485 devices sharing one pair of wires)
	IDREQ=N	Commands received via the RS-485 interface are not preceded with #NN where NN is the RS-485 ID (Only one SBE 38 is connected)
	TXDELAY=n	Set the delay after transmitting a reply until the transmitter is disabled to n msec (range is 1-500 msec, default is 25 msec)
	RXDELAY=n	Set the delay after receiving a command until enabling the transmitter to n msec (range is 1-500 msec, default is 25 msec)
Global Commands (These commands never require the #NN preface.)	ID?	Display RS-485 ID and the state of ID-required flag
	*ID=NN	Set RS-485 ID to N, N= 0-99. Only one RS-485 device can be on the line when this command is sent!
	GDATA	Take a sample and hold the results
	ADATA	Take a sample and hold results. GDATA and ADATA perform the same function. Both are included to provide compatibility with the RS-485 MicroCATs.
	DATANN	Command ID NN to send held sample. This command is the same as the SH command but does not require the #NN preface and is included for compatibility with the RS-485 MicroCATs.

Appendix III: RS-485 Applications

The MAX1483 transceivers used in the SBE 38 are designed for bi-directional data communications on multi-point bus transmission lines. To minimize reflections, the line should be terminated at both ends in its characteristic impedance. Also, stub lengths off the main line should be kept as short as possible (although the slew-rate-limited MAX1483 is more tolerant of imperfect termination than standard RS-485 ICs).

In the event that termination is required at the SBE 38, a terminating resistor, which corresponds to cable length and gauge, may be placed on the circuit board of the SBE 38. The location for the terminating resistor is indicated in the layout below.



For RS-485 Specific Command Descriptions; see Section 3, Page 17.

To switch between the RS-232 and RS-485 interfaces; see Section 3, page 10.

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