

SBE 35 RT

Digital Reversing Thermometer



User's Manual

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Section 1: Introduction

This section includes contact information and manual version number.

About this manual

This manual is to be used with the SBE 35 RT Digital Reversing Thermometer.

It is organized to guide a user from installation through operation and data collection. We've included command descriptions, measurement cycle and calibration information.

If you have any questions, do not hesitate to contact us at the numbers below.

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How to contact Sea-Bird

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Our business hours are:
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(1600 to 0200 Universal Time)
Except from April to October, when we will be on "summer time"
(1500 to 0100 Universal Time)

Section 2:

Communication with the SBE 35 RT

This section describes the function and features of the SBE 35 RT.

System Description

The SBE 35RT is an accurate ocean-range temperature sensor that can act as a stand-alone substitute reversing thermometers. When used with a SBE 911*plus*, SBE 19, or SBE 25 CTD and Carousel water sampler, the SBE 35RT makes a temperature measurement each time a bottle fire confirmation is received and stores the value in EEPROM. Each stored value contains the time of day and the bottle position in addition to the temperature data to facilitate comparison of the SBE 35RT record with CTD and water bottle data. The SBE 35RT can use the built in CTD modem channel for two-way communications. It is not necessary to change cable connections to communicate and retrieve data from the SBE 35RT.

Supplied with the SBE 35RT is a powerful software package, SEASOFT, which enables the user to communicate, retrieve data, and to calculate and display temperature. SEASOFT as supplied is designed to run on IBM XT/AT/386/486/Pentium or compatible computers.

A separate software manual contains additional information on the setup and use of SEASOFT.

Communication with the SBE 35 RT

Use the program TERM35 supplied with the SBE 35RT (or any other terminal program set to 300 baud, 8 data bit, no parity) to communicate with the SBE 35RT.

For lab use :

1. Connect the SBE 35RT to a SBE 90248 opto-box using cable P/N 80555.

The opto-box isolates power to the SBE 35RT and buffers the serial communication lines in order to minimize noise input to the SBE 35RT from external sources.

2. Connect the 90248 to a serial port on a PC with a straight through cable P/N 80677.

The SBE 35RT communicates at 300 baud, 8 data bits, no parity.

Note: The orange LED will flash when the SBE 35RT transmits. The green LED will flash when the PC transmits.

3. The SBE 35RT will transmit "SBE 35RT wake up" three seconds after the 90248 opto-box is powered on.
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Section 3: SBE 35 RT Commands

This section describes the commands associated with TERM35 as part of SEASOFT.

Command Descriptions

STATUS

ds	Display Status. A typical reply would be: SBE35 V 2.0 SERIAL NO. 0013 01 Oct 1998 15:56:52 number of measurement cycles to average = 8 number of data points stored in memory = 2 bottle confirm interface = SBE 911plus S>
dc	Display Calibration Coefficients. A typical reply would be: SBE35 V 2.0 SERIAL NO. 0013 09-apr-97 A0 = 5.156252707e-03 A1 = -1.430180396e-03 A2 = 2.092145355e-04 A3 = -1.156278215e-05 A4 = 2.446454055e-07 SLOPE = 1.000000 OFFSET = 0.000000 S>

SET UP

ncycles=N	Set the number of measurement cycles per acquisition to N. Each acquisition cycle is 1.1 seconds in duration. In a thermally quiet environment the temperature noise standard deviation is: $0.000029 * \sqrt{8 / \text{ncycles}} \text{ } ^\circ\text{C}$
interface=911plus	SBE 35RT is used with a SBE 911plus CTD and Carousel
interface=32serial	SBE 35RT is used with a SBE 19 or 25 CTD and Carousel
samplenum=N	Set the sample number to N. Set N to 0 at the beginning of a cast after all previous data has been downloaded from the SBE 35RT

3: SBE 35 RT Commands

DDMMYY=ddmmyy Set current day, month, and year. This command must be followed by HHMMSS= command to set the time.
MMDDYY=mmddy Set current month, day, and year. This command must be followed by HHMMSS= command to set the time.

DDMMYY= and MMDDYY= commands are equivalent. Either one can be used to set the date.

HHMMSS=hhmmss Set the current hour, minute, and second.

Example: To set the current date and time to 10 January 1997 12:00:00:

MMDDYY=011097
HHMMSS=120000

or

DDMMYY=100197
HHMMSS=120000

ACQUISITION

Bottle Confirm

Whenever the SBE 35RT receives a valid bottle confirmation sequence (a character with decimal value 6 followed by a character with decimal value greater than 48 and less than 84) it takes a measurement ncycles in duration and stores the date, time, bottle number, maximum - minimum thermistor value, and sensor output in EEPROM.

ts Take one sample and store it in EEPROM

cal Sample continuously, do not compute temperature, do not store samples

Output Format:

column 1:	zero value
column 2:	reference resistor value
column 3:	thermistor value
column 4:	maximum - minimum zero value
column 5:	maximum - minimum reference resistor value
column 6:	maximum - minimum thermistor value
column 7:	sensor output (n)

A typical output with the SBE 35RT in a triple point of water cell with the number of cycles per measurement = 16 is:

197.21	1047557	752453.3	15	31	27	753130.0
197.87	1047563	752457.4	15	31	21	753129.0
197.64	1047565	752459.1	15	32	18	753129.5
198.08	1047566	752459.9	19	30	21	753129.5
197.73	1047554	752451.2	13	34	28	753129.6
197.91	1047555	752451.4	17	30	27	753129.2
197.71	1047551	752449.1	14	27	21	753129.2

3: SBE 35 RT Commands

run Sample continuously, compute temperature, do not store samples
The output format is the same as in page 8 but with computed temperature added in the eighth column.

*Although the total time per measurement cycle is $1.1 * n_{cycles}$ seconds the time between sample updates is $1.1 * n_{cycles} + 2.7$ seconds. The extra time is spent converting the measured values to computed temperature and transmitting the data at 300 baud.*

DATA UPLOAD

dd Dump all the data
ddB,E Dump scans B through E

The format is:

column 1: sample number
column 2,3: date and time DD MMM YYYY HH:MM:SS
column 4: bottle position
column 5: maximum - minimum thermistor value
column 6: sensor output (n)
column 7L: computed temperature [ITS-90]

A sample output with the SBE 35RT taking data in room ambient air is:

```
1 30 Sep 1998 16:15:13 bn = 8 diff = 19 val = 509867.0 t90 = 8.752364
2 30 Sep 1998 16:15:41 bn = 6 diff = 21 val = 509867.4 t90 = 8.752342

0 30 Sep 1998 10:29:29 bn = 1 diff = 268 val = 278061.1
1 30 Sep 1998 10:31:00 bn = 2 diff = 84 val = 277430.6
2 30 Sep 1998 10:31:30 bn = 3 diff = 140 val = 277357.8
3 30 Sep 1998 10:32:00 bn = 4 diff = 357 val = 277163.3
4 30 Sep 1998 10:32:30 bn = 5 diff = 367 val = 277055.7
5 30 Sep 1998 10:33:00 bn = 6 diff = 409 val = 276487.1
```

CALIBRATION COEFFICIENTS

caldate=sssss set the calibration date to sssss (factory programmed)
ta0=F set A0 coefficient = F (factory programmed)
ta1=F set A1 coefficient = F (factory programmed)
ta2=F set A2 coefficient = F (factory programmed)
ta3=F set A3 coefficient = F (factory programmed)
ta4=F set A4 coefficient = F (factory programmed)
offset=F set the offset to F
slope=F set the slope to F

TESTING

***rtctest** Test battery backed static RAM in the real-time clock module.

***eetest** Test the EEPROM memory. Allow 30 seconds for this test to complete. This command will destroy all data stored in the EEPROM and will overwrite the calibration coefficients!

Both the *rtctest and *eetest overwrite data stored in the SBE 35RT SRAM! Re-set the date, time, and number of cycles to average after running these commands.

Section 4: Operating the SBE 35 RT

This section will describe SBE 35 RT operation with Sea-Bird CTD's and the Carousel Water Sampler.

Operation

At sea, the SBE 35RT can act as a stand-alone substitute for a reversing thermometer, recording temperature with each bottle closing. In this application, the SBE 35RT is mounted in a secure area on the water sampler frame where the ocean water flushes freely and there is minimal contamination from the passive thermal mass of the metal frame or active thermal dissipation from electronic instruments.

The SBE 35RT has a time constant of 0.5 seconds so it will lag the SBE 3 if temperature is changing during the measurement interval. A first order correction is: Determine the temporal gradient during the measurement interval from the secondary SBE 3 temperature data in the .ROS file ($g = \text{temperature gradient } [^{\circ}\text{C/s}]$).

Gradient-corrected SBE 35RT temperature = SBE 35RT measured temperature + $0.5 * g$.

Use with a SBE 911plus and Carousel Water Sampler

1. Connect the SBE 11*plus* deck unit modem channel to a PC using a straight through serial cable (P/N 80073).
2. Connect the SBE 35RT to the SBE 9*plus* and Carousel water sampler using cable Y-cable SBE 171220, DWG 32208. The three arms of the Y-cable are labeled SBE 9, SBE 32, and SBE 35RT. Connect each arm to the proper device.
3. Power the SBE 9*plus* with the 11*plus* deck unit.
4. Run TERM 35 and send the display status command (DS) to verify communication with the SBE 35RT. (If no reply is received; press <F2> to bring up the setup form, select communication set up and check the COMM port setting.) In addition, check that the *bottle confirm interface* is correct for the application. If not, type "interface=" and either 911plus or 32 serial.
5. Set *samplenum* to zero and run SEASAVE to acquire the CTD cast.
6. The SBE 35RT will take a sample each time it receives a bottle confirmation and store the data in EEPROM. If a second bottle is fired before the SBE 35RT finishes sampling ($1.1 * \text{ncycles} + 2 \text{ seconds}$), the SBE 35RT will ignore the second bottle confirmation.
7. After the CTD cast run TERM 35. Press Function Key 9 to upload the data. The data file will be stored with a .ASC extension.
8. Run DATCNV. In Water Bottle Set Up, select scans marked with bottle confirm bit as the source of scan range. Set offset to 0.0 and duration = $1.1 * \text{ncycles}$.

Use with a SBE 19 or 25 CTD and Carousel Water Sampler

1. Connect the SBE 33 deck unit modem channel to a PC using a straight through serial cable (P/N 80073).
 2. Connect the SBE 35RT to the Carousel water sampler using cable SBE 171221 DWG 32209. This is **not** a straight through cable. Connect the end labeled SBE 35RT to the SBE 35RT and the end labeled SBE 32 to the Carousel.
 3. Power the Carousel with the SBE 33 deck unit.
 4. Run TERM 35 and send the display status command (DS) to verify communication with the SBE 35RT. (If no reply is received; press <F2> to bring up the setup form, select communication set up and check the COMM port setting.) In addition, check that the *bottle confirm interface* is correct for the application. If not, type “interface=” and either 911plus or 32serial.
 5. Set *samplenum* to zero and run SEASAVE to acquire the CTD cast.
 6. The SBE 35RT will take a sample each time it receives a bottle confirmation and store the data in EEPROM. If a second bottle is fired before the SBE 35RT finishes sampling ($1.1 * \text{ncycles} + 2$ seconds), the SBE 35RT will ignore the second bottle confirmation.
 7. After the CTD cast, run TERM 35. Press Function Key 9 to upload the data. The data file will be stored with a .ASC extension.
 8. Run DATCNV. In Water Bottle Set Up, select scans marked with bottle confirm bit as the source of scan range. Set offset to 0.0 and duration = $1.1 * \text{ncycles}$.
-

Section 5: Measurement Cycle

This section provides description of measurement cycle for the SBE 35 RT.

The SBE 35RT determines temperature by applying a 1.2 kHz AC excitation to a reference resistor, zero ohms and an ultrastable thermistor and digitizing the output from each with a 20 bit delta-sigma A/D converter. The reference resistor is a hermetically sealed VISHAY VHP202K inside a temperature-controlled oven. The switches are "All-Position" mercury wetted reed relays with a stable contact resistance. 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 5e-7 watts.

NR	output from the reference resistor
NZ	output from zero ohms
NT	output from the thermistor

Output from the sensor = $1048576 * (NT - NZ) / (NR - NZ)$

Each acquisition cycle is:

select zero ohms, wait 0.1 seconds for the output to stabilize
 average for 0.267 seconds, this is NZ
 select reference resistor, wait 0.1 seconds for the output to stabilize
 average for 0.267 seconds, this is NR
 select thermistor, wait 0.1 seconds for the output to stabilize
 average for 0.267 seconds, this is NT

The total time per cycle is 1.1 second.

The number of the above acquisition cycles per measurement is programmable. Increasing the number of cycles per measurement increases the time to acquire the sample while reducing the RMS temperature noise from the sensor. The following RMS noise values are typical for a SBE 35RT in a triple point of water cell:

<u>Ncycles</u>	<u>Acquisition Time</u>	<u>Standard Deviation (°C)</u>
8	8.8 seconds	0.000029
32	35.2 seconds	0.000014

Temperature is computed using the Steinhart-Hart polynomial for thermistors (Steinhart and Hart, 1968; Bennett, 1972) as follows (n is the output from the SBE 35RT):

$$t_{90L} = \frac{1.0}{a0 + a1\ln(n) + a2\ln^2(n) + a3\ln^3(n) + a4\ln^4(n)} - 273.15$$

$$t_{90} = slope \times t_{90L} + offset \quad [deg C, ITS-90]$$

Carrying the polynomial to fourth order captures the non-linearity of the SBE 35RT thermistor output to better than ± 0.0001 °C.

Section 6: Calibration

SBE 35RTs are calibrated to ITS-90 temperature using Sea-Bird's computer-controlled calibration bath. Extremely well insulated, the baths provide a uniform toroidal circulation yielding an overall transfer accuracy against an SPRT within 0.0002°C. Repeatability at each of twelve individually mapped sensor positions is better than 0.0001°C. Sea-Bird's new metrology laboratory underpins the new temperature calibration baths. Following consultation with the U.S. National Institute of Standards and Technology, the met lab was configured to achieve temperature precision of 50 μ K and accuracy of 0.0005 °C. To obtain this performance, premium primary references including four Jarrett water triple-point cells (with maintenance bath) and an Isotech gallium melt cell are operated in conjunction with two YSI 8163 standards-grade platinum resistance thermometers and an ASL F18 Automatic Temperature Bridge.

References

Steinhart, J.S. and Hart, S.R. (1968) "Calibration Curves for Thermistors", Deep-Sea Research, 15, p.497.

Bennett, A.S. (1972) "The Calibration of Thermistors over the Temperature range 0-30 °C", Deep-Sea Research, 19, p.157.