

Digital Oceanographic Thermometer

SBE 38


Sophisticated A/D acquisition electronics, ultra-stable thermistor, and state-of-the-art calibration provide the standards-level performance of an expensive AC bridge and platinum thermometer at a small fraction of the cost. The SBE 38 is unaffected by shock and vibration, has high accuracy and stability, and is easy to use. It has a rugged, corrosion-proof, 10,500 meter (34,400 foot) titanium pressure housing. Real-time temperature data is transmitted in ASCII characters (in °C or raw counts) via an RS-232 or optional RS-485 serial interface for display or logging by PC or data logger.

The SBE 38's measurement range is -5 to +35 °C; absolute accuracy is better than 0.001 °C (1 mK) and resolution is approximately 0.00025 °C (0.25 mK). Each sensor includes certification that demonstrates drift of less than 0.001 °C (1 mK) during a six-month period.

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

OPERATION

The SBE 38 operates in one of three modes:

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

On power up, the SBE 38 reads its EEPROM, which includes calibration coefficients and other setup information. As programmed, the SBE 38 samples and transmits temperature continuously, or waits for a command. For RS-485 applications with several sensors sharing one pair of wires, the SBE 38 cannot sample continuously.

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 °C 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. The 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:

$$\text{raw counts} = 1048576 * (NT) / (NR)$$

where NR is the output from the reference resistor and NT is the thermistor output.

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

$$\text{interval [seconds]} = (0.133 * \text{Navg}) + 0.339$$

where Navg is the number of acquisition cycles per sample.

The SBE 38's converted output is computed from the raw count and the calibration coefficients that are stored in EEPROM.



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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.

Temperature is computed using the Steinhart-Hart polynomial for thermistors (Steinhart and Hart, 1968; Bennett, 1972), which is based on thermistor physics. The equation characterizes the non-linear temperature versus resistance response of the sensor. Note that thermistors require individualized coefficients to the Steinhart-Hart equation, because the thermistor material is an individualized mix of dopants:

$$t_{90L} = \{ [1.0 / (a_0 + a_1 * [\ln(n)] + a_2 * [\ln^2(n)] + a_3 * [\ln^3(n)])] - 273.15 \} * \text{Slope} + \text{Offset } [^{\circ}\text{C}]$$

where n is the SBE 38 output.

SPECIFICATIONS

Interface and Power Requirements:

RS-232 (standard)

Power: 8-15 VDC at 10 milliamps average

RS-485 half duplex (optional)

Power: 8-15 VDC at 6 milliamps average

Housing:

Titanium, rated at 10,500 meters (34,400 feet)

Weight:

In Air

0.9 kg (2.0 lbs)

In Water

0.5 kg (1.2 lbs)

Range:

-5 to +35 °C

Initial Accuracy¹:

± 0.001 °C (1 mK)

Resolution:

0.00025 °C (0.25 mK)

Stability:

0.001 °C (1 mK) in six months, certified

Response Time²:

500 milliseconds

Self-heating Error:

less than 200 µK

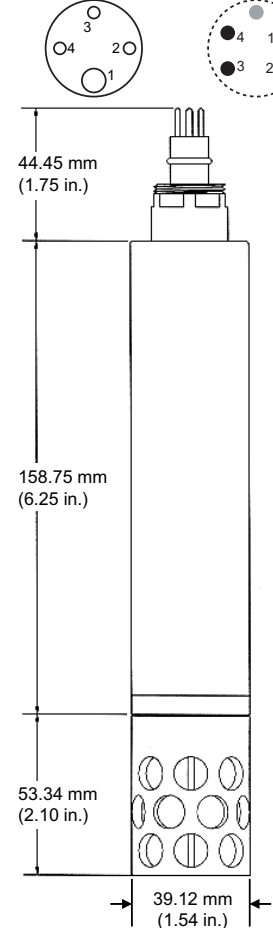
1 NIST-traceable calibration applying over the entire range.

2 Time to reach 63% of final value following a step change in temperature.

PIN	SIGNAL
1	Common
2	RS-232 Receive or RS-485 A
3	RS-232 Transmit or RS-485 B
4	Power

Standard connector:
XSG-4-BCL-HP-SS

Wet-Pluggable
MCBH-4MP (WB), TI
(3/8" length base,
1/2-20 thread)



ACTUAL CALIBRATION DATA for Sensor Number 80

CALIBRATION DATE: 02 September 1997

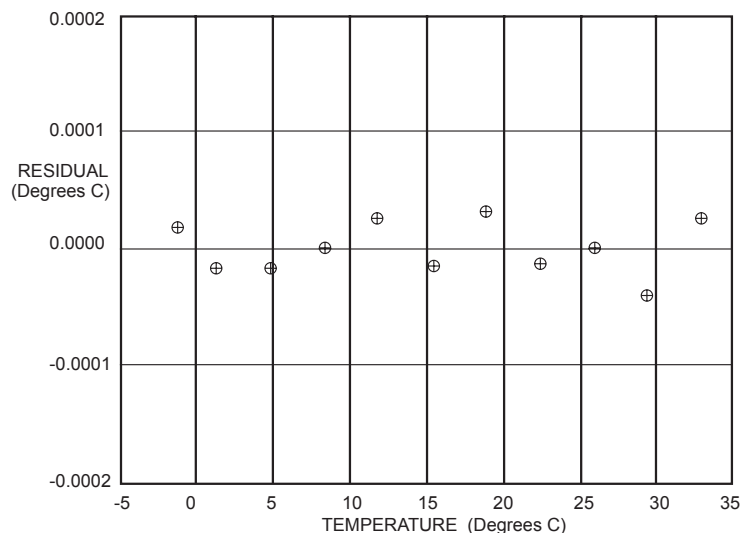
a0 = -2.809379e-05

a2 = -2.619655e-06

a1 = 2.783483e-04

a3 = 1.598734e-07

Bath Temperature [°C]	Instrument Output [n]	Instrument Temperature [°C]	Residual (Instrument - Bath) [°C]
-1.52985	824162.7	-1.52983	0.00002
1.03108	733633.1	1.03106	-0.00002
4.60520	625547.1	4.60518	-0.00002
8.11169	536776.4	8.11169	-0.00000
11.61533	462132.6	11.61536	0.00003
15.17575	398167.3	15.17574	-0.00001
18.63931	345476.6	18.63934	0.00003
22.14032	300170.8	22.14031	-0.00001
25.66793	261276.6	25.66793	0.00000
29.13948	228549.1	29.13944	-0.00004
32.61481	200420.3	32.61484	0.00003



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