

## SBE 3plus

### Premium CTD Temperature Sensor

Intended primarily for use on the SBE 911plus profiling CTD system, the SBE 3plus can also be used as a component in custom oceanographic systems or for high-accuracy industrial and environmental temperature monitoring applications.

The superior performance of the SBE 3plus results from its optimized electronic design, superior calibration, response characterization, and quality testing program. The SBE 3plus is a more rigorously tested and calibrated version of our SBE 3F, demonstrating drift of less than 0.001 °C during a six-month screening period. In addition, the time response is carefully measured and verified to be  $0.065 \pm 0.010$  sec.

## Features

- Glass-coated thermistor bead, pressure-protected in 0.8 mm diameter thin-walled stainless steel tube. Exponentially related to temperature, the thermistor resistance is the controlling element in an optimized Wien Bridge oscillator circuit. Resulting sensor frequency is inversely proportional to the square root of the thermistor resistance and ranges from approximately 2 to 6 kHz, corresponding to -5 to +35 °C.
- Built-in acquisition circuits and frequency outputs; allows for calibration as separate modules.
- Individually calibrated in Sea-Bird's computer-controlled, super-low-gradient calibration baths.
- Overall system accuracy limited only by the accuracy of the CTD's master clock. Errors from this source are demonstrably negligible (in the SBE 911plus, clock error contribution is 0.00016 °C, based on a five-year worst case error budget, including ambient temperature influence of 1 ppm total over -20 to +70 °C, plus 1 ppm first year drift, plus four additional year's drift at 0.3 ppm/ year).
- 6800 m aluminum or 10,500 m titanium housing.
- Five-year limited warranty.



## Calibration

SBE 3plus sensors are calibrated to ITS-90 temperature using Sea-Bird's computer-controlled calibration baths. 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 metrology lab underpins the temperature calibration baths. Following consultation with the U.S. National Institute of Standards and Technology, the lab was configured to achieve temperature precision of 50 µK 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.

## Calibration Equation

The calibration yields four coefficients (g, h, i, j) that are used in the following equation (Bennett):

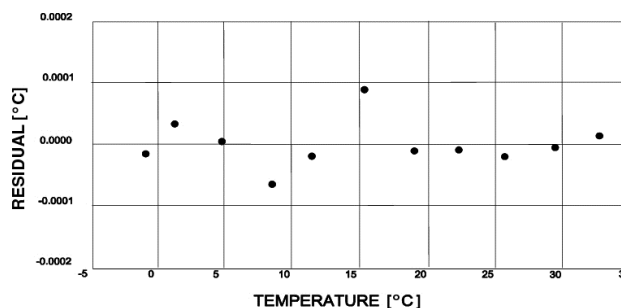
$$T = 1 / [g + h \ln(f_0/f) + i \ln^2(f_0/f) + j \ln^3(f_0/f)] - 273.15$$

where T is temperature [°C],  $\ln$  is natural log function, and f is SBE 3plus output frequency [Hz]. Note that  $f_0$ , an arbitrary scaling term used for purposes of computational efficiency, was historically chosen as the lowest sensor frequency generated during calibration. For calibration results expressed in terms of ITS-90 temperatures,  $f_0$  is set to 1000. Calibration fit residuals are typically less than 0.0001 °C.

**Example Calibration Data** (sensor serial number 2132, 31 Oct 1995):

g = 4.12744629e-03    h = 6.26321187e-04    i = 2.05376982e-05    j = 2.13741203e-06     $f_0 = 1000.000$

Bath Temperature [°C]	Instrument Frequency [Hz]	Instrument Temperature [°C]	Residual (Instrument - Bath) [°C]
-1.4309	2075.334	-1.4309	-0.00002
1.0784	2195.385	1.0785	0.00004
4.5695	2370.650	4.5695	0.00001
8.1675	2561.590	8.1674	-0.00006
11.5994	2753.736	11.5993	-0.00002
15.1570	2963.518	15.1571	0.00009
18.6607	3180.898	18.6607	-0.00001
22.1592	3408.886	22.1592	-0.00001
25.7189	3652.317	25.7188	-0.00002
29.1334	3896.897	29.1334	-0.00001
32.6673	4161.665	32.6673	0.00001



## Options

- Aluminum (6800 m) or titanium (10,500 m) housing.
- XSG or wet-pluggable MCBH connector.

## Performance

Measurement Range	-5 to +35 °C
Initial Accuracy <sup>1</sup>	± 0.001 °C
Stability	Must demonstrate < 0.001 °C drift during the 6 months prior to delivery
Resolution <sup>2</sup>	0.0003 °C at 24 samples/sec
Response Time <sup>3</sup>	0.065 sec ± 0.010 sec (1.0 m/s water velocity)
Self-heating Error	< 0.0001 °C in still water
Settling Time	< 0.5 sec to within 0.001 °C

<sup>1</sup> NIST-traceable calibration applying over entire oceanographic range.

<sup>2</sup> Achieved with SBE 911plus CTD.

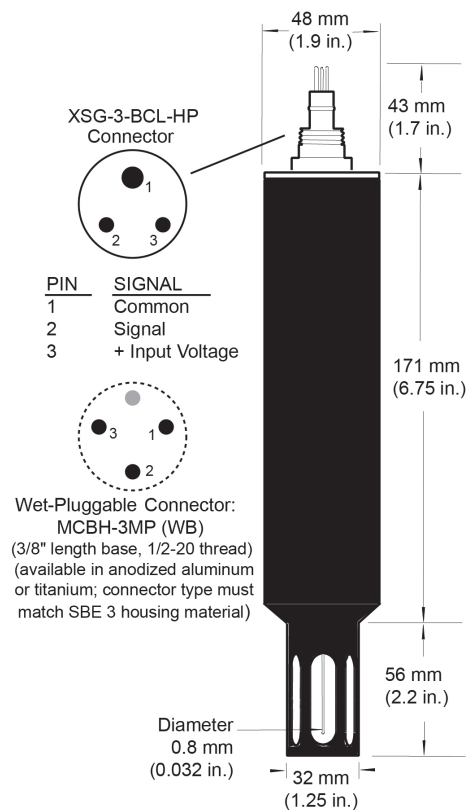
<sup>3</sup> Time to reach 63% of final value following step change in temperature.

## Electrical

Input Power	11-16 VDC, 25 mA
Output Signal	± 0.5 V square wave

## Mechanical

7075 Aluminum housing	Depth rating: 6800 m; Weight: 0.6 kg in air, 0.3 kg in water
6Al-4V Titanium housing	Depth rating: 10,500 m; Weight: 0.9 kg in air, 0.6 kg in water



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