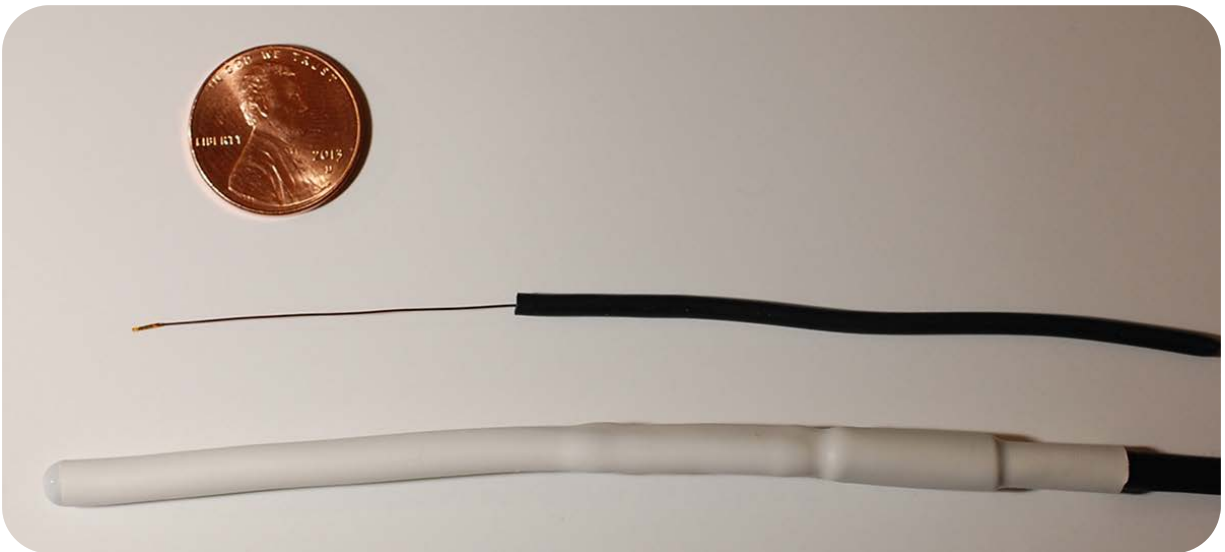




OWNER'S MANUAL

THERMISTOR TEMPERATURE SENSOR

Models: ST-100 and ST-200



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DECLARATION OF CONFORMITY

CE and ROHS Certificate of Compliance

We Apogee Instruments, Inc.
721 W 1800 N
Logan, Utah 84321
USA

Declare under our sole responsibility that the products:

Models: ST-100, ST-200
Type: Thermistor Temperature Sensor

are in conformity with the following standards and relevant EC directives:

Emissions: EN 61326-1:2013
Immunity: EN 61326-1:2013
Safety: EN 61010-1:2010

EU directive 2004/108/EC, EMC
EU directive 2002/95/EC, RoHS (Restriction of Hazardous Substances)
EU directive 2011/65/EU, RoHS2

Please be advised that based on the information available to us from our raw material suppliers, the products manufactured by us do not contain, as intentional additives, any of the restricted materials, including cadmium, hexavalent chromium, lead, mercury, polybrominated biphenyls (PBB), polybrominated diphenyls (PBDE).

Further note that Apogee Instruments does not specifically run any analysis on our raw materials or end products for the presence of these substances, but rely on the information provided to us by our material suppliers.

Bruce Bugbee
President
Apogee Instruments, Inc.
June 2013

INTRODUCTION

Temperature is generally thought of as the relative degree of 'hotness' or 'coldness' of a specific object or material. In actuality, temperature is a measure of the average thermal energy (internal kinetic energy) of an object. Thermal energy is associated with the motion (kinetic energy) of the atoms and molecules making up the object/material. Higher temperatures correspond to higher thermal energies (faster motion of atoms and molecules), whereas colder temperatures correspond to lower thermal energies (slower motion of atoms and molecules).

Thermometers are sensors that measure temperature. Thermometers are often electronic, with multiple options available. The main advantages of thermistors over other electronic thermometers (thermocouples, platinum resistance thermometers) are high signal-to-noise ratio, requirement of only a single-ended channel for measurement, and low cost, while still maintaining comparable accuracy.

Properties of materials and nearly all biological, chemical, and physical processes are temperature dependent. Temperature is also a fundamental weather variable. As a result, temperature is perhaps the most widely measured environmental variable.

Apogee Instruments ST-100 temperature sensors consist of a precision thermistor enclosed in a ceramic housing with a rubber covering, a precision bridge resistor, and lead wires to connect the sensor to a measurement device. ST-100 sensors are weatherproof and are designed for continuous temperature measurement in air or soil. ST-200 temperature sensors have a fine-wire precision thermistor, precision bridge resistor, and lead wires, but the thermistor is not packaged in a weatherproof housing. ST-200 sensors are weather resistant and are designed for temperature measurement of delicate surfaces (e.g., leaves, fruits) and small samples (where a narrow field of view infrared radiometer may not be suitable due to the integration over the conical field of view), or applications where rapid response is required. ST-100 and ST-200 temperature sensors output an analog voltage (when supplied with an input voltage) that is related to thermistor resistance. Resistance is directly related to temperature.

SENSOR MODELS

ST-100 temperature sensors include a rugged, weatherproof housing and can be exposed to a wide range of environmental conditions, including submersion in water and burial in soil/porous media. ST-200 temperature sensors do not include the weatherproof housing and are designed for fast response measurements, or measurements of small samples and fragile surfaces. The ST-110 thermistor temperature sensor is also available, and is designed for use inside the Apogee aspirated radiation shield, model TS-100; for a description of the ST-110, see manual for TS-100.



Sensor model number, serial number, and production date are located on a label near the pigtail lead wires.

SPECIFICATIONS

Measurement Range: -50 to 70 C

Measurement Uncertainty: 0.1 C (from 0 to 70 C) (ST-100)
0.2 C (from -25 to 0 C)
0.4 C (from -50 to -25 C)

0.2 C (from 0 to 70 C) (ST-200)
0.4 C (from -50 to 0 C)

Measurement Repeatability: < 0.05 C

Non-stability (Long-term Drift): < 0.02 C per year (when used in non-condensing environments where the annual average temperature is less than 30 C; continuously high temperatures or continuously humid environments increase drift rate)

Equilibration Time: 30 s and 1 s for ST-100 and ST-200, respectively

Self-Heating: < 0.01 C (typical, assuming pulsed excitation of 2.5 V DC)
0.08 C at 5 C (maximum, assuming continuous input excitation of 2.5 V DC)

Operating Environment: -50 to 70 C
0 to 100 % relative humidity

Input Voltage Requirement: 2.5 V DC excitation (recommended, see OPERATION AND MEASUREMENT section)

Output Voltage Range: 0 to 2.5 V DC (assuming input excitation of 2.5 V DC)

Current Drain: 0.1 mA DC at 70 C (maximum, assuming continuous input excitation of 2.5 V DC)

Dimensions: 7 cm length, 0.6 cm diameter

Mass: 60 g

Cable: 5 m of shielded, twisted-pair wire.
Additional cable available in multiples of 5 m
Santoprene rubber jacket (high water resistance, high UV stability, flexibility in cold conditions)
Pigtail lead wires

DEPLOYMENT AND INSTALLATION

Apogee ST series temperature sensors are designed to be mounted inside Gill-type radiation shields. ST-100 sensors can also be buried in soil/porous media, or submerged in water. ST-200 sensors have thin, flexible wires near the fine-wire thermistor and are less sensitive to breakage than similarly-sized fine-wire thermocouples.

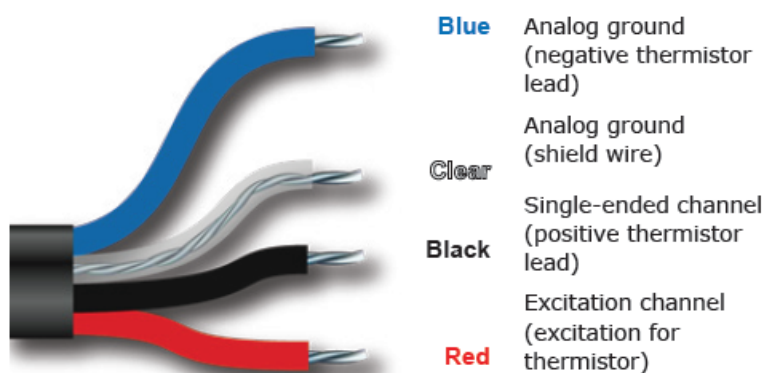
The temperature measurement returned by a temperature sensor is the temperature for the sensor itself and not that of the environment the sensor is in, unless the sensor is in thermal equilibrium with the environment. In order to get representative temperature measurements, ST series sensors must be in thermal contact with the medium of interest. Accurate air temperature measurement requires a radiation shield (see picture below) to minimize the effects of shortwave radiation absorption (causes warming; occurs during the day) and longwave radiation emission (causes cooling; occurs on clear nights) by the sensor. Proper ventilation is also required to ensure coupling and thermal equilibrium with air. Condensation on air temperature sensors can pose a problem because it is a source of latent heat that can warm the sensor. When the condensed water evaporates, it cools the sensor via removal of latent heat (evaporational cooling).



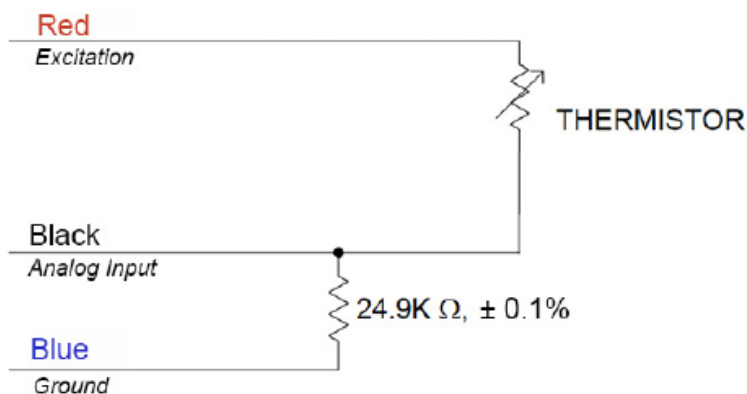
During installation of ST-100 sensors in soil, care should be taken to minimize soil disturbance, which may potentially alter soil thermal properties.

OPERATION AND MEASUREMENT

Connect the sensor to a measurement device (meter, datalogger, controller) capable of inputting 2.5 V DC, and measuring and displaying or recording a millivolt (mV) signal (an input measurement range of 0 to 2500 mV is required to cover the entire temperature range of the sensor). In order to maximize measurement resolution and signal-to-noise ratio, the input range of the measurement device should closely match the output range of the thermistor.



Measurement devices (e.g., datalogger, controller) do not measure resistance directly, but determine resistance from a half-bridge measurement, where an excitation voltage is input across the thermistor and an output voltage is measured across the bridge resistor.



An excitation voltage of 2.5 V DC is recommended to minimize self-heating and current drain, while still maintaining adequate measurement sensitivity (mV output from thermistor per C). However, other excitation voltages can be used. Decreasing the excitation voltage will decrease self-heating and current drain, but will also decrease thermistor measurement sensitivity. Increasing the excitation voltage will increase thermistor measurement sensitivity, but will also increase self-heating and current drain.

Conversion of Thermistor Resistance to Temperature:

The thermistor is a resistive element, where resistance changes with temperature. Thermistor resistance (R_T , in Ω) is measured with a half-bridge measurement, requiring an excitation voltage input (V_{EX}) and a measurement of output voltage (V_{OUT}):

$$R_T = 24900 \left(\frac{V_{EX}}{V_{OUT}} - 1 \right) \quad (1)$$

where 24900 is the resistance of the bridge resistor in Ω . From resistance, temperature (T_K , in Kelvin) is calculated with the Steinhart-Hart equation and thermistor specific coefficients:

$$T_K = \frac{1}{A + B \ln(R_T) + C(\ln(R_T))^3} \quad (2)$$

where $A = 1.129241 \times 10^{-3}$, $B = 2.341077 \times 10^{-4}$, and $C = 8.775468 \times 10^{-8}$ (Steinhart-Hart coefficients). If desired, measured temperature in Kelvin can be converted to Celsius (T_C):

$$T_C = T_K - 273.15. \quad (3)$$

MAINTENANCE AND RECALIBRATION

Apogee ST-100 temperature sensors are weatherproof and can be submerged in water or buried in soil/porous media. ST-200 series sensors are weather resistant, but not weatherproof. When sensors are not in use, it is recommended that they be removed from the measurement environment, cleaned, and stored. ST series temperature sensors used to measure air temperature should be periodically cleaned to remove all dust and debris.

Apogee ST-100 and ST-200 temperature sensors are not factory calibrated, but come with a generic calibration (see Steinhart-Hart coefficients in OPERATION AND MEASUREMENT section). A custom calibration can be derived by comparing the temperature from the thermistor to a reference temperature measurement. Often, a simple offset can be used to make measured temperature match reference temperature.

TROUBLESHOOTING AND CUSTOMER SUPPORT

Independent Verification of Functionality:

Apogee ST series temperature sensors yield a resistance proportional to temperature. A quick and easy check of thermistor functionality can be accomplished with an ohmmeter. Connect the lead wires of the ohmmeter to the green and white wires from the sensor. The resistance should read 10 k Ω (10,000 ohms) at 25 C. If sensor temperature is less than 25 C, resistance will be higher. If sensor temperature is greater than 25 C, resistance will be lower. Connect the lead wires of the ohmmeter to the green and blue wires from the sensor. The resistance should read 24.9 k Ω , and should not vary. Connect the lead wires of the ohmmeter to the white and blue wires from the sensor. The resistance should be the sum of resistances measured across the green and white wires, and green and blue wires (e.g., 10 k Ω plus 24.9 k Ω at 25 C).

Compatible Measurement Devices (Dataloggers/Controllers/Meters):

Measurement of thermistor resistance requires an input excitation voltage, where 2.5 V DC is recommended. A compatible measurement device should have the capability to supply the necessary voltage.

The sensitivity (mV output from thermistor per C) of the temperature measurement varies with the excitation voltage, and varies as a function of temperature. With an excitation voltage of 2.5 V DC, the sensitivity is lowest near the ends of the measurement range, -50 and 70 C. A compatible measurement device (e.g., datalogger or controller) should have resolution of at least 0.6 mV, in order to produce temperature resolution of less than 0.1 C across the entire temperature measurement range (less than 0.05 C from -35 to 45 C).

An example datalogger program for Campbell Scientific dataloggers can be found on the Apogee webpage at <http://www.apogeeinstruments.com/content/Thermistor-Temperature-Sensor.CR1>.

Modifying Cable Length:

When the sensor is connected to a measurement device with high input impedance, sensor output signals are not changed by splicing on additional cable in the field. Tests have shown that if the input impedance of the measurements device is 1 mega-ohm or higher then there is negligible effect on ST series temperature sensors, even after adding up to 100 m of cable. See Apogee webpage for details on how to extend sensor cable length (<http://www.apogeeinstruments.com/how-to-make-a-weatherproof-cable-splice/>). For cable extensions, shielded, twisted pair cable is recommended, in order to minimize electromagnetic interference. This is particularly important for long lead lengths in electromagnetically noisy environments.

The precision bridge resistor is located at the pigtail end of the cable. Thus, ST series temperature sensor cables should not be shortened, otherwise the bridge resistor will be removed.

RETURN AND WARRANTY POLICY

RETURN POLICY

Apogee Instruments will accept returns within 30 days of purchase as long as the product is in new condition (to be determined by Apogee). Returns are subject to a 10 % restocking fee.

WARRANTY POLICY

What is Covered

All products manufactured by Apogee Instruments are warranted to be free from defects in materials and craftsmanship for a period of four (4) years from the date of shipment from our factory. To be considered for warranty coverage an item must be evaluated either at our factory or by an authorized distributor.

Products not manufactured by Apogee (spectroradiometers, chlorophyll content meters) are covered for a period of one (1) year.

What is Not Covered

The customer is responsible for all costs associated with the removal, reinstallation, and shipping of suspected warranty items to our factory.

The warranty does not cover equipment that has been damaged due to the following conditions:

1. Improper installation or abuse.
2. Operation of the instrument outside of its specified operating range.
3. Natural occurrences such as lightning, fire, etc.
4. Unauthorized modification.
5. Improper or unauthorized repair.

Please note that nominal accuracy drift is normal over time. Routine recalibration of sensors/meters is considered part of proper maintenance and is not covered under warranty.

Who is Covered

This warranty covers the original purchaser of the product or other party who may own it during the warranty period.

What We Will Do

At no charge we will:

1. Either repair or replace (at our discretion) the item under warranty.
2. Ship the item back to the customer by the carrier of our choice.

Different or expedited shipping methods will be at the customer's expense.

How To Return An Item

1. Please do not send any products back to Apogee Instruments until you have received a Return Merchandise Authorization (RMA) number from our technical support department by calling (435) 792-4700 or by submitting an online RMA form at www.apogeeinstruments.com/tech-support-recalibration-repairs/. We will use your RMA number for tracking of the service item.
2. Send all RMA sensors and meters back in the following condition: Clean the sensor's exterior and cord. Do not modify the sensors or wires, including splicing, cutting wire leads, etc. If a connector has been attached to the cable end, please include the mating connector – otherwise the sensor connector will be removed in order to complete the repair/recalibration.

3. Please write the RMA number on the outside of the shipping container.
4. Return the item with freight pre-paid and fully insured to our factory address shown below. We are not responsible for any costs associated with the transportation of products across international borders.
5. Upon receipt, Apogee Instruments will determine the cause of failure. If the product is found to be defective in terms of operation to the published specifications due to a failure of product materials or craftsmanship, Apogee Instruments will repair or replace the items free of charge. If it is determined that your product is not covered under warranty, you will be informed and given an estimated repair/replacement cost.

Apogee Instruments, Inc.
721 West 1800 North Logan, UT
84321, USA

OTHER TERMS

The available remedy of defects under this warranty is for the repair or replacement of the original product, and Apogee Instruments is not responsible for any direct, indirect, incidental, or consequential damages, including but not limited to loss of income, loss of revenue, loss of profit, loss of wages, loss of time, loss of sales, accrual of debts or expenses, injury to personal property, or injury to any person or any other type of damage or loss.

This limited warranty and any disputes arising out of or in connection with this limited warranty ("Disputes") shall be governed by the laws of the State of Utah, USA, excluding conflicts of law principles and excluding the Convention for the International Sale of Goods. The courts located in the State of Utah, USA, shall have exclusive jurisdiction over any Disputes.

This limited warranty gives you specific legal rights, and you may also have other rights, which vary from state to state and jurisdiction to jurisdiction, and which shall not be affected by this limited warranty. This warranty extends only to you and cannot be transferred or assigned. If any provision of this limited warranty is unlawful, void or unenforceable, that provision shall be deemed severable and shall not affect any remaining provisions. In case of any inconsistency between the English and other versions of this limited warranty, the English version shall prevail.

This warranty cannot be changed, assumed, or amended by any other person or agreement.

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