

BlackGlobe

Temperature Sensor
for Heat Stress



Guarantee

This equipment is guaranteed against defects in materials and workmanship. We will repair or replace products which prove to be defective during the guarantee period as detailed on your invoice, provided they are returned to us prepaid. The guarantee will not apply to:

- Equipment which has been modified or altered in any way without the written permission of Campbell Scientific
- Batteries
- Any product which has been subjected to misuse, neglect, acts of God or damage in transit.

Campbell Scientific will return guaranteed equipment by surface carrier prepaid. Campbell Scientific will not reimburse the claimant for costs incurred in removing and/or reinstalling equipment. This guarantee and the Company's obligation thereunder is in lieu of all other guarantees, expressed or implied, including those of suitability and fitness for a particular purpose. Campbell Scientific is not liable for consequential damage.

Please inform us before returning equipment and obtain a Repair Reference Number whether the repair is under guarantee or not. Please state the faults as clearly as possible, and if the product is out of the guarantee period it should be accompanied by a purchase order. Quotations for repairs can be given on request. It is the policy of Campbell Scientific to protect the health of its employees and provide a safe working environment, in support of this policy a "Declaration of Hazardous Material and Decontamination" form will be issued for completion.

When returning equipment, the Repair Reference Number must be clearly marked on the outside of the package. Complete the "Declaration of Hazardous Material and Decontamination" form and ensure a completed copy is returned with your goods. Please note your Repair may not be processed if you do not include a copy of this form and Campbell Scientific Ltd reserves the right to return goods at the customers' expense.

Note that goods sent air freight are subject to Customs clearance fees which Campbell Scientific will charge to customers. In many cases, these charges are greater than the cost of the repair.



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About this manual

Please note that this manual was originally produced by Campbell Scientific Inc. primarily for the North American market. Some spellings, weights and measures may reflect this origin.

Some useful conversion factors:

Area: 1 in² (square inch) = 645 mm²

Length: 1 in. (inch) = 25.4 mm
1 ft (foot) = 304.8 mm
1 yard = 0.914 m
1 mile = 1.609 km

Mass: 1 oz. (ounce) = 28.35 g
1 lb (pound weight) = 0.454 kg

Pressure: 1 psi (lb/in²) = 68.95 mb

Volume: 1 UK pint = 568.3 ml
1 UK gallon = 4.546 litres
1 US gallon = 3.785 litres

In addition, while most of the information in the manual is correct for all countries, certain information is specific to the North American market and so may not be applicable to European users.

Differences include the U.S standard external power supply details where some information (for example the AC transformer input voltage) will not be applicable for British/European use. *Please note, however, that when a power supply adapter is ordered it will be suitable for use in your country.*

Reference to some radio transmitters, digital cell phones and aerials may also not be applicable according to your locality.

Some brackets, shields and enclosure options, including wiring, are not sold as standard items in the European market; in some cases alternatives are offered. Details of the alternatives will be covered in separate manuals.

Part numbers prefixed with a “#” symbol are special order parts for use with non-EU variants or for special installations. Please quote the full part number with the # when ordering.

Recycling information



At the end of this product's life it should not be put in commercial or domestic refuse but sent for recycling. Any batteries contained within the product or used during the products life should be removed from the product and also be sent to an appropriate recycling facility.

Campbell Scientific Ltd can advise on the recycling of the equipment and in some cases arrange collection and the correct disposal of it, although charges may apply for some items or territories.

For further advice or support, please contact Campbell Scientific Ltd, or your local agent.



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Safety

DANGER — MANY HAZARDS ARE ASSOCIATED WITH INSTALLING, USING, MAINTAINING, AND WORKING ON OR AROUND **TRIPODS, TOWERS, AND ANY ATTACHMENTS TO TRIPODS AND TOWERS SUCH AS SENSORS, CROSSARMS, ENCLOSURES, ANTENNAS, ETC.** FAILURE TO PROPERLY AND COMPLETELY ASSEMBLE, INSTALL, OPERATE, USE, AND MAINTAIN TRIPODS, TOWERS, AND ATTACHMENTS, AND FAILURE TO HEED WARNINGS, INCREASES THE RISK OF DEATH, ACCIDENT, SERIOUS INJURY, PROPERTY DAMAGE, AND PRODUCT FAILURE. TAKE ALL REASONABLE PRECAUTIONS TO AVOID THESE HAZARDS. CHECK WITH YOUR ORGANIZATION'S SAFETY COORDINATOR (OR POLICY) FOR PROCEDURES AND REQUIRED PROTECTIVE EQUIPMENT PRIOR TO PERFORMING ANY WORK.

Use tripods, towers, and attachments to tripods and towers only for purposes for which they are designed. Do not exceed design limits. Be familiar and comply with all instructions provided in product manuals. Manuals are available at www.campbellsci.eu or by telephoning +44(0) 1509 828 888 (UK). You are responsible for conformance with governing codes and regulations, including safety regulations, and the integrity and location of structures or land to which towers, tripods, and any attachments are attached. Installation sites should be evaluated and approved by a qualified engineer. If questions or concerns arise regarding installation, use, or maintenance of tripods, towers, attachments, or electrical connections, consult with a licensed and qualified engineer or electrician.

General

- Prior to performing site or installation work, obtain required approvals and permits. Comply with all governing structure-height regulations, such as those of the FAA in the USA.
- Use only qualified personnel for installation, use, and maintenance of tripods and towers, and any attachments to tripods and towers. The use of licensed and qualified contractors is highly recommended.
- Read all applicable instructions carefully and understand procedures thoroughly before beginning work.
- Wear a **hardhat** and **eye protection**, and take **other appropriate safety precautions** while working on or around tripods and towers.
- **Do not climb** tripods or towers at any time, and prohibit climbing by other persons. Take reasonable precautions to secure tripod and tower sites from trespassers.
- Use only manufacturer recommended parts, materials, and tools.

Utility and Electrical

- **You can be killed** or sustain serious bodily injury if the tripod, tower, or attachments you are installing, constructing, using, or maintaining, or a tool, stake, or anchor, come in **contact with overhead or underground utility lines**.
- Maintain a distance of at least one-and-one-half times structure height, or 20 feet, or the distance required by applicable law, **whichever is greater**, between overhead utility lines and the structure (tripod, tower, attachments, or tools).
- Prior to performing site or installation work, inform all utility companies and have all underground utilities marked.
- Comply with all electrical codes. Electrical equipment and related grounding devices should be installed by a licensed and qualified electrician.

Elevated Work and Weather

- Exercise extreme caution when performing elevated work.
- Use appropriate equipment and safety practices.
- During installation and maintenance, keep tower and tripod sites clear of un-trained or non-essential personnel. Take precautions to prevent elevated tools and objects from dropping.
- Do not perform any work in inclement weather, including wind, rain, snow, lightning, etc.

Maintenance

- Periodically (at least yearly) check for wear and damage, including corrosion, stress cracks, frayed cables, loose cable clamps, cable tightness, etc. and take necessary corrective actions.
- Periodically (at least yearly) check electrical ground connections.

WHILE EVERY ATTEMPT IS MADE TO EMBODY THE HIGHEST DEGREE OF SAFETY IN ALL CAMPBELL SCIENTIFIC PRODUCTS, THE CUSTOMER ASSUMES ALL RISK FROM ANY INJURY RESULTING FROM IMPROPER INSTALLATION, USE, OR MAINTENANCE OF TRIPODS, TOWERS, OR ATTACHMENTS TO TRIPODS AND TOWERS SUCH AS SENSORS, CROSSARMS, ENCLOSURES, ANTENNAS, ETC.

Table of contents

1. Introduction	1
2. Precautions	1
3. Initial inspection	1
4. QuickStart	2
5. Overview	6
6. Specifications	7
7. Installation	7
7.1 Wiring to data logger	8
7.2 Data logger programming	8
7.2.1 Therm108() instruction	9
7.3 Siting	9
7.4 Assembly and mounting	9
7.4.1 Mounting the BlackGlobe on the mounting arm	10
7.4.2 Mounting the BlackGlobe assembly on a horizontal crossarm	12
8. Operation	13
8.1 Sensor schematic	13
8.2 Measurement and output linearization	13
8.3 Electrically noisy environments	14
8.4 Long cable lengths	14
8.5 Calculations	15
8.5.1 Wet-bulb globe thermometer index (WBGT)	15
8.5.2 Dewpoint	15
8.5.3 Vapour pressure	15
8.5.4 Saturated vapour pressure	16
8.5.5 Wet-bulb	16
8.5.6 Mean site barometric pressure calculation (SP_kPa)	17
9. Troubleshooting and maintenance	17
9.1 Troubleshooting	17
9.2 Maintenance	18

9.3 Calibration	18
10. Attributions and references	18
Appendix A. Importing Short Cut code into CRBasic Editor	19
Appendix B. Thermistor resistance and temperature	20

1. Introduction

The BlackGlobe Temperature Sensor for Heat Stress (BlackGlobe) measures radiant temperature. This measurement, along with the measurement of ambient air and wet-bulb temperatures, is used to calculate the wet-bulb globe temperature (WBGT). The WBGT index combines the effects of temperature, humidity, radiant heat, and wind into one single index employed to express environmental heat stress. The measurement of heat stress is important because loss of physical and mental efficiency occurs under definable degrees of heat stress. Severe heat stress can lead to fatigue, exhaustion and possibly even disability or death.

Before installing the BlackGlobe, please study:

- [Precautions](#) (p. 1)
- [Initial inspection](#) (p. 1)

2. Precautions

READ AND UNDERSTAND the [Safety](#) section at the front of this manual.

Do not use the BlackGlobe with long cable lengths in an electrically noisy environment.

Santoprene® rubber, which composes the black outer jacket of the BlackGlobe cable, will support combustion in air. It is used because of its resistance to temperature extremes, moisture, and UV degradation. It is rated as slow burning when tested according to U.L. 94 H.B. and passes FMVSS302. However, local fire codes may preclude its use inside buildings.



3. Initial inspection

Check the packaging and contents of the shipment. If damage occurred during transport, immediately file a claim with the carrier. Contact Campbell Scientific to facilitate repair or replacement.

Check model information against the shipping documents to ensure the expected products and the correct lengths of cable are received. Model numbers are found on each product. On cables and cabled items, the model number is usually found at the connection end of the cable. Report any shortages immediately to Campbell Scientific.

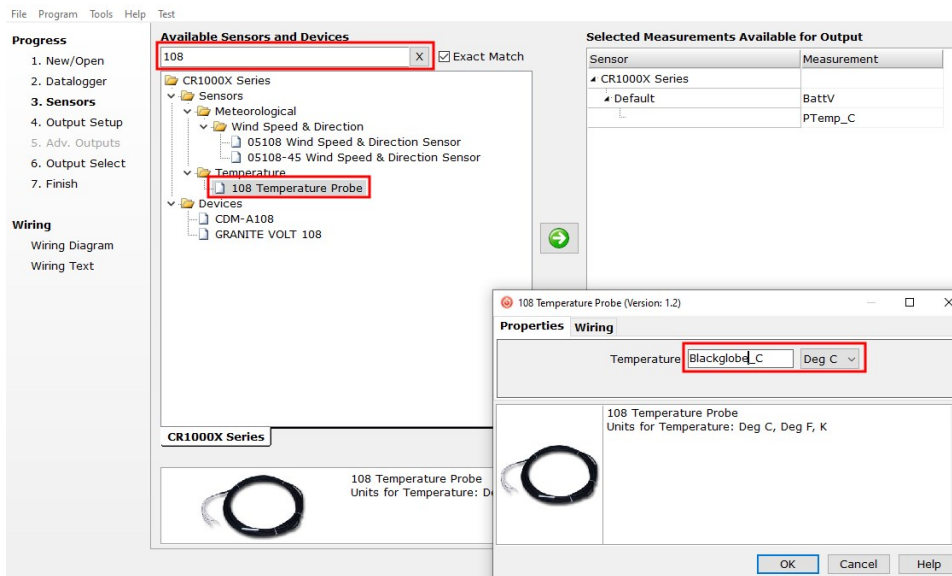
4. QuickStart

A video that describes data logger programming using *Short Cut* is available at:

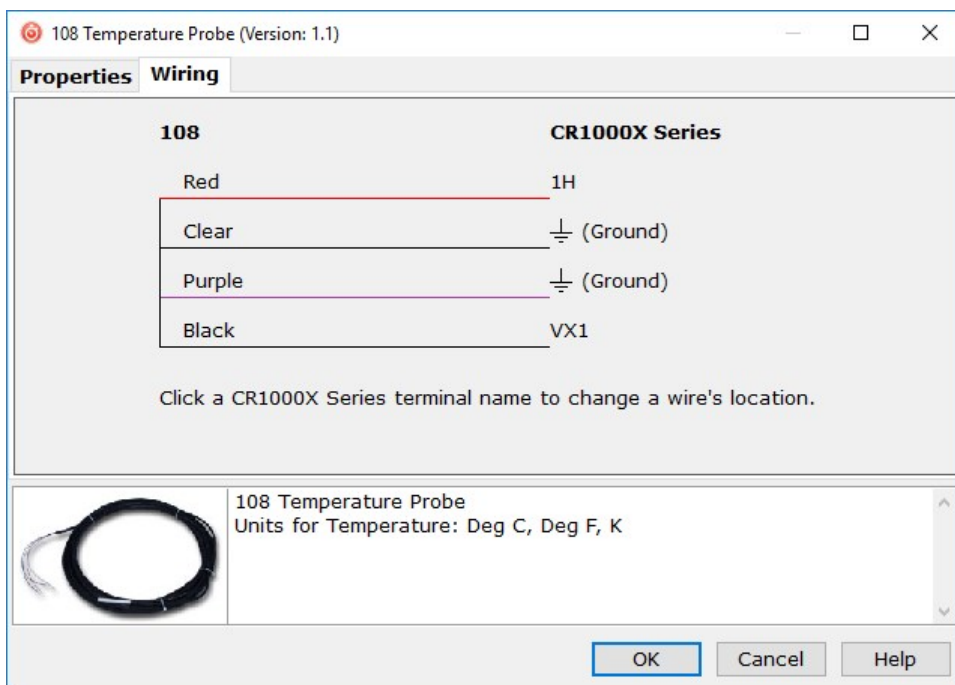
www.campbellsci.eu/videos/cr1000x-data-logger-getting-started-program-part-3.  **Short Cut** is an easy way to program your data logger to measure the sensor and assign data logger wiring terminals. *Short Cut* is available as a download on www.campbellsci.eu.  It is included in installations of *LoggerNet*, *RTDAQ*, and *PC400*.

The following procedure shows using *Short Cut* to program the BlackGlobe and an air temperature and relative humidity sensor, then calculate dewpoint, wet-bulb, and WBGT index. Measurements from a temperature and relative humidity sensor are required for the wet-bulb temperature calculation.

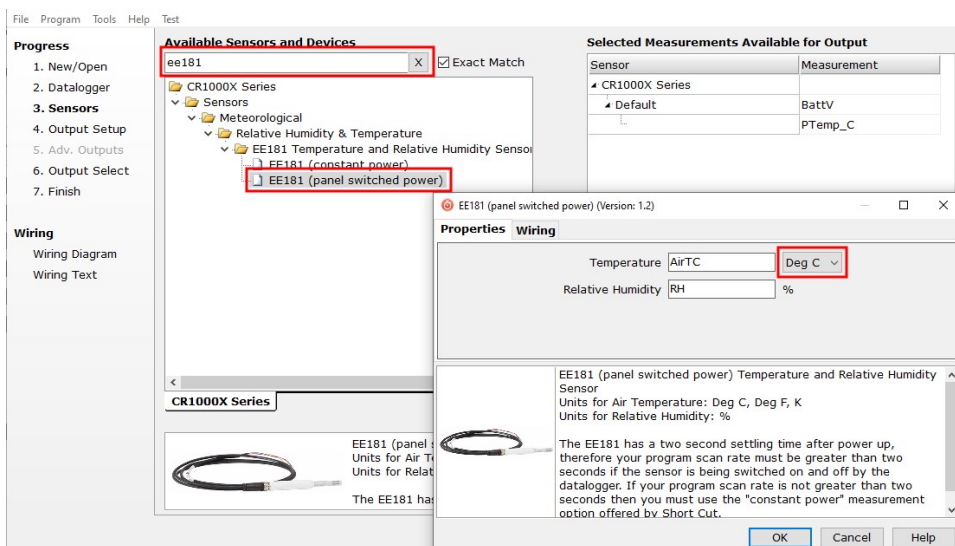
1. Open *Short Cut* and click **Create New Program**.
2. Double-click the data logger model.
3. In the **Available Sensors and Devices** box, type 108 (the temperature sensor inside the BlackGlobe) or find the 108 in the **Sensors > Temperature** folder. Double-click the **108 Temperature Probe**. Use the data defaults of degree Celsius, and type a more meaningful variable name such as BlackGlobe_C.



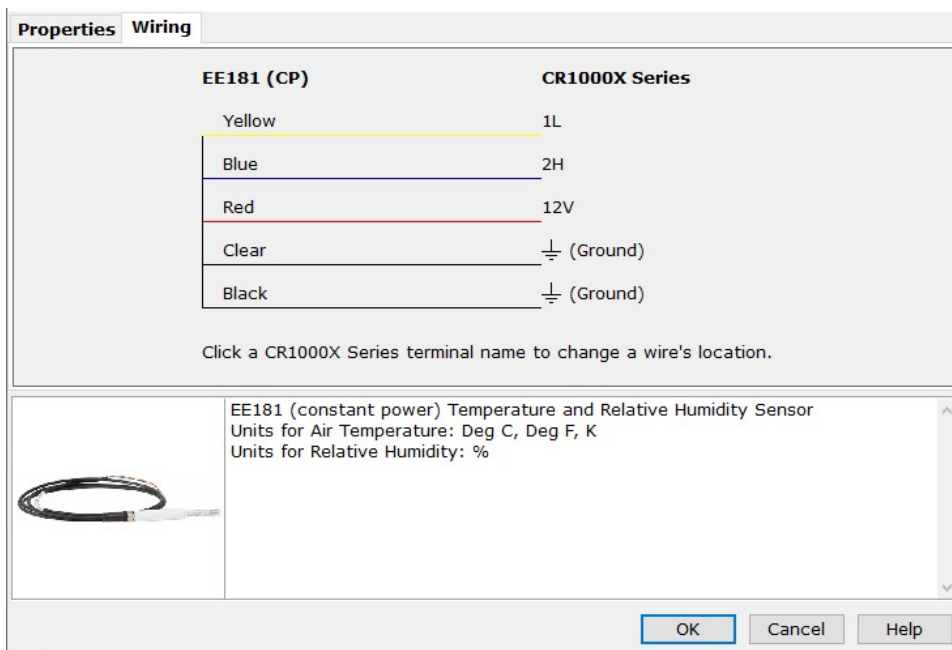
- Click the **Wiring** tab to see how the sensor is to be wired to the data logger. Click **OK** after wiring the sensor.



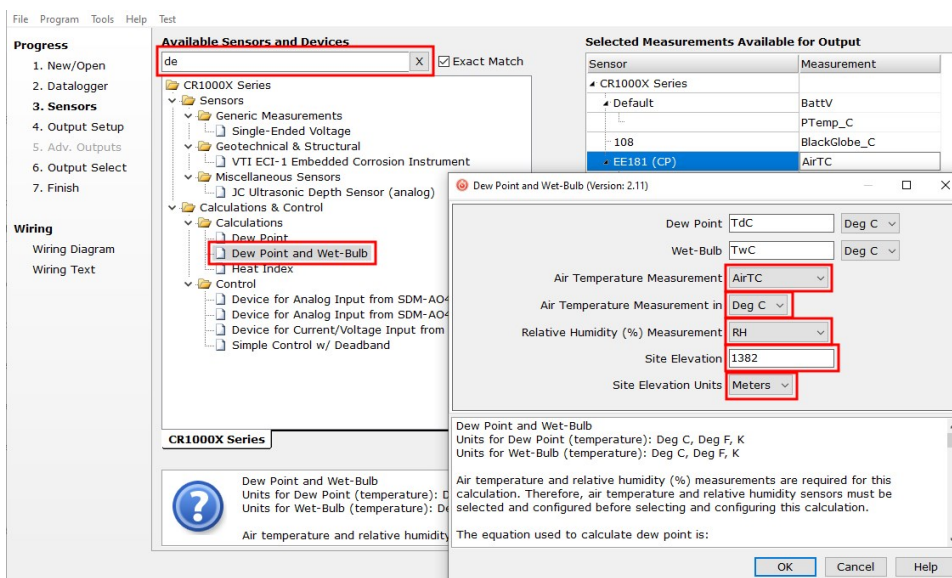
- In the **Available Sensors and Devices** box, type your air temperature and relative humidity sensor (EE181 shown) or find the sensor in the **Sensors > Meteorological > Relative Humidity & Temperature** folder. Double-click the sensor. Use the default temperature units of degrees Celsius.



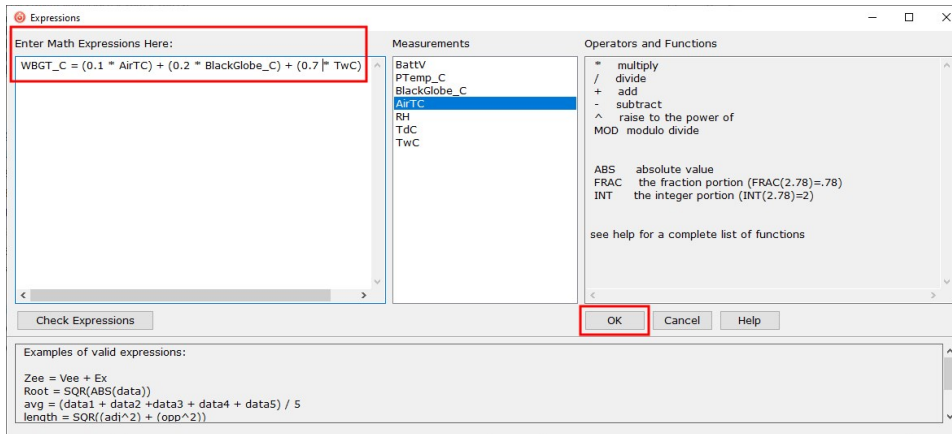
- Click the **Wiring** tab to see how the sensor is to be wired to the data logger. Click **OK** after wiring the sensor.



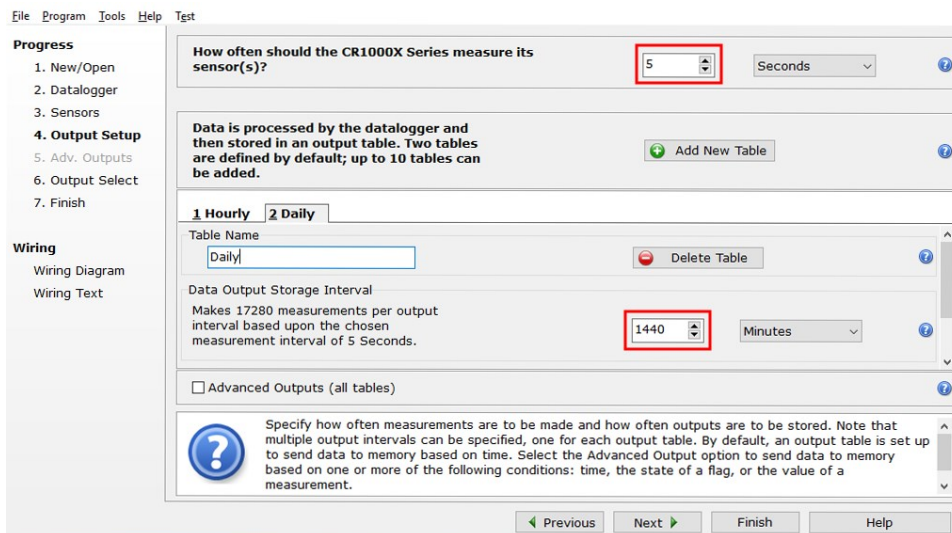
- In the **Available Sensors and Devices** box, type **Dew Point and Wet Bulb** or find the calculation under **Calculations & Control > Calculations** folder and double-click **Dew Point and Wet Bulb**. Type the **Site Elevation**; the elevation units default to metres. This can be changed by clicking on the **Site Elevation Units** box and selecting **Feet**. Select the variables from the temperature and RH sensor for the **Air Temperature Measurement** and **Relative Humidity (%) Measurement**. Use the default units of degree Celsius.



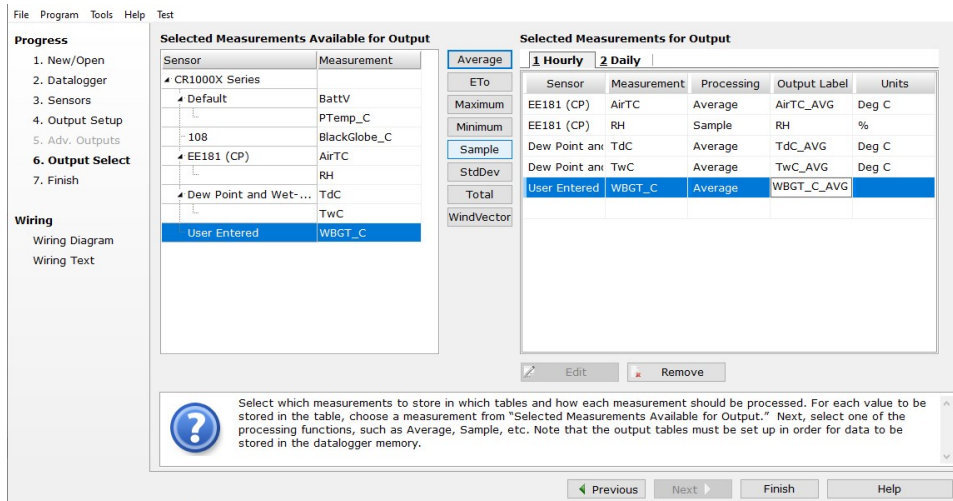
8. In the **Available Sensors and Devices** box, type **User Entered** or find the calculation under **Calculations & Control > Calculations** folder and double-click **User Entered**. Type $WBGT_C = (0.1 * AirTC) + (0.2 * BlackGlobe_C) + (0.7 * TwC)$. AirTC is the air temperature variable from the temperature and relative humidity probe; BlackGlobe_C is the BlackGlobe temperature variable; TwC is the wet bulb temperature variable. Click **OK**.



9. Repeat steps three and four for other sensors being measured. Click **Next**.
10. In **Output Setup**, type the scan rate, **Data Output Storage Intervals**, and meaningful table names.



11. Select the measurement and its associated output option.



12. Click **Finish** and save the program. Send the program to the data logger if the data logger is connected to the computer.
13. If the sensor is connected to the data logger, check the output of the sensor in the data display in *LoggerNet*, *RTDAQ*, or *PC400* to make sure it is making reasonable measurements.

5. Overview

The BlackGlobe uses a thermistor inside a 15.24 cm (6 in) hollow copper sphere, painted black to measure radiant temperature. To calculate the wet-bulb-globe-temperature (WBGT) index, the measurement of the BlackGlobe (radiant heat), wet-bulb (evaporative heat), and ambient air (dry-bulb) temperatures are required. The wet-bulb temperature can be calculated using air temperature and relative humidity if a wet-bulb thermometer is not available. See [Calculations](#) (p. 15).

Features

- Helps manage heat stress
- Compatible with the following CRBasic data loggers: CR6, CR1000X, CR800-series, CR300-series, CR3000, CR1000

6. Specifications

Sensor element:	Measurement Specialties 100K6A1iA thermistor
Survival range:	–50 to 100 °C
Measurement range:	–5 to 95 °C
Time constant in air:	200 ± 10 s
Maximum cable length:	305 m (1000 ft)
Accuracy ¹	
Worst case:	±0.3 °C (–3 to 90 °C) ±0.7 °C (–5 to 95 °C)
Interchangeability error:	±0.10 °C (0 to 70 °C) ±0.14 °C at –5 °C ±0.25 °C at 85 °C ±0.35 °C at 95 °C
Steinhart-Hart equation error:	≤ ±0.01 °C (–35 to 50 °C)
Near normal emittance:	0.957
Compliance:	View the EU Declaration of Conformity at

¹Overall probe accuracy is a combination of thermistor interchangeability, bridge-resistor accuracy, and error of the Steinhart-Hart equation. Bridge resistors have 0.1% tolerance with a 10 ppm temperature coefficient. Interchangeability is the principle component error. If needed, an estimate of the interchangeability error for 0 to 50 °C, that can be used as the **Offset** parameter of the instruction, can be determined with a 1-point or 2-point calibration.

7. Installation

If you are programming your data logger with *Short Cut*, skip [Wiring to data logger](#) (p. 8) and [Data logger programming](#) (p. 8). *Short Cut* does this work for you. See [QuickStart](#) (p. 2) for a *Short Cut* tutorial.

7.1 Wiring to data logger

Table 7-1: Wire colour, function, and data logger connection

Wire colour	Wire function	Data logger connection terminal
Black	Voltage-excitation input	U configured for voltage excitation ¹ , EX, VX (voltage excitation)
Red	Analogue-voltage output	U configured for single-ended analogue input ¹ , SE (single-ended, analogue-voltage input)
Purple	Bridge-resistor	⏏ (analogue ground)
Clear	EMF shield	⏏ (analogue ground)

¹U terminals are automatically configured by the measurement instruction.


7.2 Data logger programming

Short Cut is the best source for up-to-date data logger programming code.

If your data acquisition requirements are simple, you can probably create and maintain a data logger program exclusively with **Short Cut**. If your data acquisition needs are more complex, the files that **Short Cut** creates are a great source for programming code to start a new program or add to an existing custom program.

NOTE:

Short Cut cannot edit programs after they are imported and edited in **CRBasic Editor**.

A **Short Cut** tutorial is available in [QuickStart](#) (p. 2). If you wish to import **Short Cut** code into **CRBasic Editor** to create or add to a customized program, follow the procedure in [Importing Short Cut code into CRBasic Editor](#) (p. 19). Programming basics are provided in the following section. Downloadable example program is available at www.campbellsci.eu/downloads/blackglobe-example-program. 

If the BlackGlobe probe is to be used with long cable lengths or in electrically noisy environments, consider employing the measurement programming techniques outlined in [Electrically noisy environments](#) (p. 14) and [Long cable lengths](#) (p. 14).

Details of BlackGlobe probe measurement and linearization of the thermistor output are provided in [Measurement and output linearization](#) (p. 13).

7.2.1 Therm108() instruction

The **Therm108()** measurement instruction programs CRBasic data loggers to measure this sensor. It applies a precise excitation voltage, makes a half-bridge resistance measurement, and converts the result to temperature using the Steinhart-Hart equation. See [Measurement and output linearization](#) (p. 13) for more information. **Therm108()** instruction and parameters are as follows:

Therm108(Dest, Reps, SEChan, VxChan, SettlingTime, Integ/f_{N1}, Mult, Offset)

Variations:

- Temperature reported as °C — set **Mult** to 1 and **Offset** to 0
- Temperature reported as °F — set **Mult** to 1.8 and **Offset** to 32
- AC mains noise filtering — set **Integ/f_{N1}** to the 60 Hz or 50 Hz option (see [Electrically noisy environments](#) [p. 14])
- Compensate for long cable lengths — Set **SettlingTime** to 20000 (see [Long cable lengths](#) [p. 14])

7.3 Siting

The BlackGlobe must be mounted in a location that will not be shadowed and is representative of the environmental conditions to be measured.

7.4 Assembly and mounting

Tools required for installing on a tripod or tower:

- Adjustable end wrench or 7/16 in. and 1/2 in. open end wrench
- Small screwdriver provided with the data logger
- Small pair of diagonal-cutting pliers
- UV resistant cable ties provided with the BlackGlobe

7.4.1 Mounting the BlackGlobe on the mounting arm

The BlackGlobe and mounting kit requires some assembly before installation. The mounting kit comes with (see [Figure 7-1](#) [p. 10]):

- Mounting arm
- Mounting bolt
- Two lock washers
- Two nuts
- Two pipe clamps (not used when mounted to a horizontal pipe cross arm)
- U-bolt with associated nuts and washers

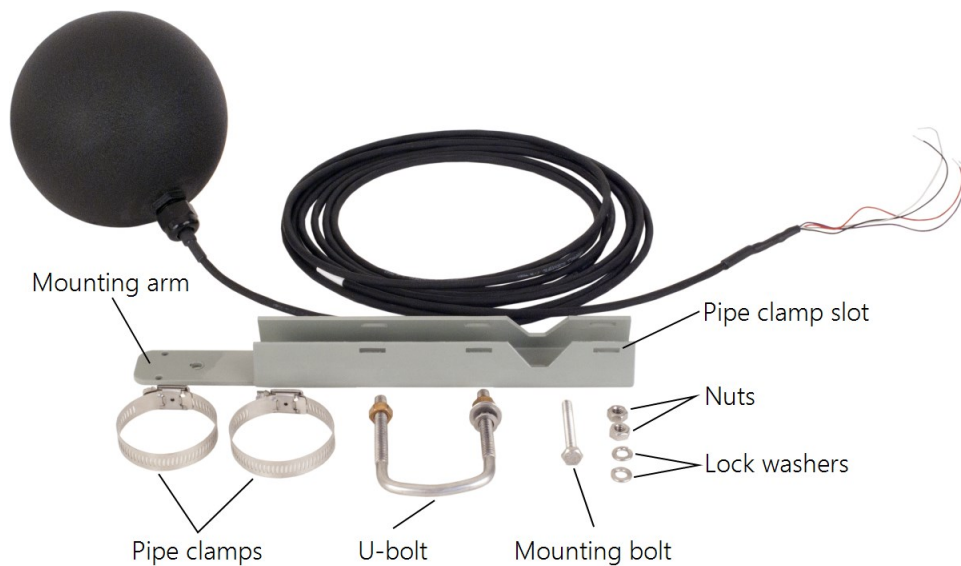


Figure 7-1. Mounting kit components

1. Place the mounting bolt through the hole in the mounting arm as shown in [Figure 7-2](#) (p. 11).
2. Slide one of the lock washers against the mounting arm.

3. Thread both nuts about half way down the bolt and then slide on the last lock washer. The hardware should be arranged as shown in [Figure 7-2](#) (p. 11).



Figure 7-2. Nuts and lock washers on mounting bolt

4. Tighten down the nut closest to the mounting arm so the bolt is held firmly in place.
5. Thread the BlackGlobe fitting onto the bolt. Thread it as far down as it will go, but you may have to back it off a bit. The cable gland and cable should align with the mounting arm as shown in [Figure 7-3](#) (p. 11).
6. Tighten down the nut closest to the BlackGlobe fitting. The BlackGlobe and mounting bolt should not move when the all the hardware is tightened down.



Figure 7-3. BlackGlobe fitting and cable alignment

7.4.2 Mounting the BlackGlobe assembly on a horizontal crossarm

The BlackGlobe assembly must be mounted on a horizontal crossarm.

1. Position the sensor so that the cable gland is facing down ([Figure 7-3](#) [p. 11]).
2. Use the mounting hardware supplied to hold the sensor on the horizontal crossarm. [Figure 7-4](#) (p. 12) and [Figure 7-5](#) (p. 12) show a BlackGlobe mounted on a crossarm by using the U-bolts.
3. Use the wire ties provided with the unit to secure the cabling to the crossarm.
4. Leave a small loop of cable at the cable entry into the sensor to act as a drip line for any condensed moisture or rain ([Figure 7-4](#) (p. 12)).



Figure 7-4. BlackGlobe mounted to a crossarm (front view)



Figure 7-5. BlackGlobe mounted to a crossarm (back view)

8. Operation

8.1 Sensor schematic

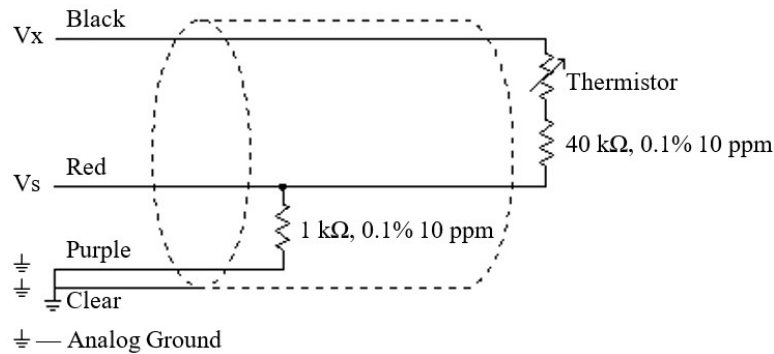


Figure 8-1. 108 thermistor probe schematic

8.2 Measurement and output linearization

CRBasic instruction [Therm108\(\)](#) measures the 108 probe thermistor and automatically converts the result to temperature. With reference to the previous [Figure 8-1](#) (p. 13), [Therm108\(\)](#) applies 1000 mV excitation at the Vx line and measures the voltage drop across the 1 kΩ resistor at the Vs line.

The ratio of measured voltage (Vs) to excitation voltage (Vx) is related to thermistor resistance (Rs), and the 1 kΩ and 40 kΩ fixed resistors as described in the following equations:

$$V_s/V_x = 1000 / (R_s + 40000 \Omega + 1000 \Omega)$$

Solving for Rs:

$$R_s + 41000 \Omega = 1000 \cdot (V_x/V_s)$$

$$R_s = 1000 \cdot (V_x/V_s) - 41000 \Omega$$

The relationship of Rs to temperature is tabulated in [Thermistor resistance and temperature](#) (p. 20), but is calculated by [Therm108\(\)](#) using the Steinhart-Hart equation, described as follows:

$$T_c = (1 / (A + B \cdot \ln(R_s) + C \cdot (\ln(R_s))^3)) - 273.15$$

where:

T_c = temperature in degrees Celsius (°C)

$$A^1 = 8.271111E-4$$

$$B^1 = 2.088020E-4$$

$$C^1 = 8.059200E-8$$

¹Coefficients provided by Measurement Specialties™.

8.3 Electrically noisy environments

EMF noise emanating from the ac mains power grid can be a significant source of measurement error. 60 Hz noise is common in the United States. 50 Hz noise is common in Europe and other regions. This noise can usually be filtered out.

The following code snip examples filter 60 Hz noise.

CR6-series data logger example:

```
Therm108(T108_C,1,U1,U10,0,60,1.0,0.0)
```

CR800-series and CR3000 data loggers example:

```
Therm108(T108_C,1,1,Vx1,0,_60Hz,1.0,0.0)
```

8.4 Long cable lengths

Long cable lengths (>50 ft) may require longer than normal analogue measurement settling times. Enter a longer settling time in the **SettlingTime** parameter of the [Therm108\(\)](#) instruction. Campbell Scientific suggests doubling the settling time every 50 ft. The following code snip examples increase settling time by 20000 µs by placing **20000** as the argument in the **SettlingTime** parameter:

CR6-series data logger example:

```
Therm108(T108_C,1,U1,U10,20000,60,1.0,0.0)
```

CR800-series and CR3000 data loggers example:

```
Therm108(T108_C,1,1,1,20000,_60Hz,1.0,0.0)
```

8.5 Calculations

8.5.1 Wet-bulb globe thermometer index (WBGT)

To calculate the WBGT index, a measurement of the BlackGlobe (radiant heat), wet-bulb (evaporative heat), and ambient air (dry-bulb) temperatures are required (Eq. 1 [p. 15]). In the approach discussed here, air temperature and relative humidity measurements are used to calculate the actual vapour pressure, and a dewpoint temperature is used to calculate the wet-bulb temperature.

Campbell Scientific offers a variety of air temperature and relative humidity sensors that can provide the measurements required for this calculation.

Ultimately,

$$\text{WBGT} = (0.2 \times \text{BlackGlobe Temp}) + (0.7 \times \text{Wet-Bulb Temp}) + (0.1 \times \text{Dry-Bulb Temp}) \quad \text{Eq. 1}$$

Dewpoint and wet-bulb temperature units include: °C, °F, °K

8.5.2 Dewpoint

Eq. 2 (p. 15) is used to calculate dewpoint.

$$T_d = (241.88 \times \ln(P/0.61078)) / (17.558 - \ln(P/0.61078)) \quad \text{Eq. 2}$$

where

T_d = dewpoint (°C)

P = vapor pressure (kPa)

The equation is an inverse of a version of Tetens's equation (Tetens, 1930), optimized for dewpoints in the range –35 to 50 °C, and is accurate to within plus or minus 0.1 °C within that range.

8.5.3 Vapour pressure

Vapour pressure is calculated by the data logger using Eq. 3 (p. 15).

$$P = \text{RH} \times P_{sw} / 100 \quad \text{Eq. 3}$$

where

RH = relative humidity (%)

P_{sw} = saturation vapour pressure (kPa) over water

8.5.4 Saturated vapour pressure

Saturation vapour pressure over water is calculated by the data logger using [Eq. 4](#) (p. 16).

$$P_{sw} = (A_0 + A_1 \times T + A_2 \times T^2 + A_3 \times T^3 + A_4 \times T^4 + A_5 \times T^5 + A_6 \times T^6) \times 0.1 \quad \text{Eq. 4}$$

Where

T = air temperature (dry-bulb or ambient air temperature) (°C)

$$A_0 = 6.107799961$$

$$A_1 = 4.436518521 \times 10^{-1}$$

$$A_2 = 1.428945805 \times 10^{-2}$$

$$A_3 = 2.650648471 \times 10^{-4}$$

$$A_4 = 3.031240396 \times 10^{-6}$$

$$A_5 = 2.034080948 \times 10^{-8}$$

$$A_6 = 6.136820929 \times 10^{-11}$$

8.5.5 Wet-bulb

Wet-bulb is derived using an iterative process. The wet-bulb temperature lies somewhere between the dry-bulb temperature (air temperature) and the dewpoint temperature. The data logger uses [Eq. 5](#) (p. 16) to calculate vapour pressure using the dry-bulb temperature and a wet-bulb temperature estimate:

$$P = P_w - (0.000660 \times (1 + 0.00115 \times T_w) \times (T - T_w) \times SP) \quad \text{Eq. 5}$$

where

P_w = saturation vapour pressure (kPa) at the wet-bulb temperature (°C)

T_w = wet-bulb temperature (°C)

T = air temperature (dry-bulb temperature) (°C)

SP = standard air pressure (kPa) at the user entered elevation

The resulting vapour pressure is compared to the true vapour pressure (see above) and the difference determines the next wet-bulb temperature estimate. The process repeats until the difference between the current wet-bulb temperature estimate and the previous wet-bulb temperature estimate is only plus or minus 0.01 °C. The data logger thus derives the wet-bulb temperature.

8.5.6 Mean site barometric pressure calculation (SP_kPa)

The wet-bulb instruction needs mean barometric pressure which is closely related to elevation of the site. U.S. Standard Atmosphere and dry air were assumed when [Eq. 6](#) (p. 17) was derived (Wallace & Hobbes, 1977).

$$SP_{kPa} = 101.325 - 101.325 \left\{ 1 - \left(1 - \frac{E}{44307.69231} \right)^{5.25328} \right\} \quad \text{Eq. 6}$$

The value of SP_{kPa} is in kilopascals and the site elevation, E , is in metres.

Use [Eq. 7](#) (p. 17) to convert feet to metres.

$$E(m) = \frac{E(ft)}{3.281ft/m} \quad \text{Eq. 7}$$

The value for SP_{kPa} must be put into the data logger program.

9. Troubleshooting and maintenance

NOTE:

All factory repairs and recalibrations require a returned material authorization (RMA) and completion of the "Declaration of Hazardous Material and Decontamination" form. Refer to the [About this manual](#) page at the front of this manual for more information.

9.1 Troubleshooting

Symptom: Temperature is reported as **NAN**, **-INF**, or incorrect temperature.

Verify wires are connected to the terminals specified in the instruction: red to single-ended analogue input (**SE** or **U**), black to switched excitation (**VX/EX** or **U**), and purple to ground

(**⊕**). Symptom: Incorrect temperature is reported.

Verify the **MuIt** and **Offset** arguments in are correct for the desired units ([Data logger programming](#) [p. 8]). Check the cable for signs of damage and possible moisture intrusion.

Symptom: Unstable temperature is reported.

Probably a result of electromagnetic interference. Try using the 50 Hz or 60 Hz options for the f_{N1} parameter, and/or increasing the settling time as described in [Electrically noisy environments](#) (p. 14) and [Long cable lengths](#) (p. 14). Ensure the clear wire is connected to data logger ground, and the data logger is properly grounded.

9.2 Maintenance

The BlackGlobe requires minimal maintenance. Check monthly to ensure the sphere is free from dirt and debris. Clean with water and soft cloth if necessary. Do not use solvents as they may dissolve the paint.

9.3 Calibration

If needed, an estimate of the interchangeability error for 0 to 50 °C, that can be used as the **Offset** parameter of the instruction, can be determined with a 1-point or 2-point calibration. Calibration of the BlackGlobe probe is not necessary unless the accuracy needed in the sensor data requires correction of the thermistor interchangeability offset described in [Specifications](#) (p. 7).

10. Attributions and references

Santoprene® is a registered trademark of Exxon Mobile Corporation.

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Lowe, P.R. 1977. J. Appl. Meteor., 16:100-103

Tetens, O. 1930. Z. Geophys., 6:297

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Appendix A. Importing *Short Cut* code into *CRBasic Editor*


Short Cut creates a .DEF file that contains wiring information and a program file that can be imported into the *CRBasic Editor*. By default, these files reside in the C:\campbellsci\SCWin folder.

Import *Short Cut* program file and wiring information into *CRBasic Editor*:

1. Create the *Short Cut* program. After saving the *Short Cut* program, click the **Advanced** tab then the **CRBasic Editor** button. A program file with a generic name will open in CRBasic. Provide a meaningful name and save the CRBasic program. This program can now be edited for additional refinement.

NOTE:

Once the file is edited with *CRBasic Editor*, *Short Cut* can no longer be used to edit the program it created.

2. To add the *Short Cut* wiring information into the new CRBasic program, open the .DEF file located in the C:\campbellsci\SCWin folder, and copy the wiring information, which is at the beginning of the .DEF file.
3. Go into the CRBasic program and paste the wiring information into it.
4. In the CRBasic program, highlight the wiring information, right-click, and select **Comment Block**. This adds an apostrophe (') to the beginning of each of the highlighted lines, which instructs the data logger compiler to ignore those lines when compiling. The **Comment Block** feature is demonstrated at about 5:10 in the [CRBasic | Features](#) video .

Appendix B. Thermistor resistance and temperature

Table B-1: 108 thermistor resistance and temperature ¹		
Actual temperature (°C)	100K6A1iA thermistor resistance (Ω)	CRBasic Therm108() output (°C)
-10	612407	-10.00
-9	578366	-9.00
-8	546408	-8.00
-7	516394	-7.00
-6	488196	-6.00
-5	461695	-5.00
-4	436779	-4.00
-3	413346	-3.00
-2	391300	-2.00
-1	370551	-1.00
0	351017	0.00
1	332620	1.00
2	315288	2.00
3	298954	3.00
4	283555	4.00
5	269034	5.00
6	255335	6.00
7	242408	7.00
8	230206	8.00
9	218684	9.00

Table B-1: 108 thermistor resistance and temperature ¹		
Actual temperature (°C)	100K6A1iA thermistor resistance (Ω)	CRBasic Therm108() output (°C)
10	207801	10.00
11	197518	11.00
12	187799	12.00
13	178610	13.00
14	169921	14.00
15	161700	15.00
16	153921	16.00
17	146558	17.00
18	139586	18.00
19	132983	19.00
20	126727	20.00
21	120799	21.00
22	115179	22.00
23	109850	23.00
24	104795	24.00
25	100000	25.00
26	95449	26.00
27	91129	27.00
28	87027	28.00
29	83131	29.00
30	79430	30.00
31	75913	31.00
32	72569	32.00
33	69390	33.00
34	66367	34.00
35	63491	35.00

Table B-1: 108 thermistor resistance and temperature¹

Actual temperature (°C)	100K6A1iA thermistor resistance (Ω)	CRBasic Therm108() output (°C)
36	60755	36.00
37	58150	37.00
38	55670	38.00
39	53309	39.00
40	51060	40.00
41	48917	41.00
42	46875	42.00
43	44929	43.00
44	43073	44.00
45	41303	45.00
46	39615	46.00
47	38005	47.00
48	36467	48.00
49	35000	49.00
50	33599	50.00
51	32262	51.00
52	30984	52.00
53	29763	53.00
54	28596	54.00
55	27481	55.00
56	26415	56.00
57	25395	57.00
58	24420	58.00
59	23487	59.00
60	22594	60.00
61	21740	61.00

Table B-1: 108 thermistor resistance and temperature ¹		
Actual temperature (°C)	100K6A1iA thermistor resistance (Ω)	CRBasic Therm108() output (°C)
62	20922	62.00
63	20138	63.00
64	19388	64.00
65	18670	65.00
66	17981	66.00
67	17322	67.00
68	16689	68.00
69	16083	69.00
70	15502	70.00
71	14945	71.00
72	14410	72.00
73	13897	73.00
74	13405	74.00
75	12932	75.00
76	12478	76.00
77	12043	77.00
78	11625	78.00
79	11223	79.00
80	10837	80.00
81	10466	81.00
82	10109	82.00
83	9767	83.00
84	9437	84.00
85	9121	85.00
86	8816	86.00
87	8523	87.00

Table B-1: 108 thermistor resistance and temperature ¹		
Actual temperature (°C)	100K6A1iA thermistor resistance (Ω)	CRBasic Therm108() output (°C)
88	8241	88.00
89	7970	89.00
90	7708	90.00
91	7457	91.00
92	7215	92.00
93	6982	93.00
94	6758	94.00
95	6541	95.00
96	6333	96.00
97	6132	97.00
98	5939	98.00
99	5753	99.00
100	5573	100.00
¹ Data from Measurement Specialties™		



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