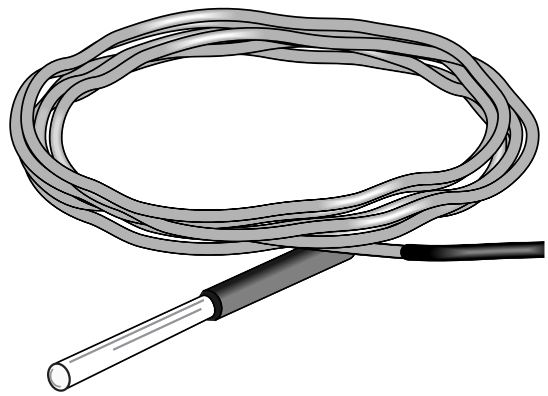
INSTRUCTION MANUAL

Model 109 Temperature Probe

Revision: 11/11



WARRANTY AND ASSISTANCE

This equipment is warranted by CAMPBELL SCIENTIFIC (CANADA) CORP. ("CSC") to be free from defects in materials and workmanship under normal use and service for **twelve (12) months** from date of shipment unless specified otherwise. ***** **Batteries are not warranted.** ***** CSC's obligation under this warranty is limited to repairing or replacing (at CSC's option) defective products. The customer shall assume all costs of removing, reinstalling, and shipping defective products to CSC. CSC will return such products by surface carrier prepaid. This warranty shall not apply to any CSC products which have been subjected to modification, misuse, neglect, accidents of nature, or shipping damage. This warranty is in lieu of all other warranties, expressed or implied, including warranties of merchantability or fitness for a particular purpose. CSC is not liable for special, indirect, incidental, or consequential damages.

Products may not be returned without prior authorization. To obtain a Return Merchandise Authorization (RMA), contact CAMPBELL SCIENTIFIC (CANADA) CORP., at (780) 454-2505. An RMA number will be issued in order to facilitate Repair Personnel in identifying an instrument upon arrival. Please write this number clearly on the outside of the shipping container. Include description of symptoms and all pertinent details.

CAMPBELL SCIENTIFIC (CANADA) CORP. does not accept collect calls.

Non-warranty products returned for repair should be accompanied by a purchase order to cover repair costs.

CAMPBELLSCIENTIFIC
CANADA CORP.
11564 - 149 street - edmonton - alberta - T5M 1W7
tel 780.454.2505 fax 780.454.2655
www.campbellsci.ca

PLEASE READ FIRST

About this manual

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

Some useful conversion factors:

Area:	1 in^2 (square inch) = 645 mm^2
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 US gallon = 3.785 litres

In addition, part ordering numbers may vary. For example, the CABLE5CBL is a CSI part number and known as a FIN5COND at Campbell Scientific Canada (CSC). CSC Technical Support will be pleased to assist with any questions.

109 Table of Contents

PDF viewers: These page numbers refer to the printed version of this document. Use the PDF reader bookmarks tab for links to specific sections.

Figures

Tables

Model 109 Temperature Probe

1. General

The 109 probe uses a thermistor to measure temperature. It is designed for use with the CR200(X) series datalogger, which has a special instruction, the Therm109, for measuring it. The Therm109 instruction is also available for the CR800, CR850, CR1000, and CR3000 dataloggers. The probe can be measured with other Campbell Scientific dataloggers using generic measurement instructions.

The 109 Temperature Probe can measure air/soil/water temperatures. For air temperature, a 41303-5A radiation shield is used to mount the 109 probe and limit solar radiation loading. The probe can be buried in soil or submerged in water to 50 ft (21 psi).

The -L portion of the probe's model number indicates that the cable length is user specified. This manual refers to the sensor as the 109.

Cable length for the 109 is specified when the sensor is ordered. Table 1-1 gives the recommended cable length for mounting the sensor on a tripod or tower.

TABLE 1-1. Recommended Cable Lengths

2 m Height		**Atop a tripod or tower via a 2 ft crossarm such as the CM202**							
Mast/Leg	**CM202**	**CM6**	**CM10**	**CM110**	**CM115**	**CM120**	**UT10**	**UT20**	**UT30**
9 ft	11 ft	11 ft	14 ft	14 ft	19 ft	24 ft	14 ft	24 ft	37 ft

Note: *Add two feet to the cable length if you are mounting the enclosure on the leg base of a light-weight tripod.*

The 109 ships with:

(1) Resource CD

1.1 Specifications

Sensor:	BetaTherm 10K3A1 Thermistor
Temperature Measurement Range:	-50° to +70°C
Thermistor Interchangeability Error:	Typically <±0.2°C over 0° to 70°C; ±0.5 @ -50°C
Temperature Survival Range:	-50° to +100°C
Linearization Error:	The Steinhart and Hart equation used to calculate temperature is fit to the range of 0 to 70°C; maximum error is 0.03°C at -50°C.

Time Constant
In Air: Between 30 and 60 seconds in a wind speed of 5 m s^{-1}

Maximum Lead Length: 1000 ft.

NOTE The black outer jacket of the cable is Santoprene® rubber. This compound was chosen for its resistance to temperature extremes, moisture, and UV degradation. However, this jacket will support combustion in air. It is rated as slow burning when tested according to U.L. 94 H.B. and will pass FMVSS302. Local fire codes may preclude its use inside buildings.

2. Accuracy

The overall probe accuracy is a combination of the thermistor's interchangeability specification and the accuracy of the bridge resistor. The Steinhart and Hart equation used to calculate temperature has a negligible error (Figure 2-1). In a "worst case" the errors add to an accuracy of ±0.6°C over the range of -50° to 70°C and ±0.25°C over the range of -10°C to 70°C. The major error component is the interchangeability specification of the thermistor. The bridge resistor has a 0.1% tolerance with a 10 ppm temperature coefficient. Figure 2-2 shows the possible worst case probe and measurement errors. Note that at temperature extremes the possible error in the CR200(X) measurement may be greater than the error that may exist in the probe.

TABLE 2-1. Thermistor Interchangeability Specification

Temperature (°C)	Temperature Tolerance (±°C)
–40	0.20
–30	0.18
–20	0.15
–10	0.13
0 to +70	0.10

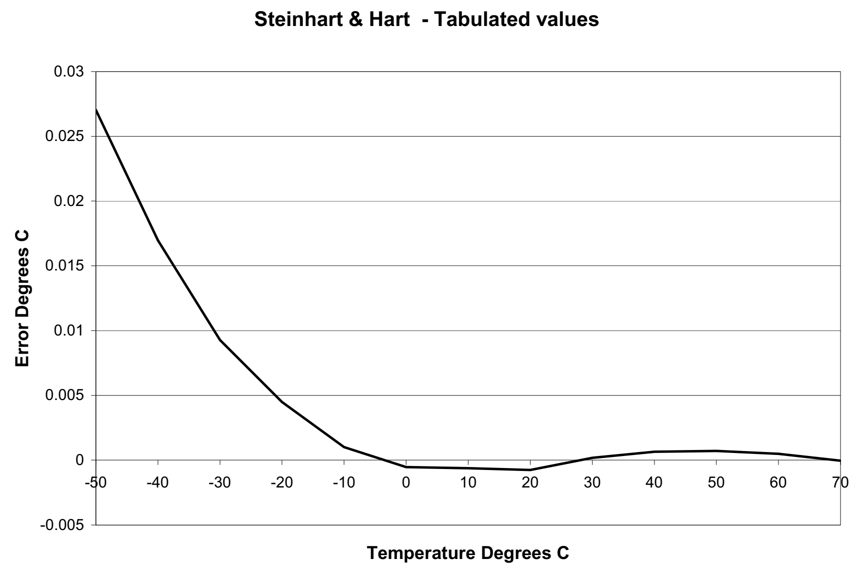


FIGURE 2-1. Steinhart and Hart

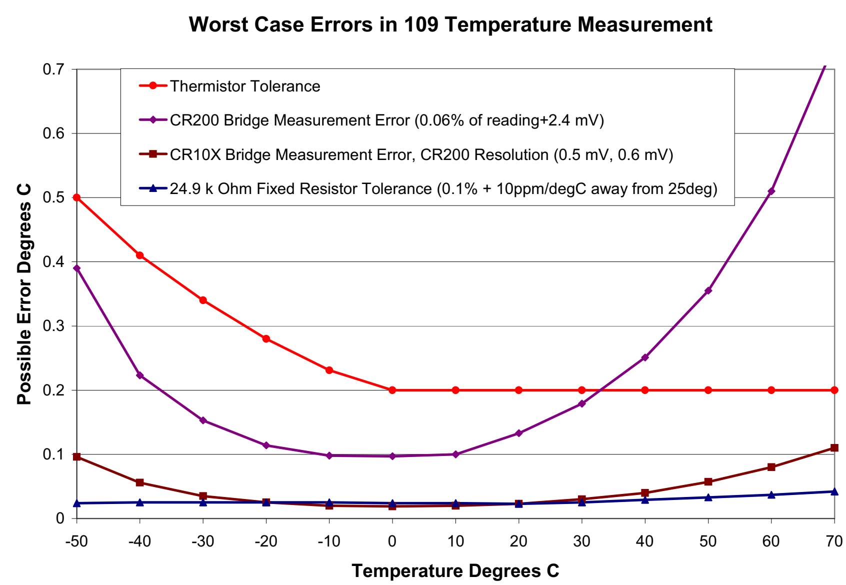


FIGURE 2-2. Possible Errors

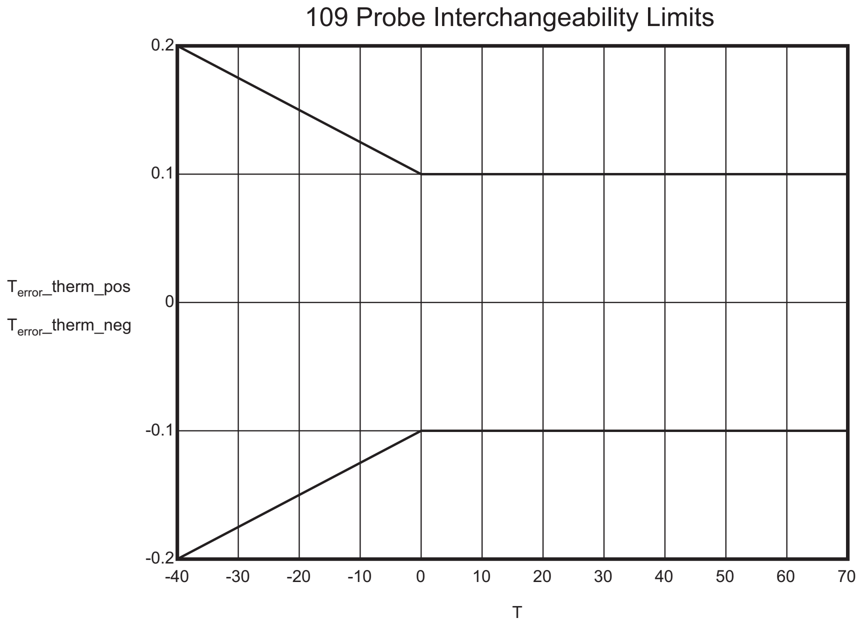


FIGURE 2-3. Probe Interchangeability Limits

3. Installation

3.1 Air Temperature

3.1.1 Siting

Sensors should be located over an open level area at least 9 m (EPA) in diameter. The surface should be covered by short grass, or where grass does not grow, the natural earth surface. Sensors should be located at a distance of at least four times the height of any nearby obstruction, and at least 30 m (EPA) from large paved areas. Sensors should be protected from thermal radiation, and adequately ventilated.

Standard measurement heights:

1.5 m +/- 1.0 m (AASC)
1.25 – 2.0 m (WMO)
2.0 m (EPA)
2.0 m and 10.0 m temperature difference (EPA)

3.1.2 Assembly and Mounting

Tools Required:

- 1/2” open end wrench
- small screw driver provided with datalogger
- small Phillips screw driver
- UV resistant cable ties
- small pair of diagonal-cutting pliers

The 109 must be housed inside a radiation shield when used in the field. The 41303-5A Radiation shield has a U-bolt for attaching the shield to tripod mast / tower leg (Figure 3-1), or CM200 series crossarm (Figure 3-2). The radiation shield ships with the U-bolt configured for attaching the shield to a vertical pipe. Move the U-bolt to the other set of holes to attach the shield to a crossarm.

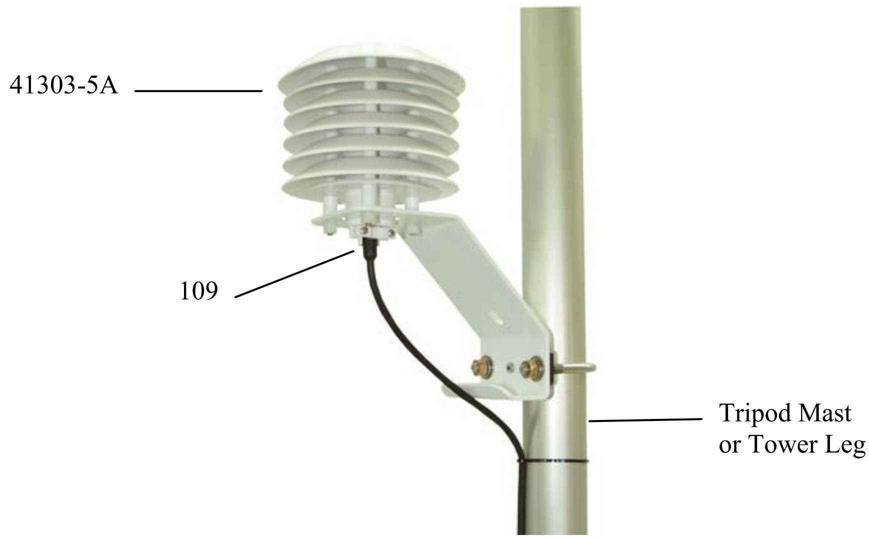


FIGURE 3-1. 109 and 41303-5A Radiation Shield on a Tripod Mast

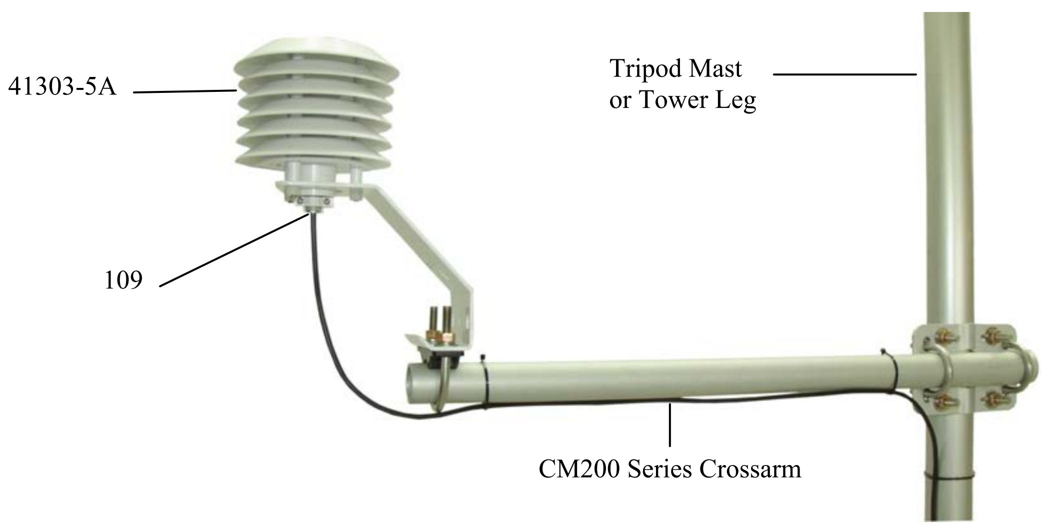


FIGURE 3-2. 109 and 41303-5A Radiation Shield on a CM200 Series Crossarm

The 109 is held within the 41303-5A by a mounting clamp on the bottom plate of the 41303-5A (Figure 3-2). Loosen the two mounting clamp screws, and insert the sensor through the clamp and into the shield. Tighten the screws to secure the sensor in the shield, and route the sensor cable to the instrument enclosure. Secure the cable to the tripod/tower using cable ties.

3.2 Soil Temperature

The 109 is suitable for shallow burial only. It should be placed horizontally at the desired depth to avoid thermal conduction from the surface to the thermistor. Placement of the cable inside a rugged conduit may be advisable for long cable runs, especially in locations subject to digging, mowing, traffic, use of power tools, or lightning strikes.

3.3 Water Temperature

The 109 can be submerged to 50 feet. Please note that the 109 is not weighted. Therefore, the installer should either add a weighting system or secure the probe to a fixed or submerged object.

4. Wiring

Connections to Campbell Scientific dataloggers are given in Table 4-1. Temperature is measured with one Single-Ended input channel and a Voltage Excitation channel. Multiple probes can be connected to the same excitation channel (the number of probes per excitation channel is physically limited by the number of lead wires that can be inserted into a single voltage excitation terminal, approximately six).

TABLE 4-1. Connections to Campbell Scientific Dataloggers

Color	**Heat Shrink Label**	**CR200(X) CR800 CR3000 CR1000**	**CR510 CR500 CR10(X)**	**CR5000 21X CR7 CR23X**
Black	Volt Excite	Switched Voltage Excitation (VX)	Switched Voltage Excitation	Switched Voltage Excitation (VX)
Red	Signal	Single-Ended Input	Single-Ended Input	Single-Ended Input
Purple	Signal Reference	⏚	AG	⏚
Clear	Shield	⏚	G	⏚

5. Programming

NOTE This section is for users who write their own datalogger programs. A datalogger program to measure this sensor can be generated using Campbell Scientific's Short Cut Program Builder software. You do not need to read this section to use Short Cut.

The datalogger is programmed using either CRBasic or Edlog. Dataloggers that use CRBasic include our CR200(X)-series, CR800, CR850, CR1000, CR3000, CR5000, and CR9000(X); see Section 5.1. Dataloggers that use Edlog include our CR510, CR10(X), CR23X, and CR7; refer to Section 5.2. Short Cut, CRBasic, and Edlog are included in our LoggerNet, PC400, and RTDAQ software.

If applicable, please read "Section 5.3—Electrical Noisy Environments" and "Section 5.4—Long Lead Lengths" prior to programming your datalogger. Measurement details are provided in Section 6.

5.1 CRBasic

In the CR200(X)-series, CR800, CR850, CR1000, and CR3000 dataloggers, Instruction Therm109 is used to measure temperature. Therm109 provides excitation, makes a single ended voltage measurement, and calculates temperature.

The Therm109 instruction has the following form:

Therm109 (Dest, Repetitions, SE Chan, Ex Chan, Multiplier, Offset)

A multiplier of 1.0 and an offset of 0.0 yields temperature in Celsius. For Fahrenheit, use a multiplier of 1.8 and an offset of 32. See Section 5.1.1 for example programs.

The CR5000 and CR9000(X) use the BrHalf instruction to read the 109's resistance. The Steinhart-Hart equation is entered as an expression to convert the resistance to degrees Celsius.

5.1.1 CRBasic Examples

TABLE 5-1. Wiring for Example Programs

Color	**Description**	**CR200(X) CR1000**
Black	Excitation	EX1 or VX1
Red	Signal	SE1
Purple	Signal Ground	⏚
Clear	Shield	⏚

5.1.1.1 Sample Program for CR200(X) Series Datalogger

```
'CR200(X) Series Datalogger

'This example program measures a single 109 Thermistor probe
'once a second and stores the average temperature every 10 minutes.

'Declare the variable for the temperature measurement
Public Air_Temp

'Define a data table for 10 minute averages:
DataTable (AvgTemp,1,1000)
    DataInterval (0,10,min)
    Average (1,Air_Temp,0)
EndTable

BeginProg
    Scan (1 ,sec)
        'Measure the temperature:
        Therm109 (Air_Temp,1,1,Ex1,1.0,0)
        'Call the data table:
        CallTable AvgTemp
    NextScan
EndProg
```

5.1.1.2 Sample Program for CR1000 Datalogger

```
'CR1000

'Declare Variables and Units
Public T109_C

Units T109_C=Deg C

'Define Data Tables
DataTable(Table1,True,-1)
    DataInterval(0,10,Min,10)
    Average(1,T109_C,FP2,False)
EndTable

'Main Program
BeginProg
    Scan(1,Sec,1,0)
        'Default Datalogger Battery Voltage measurement Batt_Volt:
        '109 Temperature Probe measurement T109_C:
        Therm109(T109_C,1,1,1,0,_60Hz,1.0,0.0)
        'Call Data Tables and Store Data
        CallTable(Table1)
    NextScan
EndProg
```

5.2 Edlog

In Edlog, Instruction 5 is typically used to measure the 109's resistance. Instruction 55 is used to apply the Steinhart and Hart equation. Instruction 55 does not allow entering the coefficients with scientific notation. In order to use this instruction with as much resolution as possible, the ln resistance term is pre scaled by 10^{-3}. This allows the first order coefficient (B) to be multiplied by 10^3, and the 3rd order coefficient (C) to be multiplied by 10^9 (see Section 5.2.1).

5.2.1 Example Edlog Programs

TABLE 5-2. Wiring for Example Programs

Color	Description	CR10X
Black	Excitation	E1
Red	Signal	SE1
Purple	Signal Ground	AG
Clear	Shield	G

5.2.1.1 Example Program for CR10X

```
;{CR10X}
;
*Table 1 Program
  01:  1              Execution Interval (seconds)

1:  AC Half Bridge (P5)
  1:   1              Reps
  2:   25             2500 mV 60 Hz Rejection Range
  3:   1              SE Channel
  4:   1              Excite all reps w/Exchan 1
  5:   2500           mV Excitation
  6:   1              Loc [ V_Vx      ]
  7:   1.0            Mult
  8:   0.0            Offset

2:  Z=1/X (P42)
  1:   1              X Loc [ V_Vx      ]
  2:   2              Z Loc [ Vx_V      ]

3:  Z=X+F (P34)
  1:   2              X Loc [ Vx_V      ]
  2:   -1             F
  3:   3              Z Loc [ Vx_V_1    ]

4:  Z=X*F (P37)
  1:   3              X Loc [ Vx_V_1    ]
  2:   24900          F
  3:   4              Z Loc [ Rtherm    ]
```

```
5:  Z=LN(X) (P40)
   1:   4               X Loc [ Rtherm    ]
   2:   5               Z Loc [ lnRt      ]

6:  Z=X*F (P37)
   1:   5               X Loc [ lnRt      ]
   2:    .001           F
   3:   6               Z Loc [ Scal_lnRt ]

7:  Polynomial (P55)
   1:   1               Reps
   2:   6               X Loc [ Scal_lnRt ]
   3:   7               F(X) Loc [ 1_Tk      ]
   4:   .001129         C0
   5:   .234108         C1
   6:   0.0             C2
   7:   87.7547         C3
   8:   0.0             C4
   9:   0.0             C5

8:  Z=1/X (P42)
   1:   7               X Loc [ 1_Tk      ]
   2:   8               Z Loc [ Tk        ]

9:  Z=X+F (P34)
   1:   8               X Loc [ Tk        ]
   2:   -273.15         F
   3:   9               Z Loc [ Air_Temp  ]

10:  If time is (P92)
   1:   0               Minutes (Seconds --) into a
   2:   10              Interval (same units as above)
   3:   10              Set Output Flag High (Flag 0)

11:  Real Time (P77)
   1:   110             Day,Hour/Minute (midnight = 0000)

12:  Average (P71)
   1:   1               Reps
   2:   9               Loc [ Air_Temp  ]

*Table 2 Program
   02:  0.0000          Execution Interval (seconds)

*Table 3 Subroutines

End Program
```

5.3 Electrical Noisy Environments

AC power lines, pumps, and motors, can be the source of electrical noise. If the 109 probe or datalogger is located in an electrically noisy environment, the 109 probe should be measured with the 60 Hz or 50 Hz integration option as shown in Examples 2 and 3. The 60 Hz and 50 Hz integration options are not available for the CR200(X).

5.4 Long Lead Lengths

Additional settling time may be required for lead lengths longer than 300 feet, where settling time is the delay before the measurement is made.

For the CR800, CR850, CR1000, and CR3000, the 60 Hz and 50 Hz integration options include a 3 ms settling time; longer settling times can be entered into the Settling Time parameter. The 60 Hz and 50 Hz integration options as well as the Settling Time parameter are not available for the CR200(X). The example Therm109 instruction listed below has a 20 mSec (20000 µSec) delay:

```
'Therm109 ( Dest, Reps, SEChan, ExChan, SettlingTime, Integ, Mult, Offset )
Therm109(T109_C,1,1,1,20000,_60Hz,1.0,0.0)
```

In Edlog, use the DC Half Bridge instruction (P4) with a 20 millisecond delay as shown below. Use P4 in place of P5 in Example 3 (the instructions that follow P5 to convert the measurement result to temperature are still required).

```
1:  Excite-Delay (SE) (P4)
  1:   1          Reps
  2:   25         2500 mV 60 Hz Rejection Range (Delay must be zero)
  3:   1          SE Channel
  4:   1          Excite all reps w/Exchan 1
  5:   2          Delay (0.01 sec units)
  6:   2500       mV Excitation
  7:   3          Loc [V_Vx   ]
  8:   .0004      Multiplier
  9:   0.0        Offset
```

6. Measurement Details

Understanding the details in this section are not necessary for general operation of the 109 Probe with CSI's dataloggers.

The Therm109 Instruction outputs a 2500 mV excitation and measures the voltage across the 24.9 K resistor (Figure 6-1). The thermistor resistance changes with temperature.

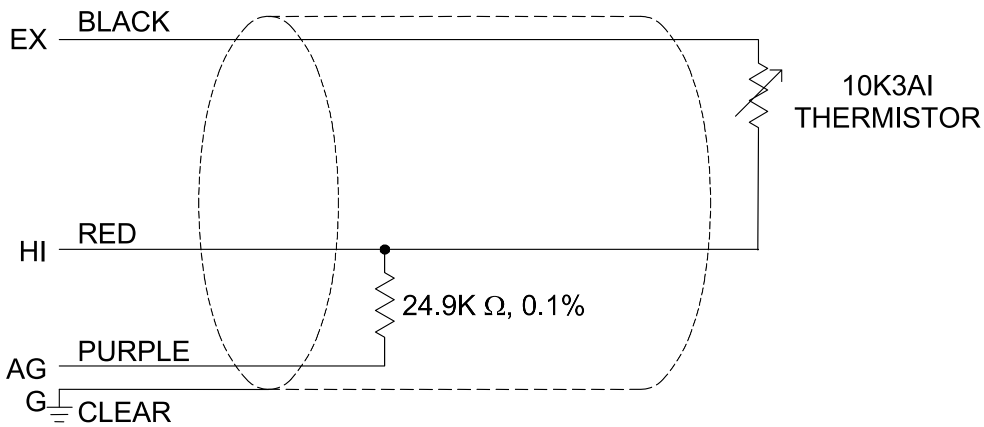


FIGURE 6-1. 109 Thermistor Probe Schematic

The measured voltage, V, is:

$$V = V_{EX}\frac{24{,}900}{24{,}900 + R_t}$$

Where V_{EX} is the excitation voltage, 24,900 ohms is the resistance of the fixed resistor and R_t is the resistance of the thermistor

The resistance of the thermistor is:

$$R_t = 24{,}900\left(\frac{V_{EX}}{V} - 1\right)$$

The Steinhart and Hart equation is used to calculate temperature from Resistance:

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

Where T_K is the temperature in Kelvin. The Steinhart and Hart coefficients used in the Therm109 instruction are:

$A = 1.129241 \times 10^{-3}$
$B = 2.341077 \times 10^{-4}$
$C = 8.775468 \times 10^{-8}$

7. Maintenance and Calibration

The 109 Probe requires minimal maintenance. Check monthly to make sure the radiation shield is free from debris. Periodically check cabling for signs of damage and possible moisture intrusion. For all factory repairs and recalibrations, customers must get a returned material authorization (RMA). Customers must also properly fill out a “Declaration of Hazardous Material and Decontamination" form and comply with the requirements specified in it. Refer to the "Warranty and Assistance" page for more information.

8. Troubleshooting

Symptom: Temperature is NAN, -INF, -9999, -273

Verify the red wire is connected to the correct Single-Ended analog input channel as specified by the measurement instruction, the black wire is connected to the switched excitation channel as specified by the measurement instruction, and the purple wire is connected to datalogger ground.

Symptom: Incorrect Temperature

Verify the multiplier and offset parameters are correct for the desired units (Section 5). Check the cable for signs of damage and possible moisture intrusion.

NOTE For all factory repairs, customers must get an RMA. Customers must also properly fill out a "Declaration of Hazardous Material and Decontamination" form and comply with the requirements specified in it. Refer to the "Warranty and Assistance" page for more information.

Symptom: Unstable Temperature

Try using the 60 Hz or 50 Hz integration options, and/or increasing the settling time as described in Sections 5.3 and 5.4. Make sure the clear shield wire is connected to datalogger ground, and the datalogger is properly grounded.

Campbell Scientific Companies

Campbell Scientific, Inc. (CSI)
815 West 1800 North
Logan, Utah 84321
UNITED STATES
www.campbellsci.com • info@campbellsci.com

Campbell Scientific Africa Pty. Ltd. (CSAf)
PO Box 2450
Somerset West 7129
SOUTH AFRICA
www.csafrica.co.za • cleroux@csafrica.co.za

Campbell Scientific Australia Pty. Ltd. (CSA)
PO Box 444
Thuringowa Central
QLD 4812 AUSTRALIA
www.campbellsci.com.au • info@campbellsci.com.au

Campbell Scientific do Brazil Ltda. (CSB)
Rua Luisa Crapsi Orsi, 15 Butantã
CEP: 005543-000 São Paulo SP BRAZIL
www.campbellsci.com.br • suporte@campbellsci.com.br

Campbell Scientific Canada Corp. (CSC)
11564 - 149th Street NW
Edmonton, Alberta T5M 1W7
CANADA
www.campbellsci.ca • dataloggers@campbellsci.ca

Campbell Scientific Centro Caribe S.A. (CSCC)
300 N Cementerio, Edificio Breller
Santo Domingo, Heredia 40305
COSTA RICA
www.campbellsci.cc • info@campbellsci.cc

Campbell Scientific Ltd. (CSL)
Campbell Park
80 Hathern Road
Shepshed, Loughborough LE12 9GX
UNITED KINGDOM
www.campbellsci.co.uk • sales@campbellsci.co.uk

Campbell Scientific Ltd. (France)
3 Avenue de la Division Leclerc
92160 ANTONY
FRANCE
www.campbellsci.fr • info@campbellsci.fr

Campbell Scientific Spain, S. L.
Avda. Pompeu Fabra 7-9, local 1
08024 Barcelona
SPAIN
www.campbellsci.es • info@campbellsci.es

Please visit www.campbellsci.com to obtain contact information for your local US or International representative.