109
Temperature Probe

User Guide

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109 Temperature Probe

1. General

The 109 Temperature Probe uses a thermistor to measure temperature. The 109 probe is designed for use with the CR200 series datalogger which has a special instruction for measuring it. The probe can also be measured with other Campbell Scientific dataloggers using generic measurement instructions.

The 109 Temperature Probe is designed for measuring air/soil/water temperatures. For air temperature, a 41303-5A radiation shield is used to mount the 109 Probe and limit solar radiation loading.

1.1 Specifications

Sensor:	BetaTherm 10K3A1 Thermistor
Temperature Measurement Range:	-50° to +70°C
Thermistor Interchangeability Error:	<±0.36°C over -25 to +50°C <±0.6°C over -50 to +70°C
Temperature Survival Range:	-55°C to +100°C
Linearization Error:	The Steinhart and Hart equation is used to calculate temperature; the maximum error is 0.03°C over -50 to +70°C.
Bridge resistor error (worst case):	<±0.035°C over -50 to +70°C
Time Constant In Air:	<80s to 63% in a wind speed of 1 m s^{-1}
Maximum recommended Lead Length:	30 m

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 ±0.7°C over the range of -50° to 70°C and ±0.4°C over the range of -25°C to 50°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 measurement may be greater than the error that may exist in the probe.

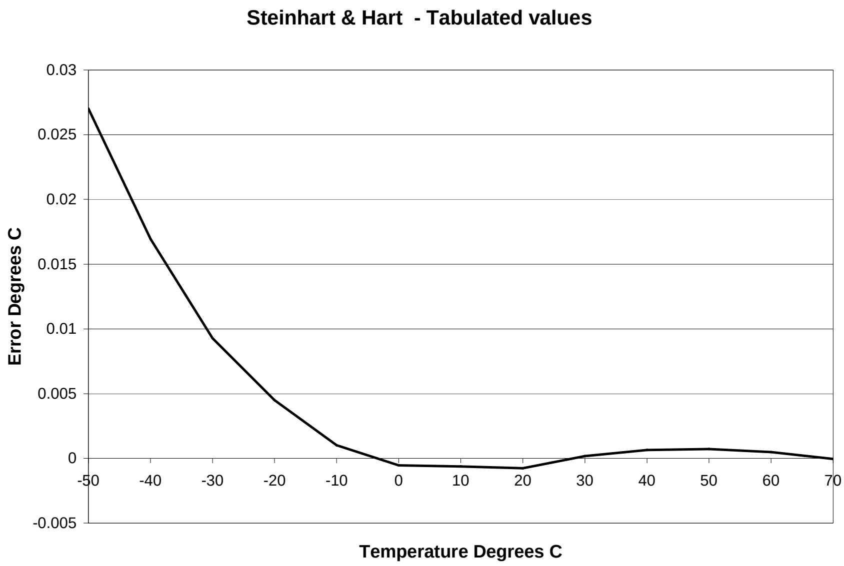

Figure 2-1. Steinhart and Hart

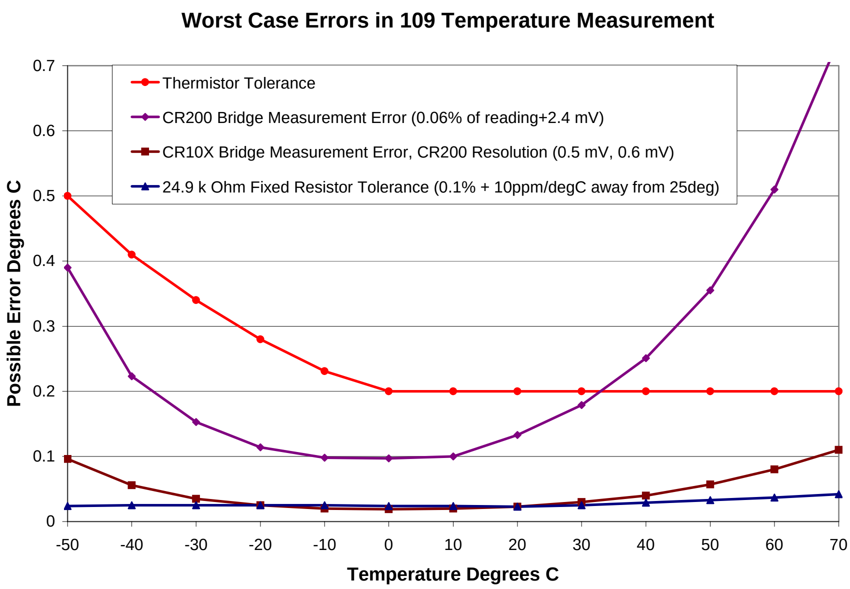

Figure 2-2. Possible Errors

3. Installation

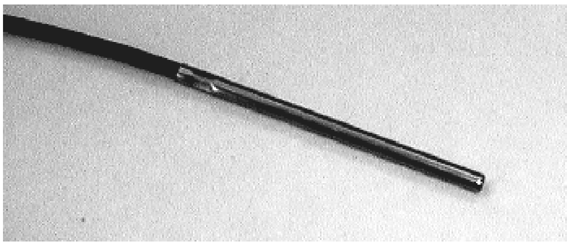

Figure 3-1. 109 Probe

To increase measurement accuracy and to avoid damage to the probe, please follow the guidelines shown below.

CAUTION Do not immerse the probe in substances which can degrade stainless steel.

3.1 Installation in Water

If the probe is being used to measure the temperature of moving water, ensure that the probe and cable are firmly attached to a fixed object to prevent unnecessary movement of the cable which might otherwise lead to a stress fracture or abrasion of the wire.

3.2 Installation in Soil

Ensure that the soil surrounding the probe cable is free from stones or other sharp objects which could puncture the cable sheath when the soil is compacted.

CAUTION Always fully excavate the soil above a buried 109 probe before attempting to remove it. Never try to pull the probe from the soil by the wire alone as this is likely to cause damage.

3.3 Installation in Air

3.3.1 General

When measuring substances with a low thermal conductivity, such as air, the 109, in common with all such temperature probes, can suffer errors as a result of heat conduction between the tip and the connection wire. For the 109 this error can approach 0.02°C for every °C difference between the temperature of the tip and that of the cable where it is joined to the metal probe.

To minimise such errors always try to make sure that the cable temperature is as close as possible to the tip temperature. For example, when measuring air temperature using a radiation shield, try to ensure the cable is routed so that it is shaded from direct sunshine. If very high solar radiation is likely, cover the exposed length of the cable closest to the sensor with a reflective material such as a length of white tubing. To prevent cable movement in windy conditions make sure that it is fixed to both the mounting arm and the tripod/tower by using cable ties at regular intervals.

3.3.2 Using the 41303-5 Radiation Shield

Figure 3-2 41303-5 Radiation Shield and Mounting Arm

Mount the shield and mounting arm onto the tower/tripod and position so that the sensor will be at approximately the required height. Tighten the U-bolts just enough to secure the arm onto the tower/tripod.

Fit the probe into the shield, reversing the sensor clamp, if necessary, to allow it to grip the body of the sensor (6mm diameter). Gently push the sensor up into the shield as far as it will go, but still allowing the plastic clamp to retain its grip on the metal body of the sensor. (If you inadvertently push the sensor body beyond the clamp, pull it back down until the clamp *fully* grips the body.)

Route the cable along the underside of the mounting arm, and secure in place by using a small cable-tie pushed through the two holes in the top plate of the arm. Try to ensure that the cable is shaded as much as possible from the sun.

Adjust for height/position, if necessary, before fully securing the sensor and mounting arm in place.

4. Wiring

Connections to Campbell Scientific dataloggers are given in Table 4-1. Temperature is measured with one Single-Ended input channel and an 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 excitation terminal, approximately six).

Table 4-1. Connections to Campbell Scientific Dataloggers

Colour	Description	CR200 CR800 CR5000 CR3000 CR1000	CR510 CR500 CR10(X)	CR21X CR7 CR23X
Black	Excitation	Switched Excitation	Switched Excitation	Switched Excitation
Red	Temperature Signal	Single-Ended Input	Single-Ended Input	Single-Ended Input
White	Signal Ground	⏚	AG	⏚
Clear	Shield	⏚	G	⏚

5. Example Programs

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

In the CR200 series dataloggers, Instruction Therm109 is used to measure temperature. Therm109 provides excitation, makes a single ended voltage measurement, and calculates temperature.

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.

Table 5-1. Wiring for Example Programs

Colour	Description	CR200 CR1000 CR5000	CR10X
Black	Excitation	EX1	E1
Red	Signal	SE1	SE1
White	Signal Ground	⏚	AG
Clear	Shield	⏚	G

The Therm109 instruction has the following form:

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

Example 1. Sample Program for CR200 Series Datalogger

```
'CR200 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
```

The next example is for the CR1000 datalogger. See Section 7 for a discussion of the measurements and processing involved.

Example 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,_50Hz,1.0,0.0)
        'Call Data Tables and Store Data
        CallTable(Table1)
    NextScan
EndProg
```

The following example is for the CR10X datalogger. See Section 7 for a discussion of the measurements and processing involved. Note that the polynomial 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 3^{rd} order coefficient (C) to be multiplied by 10^{9}.

Example 3. Example Program for CR10X

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

1:  AC Half Bridge (P5)
   1:   1              Reps
   2:   35             2500 mV 50 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
```

6. Maintenance and Calibration

The 109 Probe requires minimal maintenance. Check monthly to make sure the radiation shield is free from debris.

7. 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 7-1). The thermistor resistance changes with temperature.

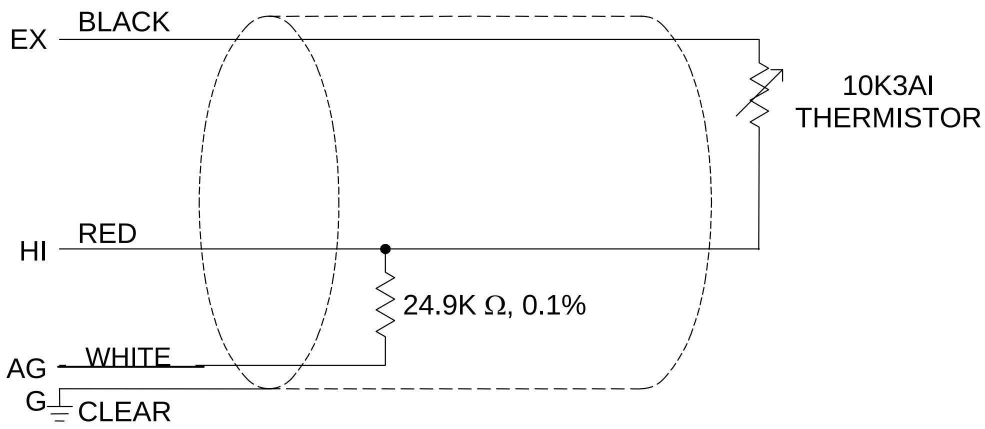

Figure 7-1. 109 Thermistor Probe Schematic

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 CR200 Therm109 instruction are:

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

8. 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 or 50 Hz rejection option as shown in Examples 2 - 3.

9. 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 CR10X:

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:   35          2500 mV 50 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
```

For the CR1000:

For CRBasic loggers, the 60 and 50 Hz integration options include a 3 ms settling time; longer settling times can be entered into the Settling Time parameter. The example Therm109 instruction listed below has a 20 mSec (20000 uSec) delay:

```
‘Therm107 ( Dest, Reps, SEChan, ExChan, SettlingTime, Integ, Mult, Offset )
Therm109(T109_C,1,1,1,20000,_50Hz,1.0,0.0)
```

10. Troubleshooting

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

Verify the red wire is connected to the correct Single-Ended analogue 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 white 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.

Symptom: Unstable Temperature

Try using the 60 or 50 Hz integration options, and/or increasing the settling time as described in Sections 8 and 9. Make sure the clear shield wire is connected to datalogger ground, and the datalogger is properly grounded.

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