INSTRUCTION MANUAL

109B & 109BAM Temperature Probe

April 2010

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Model 109B & 109BAM Temperature Probe

Table of Contents

Model 109B & 109BAM Temperature Probe

1. General

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

The 109B Temperature Probe can measure soil/water temperatures. The probe can be buried in soil (maximum of 86 psi) or submerged in water to 200 feet.

The 109BAM is typically used to measure soil or water temperature using a Campbell Scientific datalogger and a multiplexer (i.e. AM16/32B). When using the 109BAM with a multiplexer one pick off resistor is required for each single ended channel used. This will vary depending on the multiplexer configuration and the number of sensors measured.

The model name 109B will be used in this manual to refer to both 109B and 109BAM probes, unless otherwise specified. The -L option on the model 109B-L Temperature Probe indicates that the cable length is user specified. This manual refers to the sensor as the 109B.

The standard cable length for the 109B is 25 feet. However, custom lead length for the 109B-L can be specified when the sensor is ordered. Table 1-1 gives the recommended lead length for mounting the sensor on a tripod or tower.

TABLE 1-1. Recommended Lead 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'	11'	11'	14'	14'	19'	24'	14'	24'	37'

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

The 109B ships with:

(1) Resource CD

1.1 Specifications

Sensor:	US Sensor Corp. PR103J23 Thermistor
Temperature Measurement Range:	-50° to +70°C
Thermistor Interchangeability Error:	Typically <±0.2°C over 0°C to 70°C; ±0.5 @ -50°C
Temperature Survival Range:	-50°C 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.

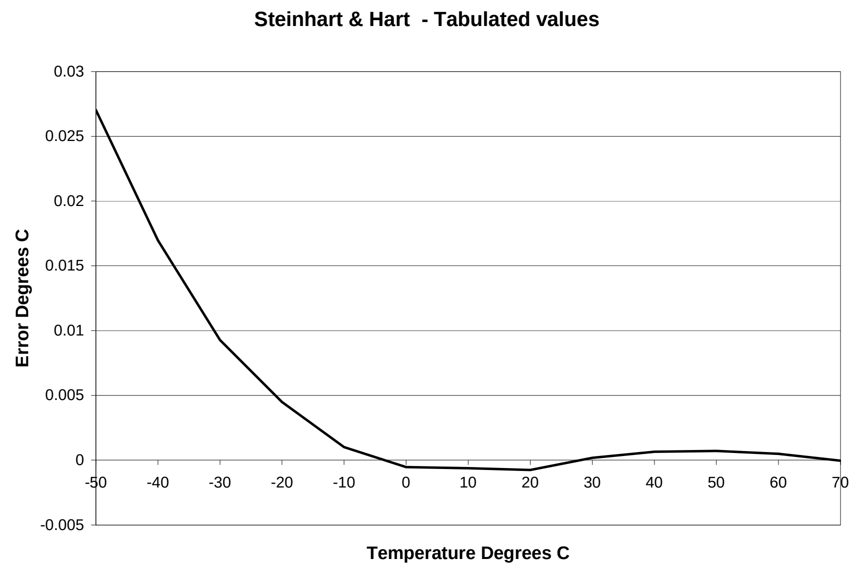

FIGURE 2-1. Steinhart and Hart

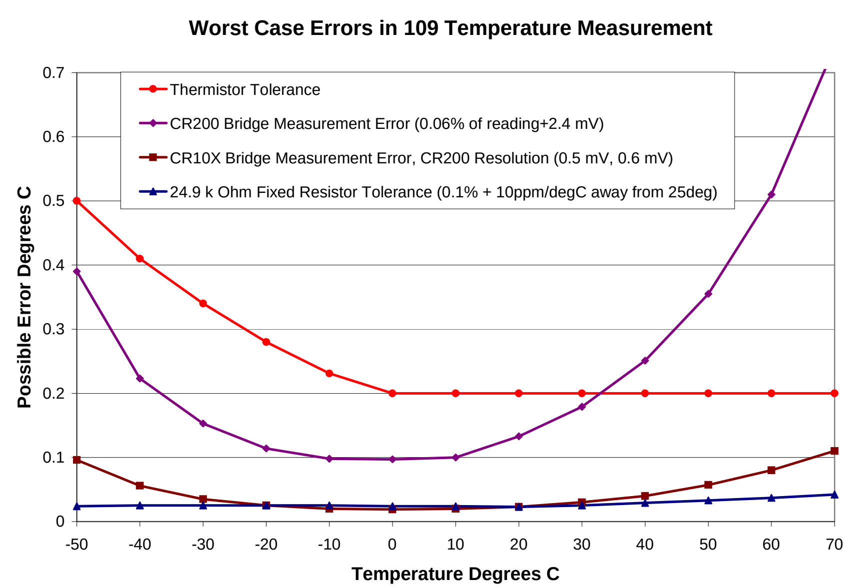

FIGURE 2-2. Possible Errors

3. Installation

3.1 Soil Temperature

The 109B is suitable for burial. Whenever possible it should be placed horizontally at the desired depth to avoid thermal conduction from the surface to the thermistor. The recommended maximum burial depth is equivalent to 86 psi.

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.

3.2 Water Temperature

The 109B can be submerged to 200 feet. Please note that the 109B 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. The 109B 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. 109B Connections to Campbell Scientific Dataloggers

Colour	**Heat Shrink Label**	**CR200(X) CR800 CR3000 CR1000**	**CR510 CR500 CR10(X)**	**CR5000 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	⏚

The 109BAM is measured directly by the multiplexer (i.e. AM16/32B) with the use of the H & L input channels. A 24.9KΩ resistor assembly (RES24.9K-0.1) is required at the datalogger to complete the half bridge measurement at each of the single ended channels used. Additional information regarding multiplexer connections can be found in the multiplexer manual.

Table 4-2 shows the wiring for up to three 109BAMs for each of the COM terminals.

TABLE 4-2. 109BAM, MUX & Datalogger Connections

Function	Colour	Multiplexer Connection	CR200(X) CR800 CR1000 CR3000	CR510 CR500 CR10(X)	CR5000 CR23X
109BAM (1,2,3) Excitation*	Black	1H terminal			
109BAM(1) Signal*	White	1L terminal			
109BAM(2) Signal*	White	2H terminal			
109BAM(3) Signal*	White	2L terminal			
109BAM(1,2,3) Clear*	Shield	⏚			
Mux Power**	Red	12V	12V	12V	12V
Power Reference**	Black	GND	G	G	G
Mux Clock**	Green	CLK	C(1)	C(1)	C(1)
Mux Reset**	White	RES	C(2)	C(2)	C(2)
Shield**	Clear		⏚	G	⏚
Excitation Source†	Red	COM ODD H	Vx(1)	E(1)	Vx(1)
Signal Return(1)†	White	COM ODD L	SE(1)††	SE(1) ††	SE(1) ††
Signal Return(2)†	Black	COM EVEN H	SE(2) ††	SE(2) ††	SE(2) ††
Signal Return(3)†	Green	COM EVEN L	SE(3) ††	SE(3) ††	SE(3) ††
Shield†	Clear	COM ⏚	⏚	G	⏚

NOTES

* The wiring assumes that the datalogger in the “4x16” configuration.
**Connections are made with the FIN4COND(-L) on the Multiplexer at the “Control” Terminals and connect the corresponding terminals on the datalogger.
† Connections are made with a second FIN4COND(-L) on the multiplexer at the “COM” terminals and connect the corresponding terminals on the datalogger.
†† Each single ended channel used requires a RES24.9K-0.1 completion resistor assembly. The RES24.9K-0.1 must be connected between the single ended channel and Ground (i.e. ⏚ or 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—Electrically 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 109B'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 Examples 5.1.1.1 & 5.1.1.2

Colour	Function	Connection
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 109B 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 T109B_C

Units T109B_C=Deg C

'Define Data Tables
DataTable(Table1,True,-1)
    DataInterval(0,10,Min,10)
    Average(1,T109B_C,FP2,False)
EndTable

'Main Program
BeginProg
    Scan(1,Sec,1,0)
        '109B Temperature Probe measurement T109B_C:
        Therm109(T109B_C,1,1,1,0,_60Hz,1.0,0.0)
        'Call Data Tables and Store Data
        CallTable(Table1)
    NextScan
EndProg
```

5.1.1.3 Sample Program for CR1000 Datalogger & AM16/32B (4x16 mode)

Wiring for this example can be found in Table 4.2.

```
'CR1000

'Declare Variables and Units
Dim LCount_4
Public T109BAM_C(6)

Units T109BAM_C=Deg C

'Define Data Tables
DataTable(Table1,True,-1)
 DataInterval(0,60,Min,10)
 Average(6,T109BAM_C(1),FP2,False)
EndTable


'Main Program
BeginProg
 Scan(5,Sec,1,0)

     'Turn AM16/32B Multiplexer On
     PortSet(2,1)
     Delay(0,150,mSec)
     'Switch to next AM16/32 Multiplexer channel set
     PulsePort(1,10000)
     '109BAM Temperature Probe (3-wire) measurements T109BAM_C(1,2,3) on the AM16/32B
     Therm109(T109BAM_C(1),3,1,1,0,_60Hz,1,0)
     'Switch to next AM16/32 Multiplexer channel set
     PulsePort(1,10000)
     '109BAM Temperature Probe (3-wire) measurements T109BAM_C(4,5,6) on the AM16/32B
     Therm109(T109BAM_C(4),3,1,1,0,_60Hz,1,0)

     'Turn AM16/32 Multiplexer Off
     PortSet(2,0)

     'Call Data Tables and Store Data
     CallTable(Table1)

     NextScan
EndProg
```

5.2 Edlog

In Edlog, Instruction 5 is typically used to measure the 109B'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 Electrically Noisy Environments

AC power lines, pumps, and motors, can be the source of electrical noise. If the 109B probe or datalogger is located in an electrically noisy environment, the 109B probe should be measured with the 60 or 50 Hz rejection option as shown in the Examples in Section 5.4.

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 CR200(X)-series, CR800, CR850, CR1000, and CR3000:

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 µSec) delay:

```
'Therm109 ( Dest, Reps, SEChan, ExChan, SettlingTime, Integ, Mult, Offset )
Therm109(T109B_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 5.2.1.1 (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 109B 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.

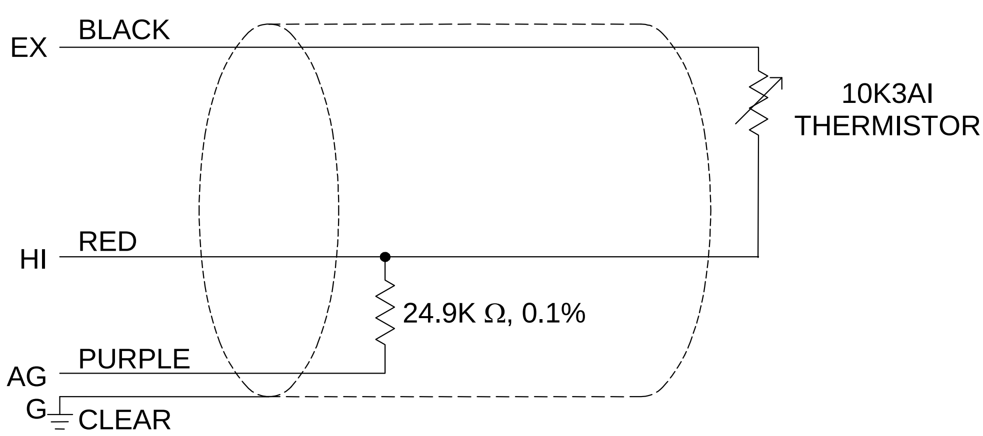

FIGURE 6-1. 109B Thermistor Probe Schematic

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 109B Probe requires minimal maintenance. 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, as described in Tables 4-1 and 4-2.

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 5.3 and 5.4. Make sure the clear shield wire is connected to datalogger ground, and the datalogger is properly grounded.

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.