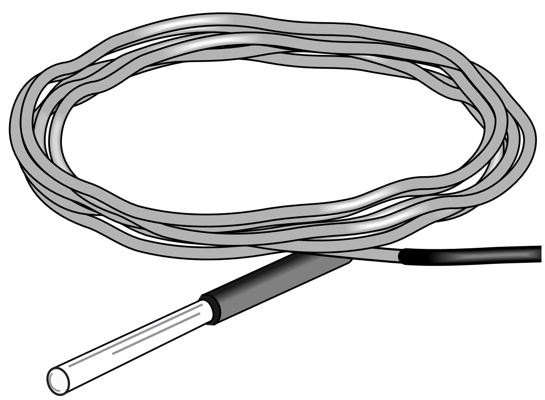
INSTRUCTION MANUAL

Model 108 Temperature Probe

Revision: 4/07



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Model 108 Temperature Probe

1. General

The 108 temperature probe uses a thermistor to measure temperature. The probe is designed for measuring air/soil/water temperatures. For air temperature, a 41303-5A radiation shield is used to mount the 108 Probe and limit solar radiation loading. The 108 temperature probe is designed to be buried or submerged in water up to 50 feet (21 psi).

The -L option on the model 108-L temperature probe indicates that the cable length is user specified. This manual refers to the sensor as the 108.

Lead length for the 108 is specified when the sensor is ordered. Table 1-1 gives the recommended lead length for mounting the sensor at the top of the tripod/tower with a 2 foot crossarm. Lead length can be 2 feet shorter when the sensor is mounted to the tripod mast / tower leg without a crossarm.

TABLE 1-1. Recommended Lead Lengths

CM6	CM10	CM110	CM115	CM120	UT10	UT20	UT30
11’	14’	14’	19’	24’	14’	24’	37’

The 108 ships with:

(1) Instruction Manual

1.1 Specifications

Sensor:	BetaTherm 100K6A Thermistor
Temperature Measurement Range:	-5° to +95°C
Survival Temperature Range:	-50° to +100°C
Thermistor Interchangeability Error:	Typically <±0.2°C over 0°C to 70°C ±0.3 @ 95°C.
Steinhart-Hart Equation Error:	≤±0.01°C (CRBasic dataloggers only)
Polynomial Linearization Error:	<±0.5°C over -7°C to +90°C (Edlog dataloggers only)

Time Constant in Air: 200 ± 10 seconds

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, the precision of the bridge resistors, and the Steinhart-Hart equation error (CRBasic dataloggers) or the polynomial error (Edlog dataloggers). In a "worst case" all errors add to an accuracy of ±0.3°C over the range of -3° to 90°C and ±0.7°C over the range of -7°C to 95°C. The major error component is the interchangeability specification of the thermistor, tabulated in Table 2-1. For the range of 0° to 50°C the interchangeability error is predominantly offset and can be determined with a single point calibration. Compensation can then be done with an offset entered in the measurement instruction. The bridge resistors are 0.1% tolerance with a 10 ppm temperature coefficient. Polynomial errors are tabulated in Table 2-2 and plotted in Figure 2-1.

TABLE 2-1. Thermistor Interchangeability Specification

Temperature (°C)	Temperature Tolerance (±°C)
–10	0.25
0 to +50	0.20
+70	0.20
+90	0.31

TABLE 2-2. Polynomial Error

-10 to +95	<±1.0°C
-7 to +95	<±0.5°C
-3 to +90	<±0.1°C

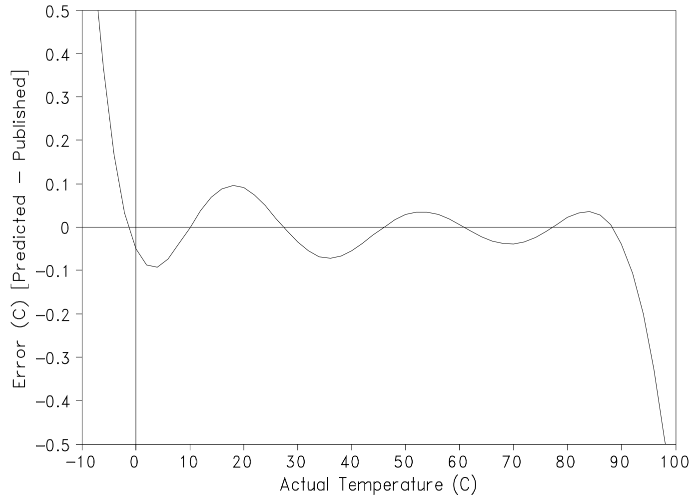

FIGURE 2-1. 108 Probe Polynomial Error Curve (Edlog dataloggers only)

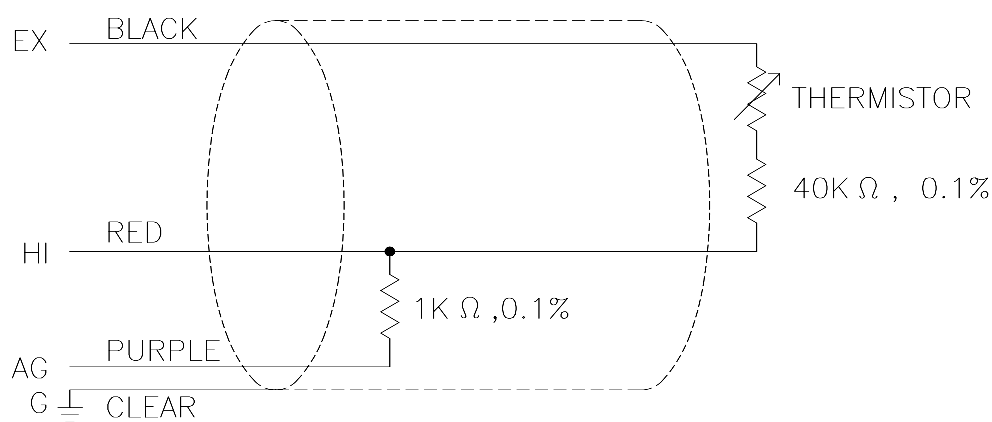

FIGURE 2-2. 108 Probe Schematic

3. Installation

3.1 Siting

For air temperature measurements, 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 air temperature 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)

The probe is designed to be buried or submerged in water up to 50’ (21 psi).

3.2 Assembly and Mounting

Tools required for installing on a tripod or tower:

- 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 108 must be housed inside a radiation shield when the sensor will be exposed to solar radiation (i.e., air temperature measurements made 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.

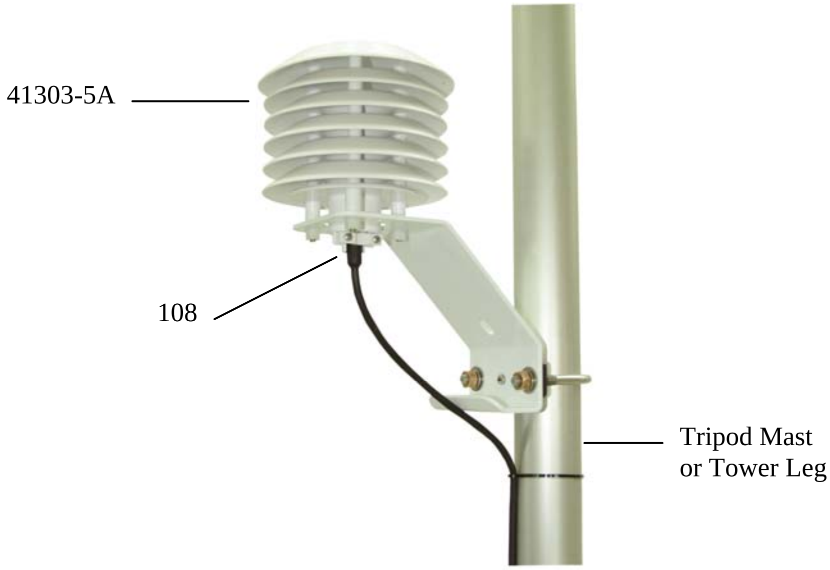

FIGURE 3-1. 108 and 41303-5A Radiation Shield on a Tripod Mast

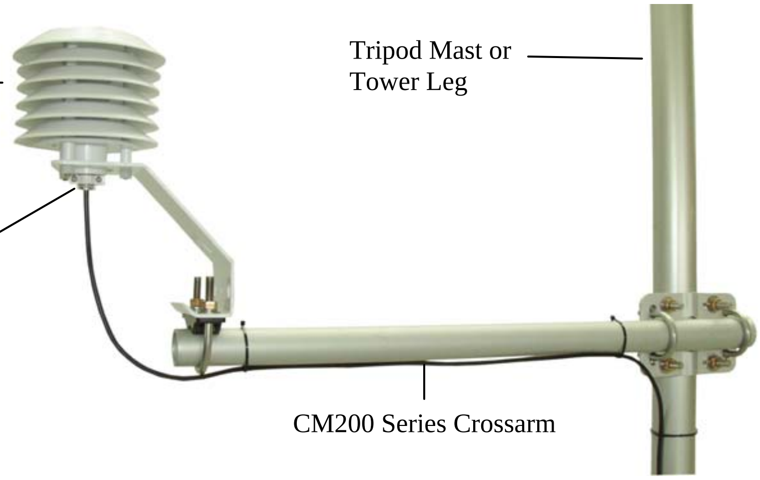

FIGURE 3-2. 108 and 41303-5A Radiation Shield on a CM200 Series Crossarm

The 108 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.

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

Color	Description	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
Purple	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.

The AC Half Bridge measurement instruction (P5), is used with dataloggers that are programmed with Edlog (e.g. CR10X, CR23X) to measure the 108 probe. Instruction P5 makes a half bridge measurement, and the measurement result is converted to temperature by the Polynomial Instruction (P55).

The Therm108 measurement instruction is used with dataloggers that are programmed with CRBasic (e.g. CR1000) to measure the 108 probe. Therm108 makes a half bridge voltage measurement, and converts the measurement result to temperature using the Steinhart-Hart equation. With a multiplier of 1 and an offset of 0, the output is temperature in degrees C. With a multiplier of 1.8 and an offset of 32, the output is temperature in degrees F.

TABLE 5-1. Wiring for Example Programs

Color	**Description**	**CR1000**	**CR10X**
Black	Excitation	EX1	E1
Red	Signal	SE1	SE1
Purple	Signal Ground	⏚	AG
Clear	Shield	⏚	G

Both example programs measure a 108 temperature probe every second and store a 60 minute average temperature.

5.1 Example Program for CR1000 Datalogger

```
'CR1000
'This example program measures a single 108 Thermistor probe
'once a second and stores the average temperature every 60 minutes.

'Declare the variables for the temperature measurement
Public T108_C

'Define a data table for 60 minute averages:
DataTable(Table1,True,-1)
	DataInterval(0,60,Min,0)
	Average(1,T108_C,IEEE4,0)
EndTable
```

```
BeginProg
    Scan(1,Sec,1,0)
        'Measure the temperature
        Therm108(T108_C,1,1,Vx1,0,_60Hz,1.0,0.0)
        'Call Data Table
        CallTable(Table1)
    NextScan
EndProg
```

5.2 Example Program for CR10X Datalogger

```
;{CR10X}
*Table 1 Program
  01: 1.0000       Execution Interval (seconds)

1:  AC Half Bridge (P5)
  1:  1            Reps
  2:  23           25 mV 60 Hz Rejection Range    ; 50 mV range on the 21X and CR7
  3:  1            SE Channel
  4:  1            Excite all reps w/Exchan 1
  5:  1000         mV Excitation                  ; 2000 mV on the 21X and CR7
  6:  1            Loc [ T108_C___ ]
  7:  200          Multiplier
  8:  0            Offset

2:  Polynomial (P55)
  1:  1            Reps
  2:  1            X Loc [ T108_C___ ]
  3:  1            F(X) Loc [ T108_C___ ]
  4:  -26.97       C0
  5:  69.635       C1
  6:  -40.66       C2
  7:  16.573       C3
  8:  -3.455       C4
  9:  0.301        C5

3:  If time is (P92)
  1:  0            Minutes (Seconds --) into a
  2:  60           Interval (same units as above)
  3:  10           Set Output Flag High (Flag 0)

4:  Set Active Storage Area (P80)
  1:  1            Final Storage Area 1
  2:  101          Array ID

5:  Real Time (P77)
  1:  1220         Year,Day,Hour/Minute (midnight = 2400)

6:  Average (P71)
  1:  1            Reps
  2:  1            Loc [ T108_C___ ]
```

6. Maintenance and Calibration

The 108 Probe requires minimal maintenance. Check monthly to make sure the radiation shield is clean and free from debris.

For most applications it is unnecessary to calibrate the 108 to eliminate the thermistor offset. However, for those users that are interested, the following briefly describes calibrating the 108 probes.

A single point calibration can be performed to determine the 108 temperature offset (thermistor interchangeability). For Edlog dataloggers, the value of the offset must be chosen so that the probe outputs the temperature calculated by the polynomial, not the actual calibration temperature. For example, a 108 is placed in a calibration chamber that is at 0°C and the probe outputs 0.1°C. An offset of -0.15 is required for Edlog dataloggers, because at 0°C the polynomial calculates a temperature of -0.05°C.

7. Measurement Details

Understanding the details in this section is not necessary for general operation of the 108 probe with CSI's dataloggers.

7.1 AC Half Bridge and Polynomial Instructions

The AC Half Bridge (P5) instruction applies a precise AC excitation voltage and measures the voltage drop across the 1K ohm resistor. The ratio of measured voltage (Vs) to the excitation voltage (Vx) is related to thermistor resistance (Rs), and the 1000 and 40K ohm fixed resistors as shown below:

$$Vs/Vx = 1000/(Rs+40000+1000)$$

The Polynomial (P55) instruction converts the measurement result Vs/Vx * 200 to temperature using a 5^{th} order polynomial. The polynomial coefficients are shown in Table 7-1. Thermistor resistance, and computed temperature over a -10 to +84 degree Celsius range is shown in Table 7-2.

7.2 Therm108 Instruction

Therm108 instruction applies a precise 2500 mV excitation voltage and measures the voltage drop across the 1K ohm resistor. The ratio of measured voltage (Vs) to the excitation voltage (Vx) is related to thermistor resistance (Rs), and the 1000 and 40K ohm fixed resistors as shown below:

$$Vs/Vx = 1000/(Rs+40000+1000)$$

Therm108 calculates Rs from the voltage ratio, and converts Rs to temperature using the Steinhart-Hart equation:

$$T = 1/(A+B(LnRs)+C(LnRs)^3) - 273.15$$

Where T is the temperature returned in degrees Celsius, and A, B, and C are coefficients provided by the thermistor manufacturer:

A = 8.271111E-4
B = 2.088020E-4
C = 8.059200E-8

TABLE 7-1. Polynomial Coefficients	
Coefficient	**Value**
C_0	-26.97
C_1	69.635
C_2	-40.66
C_3	16.573
C_4	-3.455
C_5	0.301

TABLE 7-2. Actual Temperature, Sensor Resistance, and Computed Temperature		
Temperature °C	**Resistance OHMS**	**Output °C**
-10.00	612366	-9.02
-8.00	546376	-7.36
-6.00	488178	-5.63
-4.00	436773	-3.83
-2.00	391294	-1.97
0.00	351017	-0.05
2.00	315288	1.91
4.00	283558	3.91
6.00	255337	5.93
8.00	230210	7.96
10.00	207807	10.00
12.00	187803	12.04
14.00	169924	14.07
16.00	153923	16.09
18.00	139588	18.10
20.00	126729	20.09
22.00	115179	22.07
24.00	104796	24.05
26.00	95449	26.02
28.00	87026	27.99
30.00	79428	29.97
32.00	72567	31.94
34.00	66365	33.93
36.00	60752	35.93
38.00	55668	37.93
40.00	51058	39.94
42.00	46873	41.96
44.00	43071	43.98
46.00	39613	46.00

48.00	36465	48.02
50.00	33598	50.03
52.00	30983	52.03
54.00	28595	54.03
56.00	26413	56.03
58.00	24419	58.02
60.00	22593	60.01
62.00	20921	61.99
64.00	19388	63.98
66.00	17981	65.97
68.00	16689	67.96
70.00	15502	69.96
72.00	14410	71.97
74.00	13405	73.98
76.00	12479	75.99
78.00	11625	78.01
80.00	10837	80.02
82.00	10110	82.03
84.00	9438.1	84.04
86.00	8816.9	86.03
88.00	8241.9	88.00
90.00	7709.7	89.96
92.00	7216.3	91.89
94.00	6758.9	93.80
96.00	6334.5	95.67
98.00	5940.5	97.51
100.00	5574.3	99.31

8. Electrical Noisy Environments

AC power lines, pumps, and motors, can be the source of electrical noise. If the 108 probe or datalogger is located in an electrically noisy environment, the 108 probe should be measured with the 60 or 50 Hz rejection option as shown in Examples 8-1 and 8-2.

Example 8-1. CR1000 Measurement Instruction with 60 Hz Noise Rejection

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

Example 8-2. CR10X Example with 60 Hz Noise Rejection

```
1:  AC Half Bridge (P5)
   1:    1              Reps
   2:    23             25 mV 60 Hz Rejection Range
   3:    1              SE Channel
   4:    1              Excite all reps w/Exchan 1
   5:    1000           mV Excitation
   6:    1              Loc [ T108_C___ ]
   7:    200            Multiplier
   8:    0              Offset
```

9. Long Lead Lengths

If the 108 has lead lengths of more than 300 feet, use the DC Half Bridge instruction (Instruction 4) with a 20 millisecond delay to measure temperature. The delay provides a longer settling time before the measurement is made. 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. Do not use the 108 with long lead lengths in an electrically noisy environment.

Example 9-1. CR1000 Measurement Instruction with 20 mSec (20000 uSec) Delay

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

Example 9-2. CR10X Measurement Instructions

```
01:  Excite, Delay,Volt(SE) (P4)
   1:    1              Rep
   2:    3**            ±25 mV slow range
   3:    9*             IN Chan
   4:    3*             Excite all reps w/EXchan 3
   5:    2              Delay (units .01sec)
   6:    1000**         mV Excitation
   7:    11*            Loc [:Temp_C   ]
   8:    .2***          Mult
   9:    0              Offset

02:  Polynomial (P55)
   1:    1              Reps
   2:    11             X Loc [ Tmp108C   ]
   3:    11             F(X) Loc [ Tmp108C   ]
   4:    -26.97         C0
   5:    69.635         C1
   6:    -40.66         C2
   7:    16.573         C3
   8:    -3.455         C4
   9:    .301           C5

*    Proper entries will vary with program and datalogger channel and input location assignments.
**   On the 21X and CR7 use the 50 mV input range and 2000 mV excitation.
***  Use a multiplier of 0.1 with a 21X and CR7.
```

10. 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, and the purple wire is connected to datalogger ground.

Symptom: Temperature is NAN, -26

Verify the black wire is connected to the switched excitation channel as specified by the measurement instruction.

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, 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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