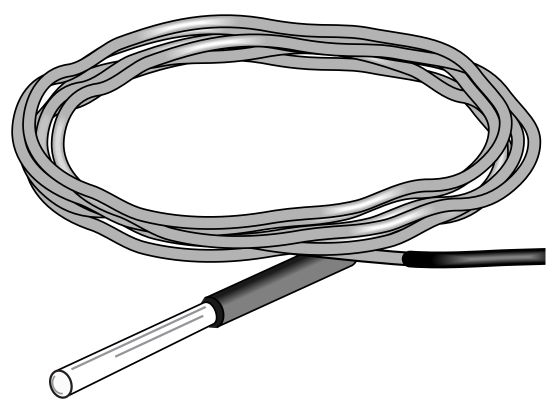
INSTRUCTION MANUAL

Model 107 Temperature Probe

Revision: 4/07



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107 Table of Contents

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Figures

Tables

Model 107 Temperature Probe

1. General

The 107 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 107 Probe and limit solar radiation loading. The probe is designed to be buried or submerged in water to 50' (21 psi).

The -L option on the model 107-L Temperature probe indicates that the cable length is user specified. This manual refers to the sensor as the 107.

Lead length for the 107 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 107 ships with:

(1) Instruction Manual

1.1 Specifications

Sensor:	BetaTherm 100K6A Thermistor
Temperature Measurement Range:	-35° to +50°C
Thermistor Interchangeability Error:	Typically <±0.2°C over 0°C to 60°C; ±0.4 @ -35°C
Temperature Survival Range:	-50°C to +100°C
Steinhart-Hart Equation Error:	≤±0.01°C over -35° to +50°C (CRBasic dataloggers only)
Polynomial Linearization Error:	<±0.5°C over -35°C to +50°C (Edlog dataloggers only)

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, the precision of the bridge resistors, and the Steinhart-Hart equation error (CRBasic dataloggers) or polynomial error (Edlog dataloggers). In a "worst case" all errors add to an accuracy of ±0.4°C over the range of -24° to 48°C and ±0.9°C over the range of -38°C to 53°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)
–40	0.40
–30	0.40
–20	0.32
–10	0.25
0 to +50	0.20

TABLE 2-2. Polynomial Error for Edlog Dataloggers

-40 to +56	<±1.0°C
-38 to +53	<±0.5°C
-24 to +48	<±0.1°C

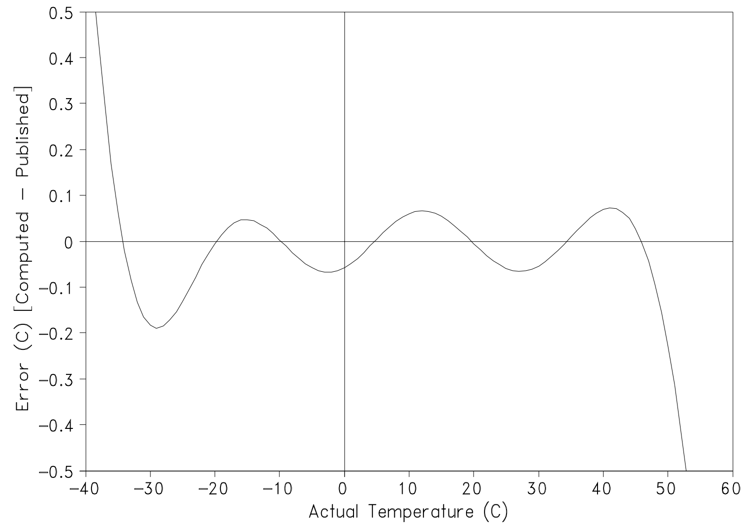

FIGURE 2-1. Error Produced by Polynomial Fit to Published Values (Edlog dataloggers only)

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 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 107 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.

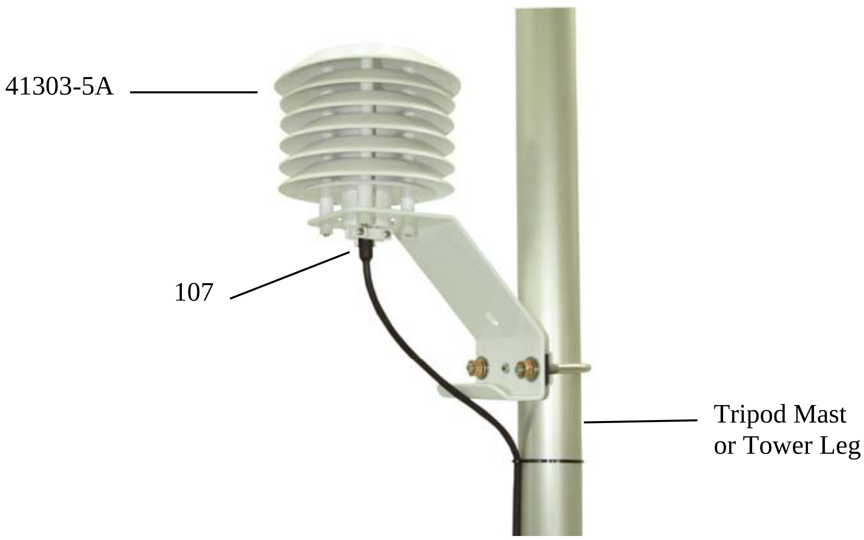

FIGURE 3-1. 107 and 41303-5A Radiation Shield on a Tripod Mast

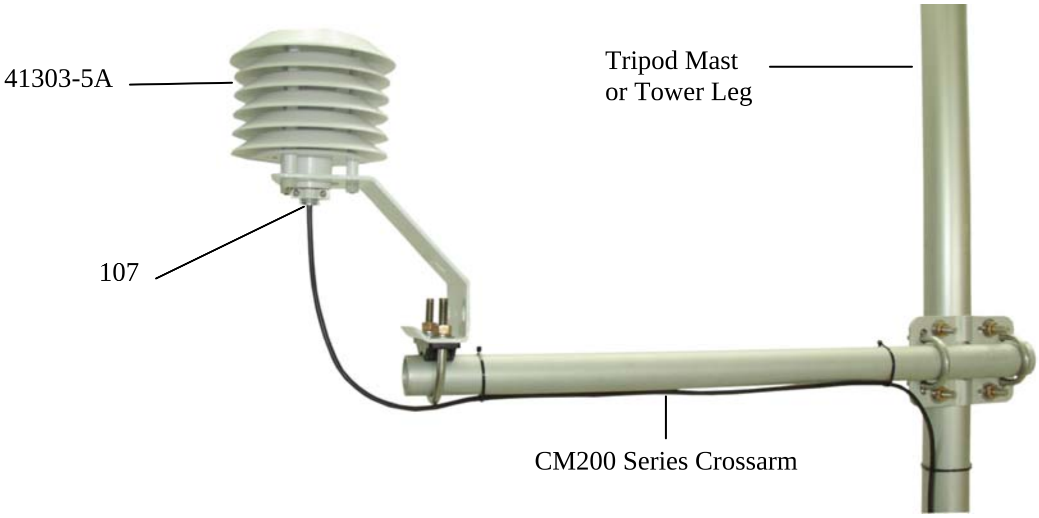

FIGURE 3-2. 107 and 41303-5A Radiation Shield on a CM200 Series Crossarm

The 107 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 Temp107 measurement instruction (P11), is used with dataloggers that are programmed with Edlog (e.g. CR10X, CR23X) to measure the 107 probe. P11 makes half bridge voltage measurement, and converts the measurement result to temperature using a fifth order polynomial. 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.

The Therm107 measurement instruction is used with dataloggers that are programmed with CRBasic (e.g. CR1000) to measure the 107 probe. Therm107 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 107 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 107 Thermistor probe
'once a second and stores the average temperature every 60 minutes.

'Declare the variables for the temperature measurement
Public T107_C

'Define a data table for 60 minute averages:
DataTable(Table1,True,-1)
    DataInterval(0,60,Min,0)
    Average(1,T107_C,IEEE4,0)
EndTable

BeginProg
    Scan(1,Sec,1,0)
        'Measure the temperature
        Therm107(T107_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:  Temp (107) (P11)
  1:    1             Reps
  2:    1             SE Channel
  3:    21            Excite all reps w/E1, 60Hz, 10ms delay
  4:    1             Loc [ T107_C    ]
  5:    1.0           Multiplier
  6:    0.0           Offset

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 [ T107_C    ]
```

6. Maintenance and Calibration

The 107 Probe requires minimal maintenance. For air temperature measurements, check monthly to make sure the radiation shield is clean and free from debris.

For most applications it is unnecessary to calibrate the 107 to eliminate the thermistor offset. However, for those users that are interested, the following briefly describes calibrating the 107 probes.

A single point calibration can be performed to determine the 107 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 107 is placed in a calibration chamber that is at 0°C and the probe outputs 0.1°C. An offset of -0.16 is required for Edlog dataloggers, because at 0°C the polynomial calculates a temperature of -0.06°C (Table 7-1).

7. Measurement Details

Understanding the details in this section are not necessary for general operation of the 107 Probe with CSI's dataloggers.

7.1 Temp(107) Instruction (P11)

The Temp(107) instruction (P11) applies a precise 2VAC (4VAC with the 21X and CR7) excitation voltage and measures the voltage drop across the 1K ohm resistor (Figure 7-1). The ratio of measured voltage (Vs) to the excitation voltage (Vx) is related to thermistor resistance (Rs), and the 1000 and 249K ohm fixed resistors as shown below:

Vs/Vx = 1000/(Rs+249000+1000)

Instruction P11 converts the ratio Vs/Vx * 800 to temperature using a 5^{th} order polynomial. The polynomial coefficients are shown in Table 7-2. Thermistor resistance, and computed temperature over a -40 to +60 degree Celsius range is shown in Table 7-1.

Parameter 3 specifies the excitation channel to be used for the measurement, with options to increment the excitation channel for each repetition, integration options for 60 or 50Hz noise rejection, and 10 ms delay for use with long lead lengths (Sections 7 and 8):

Excitation/Integration Codes

Code	**Result**
0x	excite all rep with channel x
1x	increment chan x with each rep
2x	excite all reps with channel x, 60 Hz rejection, 10 ms delay
3x	excite all reps with channel x, 50 Hz rejection, 10 ms delay
4x	increment chan x with each rep, 60 Hz rejection, 10 ms delay
5x	increment chan x with each rep, 50 Hz rejection, 10 ms delay

7.2 Therm107 Instruction

Therm107 instruction applies a precise 2500 mV excitation voltage and measures the voltage drop across the 1K ohm resistor (Figure 7-1). The ratio of measured voltage (Vs) to the excitation voltage (Vx) is related to thermistor resistance (Rs), and the 1000 and 249K ohm fixed resistors as shown below:

Vs/Vx = 1000/(Rs+249000+1000)

Therm107 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. Temperature, Resistance, and Datalogger Output

Temperature °C	Resistance OHMS	Output °C
-40.00	4067212	-39.18
-38.00	3543286	-37.55
-36.00	3092416	-35.83
-34.00	2703671	-34.02
-32.00	2367900	-32.13
-30.00	2077394	-30.18
-28.00	1825568	-28.19
-26.00	1606911	-26.15
-24.00	1416745	-24.11
-22.00	1251079	-22.05
-20.00	1106485	-20.00
-18.00	980100	-17.97
-16.00	869458	-15.95
-14.00	772463	-13.96
-12.00	687276	-11.97
-10.00	612366	-10.00
-8.00	546376	-8.02
-6.00	488178	-6.05
-4.00	436773	-4.06
-2.00	391294	-2.07
0.00	351017	-0.06
2.00	315288	1.96
4.00	283558	3.99
6.00	255337	6.02
8.00	230210	8.04
10.00	207807	10.06
12.00	187803	12.07
14.00	169924	14.06
16.00	153923	16.05
18.00	139588	18.02
20.00	126729	19.99
22.00	115179	21.97
24.00	104796	23.95
26.00	95449	25.94
28.00	87026	27.93
30.00	79428	29.95
32.00	72567	31.97
34.00	66365	33.99
36.00	60752	36.02
38.00	55668	38.05
40.00	51058	40.07
42.00	46873	42.07
44.00	43071	44.05
46.00	39613	46.00
48.00	36465	47.91
50.00	33598	49.77
52.00	30983	51.59
54.00	28595	53.35
56.00	26413	55.05
58.00	24419	56.70
60.00	22593	58.28

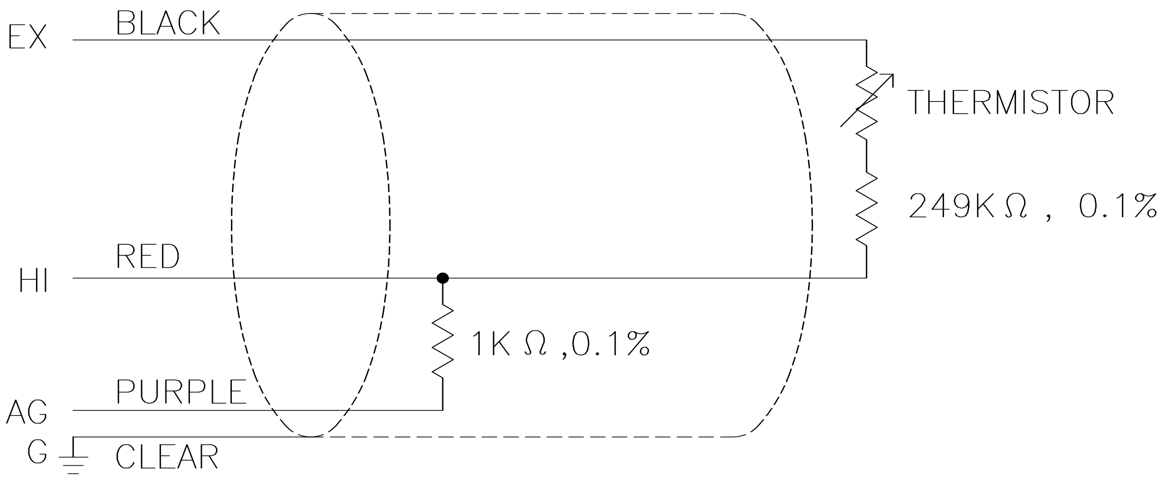

FIGURE 7-1. 107 Thermistor Probe Schematic

TABLE 7-2. Polynomial Coefficients

Coefficient	**Value**
C0	-53.4601
C1	90.807
C2	-83.257
C3	52.283
C4	-16.723
C5	2.211

8. Electrically Noisy Environments

AC power lines can be the source of electrical noise. If the datalogger is in an electronically noisy environment, the 107 temperature measurement should be measured with 60 Hz rejection. Sixty and 50 Hz rejection is available as an option in the Excitation Channel parameter of Instruction 11 for the CR10X, CR510, and CR23X dataloggers. For the CR10, CR21X and CR7, the 107 should be measured with the AC half bridge (Instruction 5). For CRBasic loggers, the Therm107 Integration parameter has options for 50 and 60 Hz rejection.

Example 8-1, CR1000 measurement instruction with 60 Hz rejection:

```
Therm107(T107_C,1,1,1,0,_60Hz,1.0,0.0)
```

Example 8-2. Sample CR10(X) Instructions Using AC Half Bridge

```
1:  AC Half Bridge (P5)
   1:              1         Reps
   2:             22         7.5 mV 60 Hz Rejection Range
   3:              9         SE Channel
   4:              3         Excite all reps w/Exchan 3
   5:           2000         mV Excitation ;Use 4000 mV on 21X and CR7
   6:              1         Loc [ Air_Temp  ]
   7:            800         Mult
   8:              0         Offset

2:  Polynomial (P55)
   1:              1         Reps
   2:              1         X Loc [ Air_Temp  ]
   3:              1         F(X) Loc [ Air_Temp  ]
   4:         -53.46         C0
   5:          90.807        C1
   6:         -83.257        C2
   7:          52.283        C3
   8:         -16.723        C4
   9:           2.211        C5
```

9. Long Lead Lengths

The 60 and 50 Hz rejection options for the CR10X, CR510, and CR23X include a delay to accommodate long lead lengths. For the CR10, 21X, and CR7, if the 107 has lead lengths of more than 300 feet, use the DC Half Bridge instruction (Instruction 4) with a 20 millisecond delay to measure temperature. 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 delay provides a longer settling time before the measurement is made. Do not use the 107 with long lead lengths in an electrically noisy environment.

Example 9-1. CR1000 measurement instruction with 20 mSec (20000 uSec) delay:

```
Therm107(T107_C,1,1,1,20000,_60Hz,1.0,0.0)
```

Example 9-2. CR10X Measurement Instructions Using DC Half Bridge with Delay

```
1:  Excite-Delay (SE) (P4)
   1:              1         Reps
   2:              2         7.5 mV Slow Range
   3:              9         SE Channel
   4:              3         Excite all reps w/Exchan 3
   5:              2         Delay (units 0.01 sec)
   6:           2000         mV Excitation ;Use 4000 mV on 21X and CR7
   7:              1         Loc [ Air_Temp  ]
   8:               .4       Mult ;Use 0.2 on 21X and CR7
   9:              0         Offset
```

```
2:  Polynomial (P55)
   1:          1        Reps
   2:          1        X Loc [ Air_Temp  ]
   3:          1        F(X) Loc [ Air_Temp  ]
   4:     -53.46        C0
   5:      90.807       C1
   6:     -83.257       C2
   7:      52.283       C3
   8:     -16.723       C4
   9:       2.211       C5
```

10. Troubleshooting

Symptom: Temperature is NAN, -INF, -9999

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 -86, -53

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, 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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