INSTRUCTION MANUAL

Model 109SS Temperature Probe

Revision: 3/14

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Model 109SS Temperature Probe

1. Introduction

The 109SS Temperature Probe uses a thermistor to measure temperature in soil and water. It is compatible with all CRBasic and Edlog dataloggers except the CR9000(X). See Section 6, *Specifications*, for a complete list of compatible dataloggers.

2. Cautionary Statements

Santoprene® rubber, which composes the black outer jacket of the 109SS cable, will support combustion in air. It is used because of its resistance to temperature extremes, moisture, and UV degradation. It is rated as slow burning when tested according to U.L. 94 H.B. and passes FMVSS302. However, local fire codes may preclude its use inside buildings.

3. Initial Inspection

- Check the packaging and contents of the shipment. If damage occurred during transport, immediately file a claim with the carrier. Contact Campbell Scientific to facilitate repair or replacement.

- Check model information against the shipping documents to ensure the expected products and the correct lengths of cable are received. Model numbers are found on each product. On cables and cabled items, the model number is usually found at the connection end of the cable. Report any shortages immediately to Campbell Scientific.

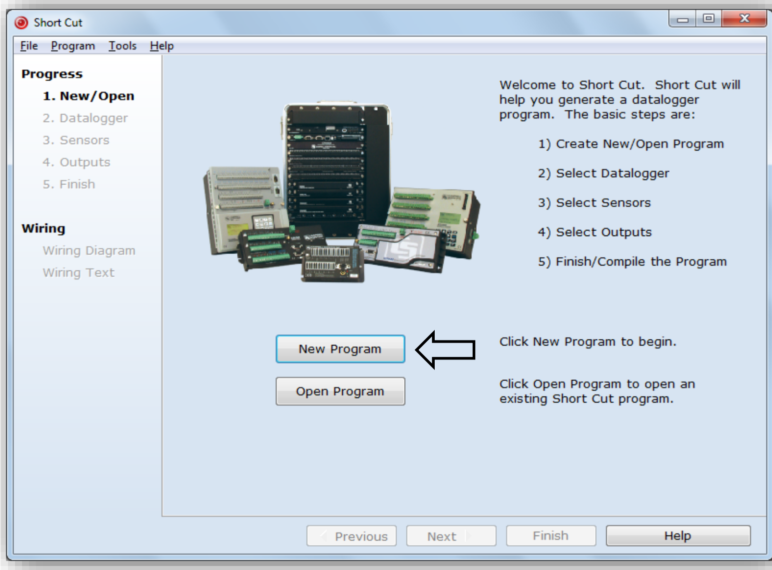
4. Quickstart

Short Cut is an easy way to program your datalogger to measure the 109SS probe and assign datalogger wiring terminals. Use the following procedure to get started.

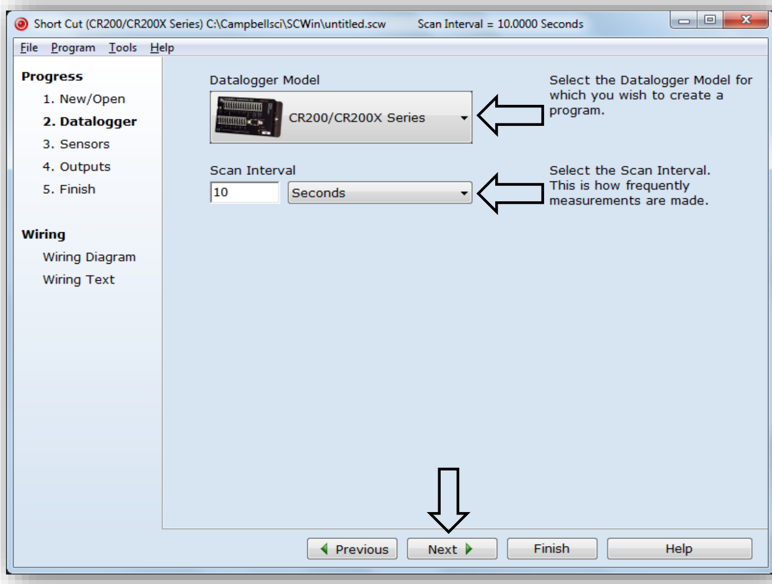
1. Install *Short Cut* by clicking on the install file icon. Get the install file from either *www.campbellsci.com*, the ResourceDVD, or find it in installations of *LoggerNet*, *PC200W*, *PC400*, or *RTDAQ* software.

2. The *Short Cut* installation should place a shortcut icon on the desktop of your computer. To open Short Cut, click on this icon.

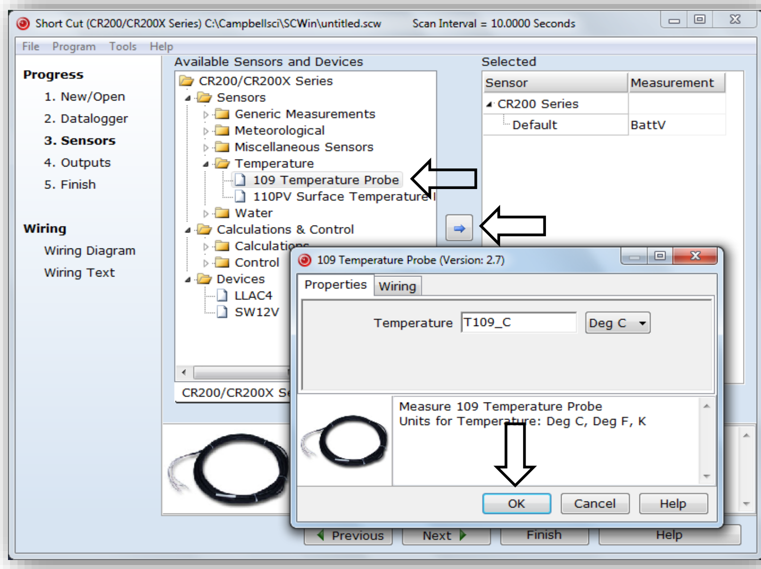
3. When *Short Cut* opens, select **New Program**.



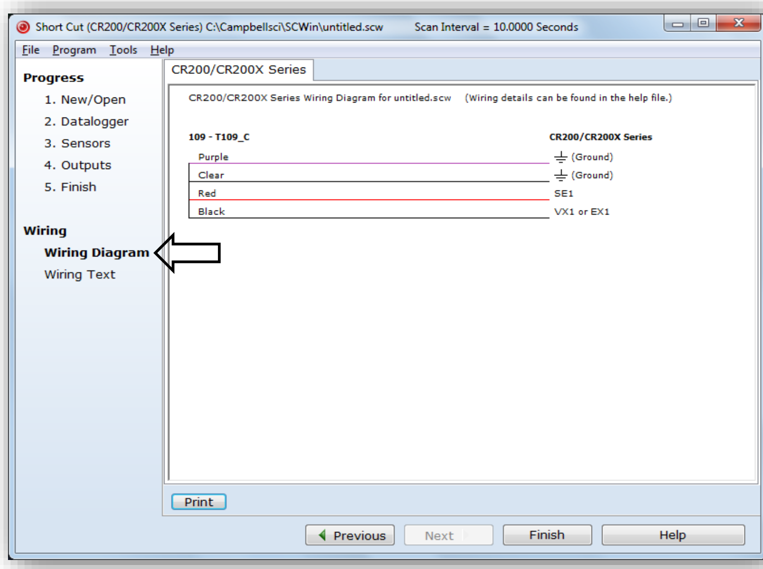
4. Select **Datalogger Model** and **Scan Interval** (default of **5** or **10** seconds is OK for most applications). Click **Next**.



5. Under the **Available Sensors and Devices** list, select the **Sensors | Temperature** folder. Select **109 Temperature Probe**. Click [→] to move the selection to the **Selected** device window. Data defaults to degree Celsius. This can be changed by clicking the **Deg C** box and selecting **Deg F,** for degrees Fahrenheit, or **K,** for Kelvin.



6. After selecting the sensor, click at the left of the screen on **Wiring Diagram** to see how the sensor is to be wired to the datalogger. The wiring diagram can be printed out now or after more sensors are added.



7. Select any other sensors you have, and then finish the remaining *Short Cut* steps to complete the program. The remaining steps are outlined in *Short Cut Help*, which is accessed by clicking on **Help | Contents | Programming Steps**.

8. If *LoggerNet*, *PC400*, *RTDAQ*, or *PC200W* is running on your PC, and the PC to datalogger connection is active, you can click **Finish** in *Short Cut* and you will be prompted to send the program just created to the datalogger.

9. If the sensor is connected to the datalogger, as shown in the wiring diagram in step 6, check the output of the sensor in the datalogger support software data display to make sure it is making reasonable measurements.

5. Overview

The 109SS is a rugged probe that accurately measures soil or water temperature in a variety of applications. The sensor consists of a thermistor encased in a stainless-steel sheath. This design protects the thermistor, allowing the 109SS to be buried or submerged in harsh, corrosive environments. It can be submerged in water to 45 m (150 ft) or 63 psi. See *Specifications* for a complete list of compatible dataloggers.

6. Specifications

Features:

- Measures soil or water temperature
- Compatible with AM16/32-series multiplexers
- Easy to install or remove
- Durable
- Compatible with Campbell Scientific CRBasic dataloggers CR200(X) series, CR800 series, CR1000, CR3000, and CR5000. Also compatible with Edlog dataloggers CR10(X), CR500, CR510, CR23X, 21X, and CR7(X)

Sensor Element:	Measurement Specialties Micro-BetaCHIP Thermistor Probe (MCD) 10K3MCD1
Survival Range:	–50 to 100 °C (thermistor) –50 to 70 °C (overmolded joint and cable)
Measurement Range:	–40 to 70 °C
Time Constant:	31 s in still air 7.5 s in a wind speed of 3 m/s 0.5 s in rolling water or antifreeze
Maximum Cable Length:	1000 ft
Accuracy[1]	
Worst case:	±0.6 °C over –40 to 70 °C ±0.49°C over –20 to 70 °C (FIGURE 6-1)
Interchangeability Error:	±0.60 °C at –40 °C ±0.38 °C at 0 °C ±0.10 °C at 25 °C ±0.30 °C at 50 °C ±0.45 °C at 70 °C

Maximum Steinhart-Hart Linearization Error:	0.02 °C at –40 °C

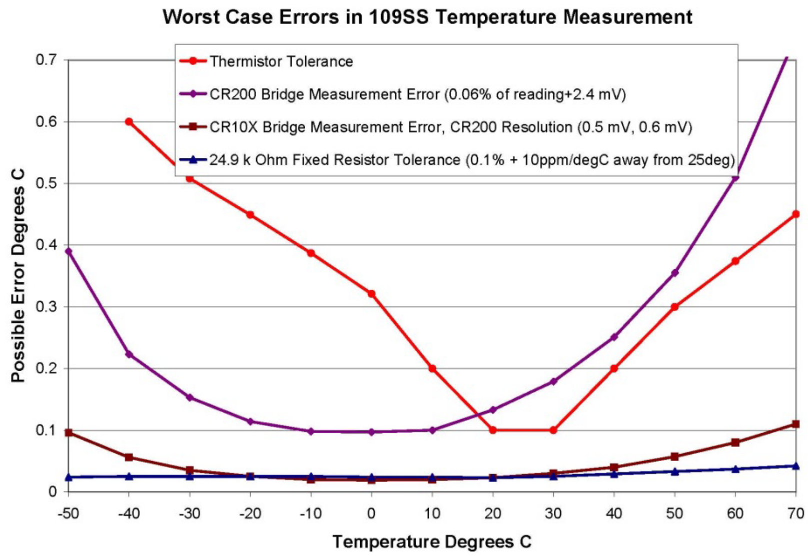


FIGURE 6-1. Worst-case probe and measurement errors

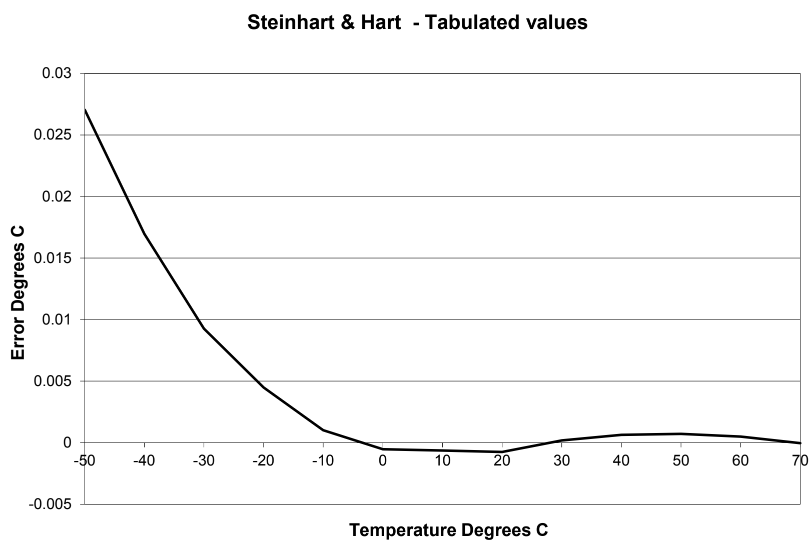


FIGURE 6-2. Steinhart-Hart linearization error

[1]The overall probe accuracy is a combination of the thermistor interchangeability specification and the accuracy of the bridge resistor. The Steinhart-Hart equation used in CRBasic instruction **Therm109()** (CRBasic dataloggers) has negligible error. 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.

Stainless-Steel Sheath
Diameter: 0.16 cm (0.063 in)
Length: 5.84 cm (2.3 in)

Overmolded Joint
Diameter: 1.02 cm (0.40 in)
Length: 4.24 cm (1.67 in)

Cable: Santoprene®, 0.220 in diameter

Cable/Probe Connection: ATUM™ heat shrink
Macromelt® overmolded joint

Weight: 0.2 lb per 10.5 ft cable

7. Installation

If you are programming your datalogger with *Short Cut*, skip Section 7.1, *Wiring to Datalogger*, and Section 7.2, *Datalogger Programming*. *Short Cut* does this work for you. See Section 4, *Quickstart*, for a *Short Cut* tutorial.

7.1 Wiring to Datalogger

TABLE 7-1. Wire Color, Function, and Datalogger Connection

Wire Color	Wire Function	Datalogger Connection Terminal
Black	Voltage-excitation input	**EX**, **VX** (voltage excitation)
Red	Analog-voltage output	**SE** (single-ended, analog-voltage input)
Purple	Bridge-resistor lead	**AG** or ⏚ (analog ground)
Clear	EMF shield	**G** (power ground)

7.2 Datalogger Programming

Short Cut is the best source for up-to-date datalogger programming code. Programming code is needed when:

- Creating a program for a new datalogger installation.
- Adding sensors to an existing datalogger program.

If your data acquisition requirements are simple, you can probably create and maintain a datalogger program exclusively with *Short Cut*. If your data acquisition needs are more complex, the files that *Short Cut* creates are a great source for programming code to start a new program or add to an existing custom program.

NOTE *Short Cut* cannot edit programs after they are imported and edited in *CRBasic Editor*.

A *Short Cut* tutorial is available in Section 4, *Quickstart*. If you wish to import *Short Cut* code into either *Edlog* or *CRBasic Editor* to create or add to a customized program, follow the procedure in Appendix A.1, *Importing Short Cut Code into a Program Editor*. Programming basics for CRBasic and Edlog dataloggers are provided in the following sections. Complete program examples for select dataloggers can be found in Appendix B, *Example Programs*.

If the 109SS probe is to be used with long cable lengths or in electrically noisy environments, consider employing the measurement programming techniques outlined in Section 8.3, *Electrically Noisy Environments*, and Section 8.4, *Long Cable Lengths*.

Details of 109SS probe measurement and linearization of the thermistor output are provided in Section 8.2, *Measurement and Output Linearization*.

7.2.1 CRBasic

The **Therm109()** measurement instruction programs most CRBasic dataloggers (CR200(X) series, CR800 series, CR1000, CR3000, CR5000) to measure the 109SS probe. It makes a half-bridge resistance measurement and converts the result to temperature using the Steinhart-Hart equation (see Section 8.2, *Measurement and Output Linearization*, for more information):

```
Therm109(Dest,Reps,SEChan,VxChan,SettlingTime,Integ,Mult,Offset)
```

The instruction for CR200(X) series dataloggers excludes the Settling Time and Integration parameters.

Variations:

- Temperature reported as °C — set **Mult** to **1** and **Offset** to **0**
- Temperature reported as °F — set **Mult** to **1.8** and **Offset** to **32**
- Ac mains noise filtering — set **Integ** to **_60Hz** or **_50Hz** (see Section 8.3, *Electrically Noisy Environments*)
- Compensate for long cable lengths — Set **SettlingTime** to **20000** (see Section 8.4, *Long Cable Lengths*)

7.2.2 Edlog

The **AC Half Bridge (P5)** instruction programs Edlog dataloggers (CR10(X), CR510, CR500, CR23X, 21X, and CR7(X)) to measure the 109SS probe in a half-bridge configuration. **Polynomial (P55)** applies the Steinhart-Hart equation using a fifth-order polynomial to convert the measurement to temperature (see Section 8.2, *Measurement and Output Linearization*, for more information):

```
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        Multiplier
 8: 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 [ Rs        ]

5:  Z=LN(X) (P40)
 1: 4        X Loc [ Rs        ]
 2: 5        Z Loc [ lnRs      ]

6:  Z=X*F (P37)
 1: 5        X Loc [ lnRs      ]
 2: 0.001    F
 3: 6        Z Loc [ Scal_lnRs ]

7:  Polynomial (P55)
 1: 1        Reps
 2: 6        X Loc [ Scal_lnRs ]
 3: 7        F(X) Loc [ 1_Tk      ]
 4: .001129  C0
 5: .234108  C1
 6: 0        C2
 7: 87.7547  C3
 8: 0        C4
 9: 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 [ T109_C    ]
```

Variations:

- Temperature reported as °F — add a multiplier **1.8** using the **Z=X*F (P37)** instruction, and an offset of **32** using the **Z=X+F (P34)** instruction.
- Ac mains noise filtering — see Section 8.3, *Electrically Noisy Environments*
- Compensate for long cable lengths — see Section 8.4, *Long Cable Lengths*

7.3 Water Temperature Installation

109SS probes can be submerged to 45 m (150 ft) or 63 psi. The 109SS is not weighted, so a weighting system should be added, or the probe secured to a fixed submerged object such as a piling.

7.4 Soil Temperature Installation

The 109SS tends to measure the average temperature over its length, so it should generally be buried such that the measurement tip is horizontal to the soil surface at the desired depth.

One or two coils of cable should also be buried in a shallow installation. Burial of some cable mitigates the effect of solar heating of the above ground cable on the temperature measurement.

Placement of the cable inside a rugged conduit may be necessary for long cable runs, especially in locations subject to digging, mowing, traffic, use of power tools, or lightning strikes.

The maximum burial depth for soil that could become saturated with water is dictated by the maximum water pressure allowed for the sensor, which is 21 psi.

8. Operation

8.1 Sensor Schematic

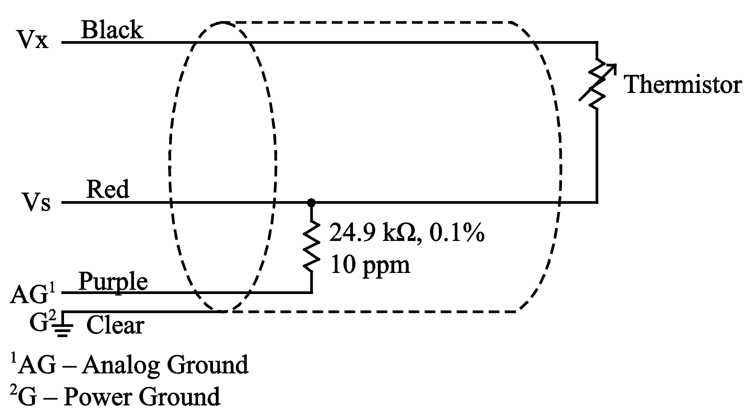


FIGURE 8-1. 109SS thermistor probe schematic

8.2 Measurement and Output Linearization

Campbell Scientific dataloggers measure the 109SS probe thermistor and convert the result to temperature. With reference to the previous FIGURE 8-1, *109SS thermistor probe schematic*, a precise excitation voltage is applied at the Vx line and the voltage drop across the 24.9 kΩ resistor is measured at the Vs line.

The ratio of measured voltage (Vs) to excitation voltage (Vx) is related to thermistor resistance (Rs) and the 24.9 kΩ fixed resistor as described in the following equation:

$$Vs/Vx = 24900 / (Rs + 24900)$$

Solving for Rs:

$$Rs + 24900 = 24900 \cdot (Vx/Vs)$$

$$Rs = 24900 \cdot ((Vx/Vs) - 1)$$

TABLE 8-1, *109SS Measurement Details*, and TABLE 8-2, *109SS Temperature Calculation,* describe how measurement results Vs/Vx and Rs are converted to temperature by Campbell Scientific dataloggers.

TABLE 8-1. 109SS-Measurement Details

Datalogger Model	Measurement Instruction	Excite mV	Voltage Input Range	Result	Scaling	Equation Applied to Scaled Result
CR200(X) Series CR800 CR1000 CR3000 CR5000	CRBasic **Therm109()**					Steinhart-Hart (automatically applied)
CR500 CR510 CR10 CR10X	Edlog **AC Half Bridge (P5)**	2500	2500 mV	Vs/Vx	ln(Rs) by 1E–3	Steinhart-Hart (use **Polynomial (P55)**)
21X CR7(X) CR23X	Edlog **AC Half Bridge (P5)**	5000	5000 mV	Vs/Vx	ln(Rs) by 1E–3	Steinhart-Hart (use **Polynomial (P55)**)

TABLE 8-2. 109SS Temperature Calculation

CRBasic Dataloggers[1]

Therm109() instruction measures the ratio Vs/Vx, calculates the thermistor resistance Rs, and converts Rs to temperature using the Steinhart-Hart equation[2]:

$$T = 1 / (A + (B \cdot \ln(Rs))) + (C \cdot ((\ln(Rs))) ^\wedge 3) – 273.15$$

where:

T = temperature in degrees Celsius

A = 1.129241E–3

B = 2.341077E–4

C = 8.775468E–8

Edlog Dataloggers[3]

AC Half Bridge (P5) instruction measures the ratio Vs/Vx. Mathematical instructions calculate and pre-scale ln(Rs) by 1E–3. This creates adequate resolution for **Polynomial (P55)** instruction to apply the Steinhart-Hart equation with a fifth-order polynomial. The inverse of the result, Tk, is found with the **Z=1/X (P42)** instruction:

$$1/Tk = C0 + C1 \cdot X + C2 \cdot X^2 + C3 \cdot X^3 + C4 \cdot X^4 + C5 \cdot X^5$$

where: Tk = temperature in Kelvin X = 0.001 • ln(Rs) C0 = A = 0.001129 C1 = B • 1E3 = 0.234108 C2 = 0 C3 = C • 1E9 = 87.7547 C4 = 0 C5 = 0 See Appendix C, *Thermistor Resistance Table*.
[1]CRBasic dataloggers are CR800, CR1000, CR3000, and CR5000. [2]Coefficients provided by the thermistor manufacturer. [3]Edlog dataloggers are CR10(X), CR510, CR500, CR23X, 21X, and CR7.

8.3 Electrically Noisy Environments

EMF noise emanating from the ac mains power grid can be a significant source of measurement error. 60 Hz noise is common in the United States. 50 Hz noise is common in Europe and other regions. Depending on the datalogger model, this noise can usually be filtered out.

The following code examples filter 60 Hz noise. The key parameters are in bold type.

CRBasic

```
Therm109(T109_C,1,1,1,20000,_60Hz,1.0,0.0)
```

NOTE Filtering parameter options are not available for CR200(X) series dataloggers.

Edlog

```
1:  AC Half Bridge (P5)
  1:   1         Reps
  2:   25        2500 mV 60 Hz Rejection Range ;CR23X:5000 mV; 21X,CR7:5000 mV slow
  3:   1         SE Channel
  4:   1         Excite all reps w/Exchan 1
  5:   2500      mV Excitation                ;CR23X,21X,CR7: 5000 mV
  6:   1         Loc [ V_Vx  ]
  7:   1.0       Mult
  8:   0.0       Offset
```

8.4 Long Cable Lengths

Long cable lengths may require longer than normal analog measurement settling times. Settling times are increased by adding a measurement delay to a datalogger program.

CRBasic

For CRBasic loggers, the 60 Hz and 50 Hz integration options include a 3 ms settling time; longer settling times also can be entered into the ***Settling Time*** parameter. The following example uses a 20000 µs settling time:

```
Therm109(T109_C,1,1,1,20000,_60Hz,1.0,0.0)
```

NOTE Integration options and the settling time parameter are not available for CR200(X) series dataloggers.

Edlog

In place of the **AC Half Bridge (P5)**, use the **Excite-Delay (SE) (P4)** instruction with a 20 ms delay to measure the probe, as shown in the following example:

```
1:  Excite-Delay (SE) (P4)
  1:   1          Reps
  2:   5          2500 mV Slow Range     ;CR23X,21X,CR7: 5000 mV
  3:   1          SE Channel
  4:   1          Excite all reps w/Exchan 1
  5:   2          Delay (0.01 sec units)
  6:   2500       mV Excitation          ;CR23X,21X,CR7: 5000 mV
  7:   3          Loc [V_Vx   ]
  8:   .0004      Multiplier
  9:   0.0        Offset
```

9. Troubleshooting and Maintenance

NOTE All factory repairs and recalibrations require a returned material authorization (RMA) and completion of the "Declaration of Hazardous Material and Decontamination" form. Refer to the *Assistance* page at the beginning of this manual for more information.

9.1 Troubleshooting

Symptom: Temperature is reported as **NAN**, **-INF**, **-9999**, or **-273**.

Recheck wiring. 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 is reported.

Verify the multiplier and offset arguments in the measurement instruction are correct for the desired units (Section 7.2, *Datalogger Programming*). Check the cable for signs of damage and possible moisture intrusion.

Symptom: Unstable temperature is reported.

Most likely a result of electromagnetic interference. Try using the 60 or 50 Hz integration options, and/or increasing the settling time as described in Section 8.3, *Electrically Noisy Environments*, and Section 8.4, *Long Cable Lengths*. Make sure the clear shield wire is connected to datalogger ground, and the datalogger is properly grounded.

9.2 Maintenance

The 109SS probe requires minimal maintenance. Periodically check cabling for signs of damage and possible moisture intrusion.

9.3 Calibration

Calibration of the 109SS probe is not necessary unless the application requires removal of the thermistor interchangeability offset described in Section 6, *Specifications*. If performing the one point calibration with an Edlog datalogger, be aware of this precaution:

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 109SS probe placed in a calibration chamber at 0 °C outputs 0.1 °C. An ***Offset*** argument of ***–0.08*** is required for Edlog dataloggers because at 0 °C, the polynomial calculates a temperature of 0.02 °C (Appendix C, *Conversion of Thermistor Resistance or Voltage Ratio to Temperature*).

10. Attributions and References

Santoprene® is a registered trademark of Exxon Mobile Corporation.

ATUM is a trademark of Tyco Electronics Corporation.

Macromelt® is a trademark of Henkel Corporation.

Appendix A. Importing Short Cut Code

This tutorial shows:

- How to import a *Short Cut* program into a program editor for additional refinement.
- How to import a wiring diagram from *Short Cut* into the comments of a custom program.

A.1 Importing Short Cut Code into a Program Editor

Short Cut creates files that can be imported into either *CRBasic Editor* or *Edlog* program editor. These files normally reside in the C:\campbellsci\SCWin folder and have the following extensions:

- .DEF (wiring and memory usage information)
- .CR1 (CR1000 datalogger code)
- .CR8 (CR800 datalogger code)
- .CR3 (CR3000 datalogger code)
- .CR5 (CR5000 datalogger code)
- .DLD (contain code for CR10(X), CR23X, CR500, CR510, 21X, or CR7(X) dataloggers)

The following procedures show how to import these files for editing.

A.1.1 CRBasic Datalogger

Use the following procedure to import *Short Cut* code into *CRBasic Editor* (CR1000, CR800, CR3000, CR5000 dataloggers).

1. Create the *Short Cut* program following the procedure in Section 4, *Quickstart*. Finish the program and exit *Short Cut*. Make note of the file name used when saving the *Short Cut* program.

2. Open *CRBasic Editor*.

3. Click **File | Open**. Assuming the default paths were used when *Short Cut* was installed, navigate to C:\CampbellSci\SCWin folder. The file of interest has a ".CR1", ".CR8", ".CR3", or ".CR5" extension, for CR1000, CR800, CR3000, or CR5000 dataloggers, respectively. Select the file and click **Open**.

4. Immediately save the file in a folder different from \Campbellsci\SCWin, or save the file with a different file name.

NOTE Once the file is edited with *CRBasic Editor*, *Short Cut* can no longer be used to edit the datalogger program. Change the name of the program file or move it, or *Short Cut* may overwrite it next time it is used.

5. The program can now be edited, saved, and sent to the datalogger.

6. Import wiring information to the program by opening the associated .DEF file. Copy and paste the section beginning with heading "-Wiring for CRXXX–" into the CRBasic program, usually at the head of the file. After pasting, edit the information such that a **'** character (single quotation mark) begins each line. This character instructs the datalogger compiler to ignore the line when compiling the datalogger code.

A.1.2 Edlog

Use the following procedure to import *Short Cut* code into the *Edlog* program editor (CR10(X), CR500, CR510, CR23X, 21X, and CR7(X) dataloggers).

1. Create the *Short Cut* program following the procedure in Section 4, *Quickstart*. Finish the program and exit *Short Cut*. Make note of the file name used when saving the *Short Cut* program.

2. Open *Edlog*.

3. Click **File | Document DLD File**. Assuming the default paths were used when *Short Cut* was installed, navigate to C:\CampbellSci\SCWin folder. The file of interest has a ".DLD" extension. Select the file and click **Open**. The .dld file, which is a type of ASCII machine code, is imported, documented, and, when saved, given a ".CSI" extension.

4. Immediately save the file in a folder different from \Campbellsci\SCWin, or save the file with a different file name.

NOTE Once the file is edited with *Edlog*, *Short Cut* can no longer be used to edit the program. Change the name of the program file or move it, or *Short Cut* may overwrite it.

5. The program can now be edited, saved, and sent to the datalogger.

6. Import wiring information to the program by opening the associated .DEF file. Copy and paste the section beginning with heading "-Wiring for CRXXX–" into the Edlog program, usually at the head of the file. After pasting, edit the information such that a **;** (semicolon) begins each line, which instructs the datalogger compiler to ignore the line when compiling the datalogger code.

Appendix B. Example Programs

B.1 Example CRBasic Programs

B.1.1 Example 1 — Sample program for CR200(X) series dataloggers

```
'Program measures one 109SS temperature probe once a second and
'stores the average temperature every 60 minutes.

'Wiring Diagram
'==============
'109SS Probe

'  Wire
'  Color      Function                       CR200(X)
'  -----      ---------                      ------
'  Black      Voltage-excitation input       VX1 or EX1
'  Red        Analog-voltage output          SE1
'  Purple     Bridge-resistor ground         AG*
'  Clear      Shield                         G*

'*AG = Analog Ground (represented by ground symbol on CR200 wiring panel

'Declare the variable for the temperature measurement
Public T109_C

'Define a data table for 60 minute averages
DataTable (Table1,True,-1)
    DataInterval (0,60,min)
    Average (1,T109_C,False)
EndTable

BeginProg
    Scan (1,sec)
        'Measure the temperature
        Therm109 (T109_C,1,1,Ex1,1.0,0)
        'Call Data Table
        CallTable Table1
    NextScan
EndProg
```

B.1.2. Example 2 — Sample program for CR800 series, CR1000, CR3000, and CR5000 dataloggers

```
'Program measures one 109SS temperature probe once a second and
'stores the average temperature every 60 minutes.

'Wiring Diagram
'==============
'109SS Probe
'
'  Wire
'  Color      Function                       CR1000
'  -----      ---------                      ------
'  Black      Voltage-excitation input       VX1 or EX1
'  Red        Analog-voltage output          SE1
'  Purple     Bridge-resistor ground         AG*
'  Clear      Shield                         G*
```

```
'*AG = Analog Ground (represented by ground symbol on CR1000 wiring panel

'Declare the variables for the temperature measurement
Public T109_C

'Define a data table for 60 minute averages
DataTable(Table1,True,-1)
    DataInterval(0,10,Min,10)
    Average(1,T109_C,FP2,False)
EndTable

'Main Program
BeginProg
    Scan(1,Sec,1,0)
        'Measure the temperature
        Therm109(T109_C,1,1,1,0,_60Hz,1.0,0)
        'Call Data Table
        CallTable(Table1)
    NextScan
EndProg
```

B.1.3 Example 3 — Sample Program using the BrHalf() instruction rather than Therm109()

```
'Program measures a single 109 Thermistor probe once a second and
'stores the average temperature every 60 minutes.

'Wiring Diagram
'==============
'109SS Probe
'
'  Wire
'  Color      Function                     CR1000
'  -----      --------                     ------
'  Black      Voltage-excitation input     VX1 or EX1
'  Red        Analog-voltage output        SE1
'  Purple     Bridge-resistor ground       AG*
'  Clear      Shield                       G*

'*AG = Analog Ground (represented by ground symbol on CR1000 wiring panel

'Declare the variables for the temperature measurement
Public T109_C

'Declare variables for the raw measurement, thermistor resistance,
'and ln(resistance):
Dim V_Vx, Rtherm, lnRt

'Define a data table for 60 minute averages
DataTable(Table1,True,-1)
    DataInterval(0,10,Min,10)
    Average(1,T109_C,IEEE4,False)
EndTable

BeginProg
    Scan (1,sec,5,0)
        'Measure the 109SS probe. The result is V/Vx.
        BrHalf (V_Vx,1,mV5000,3,Vx1,1,5000,True,0,_60Hz,1.0,0)
        'Calculate reistance:
        RTherm=24900*(1/V_Vx-1)
        'Calculate the natural log of the resistance
        lnRt=Log(Rtherm)
        'Apply the Steinhart-Hart equation and convert to degrees C in one step:
        Air_Temp=1/(1.129241e-3+2.341077e-4*lnRt+8.775468e-8*(lnRt^3))-273.15
```

```
        'Call the data table
        CallTable AvgTemp
    NextScan
EndProg
```

B.2 Example Edlog Program

This example can be used directly with CR10X dataloggers. With minor adaptations, it can also be used with CR10, CR500, CR510, CR23X, and CR7X dataloggers. More adaptation will be needed with the 21X and CR7 dataloggers. Contact a Campbell Scientific application engineer for help with any datalogger program.

```
;{CR10X}

;Program measures one 109 temperature probe once a second
;and stores the average temperature every 60 minutes.

;Wiring Diagram
;==============
;109SS Probe
;
;  Wire
;  Color      Function                        CR10X
;  -----      --------                        ------
;  Black      Voltage-excitation input        E1
;  Red        Analog-voltage output           SE1
;  Purple     Bridge-resistor ground          AG
;  Clear      Shield                          G

*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
```

Appendix C. Conversion of Thermistor Resistance or Voltage Ratio to Temperature

TABLE C-1. Voltage Ratio, Resistance, and Temperature[1]

Actual Temperature (°C)	10K3MCD1 Thermistor Resistance (Ω)	Edlog Temperature Result (°C)	CRBasic Therm109() Output (°C)
-40	336103.2	-39.99	-40.00
-39	314558	-38.99	-39.00
-38	294529.1	-37.99	-38.00
-37	275900.8	-36.99	-37.00
-36	258567	-35.99	-36.00
-35	242430.2	-34.99	-35.00
-34	227400.9	-33.99	-34.00
-33	213396.6	-32.99	-33.00
-32	200341.4	-31.99	-32.00
-31	188165.5	-30.99	-31.00
-30	176804.8	-29.99	-30.00
-29	166199.8	-28.99	-29.00
-28	156296.1	-27.99	-28.00
-27	147043.2	-26.99	-27.00
-26	138394.7	-25.99	-26.00
-25	130307.6	-24.99	-25.00
-24	122742.3	-23.99	-24.00
-23	115662.2	-22.99	-23.00
-22	109033.4	-21.99	-22.00
-21	102824.6	-20.99	-21.00
-20	97006.9	-19.99	-20.00
-19	91553.3	-18.99	-19.00
-18	86439.2	-17.99	-18.00
-17	81641.4	-16.99	-17.00
-16	77138.6	-15.99	-16.00
-15	72911.1	-14.99	-15.00
-14	68940.4	-13.99	-14.00
-13	65209.7	-12.98	-13.00
-12	61702.9	-11.98	-12.00
-11	58405.5	-10.98	-11.00
-10	55303.9	-9.98	-10.00
-9	52385.2	-8.98	-9.00
-8	49637.8	-7.98	-8.00
-7	47050.6	-6.98	-7.00
-6	44613.4	-5.98	-6.00
-5	42316.7	-4.98	-5.00
-4	40151.6	-3.98	-4.00
-3	38110	-2.98	-3.00
-2	36184	-1.98	-2.00
-1	34366.6	-0.98	-1.00
0	32650.9	0.02	0.00
1	31030.8	1.02	1.00
2	29500.5	2.02	2.00

3	28054.4	3.02	3.00
4	26687.5	4.02	4.00
5	25395	5.02	5.00
6	24172.5	6.02	6.00
7	23015.9	7.02	7.00
8	21921.2	8.02	8.00
9	20884.7	9.02	9.00
10	19903.2	10.02	10.00
11	18973.3	11.02	11.00
12	18092.2	12.02	12.00
13	17256.9	13.02	13.00
14	16464.9	14.02	14.00
15	15713.7	15.02	15.00
16	15000.9	16.02	16.00
17	14324.5	17.02	17.00
18	13682.3	18.02	18.00
19	13072.6	19.02	19.00
20	12493.3	20.02	20.00
21	11943	21.02	21.00
22	11419.9	22.02	22.00
23	10922.7	23.02	23.00
24	10449.8	24.02	24.00
25	10000	25.02	25.00
26	9572	26.02	26.00
27	9164.7	27.02	27.00
28	8777	28.02	28.00
29	8407.7	29.02	29.00
30	8056.1	30.02	30.00
31	7721	31.02	31.00
32	7401.7	32.02	32.00
33	7097.3	33.02	33.00
34	6807.1	34.02	34.00
35	6530.3	35.02	35.00
36	6266.2	36.02	36.00
37	6014.3	37.02	37.00
38	5773.8	38.02	38.00
39	5544.2	39.02	39.00
40	5325	40.02	40.00
41	5115.6	41.02	41.00
42	4915.6	42.02	42.00
43	4724.4	43.02	43.00
44	4541.7	44.02	44.00
45	4367	45.02	45.00
46	4200	46.02	46.00
47	4040.2	47.02	47.00
48	3887.4	48.02	48.00
49	3741.1	49.02	49.00
50	3601.1	50.02	50.00
51	3467	51.03	51.00
52	3338.7	52.03	52.00
53	3215.8	53.03	53.00
54	3098	54.03	54.00
55	2985.2	55.03	55.00
56	2877	56.03	56.00
57	2773.3	57.03	57.00
58	2673.9	58.03	58.00

59	2578.6	59.03	59.00
60	2487.1	60.03	60.00
61	2399.4	61.03	61.00
62	2315.2	62.03	62.00
63	2234.4	63.03	63.00
64	2156.8	64.03	64.00
65	2082.3	65.03	65.00
66	2010.8	66.03	66.00
67	1942.1	67.03	67.00
68	1876	68.03	68.00
69	1812.6	69.03	69.00
70	1751.6	70.03	70.00
71	1693	71.03	71.00
72	1636.6	72.03	72.00
73	1582.4	73.03	73.00
74	1530.2	74.03	74.00
75	1480.1	75.03	75.00
[1]Data from Measurement Specialties™			

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