Product Manual

Sensor

SI-111 and SI-111SS

Precision Infrared Radiometers

Revision: 9/18

RELIABLE SINCE 1974 MONITORING

CAMPBELL SCIENTIFIC

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Safety

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General

- Prior to performing site or installation work, obtain required approvals and permits. Comply with all governing structure-height regulations, such as those of the FAA in the USA.
- Use only qualified personnel for installation, use, and maintenance of tripods and towers, and any attachments to tripods and towers. The use of licensed and qualified contractors is highly recommended.
- Read all applicable instructions carefully and understand procedures thoroughly before beginning work.
- Wear a **hardhat** and **eye protection**, and take **other appropriate safety precautions** while working on or around tripods and towers.
- **Do not climb** tripods or towers at any time, and prohibit climbing by other persons. Take reasonable precautions to secure tripod and tower sites from trespassers.
- Use only manufacturer recommended parts, materials, and tools.

Utility and Electrical

- **You can be killed** or sustain serious bodily injury if the tripod, tower, or attachments you are installing, constructing, using, or maintaining, or a tool, stake, or anchor, come in **contact with overhead or underground utility lines**.
- Maintain a distance of at least one-and-one-half times structure height, 20 feet, or the distance required by applicable law, **whichever is greater**, between overhead utility lines and the structure (tripod, tower, attachments, or tools).
- Prior to performing site or installation work, inform all utility companies and have all underground utilities marked.
- Comply with all electrical codes. Electrical equipment and related grounding devices should be installed by a licensed and qualified electrician.

Elevated Work and Weather

- Exercise extreme caution when performing elevated work.
- Use appropriate equipment and safety practices.
- During installation and maintenance, keep tower and tripod sites clear of un-trained or non-essential personnel. Take precautions to prevent elevated tools and objects from dropping.
- Do not perform any work in inclement weather, including wind, rain, snow, lightning, etc.

Maintenance

- Periodically (at least yearly) check for wear and damage, including corrosion, stress cracks, frayed cables, loose cable clamps, cable tightness, etc. and take necessary corrective actions.
- Periodically (at least yearly) check electrical ground connections.

WHILE EVERY ATTEMPT IS MADE TO EMBODY THE HIGHEST DEGREE OF SAFETY IN ALL CAMPBELL SCIENTIFIC PRODUCTS, THE CUSTOMER ASSUMES ALL RISK FROM ANY INJURY RESULTING FROM IMPROPER INSTALLATION, USE, OR MAINTENANCE OF TRIPODS, TOWERS, OR ATTACHMENTS TO TRIPODS AND TOWERS SUCH AS SENSORS, CROSSARMS, ENCLOSURES, ANTENNAS, ETC.

Table of Contents

PDF viewers: These page numbers refer to the printed version of this document. Use the PDF reader bookmarks tab for links to specific sections.

Appendices

Figure

Tables

CRBasic Example

SI-111 and SI-111SS Precision Infrared Radiometers

1. Introduction

The SI-111 and SI-111SS are precision infrared radiometers that determine the surface temperature of an object without physical contact. They measure both the surface temperature of the subject and the body temperature of the sensor. A Campbell Scientific datalogger uses these measurements to calculate the correct temperature of the subject.

The SI-111SS replaced the SI-111 in August 2018. The SI-111SS has a stainless steel connector, a removable cable, different wiring, and a serial number of 7283 or above. Both sensors are manufactured by Apogee Instruments.

NOTE This manual provides information only for CRBasic dataloggers. For retired Edlog datalogger support, see an older manual at *www.campbellsci.com/old-manuals*.

2. Precautions

- READ AND UNDERSTAND the *Safety* section at the front of this manual.
- Although the SI-111 and SI-111SS are rugged, they are also highly precise scientific instruments and should be handled as such.
- Care should be taken when opening the shipping package to not damage or cut the cable jacket. If damage to the cable is suspected, contact Campbell Scientific.

3. Initial Inspection

- Upon receipt of the sensor, inspect the packaging for any signs of shipping damage and, if found, report the damage to the carrier in accordance with policy. The contents of the package should also be inspected and a claim filed if any shipping related damage is discovered.
- The model number is printed on a label on the cable. Check this information against the shipping documents to ensure the correct product is received.
- Each sensor is shipped with a calibration certificate that is unique for each sensor. Cross check the serial number listed on the calibration certificate against the serial number on your sensor to ensure that the given calibration coefficients correspond to your sensor.

4. QuickStart

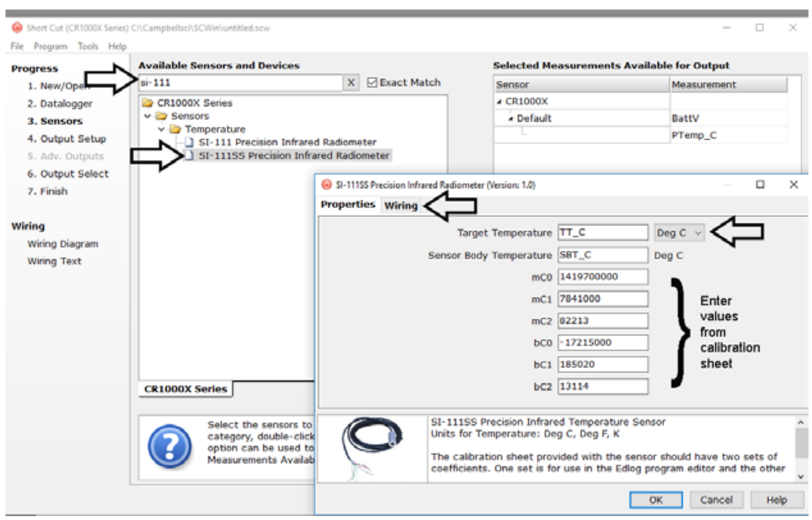
A video that describes datalogger programming using Short Cut is available at: *www.campbellsci.com/videos/cr1000x-datalogger-getting-started-program-part-3*. *Short Cut* is an easy way to program your datalogger to measure the sensor and assign datalogger wiring terminals. *Short Cut* is available as a download on *www.campbellsci.com*. It is included in installations of *LoggerNet*, *PC200W*, *PC400*, or *RTDAQ*.

The following procedure also describes programming with *Short Cut*.

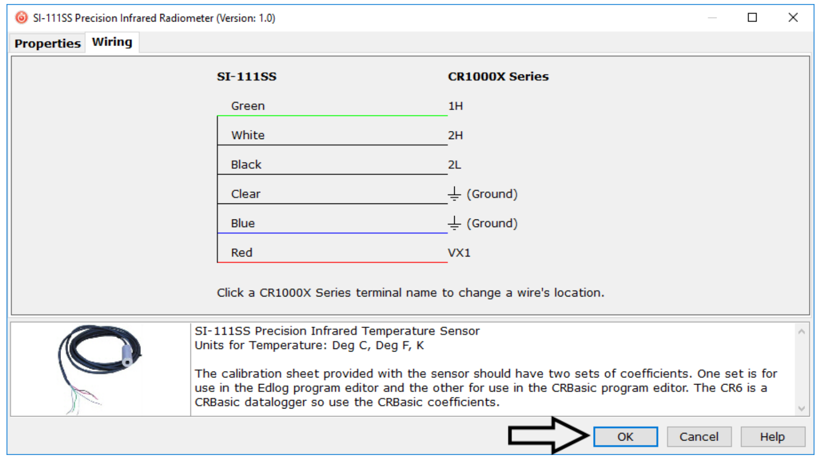
1. Open *Short Cut* and select to create a new program.

2. Double-click the datalogger model.

3. In the **Available Sensors and Devices** box, type SI-111SS or locate the sensor in the **Sensors | Temperature** folder. Double-click **SI-111SS Precision Infrared Radiometer**. Target temperature defaults to degree C. This can be changed by clicking the **Deg C** box and selecting **Deg F**, for degrees Fahrenheit, or **K** for Kelvin. Enter the **mC0, mC1, mC2, bC0, bC1**, and **bC2** values listed on the calibration sheet. These values are unique to individual sensors.

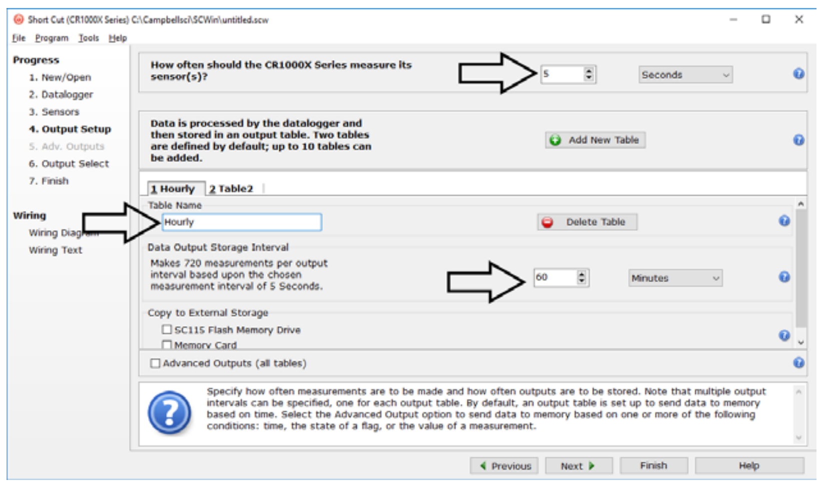


4. Click on the **Wiring** tab to see how the sensor is to be wired to the datalogger. Click **OK** after wiring the sensor.

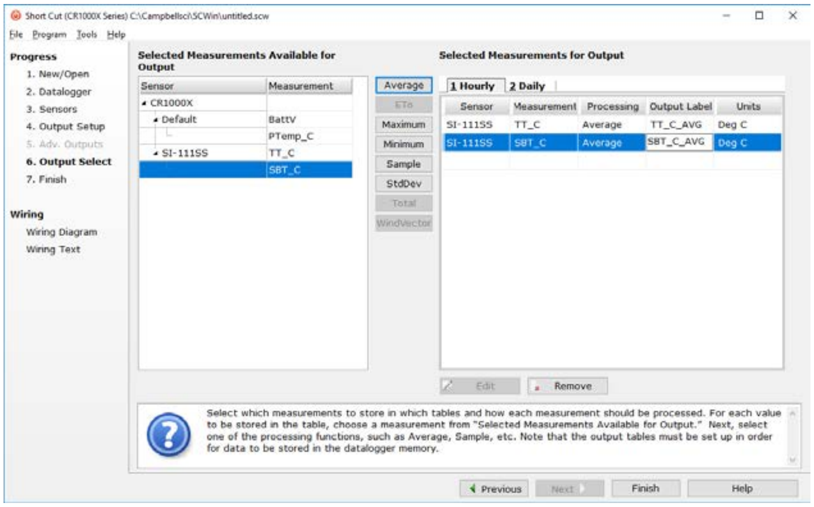


5. Repeat steps three and four for other sensors. Click **Next**.

6. In **Output Setup**, type the scan rate, meaningful table names, and the **Data Output Storage Interval**.



7. Select the measurement and its associated output options.



8. Click **Finish** and save the program. Send the program to the datalogger if the datalogger is connected to the computer.

9. If the sensor is connected to the datalogger, check the output of the sensor in the data display in *LoggerNet*, *PC400*, *RTDAQ*, or *PC200W* to make sure it is making reasonable measurements.

5. Overview

The SI-111 and SI-111SS sense the infrared radiation emitted by the target and determines surface temperature of the target without physical contact. With contact sensors, it is difficult to avoid influencing the temperature, maintain thermal contact, and provide a spatial average. By mounting infrared sensors at an appropriate distance from the target, they can measure an individual leaf, a canopy, or any surface of interest.

The SI-111 and SI-111SS consist of a thermopile, which measures surface temperature, and a thermistor, which measures sensor-body temperature. The two temperature sensors are housed in a rugged aluminum body that contains a germanium window.

Both the thermopile and the thermistor output a millivolt signal that most of our dataloggers can measure. The datalogger uses the Stefan-Boltzman equation to correct for the effect of sensor body temperature on the target temperature. The corrected readings yield an absolute accuracy of ±0.2 °C from –10 to 65 °C.

The field-of-view for infrared sensors is calculated based on the geometry of the sensor and lens. The SI-111 and SI-111SS have a 22-degree half angle field of view (FOV). The FOV is reported as the half-angle of the apex of the cone formed by the target (cone base) and the detector (cone apex). The target is a circle from which 98% of the radiation viewed by the detector is being emitted.

6. Specifications

Features:

- Measures surface temperature continuously in the field
- Provides road surface, plant canopy, soil surface, snow surface, and water surface temperature measurements
- Avoids influencing the temperature providing more accurate measurements
- Ideal for providing spatial averages
- Rugged construction—two temperature probes housed in an aluminum body with a germanium window
- Compatible with Campbell Scientific CRBasic dataloggers: CR300 series, CR6 series, CR800 series, CR1000, CR1000X, CR3000, CR5000, and CR9000(X)

Input Power:	2.5 V excitation for thermistor
Absolute Accuracy:	±0.2 °C @ –10 to 65 °C[1] ±0.5 °C @ –40 to 70 °C[2]
Uniformity:	±0.1 °C @ –10° to 65 °C ±0.3 °C @ –40° to 70 °C
Repeatability:	±0.05 °C @ –10 to 65 °C ±0.1 °C @ –40 to 70 °C
Mass:	190 g
Length:	6.3 cm
Diameter:	2.3 cm
Response Time:	Less than 1 second to changes in target temperature
Target Output Signal:	60 µV per °C difference from sensor body
Body Temperature Output Signal:	0 to 2500 mV
Optics:	Germanium lens
Wavelength Range:	8 to 14 µm
Field of View:	22° half angle
Operating Environment:	Highly water resistant, designed for continuous outdoor use; operating range is –55 to 80 °C, 0 to 100% RH

[1] Where target temperature is within 20 °C of sensor body temperature.
[2] Where target temperature is greater than 20 °C of sensor body temperature.

7. Installation

If you are programming your datalogger with *Short Cut*, skip Section 7.3, *Wiring to the Datalogger* *(p. 7)*, and Section 7.4, *Datalogger Programming* *(p. 7)*. *Short Cut* does this work for you. See Section 4, *QuickStart* *(p. 2)*, for a *Short Cut* tutorial.

7.1 Siting Considerations

Optical and atmospheric scatter and unwanted reflections from outside the field of view may influence the measurement. Under typical conditions, 95 to 98 percent of the infrared signal is from the field of view and 2 to 5 percent is from the area surrounding the field of view. If the target surface is small, for example a single leaf, try to mount the sensor close enough that the surface extends beyond the field of view.

7.2 Mounting to a Tripod, Tower, or Pole

A CM230, CM230XL, or CM220 mount can be used to mount the sensor to a CM200-series crossarm, tripod or tower mast, or a 0.75 inch-to-1-inch IPS pole. The CM230 and CM230XL are adjustable mounts that allow the sensor to be pointed at the target. The SI-111 and SI-111SS also include a hole threaded for a standard tripod camera mount screw (1/4-inch diameter; 20 threads per inch) for mounting them to a user-supplied support.

1. Remove the cap from the sensor (see FIGURE 7-1).

FIGURE 7-1. Protective cap on sensor head

2. Mount the crossarm to the tripod or tower.

3. Tighten the two nuts on the U-bolt to secure the CM230, CM230XL, or CM220 on the crossarm, mast, or pole.

4. If using the CM230 or CM230XL, place the sensor in the U-bolt and adjust the U-bolt so that the sensor points to the target. Tighten the nuts.

5. If using the CM220, place the sensor in the U-bolt with the top of the sensor pointing to the target. Tighten the nuts.

6. Route the sensor cable along the underside of the crossarm to the tripod or tower, and to the instrument enclosure.

7. Secure the cable to the crossarm and tripod or tower using cable ties.

7.3 Wiring to the Datalogger

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

SI-111 Wire Color	**SI-111SS Wire Color**	**Wire Function**	**Datalogger Connection Terminal**
Red	White	Thermopile Signal	**U** configured for differential high input[1], **DIFF H** (differential high, analog-voltage input)
Black	Black	Thermopile Signal Reference	**U** configured for differential input low[1], **DIFF L** (differential low, analog-voltage input)
Clear	Clear	Thermopile Analog Ground	⏚ (analog ground)
Green	Green	Sensor Body Signal	**U** configured for single-ended analog input[1], **SE** (single-ended, analog-voltage input)
Blue	Blue	Sensor Body Signal Reference	⏚ (analog ground)
White	Red	Voltage Excitation	**U** configured for voltage excitation[1], **VX** (voltage excitation input)

[1]**U** terminals are automatically configured by the measurement instruction.

7.4 Datalogger Programming

Short Cut is the best source for up-to-date datalogger programming code.

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* *(p. 2)*. If you wish to import *Short Cut* code into *CRBasic Editor* to create or add to a customized program, follow the procedure in Appendix A, *Importing Short Cut Code Into CRBasic Editor* *(p. A-1)*. Programming basics for CRBasic dataloggers are in the following section. Complete program examples for select CRBasic dataloggers can be found in Appendix B, *Example Program* *(p. B-1)*. Programming basics and programming examples for Edlog dataloggers are provided at *www.campbellsci.com\old-manuals*.

7.4.1 Sensor Body Temperature Measurements

7.4.1.1 Therm109() Instruction

CRBasic dataloggers measure the sensor body temperature (°C) using the **Therm109()** instruction:

Therm109(*Dest, Reps, SEChan, Mult, Offset*)

Use the default values for ***Mult*** and ***Offset,*** which output the temperature in °C.

7.4.2 Thermopile Detector

7.4.2.1 VoltDiff() Instruction

CRBasic dataloggers measure the thermopile detector using the **VoltDiff()** instruction:

VoltDiff(*Dest, Reps, Range, DiffChan, RevDiff, SettlingTime, Integ/Fnotch, Mult, Offset)*

The ***Range*** value should be ***mV200*** (CR6, CR1000X), ***mV2_5*** (CR800 series, CR1000), ***mV34*** (CR300 series), ***mV20*** (CR3000, CR5000), or ***mV50*** (CR9000(X)). The ***Integ/Fnotch*** parameter is often set to the 60 Hz option. Use the default values for the ***RevDiff***, ***SettlingTime***, ***Mult***, and ***Offset*** parameters.

7.4.3 Target Temperature Calculations

These calculations are entered in CRBasic as expressions. Calculate the target temperature using the following steps:

1. Calculate slope
2. Calculate intercept
3. Convert sensor body temperature (°C) to Kelvin.
4. Calculate target temperature (K)
5. If desired, convert target temperature (K) to degrees Celsius

Use Equation 1 to calculate slope:

m = mC2 • SBTempC^2 + mC1 • SBTempC + mC0 (1)

Where,
m = slope
SBTempC = sensor body temperature in °C
mC2 = slope polynomial coefficient (C2) from the calibration sheet
mC1 = slope polynomial coefficient (C1) from the calibration sheet
mC0 = slope polynomial coefficient (C0) from the calibration sheet

Use Equation 2 to calculate intercept:

b = bC2 • SBTempC^2 + bC1 • SBTempC + bC0 (2)

Where,

b=intercept
SBTempC = sensor body temperature in °C
bC2 = intercept polynomial coefficient (C2) from the calibration sheet
bC1 = intercept polynomial coefficient (C1) from the calibration sheet
bC0 = intercept polynomial coefficient (C0) from the calibration sheet

Equation 3 converts the sensor body temperature from degrees Celsius to Kelvin.

SBTempK = SBTempC + 273.15 (3)

Where,

SBTempK = sensor body temperature in Kelvin
SBTempC = sensor body temperature in °C

Equation 4 calculates the target temperature (K).

TargTempK = ((SBTempK^4) + m • TargmV + b)^0.25 (4)

Where,

SBTempK = sensor body temperature in Kelvin
TargmV = mV output of the thermopile infrared detector
m = slope
b=intercept

Equation 5 converts the target temperature from Kelvin to degrees Celsius.

TargTempC = TargTempK – 273.15 (5)

Where,

SBTempK = sensor body temperature in Kelvin
SBTempC = sensor body temperature in degrees Celsius

8. Maintenance

A primary source of inaccurate measurements for any radiation sensor is blocking of the optical path to the detector. The window in the infrared sensor is inset and protected, but it can become partially blocked by the following:

- Spiders can make a nest in the entrance. Use a cotton swab to apply a spider repellent around the entrance to the aperture, but not on the sensor window.
- Calcium deposits can accumulate on the window if irrigation water sprays the head. These typically leave a thin white film on the surface and can be removed with a mild acid like vinegar. Solvents such as alcohol or acetone cannot remove calcium deposits.
- Dust and dirt can be deposited in the aperture in windy environments and are best cleaned with deionized water, rubbing alcohol, or in extreme cases, acetone.

Clean the inner threads and sensor window using a cotton swab dipped in the appropriate solvent. Only use gentle pressure on the window to avoid scratching the thin optical coating on the window. Let the solvent do the cleaning, not mechanical force. Repeat the cleaning with a new cotton swab to ensure a completely clean window. In some environments, sensors can stay clean for many months, while in other environments, the sensor needs frequent cleaning.

Appendix A. Importing Short Cut Code Into CRBasic Editor

This tutorial shows:

- Importing a *Short Cut* program into a program editor for additional refinement
- Importing a wiring diagram from *Short Cut* into the comments of a custom program

Short Cut creates files, which can be imported into *CRBasic Editor*. Assuming defaults were used when *Short Cut* was installed, these files reside in the C:\campbellsci\SCWin folder:

- .DEF (wiring and memory usage information)
- .CR300 (CR300-series datalogger code)
- .CR6 (CR6-series datalogger code)
- .CR8 (CR800-series datalogger code)
- .CR1 (CR1000 datalogger code)
- .CR1X (CR1000X-series datalogger code)
- .CR3 (CR3000 datalogger code)
- .CR5 (CR5000 datalogger code)
- .CR9 (CR9000(X) datalogger code)

Import *Short Cut* code and wiring diagram into *CRBasic Editor*:

1. Create the *Short Cut* program following the procedure in Section 4, *QuickStart* *(p. 2)*. Finish the program. On the **Advanced** tab, click the **CRBasic Editor** button. The program opens in CRBasic with the name **noname.CR_**. Provide a name and save the program.

NOTE Once the file is edited with *CRBasic Editor*, *Short Cut* can no longer be used to edit the datalogger program.

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

3. Import wiring information to the program by opening the associated .DEF file. By default, it is saved in the c:\campbellsci\SCWin folder. 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 an apostrophe (') begins each line. This character instructs the datalogger compiler to ignore the line when compiling. You can highlight several lines of CRBasic code then right-click and select **Comment Block**. (This feature is demonstrated at about 5:10 in the *CRBasic | Features* video.)

Appendix B. Example Program

The example datalogger program measures the thermistor to obtain the sensor body temperature and measure the thermopile to obtain the target-to-sensor body temperature difference.

After measuring the thermopile and thermistor outputs, the sensor body temperature is used to reference the target temperature.

Wiring for the example program is shown in TABLE B-1. The actual terminals used need to be adjusted for the actual installation and application.

NOTE Coefficients used to calculate the slope (m) and intercept (b) are specific to individual sensors. The unique coefficients for each individual sensor are provided on the calibration sheet shipped with the sensor.

TABLE B-1. Wiring for Example Program

SI-111 Wire Color	SI-111SS Wire Color	Description	CR1000X
Red	White	Diff. High	**2H**
Black	Black	Diff. Low	**2L**
Clear	Clear	Analog Ground	⏚
Green	Green	Single-ended	**SE1**
Blue	Blue	Analog Ground	⏚
White	Red	Excitation	**VX1**

This example CR1000X program measures the sensor every 5 seconds and outputs a sample once every 60 seconds. The actual measurement rate and output intervals need to be adjusted for the actual installation and application.

NOTE All calibration coefficients are sensor-specific; those listed below are examples and must be changed based on the sensor being used.

CRBasic Example B-1. CR1000X Datalogger Program for Measuring SI-111 or SI-111SS

```
'CR1000X Series Datalogger Program

'Declare public variables
Public PanelT, BattV, SBTempC, SBTempK, TargmV, m, b, TargTempK, TargTempC

'Declare constants (replace the listed values with coefficients received with sensor)
Const mC2 = 82213
Const mC1 = 7841000
Const mC0 = 1419700000
Const bC2 = 13114
Const bC1 = 185020
Const bC0 = -17215000

'Define data table (table is outputting data every 60 seconds)
DataTable (IRR,1,-1)
  DataInterval (0,60,Sec,10)
  Minimum (1,BattV,FP2,0,False)
  Sample (1,PanelT,FP2)
  Average (1,TargmV,FP2,False)
  Average (1,SBTempC,FP2,False)
  Average (1,TargTempC,FP2,False)
EndTable

'Main program (program is making a measurement every 5 seconds)
BeginProg
  Scan (5,Sec,0,0)
    PanelTemp (PanelT,60)
    Battery (BattV)

'Instruction to measure sensor body temperature
    Therm109 (SBTempC,1,1,Vx1,0,60,1.0,0)

'Instruction to measure mV output of thermopile detector
    VoltDiff (TargmV,1,mV200,2,True ,0,60,1.0,0)

'Calculation of m (slope) and b (intercept) coefficients for target temperature calculation
    m = mC2 * SBTempC^2 + mC1 * SBTempC + mC0
    b = bC2 * SBTempC^2 + bC1 * SBTempC + bC0

'Calculation of target temperature
    SBTempK = SBTempC + 273.15
    TargTempK = ((SBTempK^4) + m * TargmV + b)^0.25
    TargTempC = TargTempK - 273.15

'Call output tables
    CallTable IRR
  NextScan
EndProg
```