Product Manual

Sensor

110PV

Surface Temperature Probe

RELIABLE SINCE 1974 MONITORING

CAMPBELL SCIENTIFIC

Guarantee

This equipment is guaranteed against defects in materials and workmanship. We will repair or replace products which prove to be defective during the guarantee period as detailed on your invoice, provided they are returned to us prepaid. The guarantee will not apply to:

- Equipment which has been modified or altered in any way without the written permission of Campbell Scientific
- Batteries
- Any product which has been subjected to misuse, neglect, acts of God or damage in transit.

Campbell Scientific will return guaranteed equipment by surface carrier prepaid. Campbell Scientific will not reimburse the claimant for costs incurred in removing and/or reinstalling equipment. This guarantee and the Company's obligation thereunder is in lieu of all other guarantees, expressed or implied, including those of suitability and fitness for a particular purpose. Campbell Scientific is not liable for consequential damage.

Please inform us before returning equipment and obtain a Repair Reference Number whether the repair is under guarantee or not. Please state the faults as clearly as possible, and if the product is out of the guarantee period it should be accompanied by a purchase order. Quotations for repairs can be given on request. It is the policy of Campbell Scientific to protect the health of its employees and provide a safe working environment, in support of this policy a "Declaration of Hazardous Material and Decontamination" form will be issued for completion.

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Note that goods sent air freight are subject to Customs clearance fees which Campbell Scientific will charge to customers. In many cases, these charges are greater than the cost of the repair.

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WHEN MEASUREMENTS MATTER

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PLEASE READ FIRST

About this manual

Please note that this manual was originally produced by Campbell Scientific Inc. primarily for the North American market. Some spellings, weights and measures may reflect this origin.

Some useful conversion factors:

Area:	1 in^2 (square inch) = 645 mm^2	**Mass:**	1 oz. (ounce) = 28.35 g 1 lb (pound weight) = 0.454 kg
Length:	1 in. (inch) = 25.4 mm 1 ft (foot) = 304.8 mm 1 yard = 0.914 m 1 mile = 1.609 km	**Pressure:**	1 psi (lb/in^2) = 68.95 mb
		Volume:	1 UK pint = 568.3 ml 1 UK gallon = 4.546 litres 1 US gallon = 3.785 litres

In addition, while most of the information in the manual is correct for all countries, certain information is specific to the North American market and so may not be applicable to European users.

Differences include the U.S standard external power supply details where some information (for example the AC transformer input voltage) will not be applicable for British/European use. *Please note, however, that when a power supply adapter is ordered it will be suitable for use in your country.*

Reference to some radio transmitters, digital cell phones and aerials may also not be applicable according to your locality.

Some brackets, shields and enclosure options, including wiring, are not sold as standard items in the European market; in some cases alternatives are offered. Details of the alternatives will be covered in separate manuals.

Part numbers prefixed with a "#" symbol are special order parts for use with non-EU variants or for special installations. Please quote the full part number with the # when ordering.

Recycling information

At the end of this product's life it should not be put in commercial or domestic refuse but sent for recycling. Any batteries contained within the product or used during the products life should be removed from the product and also be sent to an appropriate recycling facility.

Campbell Scientific Ltd can advise on the recycling of the equipment and in some cases arrange collection and the correct disposal of it, although charges may apply for some items or territories.

For further advice or support, please contact Campbell Scientific Ltd, or your local agent.

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Safety

DANGER — MANY HAZARDS ARE ASSOCIATED WITH INSTALLING, USING, MAINTAINING, AND WORKING ON OR AROUND **TRIPODS, TOWERS, AND ANY ATTACHMENTS TO TRIPODS AND TOWERS SUCH AS SENSORS, CROSSARMS, ENCLOSURES, ANTENNAS, ETC**. FAILURE TO PROPERLY AND COMPLETELY ASSEMBLE, INSTALL, OPERATE, USE, AND MAINTAIN TRIPODS, TOWERS, AND ATTACHMENTS, AND FAILURE TO HEED WARNINGS, INCREASES THE RISK OF DEATH, ACCIDENT, SERIOUS INJURY, PROPERTY DAMAGE, AND PRODUCT FAILURE. TAKE ALL REASONABLE PRECAUTIONS TO AVOID THESE HAZARDS. CHECK WITH YOUR ORGANIZATION'S SAFETY COORDINATOR (OR POLICY) FOR PROCEDURES AND REQUIRED PROTECTIVE EQUIPMENT PRIOR TO PERFORMING ANY WORK.

Use tripods, towers, and attachments to tripods and towers only for purposes for which they are designed. Do not exceed design limits. Be familiar and comply with all instructions provided in product manuals. Manuals are available at www.campbellsci.eu or by telephoning +44(0) 1509 828 888 (UK). You are responsible for conformance with governing codes and regulations, including safety regulations, and the integrity and location of structures or land to which towers, tripods, and any attachments are attached. Installation sites should be evaluated and approved by a qualified engineer. If questions or concerns arise regarding installation, use, or maintenance of tripods, towers, attachments, or electrical connections, consult with a licensed and qualified engineer or electrician.

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, or 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

1. Introduction

The 110PV temperature probe uses a thermistor to measure temperature from –40 to 135 °C. It is designed for measuring the back-of-photovoltaic (PV) module temperature but also can be used to measure other surface temperatures. The 110PV is compatible with all Campbell Scientific data loggers.

> NOTE:
> This manual provides information only for CRBasic data loggers. For retired Edlog data logger 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.
- Do not use epoxy to secure the sensor head to a PV module.
- Prying the sensor head off will likely damage both the sensor and PV module; see Caution at the end of Troubleshooting (p. 14).
- The 110PV cable must be properly strain relieved after mounting the probe to the measurement surface (Cable strain relief (p. 8)).
- Placement of the cable inside a rugged conduit is advisable for long cable runs, especially in locations subject to digging, mowing, traffic, use of power tools, animals, or lightning strikes.
- Santoprene® rubber, which composes the black outer jacket of the 110PV 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

- Upon receipt of the 110PV, inspect the packaging and contents for damage. File damage claims with the shipping company.
- The model number, cable length, and cable resistance are printed on a label at the connection end of the cable. Check this information against the shipping documents to ensure the expected product and cable length are received.

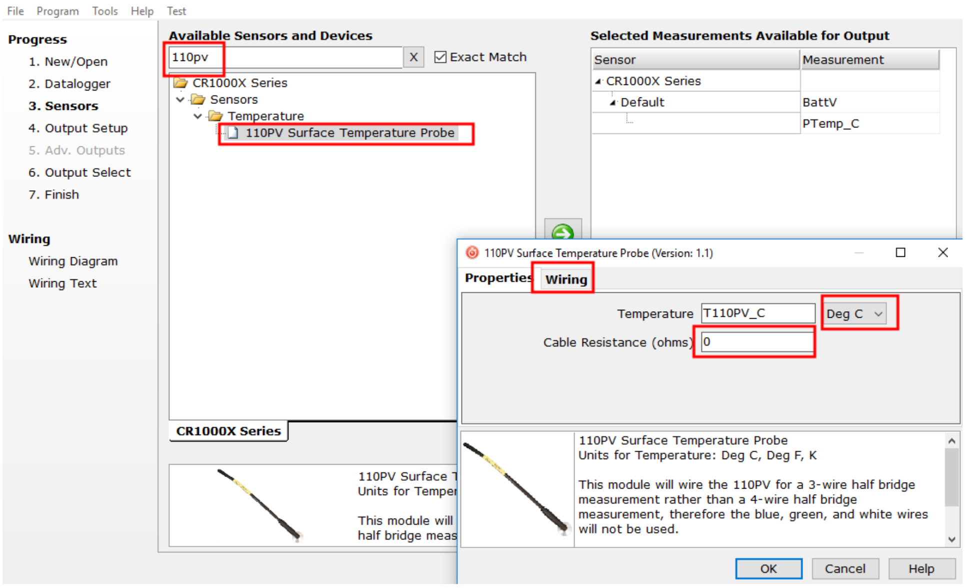
4. QuickStart

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

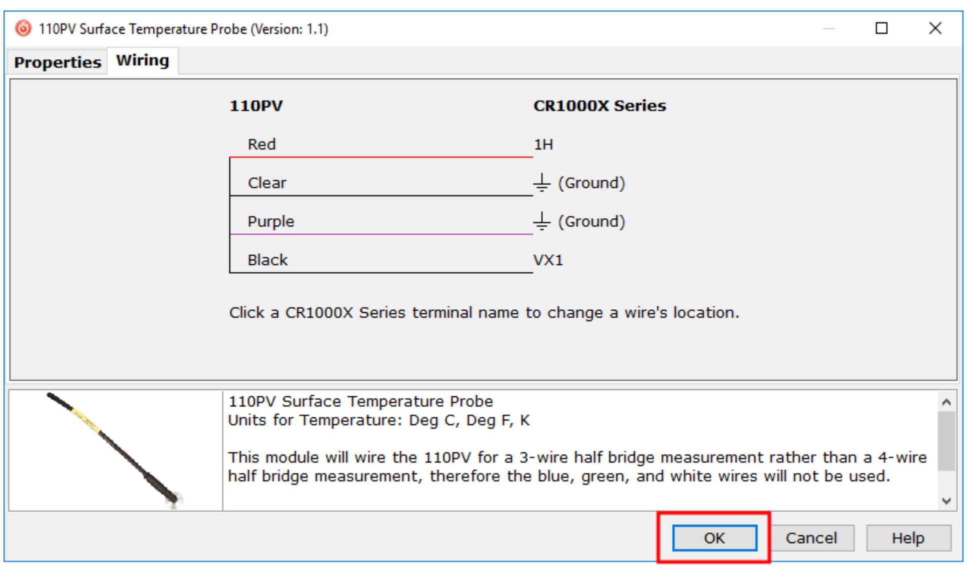
The following procedure also shows using Short Cut to program the 110PV.

1. Open Short Cut and click **Create New Program**.
2. Double-click the data logger model.

3. In the **Available Sensors and Devices** box, type 110PV. You can also locate the sensor in the **Sensors** > **Temperature** folder. Double-click **110PV**. The surface temperature defaults to degree C. This can be changed by clicking the **Temperature** box and selecting one of the other options. Enter the **Cable Resistance**. This value is unique for each 110PV, and is printed on the heat shrink label attached to the sensor cable.

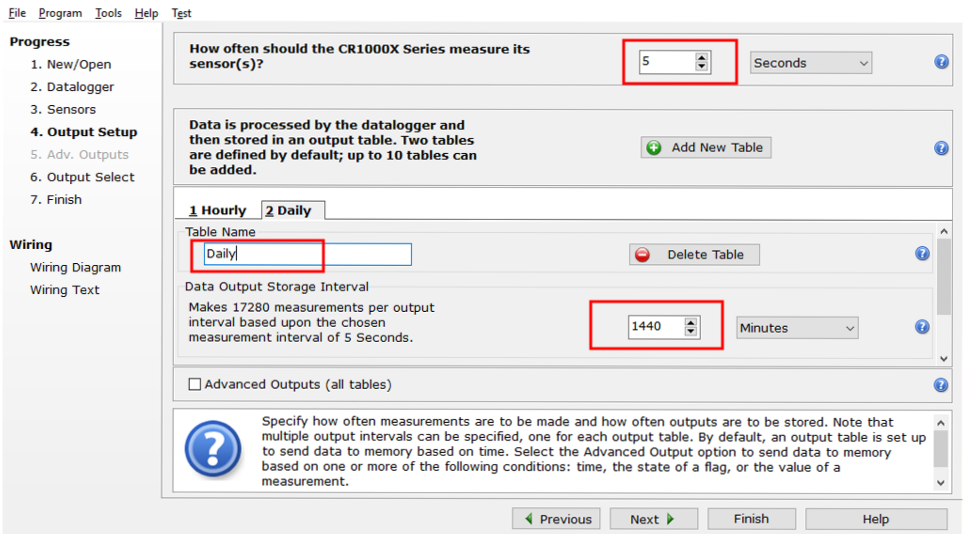


4. Click on the **Wiring** tab to see how the sensor is to be wired to the data logger. Short Cut uses a 3-wire half bridge measurement, and therefore doesn't use the blue, green, and white wires. The wiring diagram can be printed now or after more sensors are added. Click **OK** after wiring the sensor.

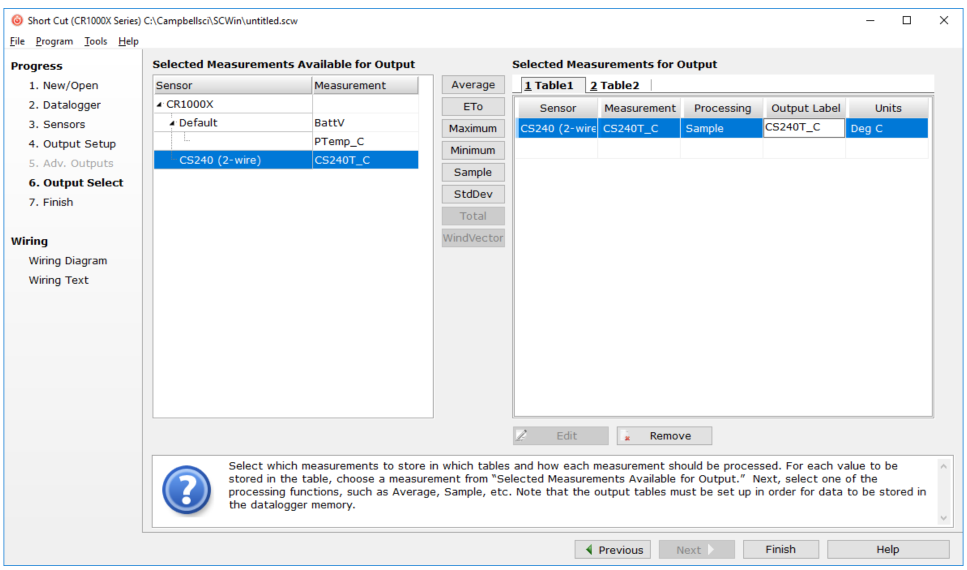


5. Repeat steps three and four for other sensors you want to measure. Click **Next**.

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



7. Select the measurement and its associated output option.



8. Click **Finish** and save the program. Send the program just created to the data logger if the data logger is connected to the computer.

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

5. Overview

The 110PV can provide the photovoltaic (PV) module temperature for solar energy applications. This measurement is useful since the output of a PV module is affected by its temperature. As the temperature of the PV module increases, its output decreases.

The 110PV consists of a thermistor encased in an aluminium disk (FIGURE 5-1 (p. 6)). The aluminium disk protects the thermistor and promotes heat transfer from surfaces. An adhesive tab on the aluminium disk fastens the 110PV to the measurement surface. If the temperature may exceed 70 °C, also use extreme sealing tape to secure the probe to the measurement surface.

Features:

- Easy to install—adhesive strips on the 110PV smooth face adhere to the back of a solar panel or other device
- Aluminium disk protects thermistor and promotes heat transfer from surfaces
- Makes accurate measurements in environments with heavy electromagnetic interference
- Compatible with Campbell Scientific CRBasic data loggers: CR6, CR3000, CR1000X, CR800 series, CR300 series, and CR1000

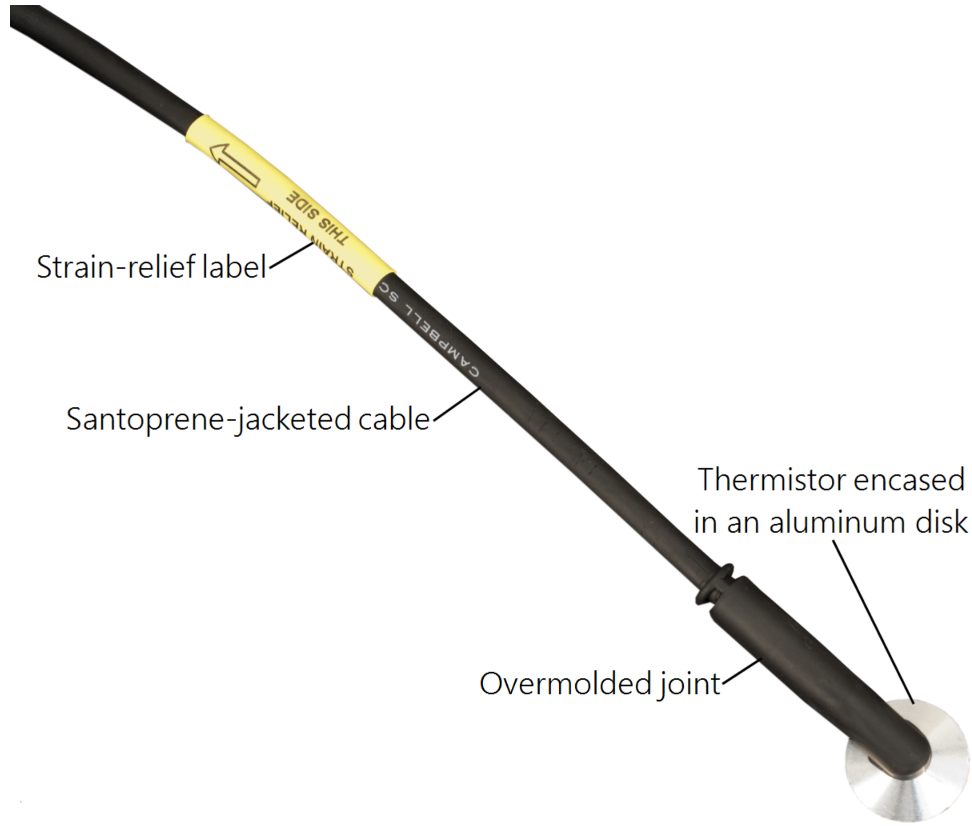


FIGURE 5-1. 110PV temperature probe

6. Specifications

Temperature range:	–40 to 135 °C
Survival range:	–50 to 140 °C
Accuracy[1]	
Worst case:	±0.2 °C (–40 to 70 °C)
	±0.5 °C (71 to 105 °C)
	±1 °C (106 to 135 °C)
Maximum Steinhart-Hart linearization error:	0.0024 °C at –40 °C
Maximum cable length:	304.8 m (1000 ft)
Disk diameter:	2.54 cm (1.0 in)
Overall probe length:	6.35 cm (2.5 in)

Overmoulded joint dimensions	
Width:	1.12 cm (0.44 in)
Height:	1.47 cm (0.58 in)
Length:	5.72 cm (2.25 in)
Cable diameter:	0.622 cm (0.245 in)
Material	
Disk:	Anodized aluminium
Cable jacket:	Santoprene®
Cable/probe connection:	Santoprene®
Weight:	90.7 g (0.2 lb) with 3.2 m (10.5 ft) cable

[1] The overall probe accuracy is a combination of the thermistor's interchangeability specification, the accuracy of the bridge resistor, and error of the Steinhart-Hart equation. The major error component is the interchangeability specification (tolerance) of the thermistor. The bridge resistor has a 0.1% tolerance with a 10 ppm temperature coefficient. Effects of cable resistance is discussed in Long cable lengths (p. 14).

7. Installation

If you are programming your data logger with Short Cut, skip Wiring (p. 10) and Data logger programming (p. 12). Short Cut does this work for you. See QuickStart (p. 2) for a Short Cut tutorial. This section discusses the following:

7.1 Placement on a photovoltaic (PV) module

The PV module may or may not have distinctive photocells. If the PV module does not have distinctive photocells, center the sensor on the back of the PV module. If the module has several distinctive photocells, center the sensor on the back of the photocell that is the middle of the PV module.

7.2 Mounting/cable strain relief

> **CAUTION:**
> Before mounting, the installers need to wash their hands and then clean the back of the PV module or other device with ethyl alcohol.

7.2.1 Adhesive mounting strip

An adhesive mounting strip is adhered to the flat surface of the aluminium disk. To mount the sensor, remove the paper from the mounting strip and adhere it to the back of the PV module or other device. The mounting strip must be adhered to a clean surface for its adhesive to function properly.

> **CAUTION:**
> Do not use epoxy to secure the sensor head to a PV module.

7.2.2 Cable strain relief

The cable must be properly strain relieved after mounting the 110PV to the measurement surface. To accomplish this, the 110PV comes with cable ties and a cable tie mount. A yellow label on the cable indicates where the cable should be tied down (FIGURE 7-1 (p. 9)).

> **NOTE:**
> Placement of the cable inside a rugged conduit is advisable for cable runs over 4.5 m (15 ft), especially in locations subject to digging, mowing, traffic, power tools, animals, or lightning strikes.

FIGURE 7-1. 110PV strain relief label

7.2.3 Extreme sealing tape

If the temperature might exceed 70 °C, extreme sealing tape is required to better secure the sensor to the measurement surface.

To ensure that the sensor disk is adequately fastened to the measurement surface, use three strips of extreme sealing tape in two places each:

1. Place a strip of tape across the sensor head, perpendicular to the cable and rub the tape surface to remove bubbles. Rub as close as possible to the sensor disk.

   > CAUTION:
   > Do not place tape over the sensor moulding; only place tape on the metal disk portion of the sensor.

2. Place the two other strips of tape on the ends of the sensor disk, perpendicular to the first piece of tape and parallel to the cable then rub the tape surface into the module surface. See the following figure.

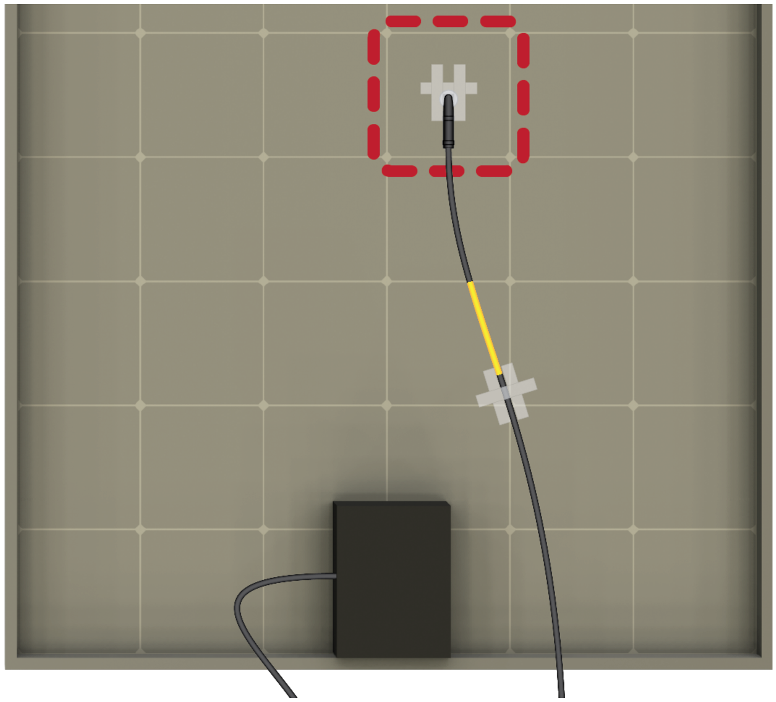


FIGURE 7-2. Proper tape usage

7.3 Wiring

FIGURE 7-3 (p. 11) provides the schematic and Table 7-1 (p. 11) provides the connections to Campbell Scientific data loggers. Either a 4-wire half bridge or 3-wire half bridge configuration can be used to measure the 110PV. The 4-wire half bridge configuration is preferred because it reduces cable errors. The 3-wire half bridge configuration uses fewer terminals.

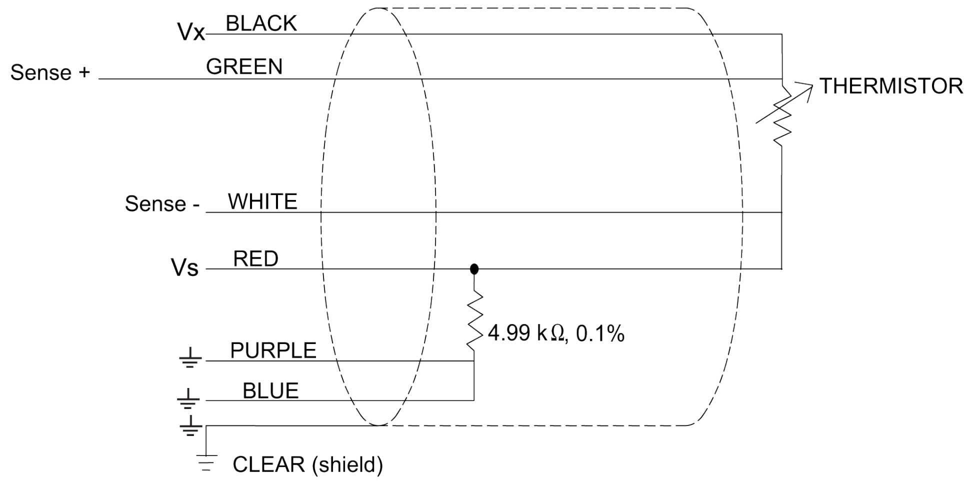


FIGURE 7-3. 110PV schematic

Table 7-1: Wire colour, function, and data logger connection

Wire colour	Function	Data logger connection using 4-wire half bridge	Data logger connection using 3-wire half bridge
Black	Voltage excitation input	**U** configured for voltage excitation[1], **EX**, **VX** (voltage excitation)	**U** configured for voltage excitation[1], **EX**, **VX** (voltage excitation)
Red	Signal	**U** configured for differential input[1], **DIFF H** (differential high, analogue voltage input)	**U** configured for differential input[1], **SE** (single-ended, analogue voltage input)
Purple	Signal reference	**U** configured for differential input[1], **DIFF L** (differential low, analogue voltage input)	⏚ (analogue ground)
Green	Signal	**U** configured for differential input[1], **DIFF H** (differential high, analogue voltage input)	Not used
White	Signal reference	**U** configured for differential input[1], **DIFF L** (differential low, analogue voltage input)	Not used
Blue	Signal reference	⏚ (analogue ground)	Not used
Clear	Shield	⏚ (analogue ground)	⏚ (analogue ground)

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

7.4 Data logger programming

Short Cut is the best source for up-to-date data logger programming code. If your data acquisition requirements are simple, you can probably create and maintain a data logger 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 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 Importing Short Cut code into CRBasic Editor (p. 16). Programming basics for CRBasic data loggers are provided in the following section. Complete program examples for select CRBasic data loggers can be found in Example programs (p. 17).

If applicable, please read Electrical noisy environments (p. 14) and Long cable lengths (p. 14) prior to programming your data logger.

7.4.1 Resistance measurement

CRBasic instructions used to measure resistance are the `BrHalf4W` (4-wire configuration) or `BrHalf` (2-wire configuration). The `BrHalf4W()` instruction reduces cable errors, and the `BrHalf()` instruction uses the fewest input terminals.

A typical `BrHalf4W()` instruction is:

```
BrHalf4W(T110PV,1,mV5000,mV5000,1,Vx1,1,2500,True,True,0,60,1.0,0.0)
```

A typical `BrHalf()` instruction is:

```
BrHalf(T110PV,1,mV5000,1,VX1,1,2500,True,0,60,1.0,0.0)
```

Use a multiplier of 1.0 and offset of 0.0 in the instructions.

7.4.2 Converting resistance measurement to temperature

The Steinhart-Hart equation is used to convert the resistance measurement to temperature.

Temp_C = (1/(A+B*LN(T110PV_Res)+C*(LN(T110PV_Res))^3))-273.15

The coefficients used for the Steinhart-Hart equation are:

$A=1.129241 \times 10^{-3}$

$B=2.341077 \times 10^{-4}$

$C=8.775468 \times 10^{-8}$

8. Operation

This section discusses the following:

8.1 Measurement details

Understanding the details in this section is not necessary for general operation of the 110PV with our data loggers.

Simple half bridge measurement, ignoring cable resistance, has a measured voltage, V, of:

$$V = V_x(4990/(4990 + R_t))$$

Where V_x is the excitation voltage, 4990 ohms is the resistance of the fixed resistor and R_t is the resistance of the thermistor.

The resistance of the thermistor is:

$$R_t = 4990((V_x/V) - 1)$$

The Steinhart-Hart equation is used to calculate temperature from resistance:

$$T_C = 1/(A + B(\ln(R_T)) + C(\ln(R_T))^3) – 273.15$$

Where T_C is the temperature in Celsius. The Steinhart-Hart coefficients used are:

$A = 1.129241 \times 10^{-3}$

$B = 2.341077 \times 10^{-4}$

$C = 8.775468 \times 10^{-8}$

8.2 Electrical noisy environments

AC power lines, pumps, power inverters, and motors can be the source of electrical noise. If the sensor or data logger is located in an electrically noisy environment, the sensor should be measured with the 60 or 50 Hz rejection option.

8.3 Long cable lengths

Cable resistance can cause significant error. The 4-wire configuration is the best configuration for long cable lengths.

The heat shrink label on the 110PV cable provides the cable resistance (ohms). When using the 2-wire configuration, subtract this cable resistance from the measured resistance value.

Additional settling time may be required for cable lengths longer than 300 feet, where settling time is the delay before the measurement is made. Longer settling times can be typed into the `Settling Time` parameter in the `BrHalf4W()` or `BrHalf()` instruction.

9. Maintenance and troubleshooting

> **NOTE:**
> For all factory repairs, customers must get an RMA number. 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 Read First page at the front of this manual for more information.

9.1 Troubleshooting

Symptom: Temperature is NAN, –INF, –9999, –273

Verify the red wire is connected to the correct single-ended analogue 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 data logger ground.

Symptom: Incorrect Temperature

Verify the multiplier and offset parameters are correct for the desired units (Data logger programming (p. 12)). Check the cable for signs of damage and possible moisture intrusion.

Symptom: Unstable Temperature

Try using the 60 or 50 Hz f_{N1} option, and/or increasing the settling time. Make sure the clear shield wire is connected to data logger ground, and the data logger is properly grounded.

CAUTION:
If the 110PV needs to be sent to Campbell Scientific for repairs, the probe must be heated to 70 to 80 °C before removing it from the measurement surface. Prying the probe off without heating it will likely damage both the probe and the PV module.

9.2 Maintenance

The 110PV sensor requires minimal maintenance. Periodically check cabling for proper connections, signs of damage, and possible moisture intrusion.

Appendix A. Importing Short Cut code into CRBasic Editor

Short Cut creates a .DEF file that contains wiring information and a program file that can be imported into the CRBasic Editor. By default, these files reside in the C:\campbellsci\SCWin folder.

Import Short Cut program file and wiring information into CRBasic Editor:

1. Create the Short Cut program. After saving the Short Cut program, click the **Advanced** tab then the **CRBasic Editor** button. A program file with a generic name will open in CRBasic. Provide a meaningful name and save the CRBasic program. This program can now be edited for additional refinement.

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

2. To add the Short Cut wiring information into the new CRBasic program, open the .DEF file located in the C:\campbellsci\SCWin folder, and copy the wiring information, which is at the beginning of the .DEF file.
3. Go into the CRBasic program and paste the wiring information into it.
4. In the CRBasic program, highlight the wiring information, right-click, and select **Comment Block**. This adds an apostrophe (') to the beginning of each of the highlighted lines, which instructs the data logger compiler to ignore those lines when compiling. The **Comment Block** feature is demonstrated at about 5:10 in the CRBasic | Features video ▶.

Appendix B. Example programs

This appendix provides example CR1000X programs; other data loggers are programmed similarly. CRBasic Example 1 (p. 18) uses the `BrHalf()` instruction to measure the 110PV and CRBasic Example 2 (p. 19) uses the `BrHalf4W()` instruction to measure the 110PV. The following table provides wiring for the example programs.

Table B-1: Wiring for example programs

Colour	Description	Data logger connection	
		BrHalf()	BrHalf4W()
Black	Voltage excitation	**VX1** or **EX1**	**VX1** or **EX1**
Red	Signal	**SE1**	**Diff 1H**
Purple	Signal reference	⏚	**Diff 1L**
Blue	Signal reference	Not used	⏚
Clear	Shield	⏚	⏚
Green	Sense +	Not used	**Diff 2H**
White	Sense –	Not used	**Diff 2L**

CRBasic Example 1: Half bridge CR1000X program

```
'CR1000X Series data logger
'This example program measures a single 110PV-L probe using
'the BrHalf instruction once a second and stores the average
'temperature in degrees C every 10 minutes.

'Declare variables for temperature measurement using Half Bridge configuration
Public T110PV_mV
Public T110PV_Res
Public T110PV_Temp_C
Public T110PV_Temp_F

'Declare Constants to be used in Steinhart-Hart equation
Const A=1.129241*10^-3
Const B=2.341077*10^-4
Const C=8.775468*10^-8
Const R_cable=0 'see sensor cable for cable resistance

'Declare variable units
Units T110PV_mV= millivolts
Units T110PV_Res=Ohms
Units T110PV_Temp_C=Deg C
Units T110PV_Temp_F=Deg F

'Define a data table for 10 minute averages
DataTable (AvgTemp,1,-1)
  DataInterval (0,10,Min,10)
  Average (1,T110PV_Temp_C,FP2,False)
EndTable

BeginProg
  Scan (1,Sec,3,0)
    'Measure 110PV-L probe
    BrHalf (T110PV_mV,1,mV5000,1,VX1,1,2500,True,0,60,1,0)
    'Convert mV to ohms
    T110PV_Res=4990*(1-T110PV_mV)/T110PV_mV
    'Subtract off cable resistance (see 110PV-L cable for R_cable)
    T110PV_Res= T110PV_Res-R_cable
    'Using the Steinhart-Hart equation to convert resistance to temperature
    T110PV_Temp_C = (1/(A+B*LN(T110PV_Res)+C*(LN(T110PV_Res))^3))-273.15
    'Convert Celsius to Fahrenheit
    T110PV_Temp_F = T110PV_Temp_C * 1.8 + 32
    'Call AvgTemp data table
    CallTable AvgTemp
  NextScan
EndProg
```

CRBasic Example 2: 4-Wire half bridge CR1000X program

```
'CR1000X Series data logger
'This example program measures a single 110PV-L probe using the
'BRHalf4W instruction once a second and stores the
'average temperature in degrees C every 10 minutes.

'Declare variables for temperature measurement using Half Bridge configuration
Public T110PV_mV
Public T110PV_Res
Public T110PV_Temp_C
Public T110PV_Temp_F

'Declare constants to be used in Steinhart-Hart equation
Const A=1.129241*10^-3
Const B=2.341077*10^-4
Const C=8.775468*10^-8

'Declare variable units
Units T110PV_mV= millivolts
Units T110PV_Res=Ohms
Units T110PV_Temp_C=Deg C
Units T110PV_Temp_F=Deg F

'Define a data table for 10 minute averages
DataTable (AvgTemp,1,-1)
  DataInterval (0,10,Min,10)
  Average (1,T110PV_Temp_C,FP2,False)
EndTable

BeginProg
  Scan (1,Sec,3,0)
    'Measure 110PV-L probe
    BrHalf4W (T110PV_mV,1,mV5000,mV5000,1,Vx1,1,2500,True,True,0,60,1.0,0)
    'Convert mV to ohms
    T110PV_Res=4990 *T110PV_mV
    'Use the Steinhart-Hart equation to convert resistance to temperature
    T110PV_Temp_C = (1/(A+B*LN(T110PV_Res)+C*(LN(T110PV_Res))^3))-273.15
    'Convert Celsius to Fahrenheit
    T110PV_Temp_F = T110PV_Temp_C * 1.8 + 32
    CallTable AvgTemp
  NextScan
EndProg
```

Appendix C. Sensor material properties

The sensor consists of 6061 aluminium (hard anodized), RTD, 3M F9473PC adhesive, and Santoprene® jacketed cable.

C.1 3M F9473PC adhesive

UV resistance: Excellent UV resistance through outdoor weathering tests.

Temperature resistance: Relatively unaffected by long-term exposure to elevated temperatures. Adhesive can tolerate periodic short-term exposures to temperatures up to 260 °C. The adhesive softens as temperature increases and gets firmer as temperature decreases. As the adhesive becomes firmer, the bond strength generally increases. However, at very low temperatures (<-40 °C), the bond strength decreases.

Solvent resistance: No apparent degradation when exposed to splash testing of many common solvents and fluids including gasoline, JP-4 fuel, mineral spirits, motor oil, ammonia cleaner, acetone and methyl ethyl ketone. Three-splash testing cycles were 20 seconds submersion and 20 seconds air dry.

Storage and shelf life: Humidity controlled storage: 16 to 27 °C (60 to 80 °F) and 40 to 60% relative humidity. If stored properly, product retains its performance and properties for 24 months from date of manufacture. If the products have been exposed to severe weather conditions, we suggest to precondition the products at the above storage conditions for at least 24 hours before using them.

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