Product Manual

Sensor

CS240 and CS240DM

PT-1000 Class A, Back-of-Module Temperature Sensors

Revision: 05/2021

RELIABLE SINCE 1974 MONITORING

CAMPBELL SCIENTIFIC

Table of contents

1. Introduction

The CS240 and CS240DM temperature sensors use a precision 1000 ohm Class A platinum resistance thermometer (PRT) to measure temperature. They are designed for measuring the back-of-photovoltaic (PV) module temperature but also can be used to measure the surface temperature of other devices. The CS240 can be measured with a 2-wire or 4-wire configuration and is compatible with most Campbell Scientific data loggers. The CS240DM has a digital RS-485 output that can be directly read by a MeteoPV, CR6, CR1000X, or Modbus RTU RS-485 network. Other Campbell Scientific data loggers can use an MD485 multidrop interface to read the RS-485 output.

> **NOTE:**
> This manual provides information only for CRBasic data loggers. The CS240 is also compatible with our retired Edlog data loggers. For Edlog data logger support, contact Campbell Scientific. Support for Edlog data loggers is no longer free; see www.campbellsci.com/news-edlog-retiring for more information.

2. Precautions

- READ AND UNDERSTAND the Safety section at the back of this manual.
- Do not use epoxy to secure the sensor head to a PV module.
- Before mounting, the installers need to wash their hands and then clean the back of the PV module or other device with ethyl alcohol.
- Do not place tape over the sensor molding; only place tape on the metal disk portion of the sensor.
- Prying the sensor head off will likely damage both the sensor and PV module.
- Proper strain relief of the cable is required after mounting the sensor to the measurement surface (Mounting/cable strain relief (p. 13)).
- 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.

3. Initial inspection

- Upon receipt of the sensor, inspect the packaging and contents for damage. File damage claims with the shipping company.
- The model number, cable length, and cable resistance (CS240 only) 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 were received.

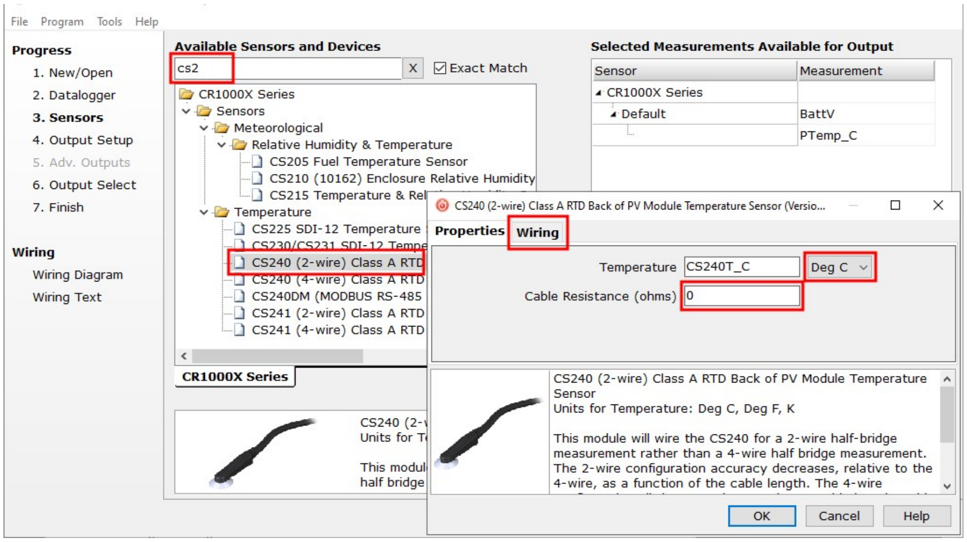
4. QuickStart

The information provided in this section is for the CS240.

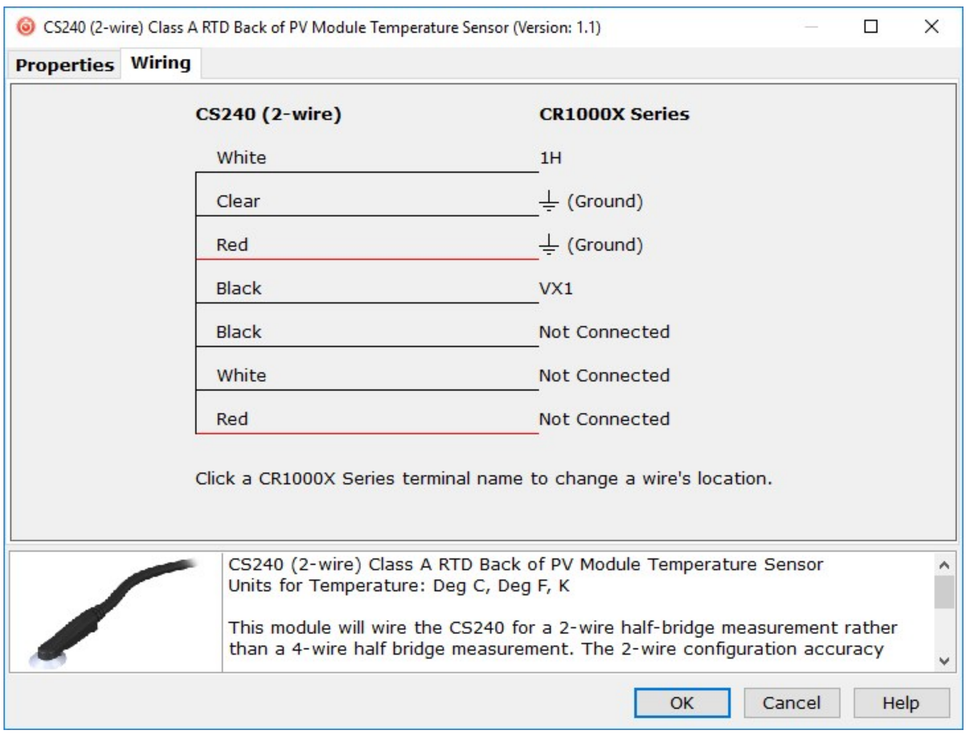
A video that describes data logger programming using ***Short Cut*** is available at: www.campbellsci.com/videos/cr1000x-data logger-getting-started-program-part-3. ***Short Cut*** is an easy way to program your data logger to measure the sensor and assign data logger wiring terminals. ***Short Cut***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

The following procedure also shows using ***Short Cut*** to program the CS240 and CS240DM.

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 CS240. You can also locate the sensor in the **Sensors** > **Temperature** folder. Double click the sensor model. The surface temperature defaults to degree C. This can be changed by clicking the **Temperature** box and selecting one of the other options. If using the 2-wire configuration, type the **Cable Resistance**. This value is unique for each sensor, and is printed on the heat shrink label attached to the sensor cable.

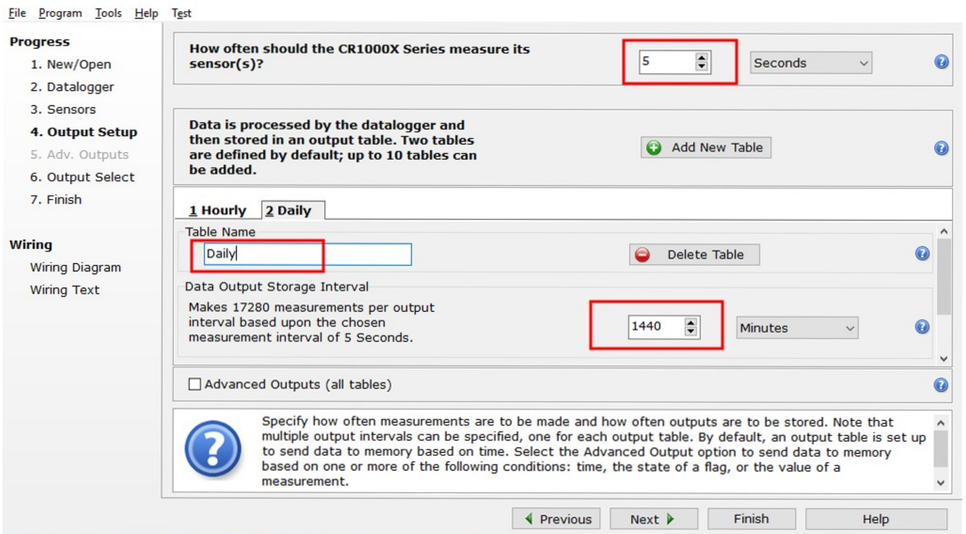


4. Click on the **Wiring** tab to see how the sensor is to be wired to the data logger. Click **OK** after wiring the sensor.

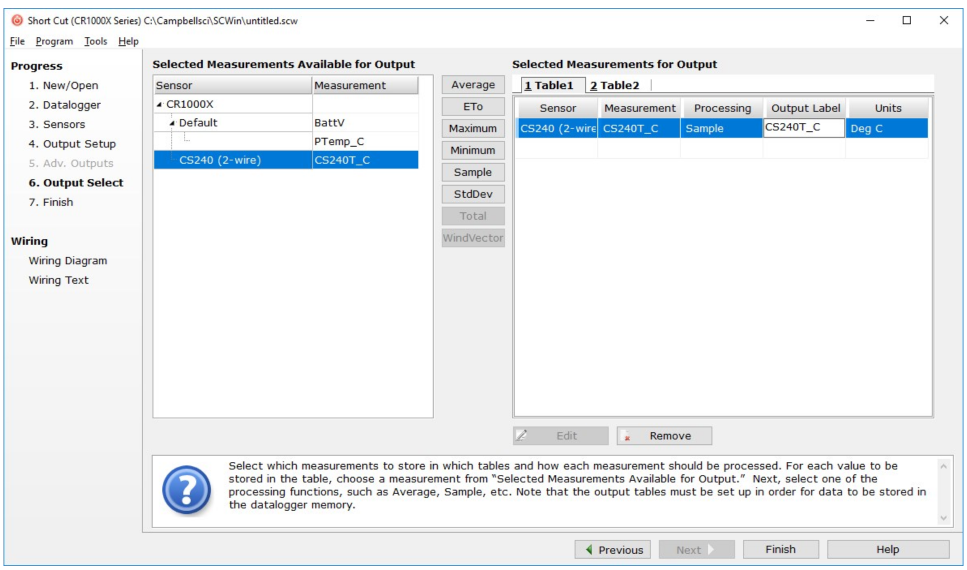


5. Repeat steps three and four for other sensors you want to measure. Click **Next**.

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***, or ***PC400*** to make sure it is making reasonable measurements.

5. Overview

The CS240 and CS240DM are surface mountable platinum resistive thermometers (PRT) that measure back-of-module temperature for solar energy applications. They use a precision PT-1000 Class A PRT to provide the highest level of accuracy. To withstand the harsh treatment that commonly occurs with meteorological station installation, the sensing element is safely housed inside a specially designed self-adhesive aluminum disk (FIGURE 5-1 (p. 5)).

The disk protects the PRT, particularly during installation, and promotes heat transfer from the surface. An adhesive tab on the disk fastens the sensor to the measurement surface. If the temperature may exceed 70 °C, extreme sealing tape is also required to secure the sensor.

The CS240DM includes a Campbell Scientific precision analog-to-digital, smart-sensor module for making the measurements. The module design is optimized for the Class A PRT that minimizes self-heating and wire resistance. Measurement electronics are surge protected with 1200 V isolation and environmentally protected with a rugged overmolding.

The CS240 and CS240DM provide PV stakeholders with highly accurate back-of-module temperature, even at long cable lengths, in power performance modeling and simulation of solar energy applications. Back-of-module temperature is critical for any evaluation of effective irradiance and power conversion.

FIGURE 5-1. CS240/CS240DM temperature sensor

Benefits and features:

- Precision PT-1000 Class A sensing element
- User-selectable and standard cable lengths offered
- Rugged design holds up in harsh conditions and conduit installations
- Self-adhesive backing for easy mounting lasts decades
- CS240 has 2-wire or 4-wire configurations to satisfy accuracy even at long cable lengths
- CS240 compatible with Campbell Scientific CRBasic data loggers: CR6, CR3000, CR1000X, CR800 series, CR300 series, CR1000
- CS240DM compatible with Campbell Scientific CRBasic data loggers: CR6, CR1000X, CR3000 (with MD485), CR800 series (with MD485), CR300 series (with MD485), CR1000 (with MD485)
- CS240DM easily interfaces with the MeteoPV platform without coding
- CS240DM can connect directly to Modbus RTU RS-485 networks
- Calibration services with certification available

6. Specifications

Sensor:	Precision 1000 ohm Class A platinum sensing element
Class A sensor accuracy:	± (0.15 + 0.002t) °C
Operating temperature range:	–40 to 135 °C
Temperature coefficient:	TCR = 3850 ppm/K
Long-term stability:	Maximum R_0 drift = 0.04% after 1000 hours at 400 °C
CS240 measuring current:	0.1 to 0.3 mA
Disk diameter:	2.54 cm (1.0 in)
Overall sensor length:	6.35 cm (2.5 in)
Overmolded 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)
Cable temperature rating:	105 °C
Disk material:	Anodized aluminum

Weight:	90.7 g (0.2 lb) with 3.2 m (10.5 ft) cable
CS240DM analog-to-digital module (DM):	24-bit ADC
A/D measurement uncertainty:	±0.015 °C
Supply voltage:	5 to 30 VDC
Power consumption:	15 mA
Surge protection:	1200 V isolation
Environmental protection:	Rugged overmolding
IP rating:	IP68 rating (self certified); 1 m submersion for 90 min
CS240DM communications:	
Protocol:	Modbus RTU (over RS-485)
Format:	8 data bits, 1 stop bit, even parity as default (user configurable)
Baud rate:	19200 bps as default (user-configurable)
Modbus ID:	Last two digits of serial number as default (user-configurable)
Approvals:	UL AWM 2586 1000V 105 °C; CSA AWM 600V 105 °C FT1 Conforms with Electromagnetic Compatibility Directive (EMC) Conforms with the Restriction of Hazardous Substances Directive (RoHS2)
Compliance:	View compliance documents at: www.campbellsci.com/cs240 or www.campbellsci.com/cs240dm
Industrial standards:	Compliant with IEC 60751, DIN EN 60751, Industrial Design (IEC Class 4) (according to IEC 751)
Cable	
Jacket material:	Black semi-gloss PVC, UL VW-1 sunlight resistant for outdoor use
Wire size and type:	24 AWG (7/32) tinned copper
Nominal wire diameter:	0.61 mm (0.024 in)

Insulation type:	PVC
UL:	AWM 10012 1000V 105 °C
Filler:	Fibrillated polypropylene as required for uniform round construction.
Drain:	24 AWG (7/32) tinned copper (cabled, touching foil)
Shield:	Aluminum/mylar (100% coverage, 25% minimum overlap, foil facing in)

CS240DM cable

Features:	High flex construction with jacket for pulling through conduit
Jacket material:	Black semi-gloss PVC, UL VW-1 sunlight resistant for outdoor use; weld spatter and oil resistant
Nominal wire diameter:	0.61 mm (0.024 in)
Agency approvals:	UL AWM Style 2463 and NEC/CEC CMX outdoor

7. Installation

If you are programming your data logger with ***Short Cut***, skip Wiring (p. 8) and Data logger programming (p. 11). ***Short Cut*** does this work for you. See QuickStart (p. 2) for a ***Short Cut*** tutorial. This section discusses the following:

7.1 Wiring

FIGURE 7-1 (p. 9) provides the circuit diagram for the CS240 2-wire configuration. FIGURE 7-2 (p. 9) provides the circuit diagram for the CS240DM or the CS240 4-wire configuration.

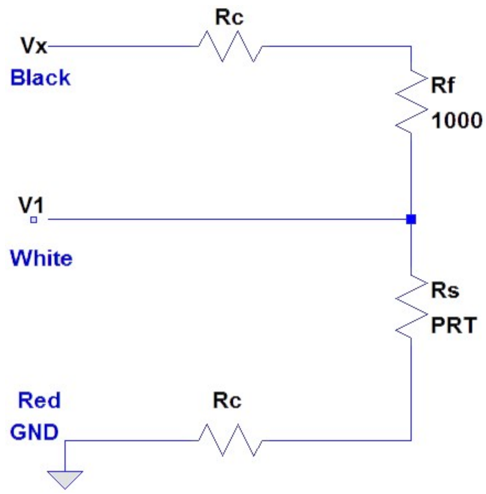


FIGURE 7-1. 2-Wire Circuit Diagram

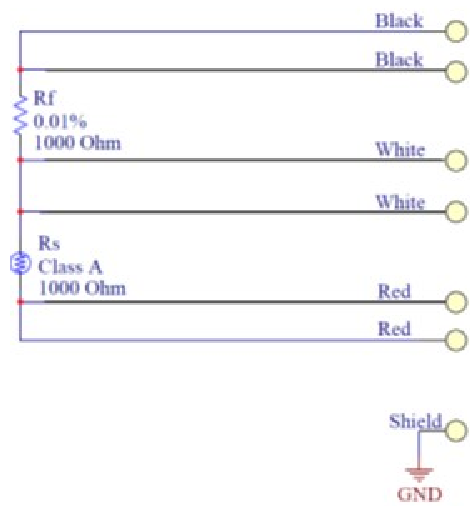


FIGURE 7-2. 4-Wire Circuit Diagram

7.1.1 CS240-to-data-logger wiring

The data loggers can measure the CS240 by using a 2-wire or 4-wire configuration (Table 7-1 (p. 10) and Table 7-2 (p. 10). The 2-wire configuration accuracy decreases, relative to the 4-wire, as a function of the cable length. The 4-wire configuration eliminates resistance due to cable length and is the most accurate way to measure this sensor. The CS240 is shipped ready for the 2-wire configuration. The wires used only for the 4-wire configuration are taped to the side of the cable.

Table 7-1: Wire color, function, and data logger connection for the CS240 2-wire configuration		
Wire color	Wire function	Data logger connection terminals
Black	Voltage excitation input	**U** configured for voltage excitation[1], **EX**, **VX** (voltage excitation)
White	Analog voltage output	**U** configured for single-ended analog input[1], **SE** (single-ended, analog input)
Red	Reference	⏚ (analog ground)
[1] **U** terminals are automatically configured by the measurement instruction.		

Table 7-2: Wire color and data logger connection for the CS240 4-wire configuration		
Wire color	Wire function	Data logger connection terminals
White	Analog voltage output[1]	**U** configured for differential high analog input[2], **DIFF H** (differential high, analog-voltage input)
Black	Reference[1]	**U** configured for differential low analog input[2], **DIFF L** (differential low, analog-voltage input)
Red	Voltage excitation input	**U** configured for voltage excitation[2], **EX**, **VX** (voltage excitation)
Red	Analog voltage output[3]	**U** configured for differential high analog input[2], **DIFF H** (differential high, analog-voltage input)
White	Reference[3]	**U** configured for differential low analog input[2], **DIFF L** (differential low, analog-voltage input)
Black	Ground	⏚ (analog ground)
Clear/shield	Shield	⏚ (analog ground)
[1] First differential terminal in the `BrHalf4W()` instruction. [2] **U** terminals are automatically configured by the measurement instruction. [3] Second differential terminal in the `BrHalf4W()` instruction.		

7.1.2 CS240DM wiring

The DM module is embedded in a short cable that attaches to the sensor head and has a 5-pin, M12 female circular connector. A standard cable or a 3-twisted-pair shielded cable with a 5-pin M12 male circular connector is used to attach the sensor to the station or data logger (Table 7-3

(p. 11)). Using connectors between the sensor head and the station or data logger cable allows in-field sensor head replacement without disconnecting the cable from the data logger.

The following table provides sensor wiring and cable pin-out. Detailed information about the cables are provided in the Specifications (p. 6). Sensor wiring is also available in the ***Device Configuration Utility*** and the ***MeteoPV User Interface***.

Table 7-3: Wire Color, Station Connection, and Function for the CS240DM

Standard cable[1] wire color	Pin-out	3-twisted pair cable[1] wire color	Station (data logger) terminal	Function
Blue	3	Green	**A–** (**C** odd)	RS-485 A/A [–]
White/blue stripe	2	White	**B+** (**C** even)	RS-485 B/B [+]
Brown	4	Red	**12V**	5 to 30 VDC
White/brown stripe	1	Black	**G**	Ground (power)
Green	5	Yellow	**G** (⏚)	Modbus common
--	N/A	Clear	**G** (⏚)	Shield

[1]Cable has an 8-pin M12 connector.

7.2 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. 22). 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. 23)

If applicable, please read Electrical noisy environments (p. 16) and Long cable lengths (p. 16) prior to programming your data logger.

7.2.1 CS240 programming

The CS240 program needs to measure the resistance of the CS240 then convert that resistance measurement to temperature.

7.2.1.1 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(CS240X,1,mV200,mV200,U1,U5,1,350,True,True,0,60,1,0)
```

A typical BrHalf() instruction is:

```
BrHalf(CS240X,1,mV200,U7,U3,1,350,True,0,60,1,0)
```

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

7.2.1.2 Converting resistance measurement to temperature

The PRTCalc() instruction converts the ratio Rs/Ro to temperature, where Rs is the measured resistance of the RTD, and Ro is the resistance of the RTD at 0 degrees Celsius (1000 Ω).

A typical PRTCalc() instruction is:

```
PRTCalc(PRTtemp,1,Rs/1000,1,1,0)
```

If the BrHalf() instruction (2-wire configuration) was used to measure resistance, the following expression also must precede the PRTCalc() instruction:

$Rs=CS240X*(1000+R_c)/(1–CS240X)–R_c$

Where CS240X value returned by the BrHalf() instruction and R_c is the cable resistance provided on the cable label.

7.2.2 CS240DM programming

> **NOTE:**
> Programming basics for the CR6 and CR1000X data loggers are provided in this section. Contact Campbell Scientific if using a data logger that requires an MD485 interface.

A CR6 or CR1000X data logger programmed as a Modbus Master can retrieve the values stored in the CS240DMCS240 and CS240DM Input Registers (Modbus register map (p. 18)). To do this, the CRBasic program requires a `SerialOpen()` instruction followed by the `ModbusMaster()` instruction.

The `SerialOpen` instruction has the following syntax:

```
SerialOpen (ComPort, Baud, Format, TXDelay, BufferSize, Mode )
```

The `Format` is typically set to **logic 1 low**; **even parity**, **one stop bit**, **8 data bits**. The `Mode` parameter should configure the `ComPort` as RS-485 half-duplex, transparent.

The `ModbusMaster()` instruction has the following syntax:

```
ModbusMaster (Result,ComPort,Baud,Addr,Function, Variable, Start, Length, Tries,
TimeOut, [ModbusOption] )
```

The `Addr` parameter must match the CS240DM Modbus address. Each Modbus address must be unique on a Modbus network. The default value for the Modbus address is the last two digits of the sensor serial number, with exceptions for serial numbers ending in 00 and 01. These exceptions default to Modbus addresses of 110 and 111, respectively. To collect all of the CS240DM values, the `Start` parameter needs to be **1** and the `Length` parameter needs to be **5**. `ModbusOption` is an optional parameter described in the CRBasic Editor Help.

7.3 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.

7.4 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.

7.4.1 Adhesive mounting strip

A pressure-activated adhesive mounting strip is adhered to the flat surface of the aluminum disk. To mount the sensor, remove the paper from the mounting strip and place the disk on the back of the PV module or other device. Press the disk firmly for 2 to 3 seconds to initiate long-term bonding of the sensor to the surface. 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.

7.4.2 Extreme sealing tape

Use extreme sealing tape for cable strain relief. A yellow label on the cable indicates where the cable must be secured (FIGURE 7-3 (p. 15)). 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 and cable are adequately fastened to the measurement surface, use three strips of tape in two places each:

1. For strain relief, place the first strip of tape across the cable just below the yellow heat shrink (FIGURE 7-4 (p. 15)) and rub the tape surface to remove bubbles.
2. Place the other strips of tape perpendicular and on top of the first strip of tape and rub the tape surface to remove bubbles. These strips of tape should form an H (FIGURE 7-4 (p. 15)).
3. To secure the sensor to the module surface, remove the paper from the bottom of the disk and adhere the disk to the PV module (Placement on a photovoltaic (PV) module (p. 13)).
4. 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 molding; only place tape on the metal disk portion of the sensor.

5. 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 FIGURE 7-4 (p. 15).

FIGURE 7-3. Strain relief label on the cable

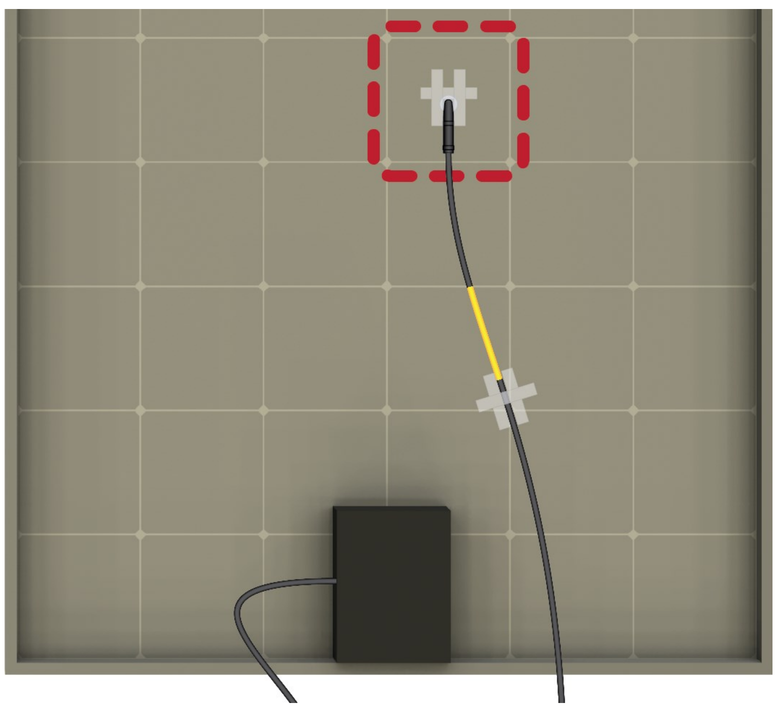


FIGURE 7-4. Proper tape usage

7.4.3 Strain relief of CS240DM analog-to-digital module

The CS240DM has an analog-to-digital, smart-sensor module incorporated that needs to be secured to the side of PV module. Use two cable tie tabs and cable ties to do this.

8. Operation

This section discusses the following:

8.1 Electrical noisy environments

AC power lines, pumps, power inverters, and motors can be the source of electrical noise. If the CS240 sensor or data logger is located in an electrically noisy environment, the CS240 sensor should be measured with the 60 or 50 Hz rejection option.

8.2 Long cable lengths

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.

8.2.1 CS240 cable resistance/long cable lengths

Cable resistance can cause significant error (FIGURE 8-1 (p. 17)). The 4-wire half bridge configuration is the best configuration for long cable lengths.

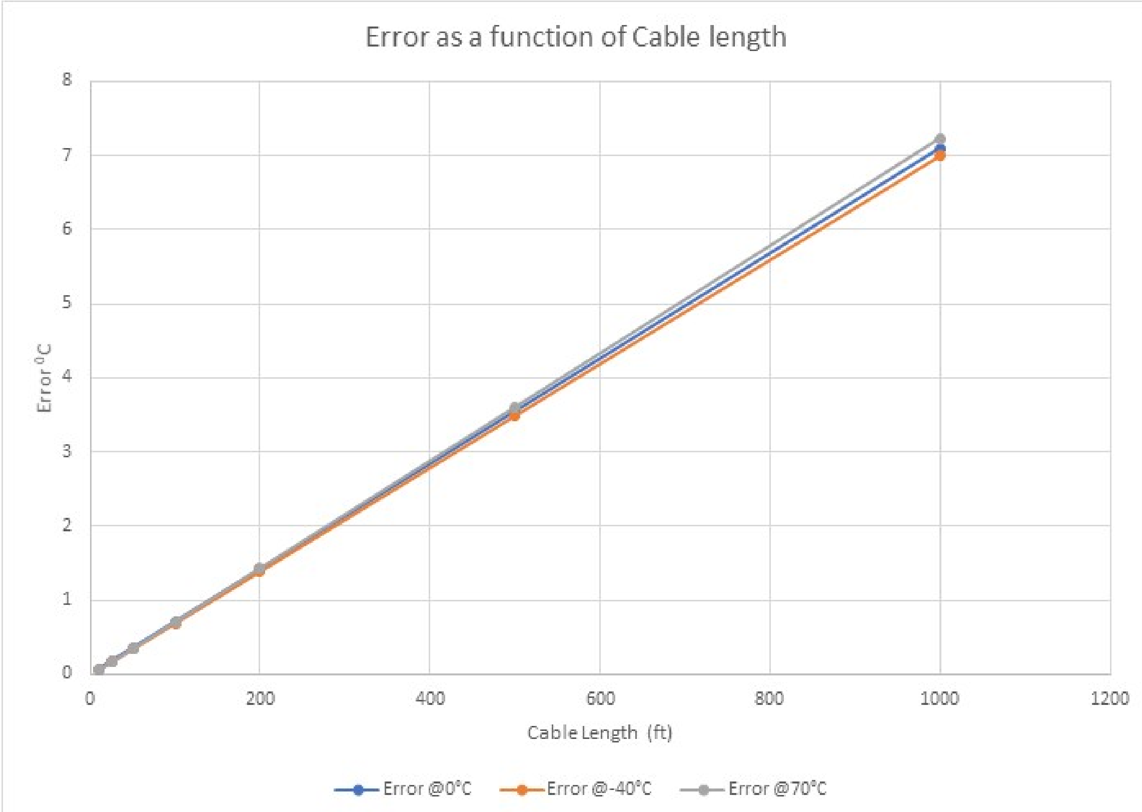


FIGURE 8-1. BrHalf (2-wire half bridge) measurement error as a function of cable length

The heat shrink label on the CS240 cable provides the cable resistance (ohms). When using the 2-wire configuration, subtract this cable resistance from the measured resistance value. The value included on the label is calculated with the following equation:

Cable resistance = 0.0274 ohm/feet x cable length (in feet)

Additional settling time may be required for cable lengths longer than 91 m (300 ft), where settling time is the delay before the measurement is made. The 60 and 50 Hz integration options include a 3 ms settling time; longer settling times can be typed into the `Settling Time` parameter in the `BrHalf4W()` or `BrHalf()` instruction.

8.2.2 CS240DM long cable lengths

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.

Digital data transfer eliminates offset errors due to cable lengths. However, digital communications can break down when cables are too long, resulting in either no response from the sensor or corrupted readings. Maximum cable lengths depend on the number of sensors connected, the type of cable used, and the environment of the application. Follow these guidelines when using long cables:

- Use low capacitance, low resistance, screened cable (as fitted by Campbell Scientific) to reach distances of several hundred meters.
- Ensure that the power ground cable has low resistance and is connected to the same ground reference as the data logger control terminals.
- Be aware that daisy-chaining sensors reduces the maximum cable length roughly in proportion to the number of sensors connected in parallel.

8.3 Modbus register map

Table 8-1 (p. 18) provides the input register map (function code 4) and Table 8-2 (p. 19) provides the holding register map (functions 3, 6, and 16).

Table 8-1: Input register map

Input register	Value	Modbus data type	Description
30001	Serial number	Float[1]	Specifies the sensor serial number assigned by the factory
30003	Temperature	Float[1]	The stored value is in degrees Celsius.
30005	Counter	Float[1]	The counter provides an indicator that the sensor is actively taking measurements. This value will increment once per measurement, resetting to 0.
30007	Sensor status	Float[1]	0 = good 1 = open/short
30009	Temperature range check	Float[1]	0 = good/in range 1 = out of range

[1]Modbus float is a 32-bit integer.

Table 8-2: Holding register map			
Holding register	Value	Modbus data type	Description
40001	Modbus address	Unsigned short[1]	Modbus device address (1 to 247)
40002	Baud rate	Unsigned short[1]	1 = 9600 bps 2 = 19200 bps 3 = 38400 bps 4 =57600 bps 5 = 115200 bps
40003	Parity	Unsigned short[1]	0 = no parity 1 = odd 2 = even
40004	Stop bit	Unsigned short[1]	1 = 1 stop bit 2 = 2 stop bits
40005	Termination resistor	Unsigned short[1]	0 = off/disable 1 = on/enable
[1]Unsigned short data is a 16-bit positive integer.			

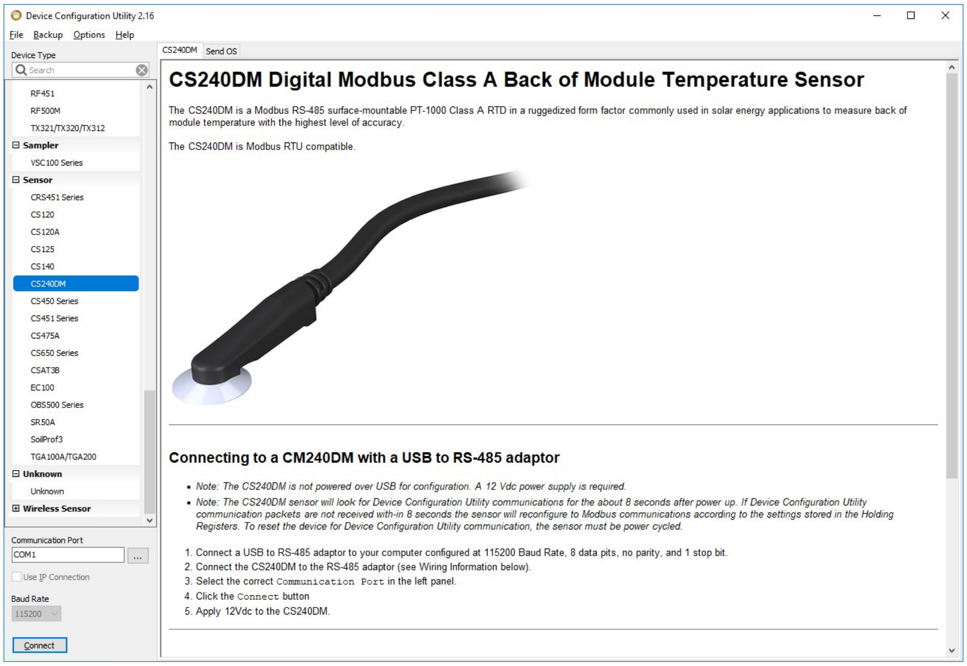
8.4 CS240DM and *Device Configuration Utility*

Device Configuration Utility is bundled in Campbell Scientific data logger support software and can also be acquired, at no cost, from www.campbellsci.com/downloads. ***Device Configuration Utility*** can be used to change the CS240DM settings, view stored values, and update the CS240DM operating system (OS). It also provides wiring information.

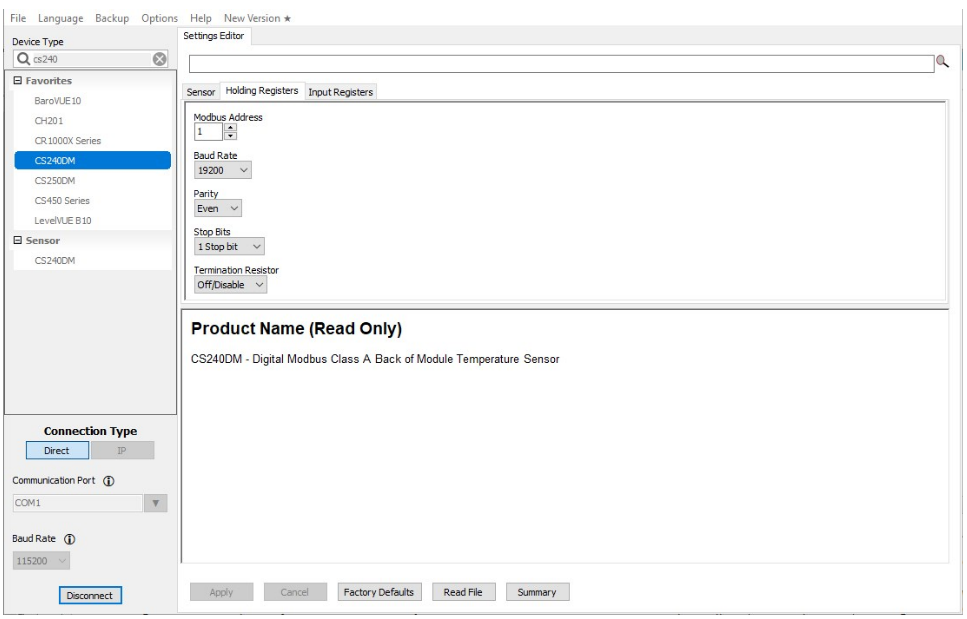
To use ***Device Configuration Utility***, the CS240DM must be connected to a computer and 12 VDC power source. A USB-to-RS-485 adapter is required to connect the CS240DM to the computer. The following is the procedure for connecting to ***Device Configuration Utility***:

1. Open the ***Device Configuration Utilit***y.
2. Under **Device Type**, click **CS240DM**.

3. Follow steps listed under **Connecting to a CM240DM with a USB to RS 485 adapter**.



The settings are changed in the **Holding Registers** tab. Except for the **Modbus Address**, the default values are typical for most Modbus systems and therefore rarely need to be changed.



The values stored are shown in the **Input Registers** tab.

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 Assistance page at the back of this manual for more information.

9.1 Maintenance

The CS240 and CS240DM sensors require minimal maintenance. Periodically check cabling for proper connections, signs of damage, and possible moisture intrusion.

9.2 Troubleshooting

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

Verify wiring of sensor to the data logger; cross-reference data logger program or the measurement system wiring diagram.

Symptom: Incorrect Temperature

Check the cable for signs of damage and possible moisture intrusion.

Symptom: Unstable Temperature

Make sure the clear shield wire is connected to data logger ground, and the data logger is properly grounded. For the CS240, try using the 60 or 50 Hz integration options and/or increasing the settling time.

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

Table B-1 (p. 23) provides wiring for the CS240 two-wire configuration programs (p. 24). Table B-2 (p. 23) provides wiring for the CS240 four-wire configuration programs (p. 28), and Table B-3 (p. 24) provides wiring for the CS240DM program (p. 31).

Table B-1: Wiring for CS240 2-wire configuration example programs

Wire color	Wire function	CR300 terminals	CR6 terminals	CR1000X terminals
Black	Voltage excitation input	VX1	U1	VX1
White	Analog voltage output	SE1	U2	SE1
Red	Reference	⏚ (analog ground)	⏚ (analog ground)	⏚ (analog ground)

Table B-2: Wiring for CS240 4-wire configuration example programs

Wire color	Wire function	CR300 terminals	CR6 terminals	CR1000X terminals
White	Analog voltage output	1H	U3	1H
Black	Reference	1L	U4	1L
Red	Voltage excitation input	VX1	U1	VX1
Red	Analog voltage output	2H	U5	2H
White	Reference	2L	U6	2L
Black	Ground	⏚ (analog ground)	⏚ (analog ground)	⏚ (analog ground)
Clear/shield	Shield	⏚ (analog ground)	⏚ (analog ground)	⏚ (analog ground)

Table B-3: Wiring for the CS240DM example program			
Standard cable wire color	3-twisted pair cable wire color	CR6 terminal	Function
Blue	Green	C1	RS-485 A/A' [–]
White/blue striped	White	C2	RS-485 B/B' [+]
Brown	Red	12V	5 to 30 VDC
White/brown striped	Black	G	Ground (power)
Green	Yellow	⏚	Modbus common
--	Clear	⏚	Shield

B.1 CS240 two-wire configuration programs

CRBasic Example 1: CR300 2-wire configuration for measuring the CS240

```
'CR300 Series

'Declare Variables and Units
Dim CS240X
Dim CS240Rs
Public CS240T_C

Units CS240T_C=Deg C

'Define Data Tables
DataTable(Hourly,True,-1)
  DataInterval(0,60,Min,10)
  Sample(1,CS240T_C,FP2)
EndTable

'Main Program
BeginProg
  'Main Scan
  Scan(5,Sec,1,0)
    'CS240 (2-wire) Class A RTD Back of PV Module Temperature Sensor
    'measurement 'CS240T_C'
    BrHalf(CS240X,1,mV2500,1,Vx1,1,350,True,0,60,1,0)

    'Convert ratio to ohms and remove cable resistance
    CS240Rs=CS240X*(1000+0.274)/(1-CS240X)-0.274
```

CRBasic Example 1: CR300 2-wire configuration for measuring the CS240

```
    'Calculate temperature from resistance
    PRTCalc(CS240T_C,1,CS240Rs/1000,1,1,0)

    'Call Data Tables and Store Data
    CallTable Hourly
  NextScan
EndProg
```

CRBasic Example 2: CR6 2-wire configuration for measuring the CS240

```
'CR6 Series

'Declare Variables and Units
Dim CS240X
Dim CS240Rs
Public CS240T_C

Units CS240T_C=Deg C

'Define Data Tables
DataTable(Hourly,True,-1)
  DataInterval(0,60,Min,10)
  Sample(1,CS240T_C,FP2)
EndTable

'Main Program
BeginProg
  'Main Scan
  Scan(5,Sec,1,0)
    'CS240 (2-wire) Class A RTD Back of PV Module Temperature Sensor
    'measurement 'CS240T_C'
    BrHalf(CS240X,1,mV200,U2,U1,1,350,True,0,60,1,0)

    'Convert ratio to ohms and remove cable resistance
    CS240Rs=CS240X*(1000+0.274)/(1-CS240X)-0.274

    'Calculate temperature from resistance
    PRTCalc(CS240T_C,1,CS240Rs/1000,1,1,0)

    'Call Data Tables and Store Data
    CallTable Hourly
  NextScan
EndProg
```

CRBasic Example 3: CR1000X 2-wire configuration for measuring the CS240

```
'CR1000X Series

'Declare Variables and Units
Dim CS240X
Dim CS240Rs
Public CS240T_C

Units CS240T_C=Deg C

'Define Data Tables
DataTable(Hourly,True,-1)
  DataInterval(0,60,Min,10)
  Sample(1,CS240T_C,FP2)
EndTable

'Main Program
BeginProg
  'Main Scan
  Scan(5,Sec,1,0)
    'CS240 (2-wire) Class A RTD Back of PV Module Temperature Sensor
    'measurement 'CS240T_C'
    BrHalf(CS240X,1,mV200,1,Vx1,1,350,True,0,60,1,0)

    'Convert ratio to ohms and remove cable resistance
    CS240Rs=CS240X*(1000+0.274)/(1-CS240X)-0.274

    'Calculate temperature from resistance
    PRTCalc(CS240T_C,1,CS240Rs/1000,1,1,0)

    'Call Data Tables and Store Data
    CallTable Hourly
  NextScan
EndProg
```

B.2 CS240 four-wire configuration programs

CRBasic Example 4: CR300 4-wire configuration for measuring the CS240

```
'CR300 Series

'Declare Variables and Units
Dim CS240X
Dim CS240Rs
Public CS240T_C

Units CS240T_C=Deg C
'Define Data Tables
DataTable(Hourly,True,-1)
  DataInterval(0,60,Min,10)
  Sample(1,CS240T_C,FP2)
EndTable

'Main Program
BeginProg
  'Main Scan
  Scan(5,Sec,1,0)
    'CS240 (4-wire) Class A RTD Back of PV Module Temperature Sensor
    'measurement 'CS240T_C'
    BrHalf4W(CS240X,1,mV2500,mV2500,1,Vx1,1,350,True,True,0,60,1,0)

    'Convert ratio to ohms
    CS240Rs=CS240X*1000

    'Calculate temperature from resistance
    PRTCalc(CS240T_C,1,CS240Rs/1000,1,1,0)

    'Call Data Tables and Store Data
    CallTable Hourly
  NextScan
EndProg
```

CRBasic Example 5: CR6 4-wire configuration for measuring the CS240

```
'CR6 Series

'Declare Variables and Units
Dim CS240X
Dim CS240Rs
Public CS240T_C

Units CS240T_C=Deg C

'Define Data Tables
DataTable(Hourly,True,-1)
  DataInterval(0,60,Min,10)
  Sample(1,CS240T_C,FP2)
EndTable

'Main Program
BeginProg
  'Main Scan
  Scan(5,Sec,1,0)
    'CS240 (4-wire) Class A RTD Back of PV Module Temperature Sensor
    'measurement 'CS240T_C'
    BrHalf4W(CS240X,1,mV200,mV200,U3,U1,1,350,True,True,0,60,1,0)

    'Convert ratio to ohms
    CS240Rs=CS240X*1000

    'Calculate temperature from resistance
    PRTCalc(CS240T_C,1,CS240Rs/1000,1,1,0)

    'Call Data Tables and Store Data
    CallTable Hourly
  NextScan
EndProg
```

CRBasic Example 6: CR1000X 4-wire configuration for measuring the CS240

```
'CR1000X Series

'Declare Variables and Units
Dim CS240X
Dim CS240Rs
Public CS240T_C

Units CS240T_C=Deg C

'Define Data Tables
DataTable(Hourly,True,-1)
  DataInterval(0,60,Min,10)
  Sample(1,CS240T_C,FP2)
EndTable

'Main Program
BeginProg
  'Main Scan
  Scan(5,Sec,1,0)
    'CS240 (4-wire) Class A RTD Back of PV Module Temperature Sensor
    'measurement 'CS240T_C'
    BrHalf4W(CS240X,1,mV200,mV200,1,Vx1,1,350,True,True,0,60,1,0)

    'Convert ratio to ohms
    CS240Rs=CS240X*1000

    'Calculate temperature from resistance
    PRTCalc(CS240T_C,1,CS240Rs/1000,1,1,0)

    'Call Data Tables and Store Data
    CallTable Hourly
  NextScan
EndProg
```

B.3 CS240DM program

CRBasic Example 7: CS240DM RS-485 modbus program

```
'CR6 Series data logger

Public PTemp
Public batt_volt

Public ResultCode(4)
Public CS240DM(20)
Public AveTemp(4)
Public SD_Temp
Public AvgTemp

Alias ResultCode(1) = CS240DM_1_ResultCode
Alias ResultCode(2) = CS240DM_2_ResultCode
Alias ResultCode(3) = CS240DM_3_ResultCode
Alias ResultCode(4) = CS240DM_4_ResultCode

Alias CS240DM(1) = CS240DM_1_SN
Alias CS240DM(2) = CS240DM_1_Temperature
Alias CS240DM(3) = CS240DM_1_Counter
Alias CS240DM(4) = CS240DM_1_SensorStatus
Alias CS240DM(5) = CS240DM_1_RangeCheck
Alias CS240DM(6) = CS240DM_2_SN
Alias CS240DM(7) = CS240DM_2_Temperature
Alias CS240DM(8) = CS240DM_2_Counter
Alias CS240DM(9) = CS240DM_2_SensorStatus
Alias CS240DM(10) = CS240DM_2_RangeCheck
Alias CS240DM(11) = CS240DM_3_SN
Alias CS240DM(12) = CS240DM_3_Temperature
Alias CS240DM(13) = CS240DM_3_Counter
Alias CS240DM(14) = CS240DM_3_SensorStatusk
Alias CS240DM(15) = CS240DM_3_RangeCheck
Alias CS240DM(16) = CS240DM_4_SN
Alias CS240DM(17) = CS240DM_4_Temperature
Alias CS240DM(18) = CS240DM_4_Counter
Alias CS240DM(19) = CS240DM_4_SensorStatus
Alias CS240DM(20) = CS240DM_4_RangeCheck

DataTable (Hourly,1,-1)
DataInterval (0,60,min,10)
  Sample (20,CS240DM(),IEEE4)
  Sample (1,AvgTemp,IEEE4)
  Sample (1,SD_Temp,IEEE4)
EndTable

BeginProg
```

CRBasic Example 7: CS240DM RS-485 modbus program

```
  SerialOpen (ComC1,19200,2,0,50,4)

  Scan (1,Sec,0,0)
    PanelTemp (PTemp,15000)
    Battery (batt_volt)
    ModbusMaster (ResultCode(1),ComC1,19200,111,4,CS240DM(1),1,5,3,100,2)
    ModbusMaster (ResultCode(2),ComC1,19200,2,4,CS240DM(6),1,5,3,100,2)
    ModbusMaster (ResultCode(3),ComC1,19200,3,4,CS240DM(11),1,5,3,100,2)
    ModbusMaster (ResultCode(4),ComC1,19200,4,4,CS240DM(16),1,5,3,100,2)

    AveTemp(1) = CS240DM(2)
    AveTemp(2) = CS240DM(7)
    AveTemp(3) = CS240DM(12)
    AveTemp(4) = CS240DM(17)

    AvgTemp = (AveTemp(1) + AveTemp(2) + AveTemp(3) + AveTemp(4))/4
    StdDevSpa (SD_Temp,4,AveTemp())

    CallTable Hourly
  NextScan
EndProg
```

Appendix C. Sensor material properties

The sensor consists of 6061 aluminum (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.

Limited warranty

Products manufactured by Campbell Scientific are warranted by Campbell Scientific to be free from defects in materials and workmanship under normal use and service for twelve months from the date of shipment unless otherwise specified on the corresponding product webpage. See Product Details on the Ordering Information pages at www.campbellsci.com. Other manufacturer's products, that are resold by Campbell Scientific, are warranted only to the limits extended by the original manufacturer.

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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.com. 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

- Protect from over-voltage.
- Protect electrical equipment from water.
- Protect from electrostatic discharge (ESD).
- Protect from lightning.
- Prior to performing site or installation work, obtain required approvals and permits. Comply with all governing structure-height regulations.
- 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, 6 meters (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.
- Only use power sources approved for use in the country of installation to power Campbell Scientific devices.

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.

Internal Battery

- Be aware of fire, explosion, and severe-burn hazards.
- Misuse or improper installation of the internal lithium battery can cause severe injury.
- Do not recharge, disassemble, heat above 100 °C (212 °F), solder directly to the cell, incinerate, or expose contents to water. Dispose of spent batteries properly.

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