Product Manual

CS240 and CS240DM

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

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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 CS240DM 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. 8)).
- 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, PC400, or PC200W.

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 CS240 and CS240DM, 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.

```
CS240 (2-wire) Class A RTD Back of PV Module Temperature Sensor
Units for Temperature: Deg C, Deg F, K
This module will wire the CS240 for a 2-wire half-bridge measurement rather than a 4-wire half bridge measurement. The 2-wire configuration accuracy decreases, relative to the 4-wire, as a function of the cable length. The 4-wire configuration accuracy assumes a matched cable length.
```

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 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 commonly seen in 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 lead-wire resistance. Measurement electronics are surge protected with 1200 V isolation and environmentally protected with a rugged overmolding with an IP65 rating.

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
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, and CR5000
- 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 with 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
Temperature range: –40 to 135 °C
Temperature coefficient: TCR = 3850 ppm/K
Long-term stability: Max Ro 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: 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 with IP65 rating

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

Compliant with IEC 60751, DIN EN 60751,
Industrial Design (IEC Class 4) (according to IEC 751)

CS240 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. 11) and Data logger programming (p. 14). Short Cut does this work for you. See QuickStart (p. 2) for a Short Cut tutorial.

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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 aluminum 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 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 7-1 (p. 10)). 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 7-2 (p. 10)) 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 7-2 (p. 10)).

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. 8)).

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 7-2 (p. 10).
FIGURE 7-1. Strain relief label on the cable

FIGURE 7-2. Proper tape usage
7.2.3 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.

7.3 Wiring

FIGURE 7-3 (p. 11) provides the circuit diagrams for the CS240 2-wire configuration. FIGURE 7-4 (p. 12) provides the circuit diagram for the CS240DM or the CS240 4-wire configuration.

![Circuit Diagram]

*FIGURE 7-3. 2-Wire Circuit Diagram*
7.3.1 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. 12) and Table 7-2 (p. 13)). 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

<table>
<thead>
<tr>
<th>Wire color</th>
<th>Wire function</th>
<th>Data logger connection terminals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black</td>
<td>Voltage excitation input</td>
<td>U configured for voltage excitation(^1), EX, VX (voltage excitation)</td>
</tr>
<tr>
<td>White</td>
<td>Analog voltage output</td>
<td>U configured for single-ended analog input(^1), SE (single-ended, analog input)</td>
</tr>
<tr>
<td>Red</td>
<td>Reference</td>
<td>☼ (analog ground)</td>
</tr>
</tbody>
</table>

\(^1\) U terminals are automatically configured by the measurement instruction.
### Table 7-2: Wire color and data logger connection for the CS240 4-wire configuration

<table>
<thead>
<tr>
<th>Wire color</th>
<th>Wire function</th>
<th>Data logger connection terminals</th>
</tr>
</thead>
<tbody>
<tr>
<td>White</td>
<td>Analog voltage output(^1)</td>
<td>U configured for differential high analog input(^2), DIFF H (differential high, analog-voltage input)</td>
</tr>
<tr>
<td>Black</td>
<td>Reference(^1)</td>
<td>U configured for differential low analog input(^2), DIFF L (differential low, analog-voltage input)</td>
</tr>
<tr>
<td>Red</td>
<td>Voltage excitation input</td>
<td>U configured for voltage excitation(^2), EX, VX (voltage excitation)</td>
</tr>
<tr>
<td>Red</td>
<td>Analog voltage output(^3)</td>
<td>U configured for differential high analog input(^2), DIFF H (differential high, analog-voltage input)</td>
</tr>
<tr>
<td>White</td>
<td>Reference(^3)</td>
<td>U configured for differential low analog input(^2), DIFF L (differential low, analog-voltage input)</td>
</tr>
<tr>
<td>Black</td>
<td>Ground</td>
<td>☯ (analog ground)</td>
</tr>
<tr>
<td>Clear/shield</td>
<td>Shield</td>
<td>☯ (analog ground)</td>
</tr>
</tbody>
</table>

\(^1\) First differential terminal in the BrHa1f4W() instruction.

\(^2\) U terminals are automatically configured by the measurement instruction.

\(^3\) Second differential terminal in the BrHa1f4W() instruction.

### 7.3.2 CS240DM wiring

The CS240DM can have a standard cable or a 3-twisted pair cable (Table 7-3 (p. 13)). The wiring for the CS240DM 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

<table>
<thead>
<tr>
<th>Standard cable wire color</th>
<th>3-twisted pair cable wire color</th>
<th>Station (data logger) terminal</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blue</td>
<td>Green</td>
<td>A– (C odd)</td>
<td>RS-485 A/A’ [-]</td>
</tr>
<tr>
<td>White/blue striped</td>
<td>White</td>
<td>B+ (C even)</td>
<td>RS-485 B/B’ [+]</td>
</tr>
<tr>
<td>Brown</td>
<td>Red</td>
<td>12V</td>
<td>5 to 30 VDC</td>
</tr>
<tr>
<td>White/brown striped</td>
<td>Black</td>
<td>G</td>
<td>Ground (power)</td>
</tr>
<tr>
<td>Green</td>
<td>Yellow</td>
<td>G (☯)</td>
<td>Modbus common</td>
</tr>
<tr>
<td>--</td>
<td>Clear</td>
<td>G (☯)</td>
<td>Shield</td>
</tr>
</tbody>
</table>
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. 21). 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. 22).

If applicable, please read Electrical noisy environments (p. 17) and Long cable lengths (p. 17) prior to programming your data logger.

7.4.1 CS240 programming

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

7.4.1.1 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:

```plaintext
BrHalf4W(CS240X,1,mV200,mV200,U1,U5,1,350,True,True,0,60,1,0)
```

A typical **BrHalf()** instruction is:

```plaintext
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.
7.4.1.2 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:

\[ Rs = \text{CS240X} \times \frac{(1000 + R_c)}{(1 - \text{CS240X})} - R_c \]

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

7.4.2 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 CS240DM Input Registers (Table 7-4 (p. 15)). To do this, the CRBasic program requires a `SerialOpen()` instruction followed by the `ModbusMaster()` instruction.

<table>
<thead>
<tr>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Serial number</td>
<td>Specifies the sensor serial number assigned by the factory</td>
</tr>
<tr>
<td>Temperature</td>
<td>The CS240DM measures temperature by using a 4-wire configuration. The stored value is in degrees Celsius.</td>
</tr>
<tr>
<td>Counter</td>
<td>The counter provides an indicator that the sensor is actively taking measurements. This value will increment once per measurement, rolling over at 10,000.</td>
</tr>
</tbody>
</table>
Table 7-4: CS240DM stored values

<table>
<thead>
<tr>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensor status</td>
<td>Value</td>
</tr>
<tr>
<td></td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Temperature range check</td>
<td>Value</td>
</tr>
<tr>
<td></td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>1</td>
</tr>
</tbody>
</table>

The **SerialOpen** instruction has the following syntax:

```plaintext
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:

```plaintext
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.

For more information, refer to **CS240DM program** (p. 30).

8. Operation

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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.

![Error as a function of Cable length](image)

**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:

\[
\text{Cable resistance} = 0.0274 \text{ ohm/feet} \times \text{cable length (in feet)}
\]

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 \text{BrHalf4W()} or \text{BrHalf()} instruction.

8.2.2 CS240DM long cable lengths

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 CS240DM and Device Configuration Utility

Device Configuration Utility (DevConfig) is bundled in Campbell Scientific’s data logger support software and can also be acquired, at no cost, from www.campbellsci.com/downloads.

DevConfig can be used to change the CS240DM settings, view stored values, and update the CS240DM operating system (OS). It also provides CS240DM wiring information.

To use DevConfig, 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 DevConfig:

1. Open DevConfig.
2. Under \text{Device Type}, click \text{CS240DM}.
3. Follow steps listed under **Connecting to a CM240DM with a USB to RS 485 adaptor**.

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 or white/green striped 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. 22) provides wiring for the CS240 two-wire configuration programs (p. 23). Table B-2 (p. 22) provides wiring for the CS240 four-wire configuration programs (p. 27), and Table B-3 (p. 23) provides wiring for the CS240DM program (p. 30).

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

<table>
<thead>
<tr>
<th>Wire color</th>
<th>Wire function</th>
<th>CR300 terminals</th>
<th>CR6 terminals</th>
<th>CR1000X terminals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black</td>
<td>Voltage excitation input</td>
<td>VX1</td>
<td>U1</td>
<td>VX1</td>
</tr>
<tr>
<td>White</td>
<td>Analog voltage output</td>
<td>SE1</td>
<td>U2</td>
<td>SE1</td>
</tr>
<tr>
<td>Red</td>
<td>Reference</td>
<td>‡ (analog ground)</td>
<td>‡ (analog ground)</td>
<td>‡ (analog ground)</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Wire color</th>
<th>Wire function</th>
<th>CR300 terminals</th>
<th>CR6 terminals</th>
<th>CR1000X terminals</th>
</tr>
</thead>
<tbody>
<tr>
<td>White</td>
<td>Analog voltage output</td>
<td>1H</td>
<td>U3</td>
<td>1H</td>
</tr>
<tr>
<td>Black</td>
<td>Reference</td>
<td>1L</td>
<td>U4</td>
<td>1L</td>
</tr>
<tr>
<td>Red</td>
<td>Voltage excitation input</td>
<td>VX1</td>
<td>U1</td>
<td>VX1</td>
</tr>
<tr>
<td>Red</td>
<td>Analog voltage output</td>
<td>2H</td>
<td>U5</td>
<td>2H</td>
</tr>
<tr>
<td>White</td>
<td>Reference</td>
<td>2L</td>
<td>U6</td>
<td>2L</td>
</tr>
<tr>
<td>Black</td>
<td>Ground</td>
<td>‡ (analog ground)</td>
<td>‡ (analog ground)</td>
<td>‡ (analog ground)</td>
</tr>
<tr>
<td>Clear/shield</td>
<td>Shield</td>
<td>‡ (analog ground)</td>
<td>‡ (analog ground)</td>
<td>‡ (analog ground)</td>
</tr>
</tbody>
</table>
### Table B-3: Wiring for the CS240DM example program

<table>
<thead>
<tr>
<th>Standard cable wire color</th>
<th>3-twisted pair cable wire color</th>
<th>CR6 terminal</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blue</td>
<td>Green</td>
<td>C1</td>
<td>RS-485 A/A' [-]</td>
</tr>
<tr>
<td>White/blue striped</td>
<td>White</td>
<td>C2</td>
<td>RS-485 B/B' [+]</td>
</tr>
<tr>
<td>Brown</td>
<td>Red</td>
<td>12V</td>
<td>5 to 30 VDC</td>
</tr>
<tr>
<td>White/brown striped</td>
<td>Black</td>
<td>G</td>
<td>Ground (power)</td>
</tr>
<tr>
<td>Green</td>
<td>Yellow</td>
<td></td>
<td>Modbus common</td>
</tr>
<tr>
<td>--</td>
<td>Clear</td>
<td></td>
<td>Shield</td>
</tr>
</tbody>
</table>

### B.1 CS240 two-wire configuration programs

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

```crbasic
'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

EndProg
```

---

CS240 and CS240DM PT-1000 Class A, Back-of-Module Temperature Sensors  23
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
  PRTC Calc(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
'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
   EndScan
EndProg
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(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, 3M9485PC adhesive, and Santoprene® jacketed cable.

C.1 3M 9485PC adhesive

**Humidity resistance:** High humidity has a minimal effect on adhesive performance. Bond strengths are generally higher after exposure for 7 days at 90 °F (32 °C) and 90% relative humidity.

**U.V. resistance:** When properly applied, nameplates and decorative trim parts are not adversely affected by outdoor exposure.

**Water resistance:** Immersion in water has no appreciable effect on the bond strength. After 100 hours in room temperature water, the bond actually shows an increase in strength.

**Temperature cycling resistance:** Bond strength generally increases after cycling four times through:

- 4 hours at 158 °F (70 °C)
- 4 hours at −20 °F (−29 °C)
- 16 hours at room temperature

**Chemical resistance:** When properly applied, adhesive will hold securely after exposure to numerous chemicals including gasoline, oil, Freon™ TF, sodium chloride solution, mild acids, and alkalis.

**Heat resistance:** Adhesive is usable for short periods (minutes, hours) at temperatures up to 350 °F (177 °C) and for intermittent longer periods (days, weeks) up to 250 °F (121 °C).

**Low temperature service:** −40 °F (−40 °C). Parts should be tested for low temperature shock service.
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.

Refer to www.campbellsci.com/terms#warranty for more information.

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To obtain a Returned Materials Authorization (RMA) number, contact CAMPBELL SCIENTIFIC, INC., phone (435) 227-9000. Please write the issued RMA number clearly on the outside of the shipping container. Campbell Scientific’s shipping address is:

CAMPBELL SCIENTIFIC, INC.
RMA#____
815 West 1800 North
Logan, Utah 84321-1784

For all returns, the customer must fill out a “Statement of Product Cleanliness and Decontamination” form and comply with the requirements specified in it. The form is available from our website at www.campbellsci.com/repair. A completed form must be either emailed to repair@campbellsci.com or faxed to (435) 227-9106. Campbell Scientific is unable to process any returns until we receive this form. If the form is not received within three days of product receipt or is incomplete, the product will be returned to the customer at the customer’s expense. Campbell Scientific reserves the right to refuse service on products that were exposed to contaminants that may cause health or safety concerns for our employees.
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.campbellsic.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, 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.

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.

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.
Campbell Scientific regional offices

**Australia**
Location: Garbutt, QLD Australia  
Phone: 61.7.4401.7700  
Email: info@campbellsci.com.au  
Website: www.campbellsci.com.au

**Brazil**
Location: São Paulo, SP Brazil  
Phone: 11.3732.3399  
Email: vendas@campbellsci.com.br  
Website: www.campbellsci.com.br

**Canada**
Location: Edmonton, AB Canada  
Phone: 780.454.2505  
Email: dataloggers@campbellsci.ca  
Website: www.campbellsci.ca

**China**
Location: Beijing, P. R. China  
Phone: 86.10.6561.0080  
Email: info@campbellsci.com.cn  
Website: www.campbellsci.com.cn

**Costa Rica**
Location: San Pedro, Costa Rica  
Phone: 506.2280.1564  
Email: info@campbellsci.cc  
Website: www.campbellsci.cc

**France**
Location: Vincennes, France  
Phone: 0033.0.1.56.45.15.20  
Email: info@campbellsci.fr  
Website: www.campbellsci.fr

**Germany**
Location: Bremen, Germany  
Phone: 49.0.421.460974.0  
Email: info@campbellsci.de  
Website: www.campbellsci.de

**India**
Location: New Delhi, DL India  
Phone: 91.11.46500481.482  
Email: info@campbellsci.in  
Website: www.campbellsci.in

**South Africa**
Location: Stellenbosch, South Africa  
Phone: 27.21.8809960  
Email: sales@campbellsci.co.za  
Website: www.campbellsci.co.za

**Spain**
Location: Barcelona, Spain  
Phone: 34.93.2323938  
Email: info@campbellsci.es  
Website: www.campbellsci.es

**Thailand**
Location: Bangkok, Thailand  
Phone: 66.2.719.3399  
Email: info@campbellsci.asia  
Website: www.campbellsci.asia

**UK**
Location: Shepshed, Loughborough, UK  
Phone: 44.0.1509.601141  
Email: sales@campbellsci.co.uk  
Website: www.campbellsci.co.uk

**USA**
Location: Logan, UT USA  
Phone: 435.227.9120  
Email: info@campbellsci.com  
Website: www.campbellsci.com