Product Manual

CS230/CS231
Temperature Profilers

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CS230/CS231 Temperature Profiler

1. Introduction

The CS230/CS231 temperature profiler provides temperature measurements both in a rigid probe assembly and external probes using digital sensor technology. It uses the SDI-12 communication protocol to communicate with an SDI-12 recorder simplifying installation and programming.

NOTE
SGB3 Surge Protectors were shipped with older CS230 temperature profilers (serial numbers < 1162). Newer CS230s (serial numbers ≥ 1162) and all CS231s include built-in surge protection, and therefore do not need the SGB3. For more information, refer to Appendix D, SGB3 Electrical Surge Protector (p. D-1).

2. Precautions

- Although the CS230/CS231 is designed to be a rugged and reliable device for field use, care should be taken when handling or moving it to avoid damage.

- There are no user-serviceable parts and disassembling the device will void the warranty.

- The black outer jacket of the cable is Santoprene® rubber. This compound was chosen for its resistance to temperature extremes, moisture, and UV degradation. However, this jacket will support combustion in air. It is rated as slow burning when tested according to U.L. 94 H.B. and will pass FMVSS302. Local fire codes may preclude its use inside buildings.

3. Initial Inspection

- Upon receipt of the CS230/CS231, inspect the packaging and contents for damage. File any damage claims with the shipping company. Immediately check package contents against the shipping documentation. Contact Campbell Scientific about any discrepancies.

- The model number and cable length 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.com/videos/cr1000x-datalogger-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 CS230/CS231.

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 CS231 or locate the sensor in the **Sensors | Temperature** folder. Double-click **CS230/CS231 SDI-12 Temperature Profiler**. Type the correct **Starting SDI-12 Address** for the first external probe or the top temperature point in the rigid probe if no external probes are included (Section 8.1.1, **SDI-12 Addressing** (p. 9)). Type the **Number of Result Sensors**.

4. Click 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 3 and 4 for other sensors.
6. In **Output Setup**, type the scan rate, meaningful table names, and **Data Output Storage Interval**.

![Output Setup](image1)

7. Select the measurement and its associated output option.

![Measurement Selection](image2)

8. Click **Finish** and save the program. Send the program 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 data display in **LoggerNet, RTDAQ, PC400, or PC200W** to make sure it is making reasonable measurements.

5. **Overview**

The CS231 offers the same precise temperature profiling as our CS230 SDI-12 Temperature Profiler, but designed for easier use in borehole and road applications. The two profilers have the same programming, wiring, and measurement specifications.

The CS230/CS231 temperature profiler uses digital sensor technology allowing for a simple 3-wire integration. The CS230/CS231 consists of a rigid probe.
assembly and up to four optional external temperature probes. The rigid probe assembly maintains the precise position of the temperature points within the profile, while protecting the temperature sensors in all mediums.

The CS230/CS231 is suited for a wide variety of applications and environments. The completely sealed probe assembly and external probes permits the CS230/CS231 to be used in roadbeds, soils, and water (snow and ice).

Examples of some applications include spring load adjustment, frost and permafrost monitoring, soil and water temperature profiling, and snowpack temperature profiling.

Features:

- Accurate and stable measurements
- Each sensor is individually addressed and referenced to its depth
- Low power consumption
- Digital SDI-12 output
- Compatible with the following data loggers: CR6, CR3000, CR1000X, CR800 Series, CR300 Series, CR1000, CR200(X) Series, CR5000

6. Specifications

Operating Range: –55 to 85 °C

Accuracy

Typical: ±0.2 °C over –40 to 85 °C,

Worst Case:
±0.4 °C over –40 to 85 °C;
±0.5 °C over –55 to –40 °C
(includes lifetime drift of sensor)

Resolution: 0.0078 °C

Output Protocol: SDI-12 1.3

Measurement Update Interval: 1 s (automatic), occurs in quiescent mode

Warm-up Time: 10 s

Time Constant (Ice Bath)

External Probe: 60 s
Tee Sensor: 720 s
Second Sensor from Tee: 420 s
Remainder of Profiler: 300 s

Maximum Sensors per Probe: 32 sensors in rigid probe assembly, 4 external sensors

External Probe Length: 45 cm (18 in)

Supply Voltage: 9 to 28 VDC
Current Consumption

**Quiescent:**  
# sensors • 1.0 mA (max)

**Active (during SDI-12 communications):**  
20 mA + (# sensors • 1.0 mA)

**Main Diameter:** 2.13 cm (0.84 in)

**Maximum Length:** 3.0 m (118 in)

**Maximum Cable Length:** 152 m (500 ft)

**Minimum Sensor Spacing:** 5 cm (1.97 in) in rigid probe assembly


### 7. Installation

#### 7.1 Siting

Install the CS230/CS231 directly in the medium that is to be measured. The types of medium that can be measured are varied, including soils, roadbeds, and water. To make the most representative measurement, it is important that consistent contact be made between the temperature profiler and the medium.

The location of the temperature profiler should be representative of the intended application. Typically, the first measurement point in the rigid assembly should have a minimum burial depth of 20 cm. This helps protect the sensor from damage in roadbed applications, and helps secure the sensor against frost heaving. Use the external probes for measurements at shallower depths. The external probes are sheathed in a stainless-steel housing to protect them against possible damage.

The installation depth of the rigid assembly is referenced at the first measurement point in the assembly (shown in FIGURE 7-1, Internal Sensor Position #4). This information needs be addressed as part of the sensor configuration process.
FIGURE 7-1. CS231 installation example with three external sensors and five internal sensors.

NOTE

FIGURE 7-1 is an example configuration with three external sensors and five internal sensors. Each profiler is custom built to the user’s specific requirements.

FIGURE 7-2 shows the label for the first and last internal sensor locations.

FIGURE 7-2. Internal sensor label
7.2 Mounting

Orient and secure the CS230/CS231 in the measurement medium. Keep materials removed during installation and use that material as backfill.

While installing the CS230/CS231, the depth must be referenced between the surface of the medium and the first measurement point in the assembly (shown in FIGURE 7-1, Internal Sensor Position #4). If the rigid assembly is not placed at the correct depth, all measurement depths will be out of place.

Install the external probes horizontally in the measurement medium. This helps ensure that the most representative measurement is taken at the given depth, and will not interfere with other nearby measurements.

Orient the signal and power cable of the CS230/CS231 towards the data logger to avoid loops or strain on the cable. Also use a suitable trench or conduit to protect the signal and power cable from damage.

7.3 Wiring

TABLE 7-1 provides the connections for the CS230/CS231 and Campbell Scientific data loggers. Refer to Appendix D, SGB3 Electrical Surge Protector (p. D-1), if the CS230 serial number is less than 1162.

<table>
<thead>
<tr>
<th>Wire Color</th>
<th>Function</th>
<th>Data Logger Connection Terminal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red</td>
<td>Power</td>
<td>12V</td>
</tr>
<tr>
<td>Green</td>
<td>SDI-12 Signal</td>
<td>C or U¹ terminal configured for SDI-12</td>
</tr>
<tr>
<td>Black</td>
<td>Power Ground</td>
<td>G</td>
</tr>
<tr>
<td>Clear</td>
<td>Shield</td>
<td>▼</td>
</tr>
</tbody>
</table>

¹ U terminals are automatically configured by the measurement instruction.

If multiple SDI-12 sensors are connected to a data logger, Campbell Scientific recommends using separate terminals when possible. For the CR6 and CR1000X, triggering conflicts may occur when a companion terminal is used for a triggering instruction such as TimerInput(), PulseCount(), or WaitDigTrig(). For example, if the CS230/CS231 is connected to C3 on a CR1000X, C4 cannot be used in the TimerInput(), PulseCount(), or WaitDigTrig() instructions.

7.4 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.

*Short Cut* cannot edit programs after they are imported and edited in CRBasic Editor.
A Short Cut tutorial is available in Section 4, QuickStart (p. 1). If you wish to import Short Cut code into CRBasic Editor to create or add to a customized program, follow the procedure in Appendix A, Importing Short Cut Code Into CRBasic Editor (p. A-1). Programming basics for CRBasic data loggers are provided in the following section. Appendix B, Example Programs (p. B-1), provides a complete CRBasic program that measures the CS230/CS231.

7.4.1 SDI12Recorder() Instruction

The SDI12Recorder() instruction is used to measure the temperature sensors in the CS230/CS231. This instruction sends a request to the sensor to make a measurement and then retrieves the measurement from the sensor. See Section 8.1, Sensor Measurements (p. 8), for more information.

For most data loggers, the SDI12Recorder() instruction has the following syntax:

\[
\text{SDI12Recorder(Destination, SDIPort, SDIAddress, "SDICommand", Multiplier, Offset, FillNAN, WaitonTimeout)}
\]

Each temperature sensor in the CS230/CS231 needs a unique SDI-12 address. For the SDIAddress, alphabetical characters need to be enclosed in quotes (for example, “A”). Also enclose the SDICommand in quotes as shown. The Destination parameter must be an array. The required number of values in the array depends on the command (TABLE 8-1).

FillNAN and WaitonTimeout are optional parameters (refer to CRBasic Help for more information).

7.4.2 Slow Sequence Program Instructions

Use the slow sequence program instructions when the CS230/CS231 measurements will exceed the program scan interval of the additional instruments included in the station. For example, if a CS230/CS231 consists of 17 or more temperature sensors, the time required to poll all sensors and receive data can be greater than 5 seconds based on the 300 ms execution time for the aR0! command. For more details on the use of the slow sequence program instructions, reference the related LoggerNet Help, data logger manual, or Appendix B.2, CR1000X Slow Sequence Program (p. B-2).

8. Operation

8.1 Sensor Measurements

The CS230/CS231 responds to the SDI-12 commands shown in TABLE 8-1. When power is supplied to the CS230/CS231, the internal electronics continuously measure temperature at a rate of approximately once per second. Every output measurement (aR0! or aM0!) obtained from the sensor is a running average of 10 consecutive readings. The accuracy specification is based on an average of 10 consecutive readings. Therefore, after initial power up, a delay of 10 s is recommended to obtain the best accuracy.

As the sensor is obtaining a measurement every second, Campbell Scientific recommends using the continuous measurement command (aR0!) to obtain the temperature readings. Using the aR0! commands reduces the time taken in comparison to the aM0! to obtain a reading via the SDI-12 protocol.
Outputs of both lifetime and user resettable minimum and maximum temperatures are also available during powered operation from each temperature point in the CS230/CS231. The user-resettable minimum and maximum temperatures can be used to monitor specific seasons or periods of measure, without having to review the entire data set. The lifetime minimum and maximum temperatures are used for maintenance and warranty records. The lifetime and user-resettable minimum and maximum temperature values are single 1-second readings.

<table>
<thead>
<tr>
<th>SDI-12 Command</th>
<th>Variable Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>aR0!</td>
<td>Temperature value</td>
<td>Temperature – floating point (°C)</td>
</tr>
<tr>
<td>aR1!</td>
<td>Serial number, location number, depth value (in cm)</td>
<td>Serial number, location number, depth value (in cm)</td>
</tr>
<tr>
<td>aR2!</td>
<td>Read user resettable min temperature</td>
<td>Min. temperature – floating point (°C)</td>
</tr>
<tr>
<td>aR3!</td>
<td>Read user resettable max temperature</td>
<td>Max. temperature – floating point (°C)</td>
</tr>
<tr>
<td>aR4!</td>
<td>Read lifetime min temperature</td>
<td>Min. temperature – floating point (°C)</td>
</tr>
<tr>
<td>aR5!</td>
<td>Read lifetime max temperature</td>
<td>Max. temperature – floating point (°C)</td>
</tr>
<tr>
<td>aR6!</td>
<td>Read and reset user resettable min temperature</td>
<td>Min. temperature – floating point (°C). This value constitutes the minimum of all 1-second measurements taken since the previous aR6! command.</td>
</tr>
<tr>
<td>aR7!</td>
<td>Read and reset user resettable max temperature</td>
<td>Max. temperature – floating point (°C). This value constitutes the maximum of all 1-second measurements taken since the previous aR7! command.</td>
</tr>
</tbody>
</table>
| aV!            | Verification command | S1 = BootRom Signature  
S2 = Firmware Signature |
| aAb!           | Change Address command | Valid addresses in sequence are:  
1–9 / A–Z / a–z (no Address 0)  
Sending a broadcast message with the address change “{” can correct units that have conflicting addresses. |
| aI!            | SDI-12 Identification command | X13CAMPBELLCS230 1.0 SN:XXXXX |

### 8.1.1 SDI-12 Addressing

Each temperature sensor has a different default SDI-12 address. The starting addresses is 1 and coincides with the first external probe or the top temperature point in the rigid probe if an external probe is not included. The last address coincides with the bottom sensor in the rigid probe assembly.

If multiple SDI-12 sensors are connected to the data logger, Campbell Scientific recommends using separate terminals when possible. However, multiple SDI-12 sensors or multiple CS230/CS231 sensors can connect to the
same data logger control or U terminal if they have different SDI-12 addresses. If changing the SDI-12 addresses, Campbell Scientific recommends starting the readdressing process with the largest temperature sensor address to avoid duplicate addresses. TABLE 8-2 provides the SDI-12 addresses and positions.

NOTE

Use the default SDI-12 addresses when possible. Inadvertently giving multiple sensors the same SDI-12 address will prevent the sensors from communicating. Use the aA! command, where a is the affected address to reset the affected sensors to their factory configured address value.

<table>
<thead>
<tr>
<th>TABLE 8-2. SDI-12 Addresses and Positions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Numeric Set</strong></td>
</tr>
<tr>
<td>1 / 1</td>
</tr>
<tr>
<td>2 / 2</td>
</tr>
<tr>
<td>3 / 3</td>
</tr>
<tr>
<td>4 / 4</td>
</tr>
<tr>
<td>5 / 5</td>
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</tbody>
</table>
8.1.2 Metadata

Every temperature point in a probe includes the following metadata, which can be retrieved using the aR! SDI-12 command. This information can be used to identify details of the temperature probe and its individual temperature points.

<table>
<thead>
<tr>
<th>Name</th>
<th>Value Range</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Serial Number</td>
<td>0 to 65534</td>
<td>The serial number that is unique to each probe unit.</td>
</tr>
<tr>
<td>Location Number</td>
<td>1 to 255</td>
<td>Each temperature sensor within a probe is assigned its own unique location number which by default is in relation to the SDI-12 address (see TABLE 8-2).</td>
</tr>
<tr>
<td>Depth Value</td>
<td>0 to 65535 cm</td>
<td>The distance values in centimeters (cm). These are intended to reflect the profile distances. Typically, the top most temperature point would be designated as 0 cm and if the next temperature point below was 10 cm away, then its distance value would be 10 cm. Users may designate other starting values. These can be configured at the time of ordering.</td>
</tr>
</tbody>
</table>

8.2 Long Cables

As the measurement data is transferred between the temperature profiler and data logger digitally, there are no offset errors incurred with increasing cable length as seen with analog sensors. However, with long enough cable lengths, the digital communications will break down, resulting in either no response from the sensor or corrupted readings. The original SDI-12 standard specifies the maximum total cable length for the cable as being 61 m (200 ft), but we are able to exceed this limit by:

- Using low capacitance, low resistance, screened cable
- Ensuring that the power ground cable has low resistance and is connected to the same ground reference as the data logger control or U terminals

8.3 Power Conservation

The CS230/CS231 draws less than 1 mA of current per sensor between polling sessions from its 12 V supply. In many applications, this is minimal compared to overall system power use, so the sensor can be permanently powered to avoid the warm-up period.

In low power applications, you can switch the power on a minimum of 10 s (allowing for the warm-up period) before polling the CS230/CS231. This switching can be achieved in different ways depending on the type and model of your data logger. If available, the switched 12 V output of the data logger can be used.
9. Maintenance, Calibration, and Troubleshooting

The CS230/CS231 probe requires no maintenance nor calibration. The following are symptoms and possible corrections.

Symptom: –9999 or NAN for temperature

1. Verify the green wire is connected to the control port specified by the SDI12 measurement instruction.

2. Verify the red power wire is connected to a 12V terminal; check the voltage with a digital volt meter. If a switched 12V terminal is used, temporarily connect the red wire to a 12V terminal (non-switched) for test purposes.

Symptom: Sensor won’t respond to command

1. Expected address not used or has been changed.
   a. Confirm all addresses in use with the aI! command to determine the individual addresses of each temperature sensor.

2. Expected sensor address has been to match another sensor address already in use.
   a. When readdressing temperature sensors, you must avoid giving multiple sensors the same address. If this does occur, you will no longer be able to communicate with these sensors. Use the aA! command, where a is the affected address. This will reset the affected sensors to their factory configured address value. For example, if two sensors have address 2, sending 2A! will reset both sensors to the original addresses.
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

B.1 CR1000X Program for Measuring 15 Temperature Sensors

In this example, a CS230/CS231 is connected to control terminal 1 on a CR1000X. The CS230/CS231 includes 15 sensors with SDI-12 addresses 1 through 9 and A through F. Every 60 s, the aR0! command polls each temperature sensor, then the data is stored in a table. Other common station data is measured every 60 seconds and stored to a daily data table.

CRBasic Example B-1. CR1000X Program for Reading CS230/CS231 with 15 Sensors

'CR1000X Series Data Logger
'This program reads a CS230/CS231 probe that has 15 temperature Sensors

'Declare Public Variables
Public PTemp, batt_volt

'Enter the number of temperature sensors that are in the probe (will need to be
'adjusted to fit specific application)
Const NumTempSensors=15

'Uses the control terminal C1 on the CR1000X
Const SDI12_Port=C1

Public TempC(NumTempSensors) As Float
Dim i As Long

'Define Data Tables
DataTable (Daily,1,-1)      
  DataInterval (0,1440,Min,10)     
  Minimum (1,batt_volt,FP2,0,False)  
  Maximum (1,batt_volt,FP2,0,False)  
  Average (1,batt_volt,FP2,0)       
  Minimum (1,PTemp,FP2,0,False)     
  Maximum (1,PTemp,FP2,0,False)     
  Average (1,PTemp,FP2,0)           
EndTable

DataTable (TempSample,1,-1)   
  DataInterval (0,60,Sec,10) 
  Sample (NumTempSensors,TempC(),IEEE4)  
EndTable

'Define Subroutines
'*****************************************************************************
'*/ ConvertSDI12addr() ----------------------------------------------- */
'*/ Convert SDI-12 character address (0->9, A->Z, and a->z) to number value */
'*/ (0->61).                                                            */
'*****************************************************************************

Function ConvertSDI12addr(address As Long) As String * 1
Select Case address
Case 0 To 9  'ASCII Code 48->57 = 0->9
  Return(CHR(address + 48))
Case 10 To 35 'ASCII Code 65->90 = A->Z = 10->35
  Return(CHR(address + 55))
Case 36 To 61 'ASCII Code 97->122 = a->z = 36->61
  Return(CHR(address + 61))
End Select
B.2 CR1000X Slow Sequence Program

In this example, a CS230/CS231 is polled on control terminal 1 of a CR1000X in a slow sequence. The CS230 includes 20 temperature sensors with SDI-12 addresses 1 through 9 and A through F. Each sensor is polled with the \texttt{aRO!} command every 60 seconds, and stored to a data table on the same interval. Other common station data is measured every 5 seconds and stored to a daily and hourly data tables.

\begin{tabular}{|p{\textwidth}|}
\hline
\textbf{CRBasic Example B-2. CR1000X Program Using Slow Sequence to Read CS230/CS231 with 20 Sensors} \\
\hline
\end{tabular}
Average (1, PTemp, FP2, 0)
EndTable

DataTable (One_Minute, 1, -1)
DataInterval (0, 60, Sec, 10)
Sample (NumTempSensors, TempC(), IEEE4)
EndTable

'Define Subroutines

'*****************************************************************************
' *  ------------------------- ConvertSDI12addr() --------------------------  *
' *  Convert SDI-12 character address (0->9, A->Z, and a->z) to number value  *
' *  (0->61).                                                              *
'*****************************************************************************

Function ConvertSDI12addr(address As Long) As String * 1
Select Case address
Case 0 To 9    'ASCII Code 48->57 = 0->9
  Return(CHR(address + 48))
Case 10 To 35  'ASCII Code 65->90 = A->Z = 10->35
  Return(CHR(address + 55))
Case 36 To 61  'ASCII Code 97->122 = a->z = 36->61
  Return(CHR(address + 61))
EndSelect
Return(""")
EndFunction  'ConvertSDI12addr()

'EndSub

'Main Program
BeginProg

Scan (5, Sec, 0, 0)
  PanelTemp (PTemp, 250)
  Battery (batt_volt)
  CallTable Daily
  CallTable Hourly

NextScan

'Poll CS230/CS231 in Slow Sequence every minute
SlowSequence
Scan (60, Sec, 3, 0)

'Read the current temperature value
For i = 1 To NumTempSensors
  SDI12Recorder (TempC(i), SDI12_Port, ConvertSDI12addr(i), "R0!", 1.0, 0)
Next

CallTable One_Minute

NextScan
EndProg

B.3 CR1000X Program to Read Metadata of 15 Temperature Sensors

In this example, a CS230/CS231 is on control terminal 1 of a CR1000X. The CS230/CS231 includes 15 sensors with SDI-12 addresses 1 through 9 and A through F. Each temperature sensor is polled on power up and daily with the aR1! command to determine metadata, which is stored in a daily data table.
Other common station data is measured every 60 seconds and stored to a separate daily data table.

CRBasic Example B-3. CR1000X Program Reading Metadata of CS230/CS231 with 15 Sensors

'CR1000X Series Data Logger
'This program reads a CS230/CS231 probe that has 15 temperature sensors

'Declare Public Variables
Public PTemp, batt_volt

'Enter the number of temperature sensors that are in the probe (will need to be adjusted to fit specific application)
Const NumTempSensors=15
'Calculate the number of Metadata points based on the number of sensors
Const MetaData_pts=NumTempSensors*3
'Uses the control terminal C1 on the CR1000X
Const SDI12_Port=C1

Public Meta(NumTempSensors,3) As Float
Dim i As Long

'Declare Variables
DataTable (MetaData,1,-1)
DataInterval (0,1,Day,10)
Sample (MetaData_pts,Meta(),FP2)
EndTable

'Declare Subroutines
'*****************************************************************************
'*  ------------------------- ConvertSDI12addr() --------------------------  *
'*  Convert SDI-12 character address (0->9, A->Z, and a->z) to number value  *
'*  (0->61).                                                               *
'*****************************************************************************
Function ConvertSDI12addr(address As Long) As String * 1
Select Case address
Case 0 To 9 'ASCII Code 48->57 = 0->9
  Return(CHR(address + 48))
Case 10 To 35 'ASCII Code 65->90 = A->Z = 10->35
  Return(CHR(address + 55))
Case 36 To 61 'ASCII Code 97->122 = a->z = 36->61
  Return(CHR(address + 61))
EndSelect
Return(""")
EndFunction 'ConvertSDI12addr()
'EndSub

'Main Program
BeginProg
  Scan (60,Sec,0,0)
  PanelTemp (PTemp,250)
  Battery (batt_volt)

  'Read the Metadata from the sensor daily
  'Also read if a non-valid serial number is present (Startup values should be zero).
  'A valid serial number will be greater than 1
  If (Meta(1,1) < 1) OR (TimeIntoInterval (0,1440,Min)) Then
    For i=1 To NumTempSensors
      SDI12Recorder(Meta(i,1),SDI12_Port,ConvertSDI12addr(i),"R1!",1.0,0)
    Next
  EndIf

  CallTable MetaData

NextScan
EndProg
B.4 CR1000X Program to Read Metadata and Measurements of 15 Temperature Sensors

In this example a single CS230/CS231 is on control terminal 1 of a CR1000X. The CS230/CS231 includes 15 sensors with SDI-12 addresses 1 through 9 and A through F. Each temperature sensor is polled on power up and daily with the \texttt{aR1!} command to determine metadata, which is stored in a daily data table. The minimum and maximum temperature of each sensor is polled (\texttt{aR6!} and \texttt{aR7!} respectively) every 5 minutes and stored to a data table on the same interval. Other common station data is measured every 60 seconds and stored to a separate daily data table.

\begin{verbatim}
'CR1000X Series Data Logger
'This program reads a CS230/CS231 probe that has 15 temperature sensors.
'Individual temperatures, user minimum and maximum are recorded every 5 minutes, and
'Metadata is collected daily.

'Declare Public Variables
Public PTemp, batt_volt

'Enter the number of temperature sensors that are in the probe (will need to be
'adjusted to fit specific application)
Const  NumTempSensors=15
'Caculate the number of metadata points based on the number of sensors
Const  MetaData_pts=NumTempSensors*3

'Uses the control terminal C1 on the CR1000X
Const  SDI12_Port=C1
Public TempC(NumTempSensors) As Float
Public TempCMax(NumTempSensors) As Float
Public TempCMin(NumTempSensors) As Float
Public Meta(NumTempSensors,3) As Float
Dim  i  As  Long

'Define Data Tables
DataTable (Daily,1,-1)
  DataInterval (0,1,Day,10)
  Minimum (1,batt_volt,FP2,0,False)
  Maximum (1,batt_volt,FP2,0,False)
  Average (1,batt_volt,FP2,0)
EndTable

DataTable (MetaData,1,-1)
  DataInterval (0,1,Day,10)
  Sample (MetaData_pts,Meta(),FP2)
EndTable

DataTable (TempSample,1,-1)
  DataInterval (0,5,Min,10)
  Sample (NumTempSensors,TempCMin(),IEEE4)
  Sample (NumTempSensors,TempCMax(),IEEE4)
EndTable

'Define Subroutines
\end{verbatim}
Appendix B. Example Program

Function ConvertSDI12addr(address As Long) As String * 1
    Select Case address
    Case 0 To 9 'ASCII Code 48->57 = 0->9
        Return(CHR(address + 48))
    Case 10 To 35 'ASCII Code 65->90 = A->Z = 10->35
        Return(CHR(address + 55))
    Case 36 To 61 'ASCII Code 97->122 = a->z = 36->61
        Return(CHR(address + 61))
    EndSelect
    Return("")
EndFunction 'ConvertSDI12addr()

'Main Program
BeginProg

    Scan (60,Sec,0,0)
    PanelTemp (PTemp,250)
    Battery (batt_volt)

    'Read the Metadata from the sensor daily
    'Also read if a non-valid serial number is present (Startup values should be zero).
    'A valid serial number will be greater than 1
    If (Meta(1,1) < 1) OR (IfTime (0,1440,Min)) Then
        For i=1 To NumTempSensors
            SDI12Recorder(Meta(i,1),SDI12_Port,ConvertSDI12addr(i),"R1!",1.0,0)
        Next
    EndIf

    'Read the current Temperature Min and Max Values Every 5 minutes and Reset the Value
    If TimeIntoInterval(0,5,Min) Then
        For i=1 To NumTempSensors
            'Read the current Temperature Value
            SDI12Recorder (TempC(i),SDI12_Port,ConvertSDI12addr(i),"R0!",1.0,0)

            'To Read and Reset the User Min Values use SDI-12 R6! or M6! Command. This command
            'is preferred over the minimum instruction as it constitutes the minimum of all
            '1 s measurements taken since the previous aR6! Command.
            SDI12Recorder (TempCMin(i),SDI12_Port,ConvertSDI12addr(i),"R6!",1.0,0)

            'To Read and Reset the User Max Values use SDI-12 R7! or M7! Command. This
            'command is preferred over the maximum instruction as it constitutes the
            'maximum of all 1 s measurements taken since the previous aR6! Command.
            SDI12Recorder (TempCMax(i),SDI12_Port,ConvertSDI12addr(i),"R7!",1.0,0)
        Next
    EndIf

    CallTable Daily
    CallTable MetaData
    CallTable TempSample

    NextScan
EndProg
Appendix C. SDI-12 Sensor Support

C.1 Introduction

SDI-12, Serial Data Interface at 1200 baud, is a protocol developed to simplify sensor and data logger compatibility. Only three wires are necessary — serial data, ground, and 12 V. With unique addresses, multiple SDI-12 sensors can connect to a single SDI-12 terminal on a Campbell Scientific data logger.

This appendix discusses the structure of SDI-12 commands and the process of querying SDI-12 sensors. For more detailed information, refer to version 1.4 of the SDI-12 protocol, available at www.sdi-12.org.

For additional information, refer to the SDI-12 Sensors | Transparent Mode and SDI-12 Sensors | Watch or Sniffer Mode videos.

C.2 SDI-12 Command Basics

SDI-12 commands have three components:

Sensor address (a) – a single character and the first character of the command. Use the default address of zero (0) unless multiple sensors are connected to the same terminal.

Command body – an upper case letter (the “command”), optionally followed by one or more alphanumeric qualifiers.

Command termination (!) – an exclamation mark.

An active sensor responds to each command. Responses have several standard forms and always terminate with <CR><LF> (carriage return and line feed). Standard SDI-12 commands are listed in TABLE C-1.

<table>
<thead>
<tr>
<th>Name</th>
<th>Command</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acknowledge Active</td>
<td>a!</td>
<td>a&lt;CR&gt;&lt;LF&gt;</td>
</tr>
</tbody>
</table>
| Send Identification | al!     | allccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccc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TABLE C-1. Campbell Scientific Sensor SDI-12 Command and Response Set

<table>
<thead>
<tr>
<th>Name</th>
<th>Command</th>
<th>Response(^1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Send Data</td>
<td>aD0!...aD9!</td>
<td>a&lt;values&gt;&lt;CR&gt;&lt;LF&gt; or a&lt;values&gt;&lt;CRC&gt;&lt;CR&gt;&lt;LF&gt;</td>
</tr>
<tr>
<td>Continuous Measurement</td>
<td>aR0!...aR9!</td>
<td>a&lt;values&gt;&lt;CR&gt;&lt;LF&gt;</td>
</tr>
</tbody>
</table>

\(^1\) Information on each of these commands is given in following sections.

C.2.1 Acknowledge Active Command (a!)

The Acknowledge Active command (a!) is used to test a sensor on the SDI-12 bus. An active sensor responds with its address.

C.2.2 Send Identification Command (aI!)

Sensor identifiers are requested by issuing command aI!. The reply is defined by the sensor manufacturer but usually includes the sensor address, SDI-12 version, manufacturer’s name, and sensor model information. Serial number or other sensor specific information may also be included.

<table>
<thead>
<tr>
<th>Command</th>
<th>Response</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>aI!</td>
<td>allccccccccmmmmmvvvxxx...xx&lt;CR&gt;&lt;LF&gt;</td>
<td>Sensor SDI-12 address followed by vendor identification and sensor model information</td>
</tr>
<tr>
<td>a</td>
<td>Sensor SDI-12 address</td>
<td></td>
</tr>
<tr>
<td>ll</td>
<td>SDI-12 version number (indicates compatibility)</td>
<td></td>
</tr>
<tr>
<td>cccccc</td>
<td>8-character vendor identification</td>
<td></td>
</tr>
<tr>
<td>mmmmmm</td>
<td>6 characters specifying the sensor model</td>
<td></td>
</tr>
<tr>
<td>vvv</td>
<td>3 characters specifying the sensor version (operating system)</td>
<td></td>
</tr>
<tr>
<td>xxx...xx</td>
<td>Up to 13 optional characters used for a serial number or other specific sensor information that is not relevant for operation of the data logger</td>
<td></td>
</tr>
<tr>
<td>&lt;CR&gt;&lt;LF&gt;</td>
<td>Terminates the response</td>
<td></td>
</tr>
</tbody>
</table>

Source: SDI-12: A Serial-Digital Interface Standard for Microprocessor-Based Sensors (see Appendix C.4, References (p. C-5)).

C.2.3 Start Verification Command (aV!)

The response to a Start Verification command can include hardware diagnostics, but like the aI! command, the response is not standardized.

Command: aV!
Response: atttn<CR><LF>

\(a\) = sensor address

\(ttt\) = time, in seconds, until verification information is available
Appendix C.  SDI-12 Sensor Support

$n = \text{the number of values to be returned when one or more subsequent D! commands are issued}$

C.2.4 Address Query Command (?!)

Command ?! requests the address of the connected sensor. The sensor replies to the query with the address, $a$. This command should only be used with one sensor on the SDI-12 bus at a time.

C.2.5 Change Address Command (aAb!)

Multiple SDI-12 sensors can connect to a single SDI-12 terminal on a data logger. Each device on a single terminal must have a unique address.

A sensor address is changed with command aAb!, where $a$ is the current address and $b$ is the new address. For example, to change an address from 0 to 2, the command is 0A2!. The sensor responds with the new address $b$, which in this case is 2.

**NOTE** Only one sensor should be connected to a particular terminal at a time when changing addresses.

C.2.6 Start Measurement Commands (aM!)

A measurement is initiated with the M! command. The response to each command has the form $atttn<CR><LF>$, where

$a =$ sensor address

$ttt =$ time, in seconds, until measurement data is available. When the data is ready, the sensor notifies the data logger, and the data logger begins issuing D commands.

$n = \text{the number of values returned when one or more subsequent D commands are issued. For the aM! command, n is an integer from 0 to 9.}$

When the aM! is issued, the data logger pauses its operation and waits until either it receives the data from the sensor or the time, $ttt$, expires. Depending on the scan interval of the data logger program and the response time of the sensor, this may cause skipped scans to occur. In this case make sure your scan interval is longer than the longest measurement time ($ttt$).

<table>
<thead>
<tr>
<th>TABLE C-2. Example aM! Sequence</th>
</tr>
</thead>
<tbody>
<tr>
<td>0M!</td>
</tr>
<tr>
<td>00352&lt;CR&gt;&lt;LF&gt;</td>
</tr>
<tr>
<td>0&lt;CR&gt;&lt;LF&gt;</td>
</tr>
</tbody>
</table>
Appendix C. SDI-12 Sensor Support

<table>
<thead>
<tr>
<th>TABLE C-2. Example aM! Sequence</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>000!</strong></td>
</tr>
<tr>
<td>0+.859+3.54&lt;CR&gt;&lt;LF&gt;</td>
</tr>
</tbody>
</table>

C.2.7 Stopping a Measurement Command

A measurement command (M!) is stopped if it detects a break signal. A break signal is sent by the data logger before most commands.

C.2.8 Send Data Command (aD0! … aD9!)

The Send Data command requests data from the sensor. It is issued automatically with every type of measurement command (aM!). The data logger issues the aD0! command once a service request has been received from the sensor. In transparent mode (Appendix C.3, SDI-12 Transparent Mode (p. C-4)), the user asserts this command to obtain data.

Depending on the type of data returned and the number of values a sensor returns, the data logger may need to issue aD0! up to aD9! to retrieve all data. A sensor may return up to 35 characters of data in response to a D command that follows an M! command.

Command: aD0! (aD1! ... aD9!)
Response: a<values><CR><LF> or a<values><CRC><CR><LF>

where:

a = the sensor address
<values> = values returned with a polarity sign (+ or −)
<CR><LF> = terminates the response

C.2.9 Continuous Measurement Command (aR0! … aR9!)

Sensors that are able to continuously monitor the phenomena to be measured can be read directly with the R commands (R0!...R9!). The response to the R commands mirrors the Send Data command (aD0!). A maximum of 75 characters can be returned in the <values> part of the response to the R command.

C.3 SDI-12 Transparent Mode

System operators can manually interrogate and enter settings in probes using transparent mode. Transparent mode is useful in troubleshooting SDI-12 systems because it allows direct communication with probes. Data logger security may need to be unlocked before activating the transparent mode.

Transparent mode is entered while the computer is communicating with the data logger through a terminal emulator program. It is accessed through Campbell Scientific data logger support software or other terminal emulator programs. Data logger keyboards and displays cannot be used.
The terminal emulator is accessed by navigating to the Datalogger list in PC200W, the Tools list in PC400, or the Datalogger list in the Connect screen of LoggerNet.

Watch the video: SDI-12 Sensors | Transparent Mode.

The following examples show how to enter transparent mode and change the SDI-12 address of an SDI-12 sensor. The steps shown in Appendix C.3.1, Changing an SDI-12 Address (p. C-5), are used with most Campbell Scientific data loggers.

C.3.1 Changing an SDI-12 Address

The following example was done with a CR1000, but the steps are only slightly different for CR1000X-series, CR300-series, CR6-series, CR800-series, and CR3000 data loggers.

1. Connect an SDI-12 sensor to the CR1000.
2. In LoggerNet Connect, under Datalogger, click Terminal Emulator. The terminal emulator window opens.
3. Under Select Device, located in the lower left side of the window, select the CR1000 station.
4. Click Open Terminal.
5. Select All Caps Mode.
6. Press Enter until the data logger responds with the CR1000> prompt.
7. Type SDI12 and press Enter.
8. At the Select SDI12 Port prompt, type the number corresponding to the control terminal where the sensor is connected and press Enter. The response Entering SDI12 Terminal indicates that the sensor is ready to accept SDI-12 commands.
9. To query the sensor for its current SDI-12 address, type ?! and press Enter. The sensor responds with its SDI-12 address. If no characters are typed within 60 seconds, the mode is exited. In that case, simply type SDI12 again, press Enter, and type the correct control terminal number when prompted.
10. To change the SDI-12 address, type aAb!, where \( a \) is the current address from the preceding step and \( b \) is the new address. Press Enter. The sensor changes its address and responds with the new address.
11. To exit SDI-12 transparent mode, click Close Terminal.

C.4 References

SGB3 Surge Protectors (FIGURE D-1) were required with older CS230 temperature profilers (serial numbers < 1162). Newer CS230 (serial numbers ≥ 1162) and all CS231 profilers include built-in surge protection, and therefore do not need the SGB3.

FIGURE D-1.  SGB3 3-line surge protector

D.1 SGB3 3-Line Surge Protector Specifications

<table>
<thead>
<tr>
<th>Specification</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating Range:</td>
<td>-55 to 85 °C</td>
</tr>
<tr>
<td>Maximum Voltage:</td>
<td>±28 VDC / 20 VAC (L1, L2, L3 with respect to G terminals)</td>
</tr>
<tr>
<td>Maximum Current:</td>
<td>2 A per terminal, 4 A total (requires both ground terminals for return current)</td>
</tr>
<tr>
<td>Maximum Rated Surge:</td>
<td>1200 A (8/20 μs)</td>
</tr>
</tbody>
</table>

D.2 SGB3 3-Line Surge Protector Mounting and Wiring

Older CS230 profilers were shipped with the SGB3, a 2-ft cable for connecting the SGB3 to the data logger, and two pan Phillips screws and two grommets for mounting the SGB3 to an enclosure backplate. The case of the SGB3 is suited for mounting to a back plate with 1 inch on center spacing.

TABLE D-1 provides the connections for the SGB3 surge protector, CS230, and Campbell Scientific data loggers.
### TABLE D-1. Wire Color, Function, and Connections to the SGB3 and Data Logger

<table>
<thead>
<tr>
<th>CS230 Wire Color</th>
<th>Function</th>
<th>SGB3 Connection</th>
<th>Data Logger Connection Terminal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red</td>
<td>Power</td>
<td>L1</td>
<td>12V</td>
</tr>
<tr>
<td>Green</td>
<td>SDI-12 Signal</td>
<td>L2</td>
<td>C or U² terminal configured for SDI-12</td>
</tr>
<tr>
<td>Black</td>
<td>Ground</td>
<td>G</td>
<td>G</td>
</tr>
<tr>
<td>Clear</td>
<td>Shield</td>
<td>G</td>
<td>⊥</td>
</tr>
</tbody>
</table>

1 The SGB3 connects to the data logger using the 2 ft cable shipped with the CS230.
2 U terminals are automatically configured by the measurement instruction.

If multiple SDI-12 sensors are connected to a data logger, Campbell Scientific recommends using separate terminals when possible. For the CR6 and CR1000X, triggering conflicts may occur when a companion terminal is used for a triggering instruction such as `TimerInput()`, `PulseCount()`, or `WaitDigTrig()`. For example, if the CS230/CS231 is connected to C3 on a CR1000X, C4 cannot be used in the `TimerInput()`, `PulseCount()`, or `WaitDigTrig()` instructions.
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CAMPBELL SCIENTIFIC, INC.
RMA#_____
815 West 1800 North
Logan, Utah 84321-1784

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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.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.
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