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SDM-AO4A Table of Contents

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# SDM-AO4A Four Channel Analog Output

## 1. Function

The SDM-AO4A is designed to output four continuous voltages at levels set by a Campbell Scientific datalogger.

The SDM-AO4A is a replacement for the SDM-AO4. However, the SDM-AO4A offers several new features including a 0-10 V Mode, a choice of synchronous or sequential operation, and SDM signature checking. In addition, the SDM-AO4A has higher resolution, improved accuracy, and high drive current for sensor excitation.

## 2. Specifications

<table>
<thead>
<tr>
<th></th>
<th>± 5 V mode</th>
<th>10 V mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vsupply</td>
<td>12 V Nominal (9.6 to 16 V)</td>
<td></td>
</tr>
<tr>
<td>Iq (no load, Vout = 0, Vsupply = 12 V)</td>
<td>11 mA typical</td>
<td>21 mA typical</td>
</tr>
<tr>
<td>Iq (no load, Vout = Fullscale, Vsupply = 12 V)</td>
<td>13 mA typical</td>
<td>28 mA typical</td>
</tr>
<tr>
<td>Iq (w/ load, Vsupply = 12 V)</td>
<td>13 mA + load typical</td>
<td>28 mA + 2.4*load typical</td>
</tr>
<tr>
<td>Iq (power down mode, Vsupply = 12 V)</td>
<td>1.1 mA typical</td>
<td></td>
</tr>
<tr>
<td>Range</td>
<td>± 5 V</td>
<td>0-10 V</td>
</tr>
<tr>
<td>Resolution</td>
<td>167 µV</td>
<td></td>
</tr>
<tr>
<td>Accuracy @ 25°C (20 kOhm load)</td>
<td>± (0.05% of</td>
<td>Vout(V)</td>
</tr>
<tr>
<td>Accuracy @ -40° to 60°C (20 kOhm load)</td>
<td>± (0.1% of</td>
<td>Vout(V)</td>
</tr>
<tr>
<td>Additional Fullscale Error w/ 50 mA load</td>
<td>-1.3 mV typical</td>
<td>-1.5 mV typical</td>
</tr>
<tr>
<td>Max Iout per Channel</td>
<td>50 mA</td>
<td></td>
</tr>
<tr>
<td>Max Iout Total</td>
<td>100 mA</td>
<td></td>
</tr>
<tr>
<td>Overcurrent shutdown point</td>
<td>130 ± 15 mA</td>
<td></td>
</tr>
<tr>
<td>Size</td>
<td>5.3&quot; x 3.35&quot; x 0.95&quot; (13.46 x 8.51 x 2.41 cm)</td>
<td></td>
</tr>
<tr>
<td>Weight</td>
<td>6.2 oz (175 grams)</td>
<td></td>
</tr>
<tr>
<td>Operating Temperature Range</td>
<td>-40° to +60°C</td>
<td></td>
</tr>
</tbody>
</table>
3. Power Supply

It is often convenient to power the SDM-AO4A from the datalogger power supply, but when doing so consideration must be given to the SDM-AO4A's continuous current drain (the current drain is 11 mA in ±5V mode and 21 mA in 10V mode). The alkaline supply available with the datalogger has 7.5 Amp-hours and will power one SDM-AO4A for less than one month. This supply is not recommended for continuous long-term operation. The rechargeable lead acid option, float charged by an AC supply or solar panel, may be used for long term operation.

The SDM-AO4A may also be powered from an external 12 Volt supply, independent from the datalogger supply. The low side of an external 12 Volt supply should be connected to datalogger ground and not directly earth grounded.

Slight alterations in ground potential across a 21X terminal strip are created when the 21X 12 Volt supply is used to power peripherals. Therefore, low level voltage measurements (e.g., thermocouples, thermopiles, and radiometers) should be made differentially when powering the SDM-AO4A with a 21X 12 Volt output.

4. Physical Connections

Figure 1 shows the front panel of the SDM-AO4A. The terminal block on the left is used for connection to the datalogger and the terminal block on the right provides the continuous analog output. The two ground ports on the left block are identical and connected internally.

Table 1 describes the terminal block connections. Multiple SDM-AO4As may be used by connecting the datalogger side of one SDM-AO4A to the next.

The CABLE5CBL-L or similar cable is used to connect the module to the datalogger. A 1-ft cable length should be sufficient when both datalogger and module are housed within an ENC12/14 enclosure; a 2-ft length may be required if the datalogger and SDM-AO4A are housed at opposite ends of an ENC16/18 enclosure.

CRBasic dataloggers should use the SDMSpeed instruction if the cable length is longer than 20 feet (see Section 7.1.2). The maximum recommended cable length for the CR7 is 600 ft. For other Edlog dataloggers, the maximum recommended cable length is 20 feet.

---

**CAUTION**

Cables connecting the terminals of the datalogger and SDM device should be as short as possible to minimize the risk of corruption of the signal and damage from induced surges.

When first powered up, the device is in low-power mode until the first valid SDM instruction is received. In this mode, outputs are pulled to GND.

**CAUTION**

The order of connections is critical. ALWAYS CONNECT GROUND FIRST, followed by 12V and then the Control Ports.

Shielded twisted pair cabling is recommended for wiring the continuous analog outputs.
FIGURE 1. Front Panel of the SDM-AO4A

<table>
<thead>
<tr>
<th>TABLE 1. Description of Terminal Block Connections</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SDM-AO4A to Datalogger Connections</strong></td>
</tr>
<tr>
<td>12V</td>
</tr>
<tr>
<td>G</td>
</tr>
<tr>
<td>G</td>
</tr>
<tr>
<td>C1</td>
</tr>
<tr>
<td>C2</td>
</tr>
<tr>
<td>C3</td>
</tr>
<tr>
<td><strong>SDM-AO4A to Analog Output Connections</strong></td>
</tr>
<tr>
<td>1</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>2</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>3</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>4</td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>
5. Addressing

The SDM-AO4A is a synchronously addressed datalogger peripheral. Control Ports 1, 2, and 3, are used to address an SDM-AO4A and send out the digital millivolt settings for subsequent analog output. Addressing allows multiple SDM peripherals to be connected to one datalogger.

The SDM-AO4A has sixteen possible addresses, as shown in Table 2. The address is hardware selectable using the rotary switch on the SDM-AO4A. All SDM-AO4As are shipped with the address set at zero.

<table>
<thead>
<tr>
<th>Address</th>
<th>Base 10 [CRBasic Loggers]</th>
<th>Base 4 [CR10(X), 21X, CR23X]</th>
<th>Rotary Switch</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>10</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>5</td>
<td>11</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>6</td>
<td>12</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>7</td>
<td>13</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>8</td>
<td>20</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>9</td>
<td>21</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>10</td>
<td>22</td>
<td>A</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>23</td>
<td>B</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>30</td>
<td>C</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>31</td>
<td>D</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>32</td>
<td>E</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>33</td>
<td>F</td>
<td></td>
</tr>
</tbody>
</table>

6. Operational Modes

The SDM-AO4A can be operated in ±5 V mode or 10 V mode. In each of these modes, the SDM-AO4A can operate synchronously or sequentially.

In synchronous mode, all channels are set at the same time. This mode is slower since for large changes in voltage it may take multiple charging cycles to arrive at the final voltage. The steps occur at 5 ms intervals, thus, for a 10V step in output voltage it may take up to three charge cycles (or 15 ms) to settle to the 16-bit level. For most slowly changing signals, it will settle in a single charge cycle.
FIGURE 2. Synchronous Mode

In sequential mode, the channels are set sequentially. The output signal can take from 600 µsecs to 1 ms (worst case) to settle to 16-bit resolution with a 10V step change. The four outputs then update 1 ms apart.
7. Programming

The datalogger is programmed using either CRBasic or Edlog. Dataloggers that use CRBasic include our CR800, CR850, CR1000, CR3000, and CR5000. Dataloggers that use Edlog include our CR7, CR10X, CR10, CR23X, and 21X. Both CRBasic and Edlog are included in PC400 and LoggerNet datalogger support software.

In both CRBasic and Edlog, the datalogger programming instruction allows the user to set four separate voltage levels in one SDM-AO4A, or more voltage levels with multiple SDM-AO4As. Voltage levels are reset each time the instruction is executed.

NOTE

This section describes how to write an SDM-AO4A program using CRBasic or Edlog. An SDM-AO4A program can also be generated using Campbell Scientific’s Short Cut Program Generator.
7.1 CRBasic

7.1.1 SDMAO4A Instruction

The SDMAO4A instruction is used to set the voltage to an SDM-AO4A.

NOTE

The SDM-AO4A is backwards compatible with the SDMAO4 CRBasic instruction. Therefore, programs written using the SDMAO4 instruction will work with an SDM-AO4A but will not take advantage of any of the SDM-AO4A’s additional features. If the older instruction is used, the device will use the default option code 1.

The SDMAO4A instruction has the following syntax:

SDMAO4A (Source, SDMAO4ADest, SDMAddress, SDMAO4AStartChan, Reps, SDMAO4AOption )

The SDMAO4A instruction has the following parameters:

Source: The Source parameter is the variable or variable array that holds the voltage(s), in millivolts, that will be sent to the SDM-AO4A(s). If multiple SDM-AO4As are to be triggered with one instruction, this parameter must be dimensioned to the total number of channels for all the devices being set (e.g., if all four channels are being set on two SDM-AO4 devices, Source must be dimensioned to eight).

SDMAO4ADest: The SDMAO4ADest parameter is a variable that holds a status code indicating success or failure of the instruction.

Response Code Description
240 Successful
241 Signature error
242 Current overload error
243 Current overload and signature error

A current overload error occurs when current overload protection is triggered (130 mA, +/- 15 mA). A signature error usually indicates noise on the line. Any other response code returned indicates failed communication.

SDMAddress: The SDMAddress parameter defines the address of the first SDM-AO4A to which a voltage should be applied. Valid SDM addresses are 0 through 14. Address 15 is reserved for the SDMTrigger instruction.

SDMAO4AStartChan: The SDMAO4AStartChan parameter is used to define the first channel on the SDMAO4A that should be set. Any reps will occur on subsequent channels.

Reps: The Reps parameter determines the number of SDM-AO4A output channels that will be set. If this parameter is greater than four (i.e., voltage is being set for more than one SDM-AO4 device), voltage is set on the next consecutively addressed SDM-AO4A device. In this case, the SDM-AO4As must have sequential SDM addresses.
SDMAO4AOption: The SDMAO4AOption parameter is used to set the operating mode for the SDMAO4A.

<table>
<thead>
<tr>
<th>Option Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Power down</td>
</tr>
<tr>
<td>1</td>
<td>5V synchronous</td>
</tr>
<tr>
<td>2</td>
<td>5V sequential</td>
</tr>
<tr>
<td>3</td>
<td>10V synchronous</td>
</tr>
<tr>
<td>4</td>
<td>10V sequential</td>
</tr>
</tbody>
</table>

In the synchronous mode, all channels are set at the same time. This mode is slower since for large changes in voltage it may take multiple charging cycles to arrive at the final voltage. The steps occur at 5 ms intervals, thus, for a 10V step it may take up to three charge cycles (or 15 ms) to settle to the 16-bit level.

In sequential mode, the channels are set sequentially. The output signal can take from 600 usecs to 1 ms (worst case) to settle to 16-bit resolution with a 10V step change. The four outputs then update 1 ms apart.

### 7.1.2 SDMSpeed Instruction

The SDMSpeed instruction is used to change the bit period that the datalogger uses to clock the SDM data. Slowing down the clock rate may be necessary when long cable lengths are used to connect the datalogger and SDM devices.

The syntax of this instruction is as follows:

SDMSpeed (BitPeriod)

The BitPeriod argument can be an integer or a variable. If the SDMSpeed instruction is not in the program, a default bit period is used. If 0 is used for the argument, the minimum allowable bit period is used. Table 3 shows the default, minimum allowable, and maximum bit period for each of our CRBasic dataloggers.

<table>
<thead>
<tr>
<th>Datalogger</th>
<th>Default Bit Period</th>
<th>Minimum Allowable Bit Period</th>
<th>Maximum Bit Period</th>
</tr>
</thead>
<tbody>
<tr>
<td>CR800, CR850</td>
<td>26.04 µsec</td>
<td>8.68 µsec</td>
<td>2.2 msec</td>
</tr>
<tr>
<td>CR1000</td>
<td>26.04 µsec</td>
<td>8.68 µsec</td>
<td>2.2 msec</td>
</tr>
<tr>
<td>CR3000</td>
<td>26.04 µsec</td>
<td>8.68 µsec</td>
<td>2.2 msec</td>
</tr>
<tr>
<td>CR5000</td>
<td>30 µsec</td>
<td>8 µsec</td>
<td>3 msec</td>
</tr>
</tbody>
</table>

The equation used to calculate the bit rate depends on the datalogger used. The datalogger will round down to the next faster bit rate.
Equation for CR800, CR850, and CR1000:

\[ \text{bit\_rate} = \text{INT}\left(\frac{k \times 72}{625}\right) \times \text{Resolution} \]

Where:
- \( k \) = the value entered in BitPeriod
- Resolution = 8.68 microseconds

Equation for CR3000:

\[ \text{bit\_rate} = \text{INT}\left(\frac{k \times 144}{625}\right) \times \text{Resolution} \]

Where:
- \( k \) = the value entered in BitPeriod
- Resolution = 4.34 \( \mu \)sec.

Equation for CR5000:

\[ \text{bit\_rate} = \text{INT}\left(k \times 20\right) \times \text{Resolution} \]

Where:
- \( k \) = the value entered in BitPeriod
- Resolution = 50 nsec.

### 7.2 Edlog

The Edlog dataloggers are programmed with the SDM-AO4 Instruction 103 (See Table 4):

SDM-AO4 (P103)

1: 1 Reps
2: 00 SDM Address
3: 0000 Loc [ _________ ]

The number of repetitions, Parameter 01, specifies the total number of SDM-AO4A output channels to be set. The address of the first SDM-AO4A is specified with Parameter 02, multiple SDM-AO4As must have consecutive addresses. Parameter 3 is the starting Input Location containing the first millivolt level to be output on the first channel of the first SDM-AO4A. Subsequent millivolt levels must be contained in consecutive Input Locations immediately after the first Input Location specified in Parameter 3.

For example, two SDM-AO4As can be used to output eight voltage levels which are contained in Input Locations 15 through 22. There are eight repetitions, so eight (8) will be entered for Parameter 1. The SDM-AO4As must have consecutive addresses (e.g., 31 and 32), and Parameter 2 would contain 31 in this case. Fifteen (15) will be entered for Parameter 3.
TABLE 4. Description of Instruction 103

<table>
<thead>
<tr>
<th>Par. No.</th>
<th>Data Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>01:</td>
<td>2</td>
<td>Reps - Number of analog outputs.</td>
</tr>
<tr>
<td>02:</td>
<td>2</td>
<td>Address of SDM-AO4A in base 4 (00 to 33)</td>
</tr>
<tr>
<td>03:</td>
<td>4</td>
<td>Input Location containing millivolt output level</td>
</tr>
</tbody>
</table>

Execution Time: 1.0 ms + (0.8 ms) * R (R=Repetitions)

NOTE
Edlog dataloggers are programmed using the SDM-AO4 instruction, and are not able to take advantage of the additional features of the SDM-AO4A.

7.3 Programming Examples

The following program examples are given to help the user understand the general principles involved in the use of the SDM-AO4A with CSI dataloggers.

Both of the example programs are for weather stations with a datalogger measuring wind speed, wind direction, temperature, and relative humidity. Each parameter is then scaled to 0 to 1000 mVDC, and output to a strip chart recorder through the SDM-AO4A.

7.3.1 CR5000 Program Example

Although this program is for a CR5000 datalogger, programming for other CRBasic dataloggers is similar.

`CR5000 SDM-AO4A Program Example`

```
Public WS_ms
Public WD_0_360
Public Temp_C
Public RH
Public WD_0_540
Public Flag
Public AO4AOutput(4)
Public AO4AReponse

Alias AO4AOutput(1) = WSOut
Alias AO4AOutput(2) = WDOut
Alias AO4AOutput(3) = TempOut
Alias AO4AOutput(4) = RHOut
```
'Code for DataTable OneMin
DataTable(OneMin,1,-1)
    DataInterval(0,1,Min,0)
    WindVector (1, WS_ms, WD_0_360, IEEE4, 0, 0, 0, 0)
    Average(1,Temp_C,IEEE4,0)
    Sample(1,RH, IEEE4)
EndTable

BeginProg
    Scan(1,Sec,1,0)
    '  Code for 03001 wind measurements, WS_ms & WD_0_360:
    PulseCount(WS_ms, 1, 1, 1, 1, 0.75, 0.2)
    BrHalf(WD_0_360, 1, mV1000, 1, 1, 1, 1000, True, 1000, 255, 0)
    '  Code for CS500 measurement, AirTC and RH:
    VoltSE(Temp_C,1,mV5000,3,0, _60Hz,0.1,-40.0)
    VoltSE(RH,1,mV5000,2,0, _60Hz,0.1, 0)
    '  Call Data Table
    CallTable(OneMin)
    '  Convert 0-360 WD to 0-540:
    If WD_0_540 >= 270 and WD_0_360 < 180 Then
        WD_0_540 = WD_0_360 + 360
    Else
        WD_0_540 = WD_0_360
    EndIf
    '  Scale the measurements for the SDM-AO4A to output 0-1000 mV
    WSOut = WS_ms*20 'WS: 0-50 m/s = 0-1000 mV
    WDOut = WD_0_540 *1.859 'WD: 0-540 deg = 0-1000mV
    TempOut= 10*(Temp_C+40) 'Temp: -40-60 deg C = 0-1000 mV
    RHOut = RH *10 'RH: 0-100 % RH = 0-1000 mV
    '  Send mV outputs to SDM-AO4A at SDM Address 12 (Rotary Switch at C)
    SDMAO4A (AO4AOutput(),AO4AResponse,12,1,4,1)
EndProg

7.3.2 CR10X Program Example

Although this program is for a CR10X, programming for other Edlog dataloggers is similar.

;{CR10X}
*Table 1 Program
  01: 1.0000 Execution Interval (seconds)

; Code for 03001 wind measurements, WS_ms & WindDir:

  1: Pulse (P3)
      1: 1 Reps
      2: 1 Pulse Channel 1
      3: 21 Low Level AC, Output Hz
      4: 1 Loc [ WS_ms ]
      5: 0.75 Mult
      6: 0.2 Offset
2: Excite-Delay (SE) (P4)
   1: 1 Reps
   2: 5 2500 mV Slow Range
   3: 1 SE Channel
   4: 1 Excite all reps w/Exchan 1
   5: 2 Delay (0.01 sec units)
   6: 2500 mV Excitation
   7: 2 Loc [ WD_0_360 ]
   8: 0.142 Mult
   9: 0 Offset

; Code for CS500 measurement, AirTC and RH:

3: Volt (SE) (P1)
   1: 1 Reps
   2: 25 2500 mV 60 Hz Rejection Range
   3: 3 SE Channel
   4: 3 Loc [ Temp_C ]
   5: 0.1 Mult
   6: -40.0 Offset

4: Volt (SE) (P1)
   1: 1 Reps
   2: 25 2500 mV 60 Hz Rejection Range
   3: 2 SE Channel
   4: 4 Loc [ RH ]
   5: 0.1 Mult
   6: 0 Offset

; Output Data Every Minute

5: If time is (P92)
   1: 0 Minutes (Seconds --) into a
   2: 1 Interval (same units as above)
   3: 10 Set Output Flag High (Flag 0)

6: Set Active Storage Area (P80)
   ;Set array ID to 101
   1: 1 Final Storage Area 1
   2: 101 Array ID

7: Real Time (P77)
   ; Output Year, Day, Hour/Minute
   1: 1110 Year,Day,Hour/Minute (midnight = 0000)

8: Wind Vector (P69)
   ; Output Average WS, WD, StdDev WD
   1: 1 Reps
   2: 0 Samples per Sub-Interval
   3: 0 S, theta(1), sigma(theta(1)) with polar sensor
   4: 1 Wind Speed/East Loc [ WS_ms ]
   5: 2 Wind Direction/North Loc [ WD_0_360 ]

9: Average (P71)
   ; Output Average Temperature
   1: 1 Reps
   2: 3 Loc [ Temp_C ]
10: Sample (P70) ; Sample RH
  1:  1    Reps
  2:  4    Loc [ RH    ]

; Routine to convert 0-360 deg. Direction to 0-540 deg.

11: Do (P86)
  1:  21   Set Flag 1 Low

12: If (X<=F) (P89) ; Set Flag 1 if previous reading was > 270
  1:  9    X Loc [ WD_0_540 ]
  2:  3    >=
  3:  270  F
  4:  11   Set Flag 1 High

13: Z=X (P31) ; Set 0-540 value to current 0-360 reading
  1:  2    X Loc [ WD_0_360 ]
  2:  9    Z Loc [ WD_0_540 ]

14: If (X<=F) (P89) ; If current reading is <180
  1:  9    X Loc [ WD_0_540 ]
  2:  4    <
  3:  180  F
  4:  30   Then Do

15: If Flag/Port (P91) ; And if previous reading was > 270
  1:  11   Do if Flag 1 is High
  2:  30   Then Do

16: Z=X+F (P34) ; Add 360 to the current reading
  1:  9    X Loc [ WD_0_540 ]
  2:  360  F
  3:  9    Z Loc [ WD_0_540 ]

17: End (P95)

18: End (P95)

; Scale the measurements for the SDM-AO4A to output 0 to 1000 mV

19: Z=X*F (P37) ; Scale WS: 0-50 mps = 0-1000 mV
  1:  1    X Loc [ WS_ms   ]
  2:  20   F
  3:  5    Z Loc [ WSoutput ]

20: Z=X*F (P37) ; Scale WD: 0-540 deg = 0-1000 mV
  1:  9    X Loc [ WD_0_540 ]
  2:  1.859 F
  3:  6    Z Loc [ WDoutput ]

21: Z=X+F (P34) ; Scale Temperature: -40-60 deg C = 0-1000 mV
  1:  3    X Loc [ Temp_C  ]
  2:  40   F
  3:  7    Z Loc [ TempOut ]
22: Z=X*F (P37)
   1: 7  X Loc [ TempOut ]
   2: 10  F
   3: 7  Z Loc [ TempOut ]

23: Z=X*F (P37) ; Scale RH: 0-100 % RH = 0-1000 mV
   1: 4  X Loc [ RH ]
   2: 10  F
   3: 8  Z Loc [ RHout ]

; Send mV outputs to SDM-AO4A at SDM Address 30 (Rotary Switch at C)

24: SDM-AO4 (P103)
   1: 4  Reps
   2: 30  SDM Address
   3: 5  Loc [ WSoutput ]

End Program
Campbell Scientific Companies

Campbell Scientific, Inc. (CSI)
815 West 1800 North
Logan, Utah  84321
UNITED STATES
www.campbellsci.com • info@campbellsci.com

Campbell Scientific Africa Pty. Ltd. (CSAf)
PO Box 2450
Somerset West 7129
SOUTH AFRICA
www.csafrica.co.za • cleroux@csafrica.co.za

Campbell Scientific Australia Pty. Ltd. (CSA)
PO Box 444
Thuringowa Central
QLD 4812 AUSTRALIA
www.campbellsci.com.au • info@campbellsci.com.au

Campbell Scientific do Brazil Ltda. (CSB)
Rua Luisa Crips Orsi, 15 Butantã
CEP: 005543-000 São Paulo SP BRAZIL
www.campbellsci.com.br • suporte@campbellsci.com.br

Campbell Scientific Canada Corp. (CSC)
11564 - 149th Street NW
Edmonton, Alberta T5M 1W7
CANADA
www.campbellsci.ca • dataloggers@campbellsci.ca

Campbell Scientific Centro Caribe S.A. (CSCC)
300 N Cementerio, Edificio Breller
Santo Domingo, Heredia 40305
COSTA RICA
www.campbellsci.cc • info@campbellsci.cc

Campbell Scientific Ltd. (CSL)
Campbell Park
80 Hathern Road
Shepshed, Loughborough LE12 9GX
UNITED KINGDOM
www.campbellsci.co.uk • sales@campbellsci.co.uk

Campbell Scientific Ltd. (France)
3 Avenue de la Division Leclerc
92160 ANTONY
FRANCE
www.campbellsci.fr • info@campbellsci.fr

Campbell Scientific Spain, S. L.
Avda. Pompeu Fabra 7-9, local 1
08024 Barcelona
SPAIN
www.campbellsci.es • info@campbellsci.es

Please visit www.campbellsci.com to obtain contact information for your local US or International representative.