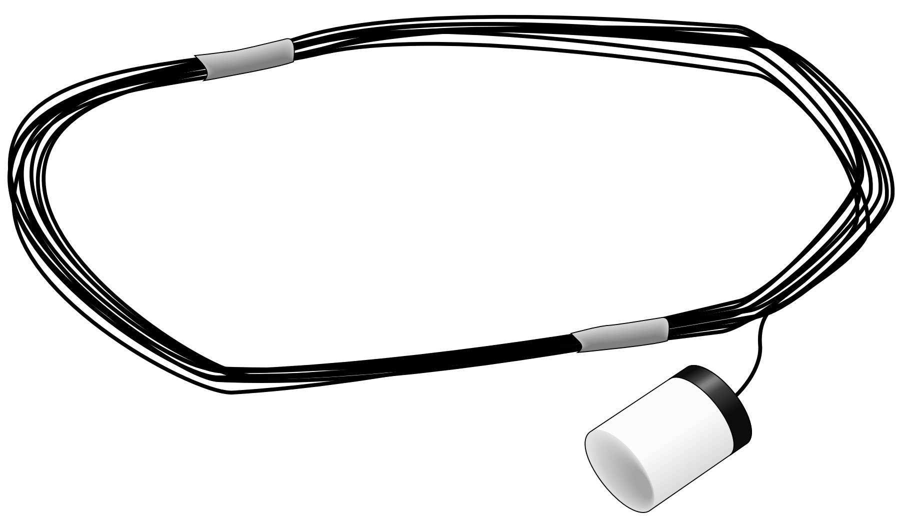
INSTRUCTION MANUAL

223 Delmhorst Cylindrical Soil Moisture Block

Revision: 5/13



Warranty

"PRODUCTS MANUFACTURED BY CAMPBELL SCIENTIFIC, INC. are warranted by Campbell Scientific, Inc. ("Campbell") to be free from defects in materials and workmanship under normal use and service for twelve (12) months from date of shipment unless otherwise specified in the corresponding Campbell pricelist or product manual. Products not manufactured, but that are re-sold by Campbell, are warranted only to the limits extended by the original manufacturer. Batteries, fine-wire thermocouples, desiccant, and other consumables have no warranty. Campbell's obligation under this warranty is limited to repairing or replacing (at Campbell's option) defective products, which shall be the sole and exclusive remedy under this warranty. The customer shall assume all costs of removing, reinstalling, and shipping defective products to Campbell. Campbell will return such products by surface carrier prepaid within the continental United States of America. To all other locations, Campbell will return such products best way CIP (Port of Entry) INCOTERM® 2010, prepaid. This warranty shall not apply to any products which have been subjected to modification, misuse, neglect, improper service, accidents of nature, or shipping damage. This warranty is in lieu of all other warranties, expressed or implied. The warranty for installation services performed by Campbell such as programming to customer specifications, electrical connections to products manufactured by Campbell, and product specific training, is part of Campbell's product warranty. CAMPBELL EXPRESSLY DISCLAIMS AND EXCLUDES ANY IMPLIED WARRANTIES OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE. Campbell is not liable for any special, indirect, incidental, and/or consequential damages."

Assistance

Products may not be returned without prior authorization. The following contact information is for US and international customers residing in countries served by Campbell Scientific, Inc. directly. Affiliate companies handle repairs for customers within their territories. Please visit *www.campbellsci.com* to determine which Campbell Scientific company serves your country.

To obtain a Returned Materials Authorization (RMA), contact CAMPBELL SCIENTIFIC, INC., phone (435) 227-9000. After an applications engineer determines the nature of the problem, an RMA number will be issued. Please write this 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 web site 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.

Table of Contents

PDF viewers: These page numbers refer to the printed version of this document. Use the PDF reader bookmarks tab for links to specific sections.

Figures

Tables

223 Delmhorst Cylindrical Soil Moisture Block

1. Introduction

The 223 is a gypsum block that determines soil water potential by measuring electrical resistance. When the 223 is wet, electrical resistance is low. As the 223 dries, resistance increases. This gypsum block connects to a datalogger via an AM16/32-series, AM32, or AM416 multiplexer.

The 223 gypsum soil moisture block is configured for use with multiplexers. The –L option on the model 223-L indicates that the cable length is user specified. This manual refers to the sensor as the 223.

Before using the 223, please study

- Section 2, *Cautionary Statements*
- Section 3, *Initial Inspection*
- Section 4, *Quickstart*

2. Cautionary Statements

- The black outer jacket of the cable is Santoprene® rubber. 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.

- Avoid installing in depressions where water will puddle after a rain storm.

- Don't place the 223 in high spots or near changes in slope unless wanting to measure the variability created by such differences.

- To maximize longevity, remove the gypsum blocks during the winter.

3. Initial Inspection

- Upon receipt of the 223, inspect the packaging and contents for damage. File damage claims with the shipping company.

- 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 correct product and cable length are received.

4. Quickstart

Please review Section 7, *Operation*, for wiring, CRBasic programming, and Edlog programming.

4.1 Installation

1. Soak blocks in water for one hour then allow them to dry.
2. Repeat Step 1.
3. Make sensor access holes to the depth required.
4. Soak the blocks for two to three minutes.
5. Mix a slurry of soil and water to a creamy consistency and place one or two tablespoons into the sensor access hole.
6. Place the blocks in the hole and force the slurry to envelope it. This will insure uniform soil contact.
7. Back fill the hole, tamping lightly at frequent intervals.

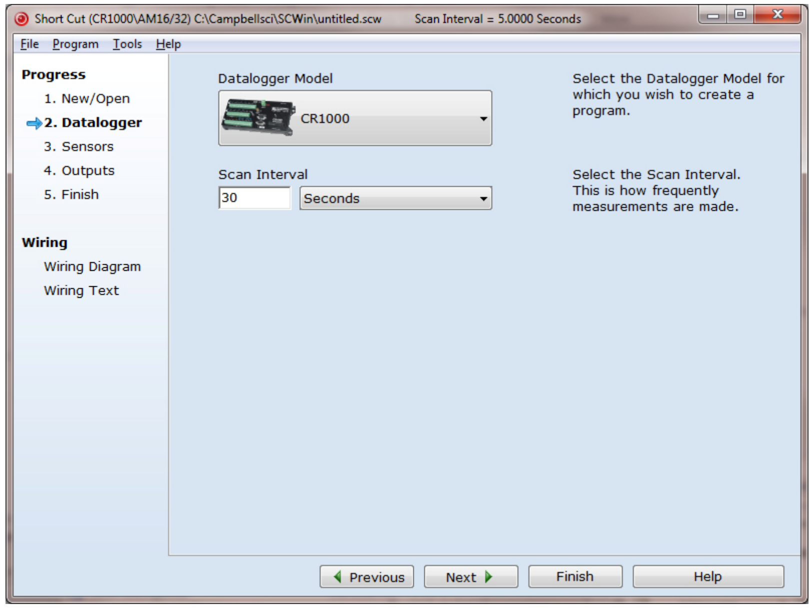
4.2 Use SCWin to Program Datalogger and Generate Wiring Diagram

The simplest method for programming the datalogger to measure the 223 is to use Campbell Scientific's SCWin Short Cut Program Generator.

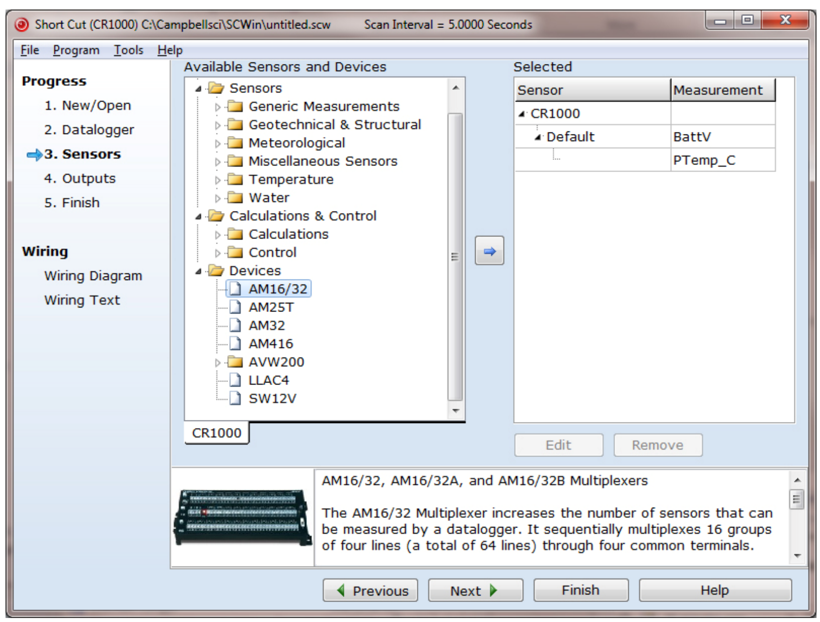
1. Open Short Cut and click on **New Program**.

2. Select the **Datalogger Model** and enter the **Scan Interval**, and then select **Next**.

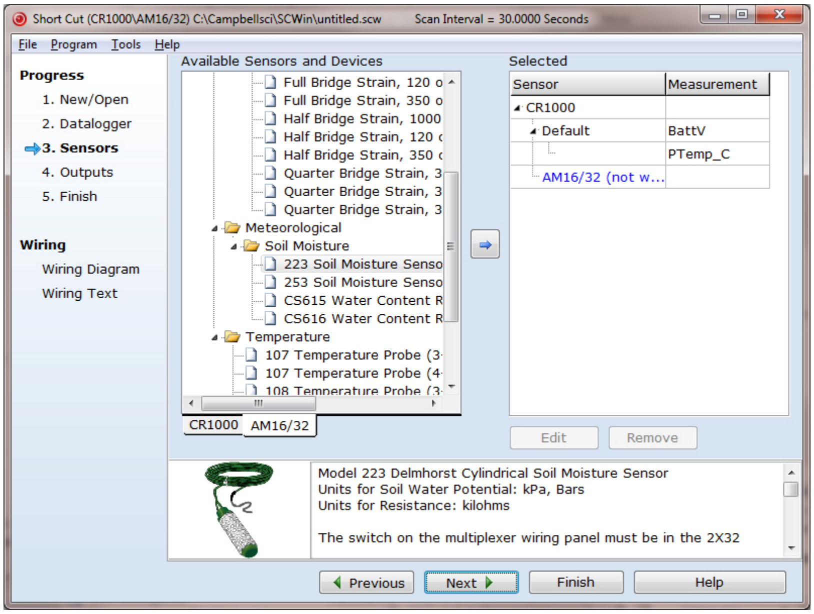
NOTE A scan rate of 30 seconds or longer is recommended when using a multiplexer.



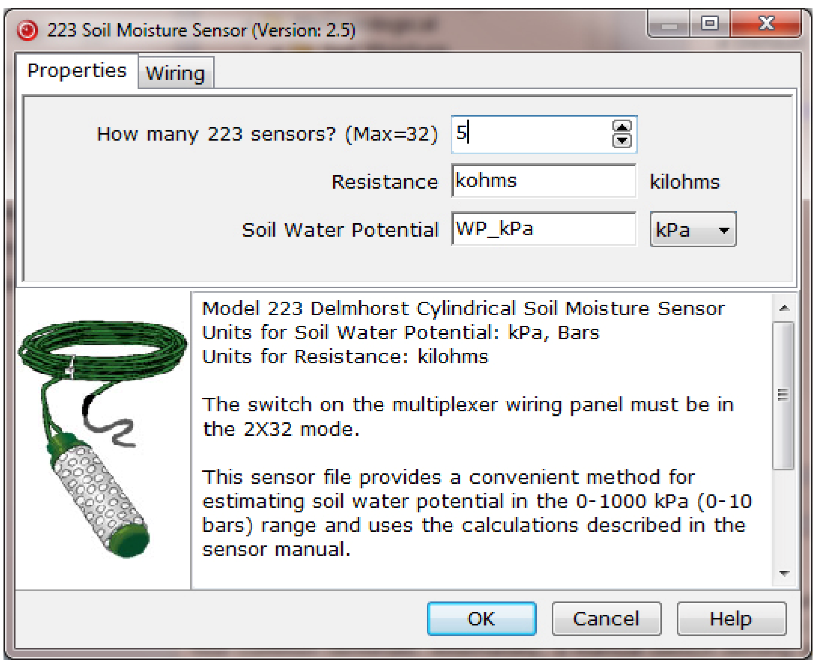
3. Under **Devices**, select **AM16/32,** and select the **right arrow** (in center of screen) to add it to the list.



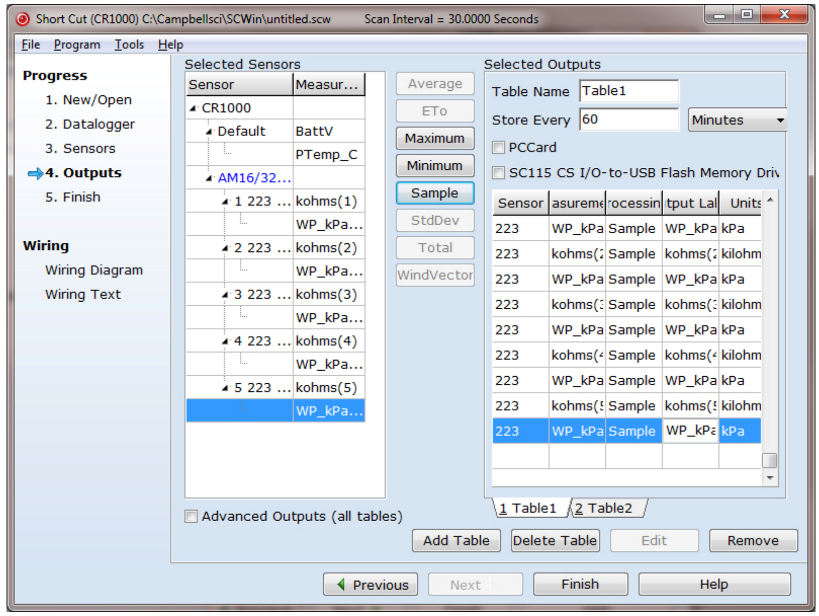
4. Select **223 Soil Moisture Sensor**, and select the **right arrow** (in center of screen) to add it to the list of sensors to be measured. The **Properties** window will appear after the **right arrow** is selected.



5. In the **Properties** window, enter the **number of sensors**, the **Resistance** units, and the **Soil Water Potential** units. After entering the information, click **OK**, and then select **Next**.



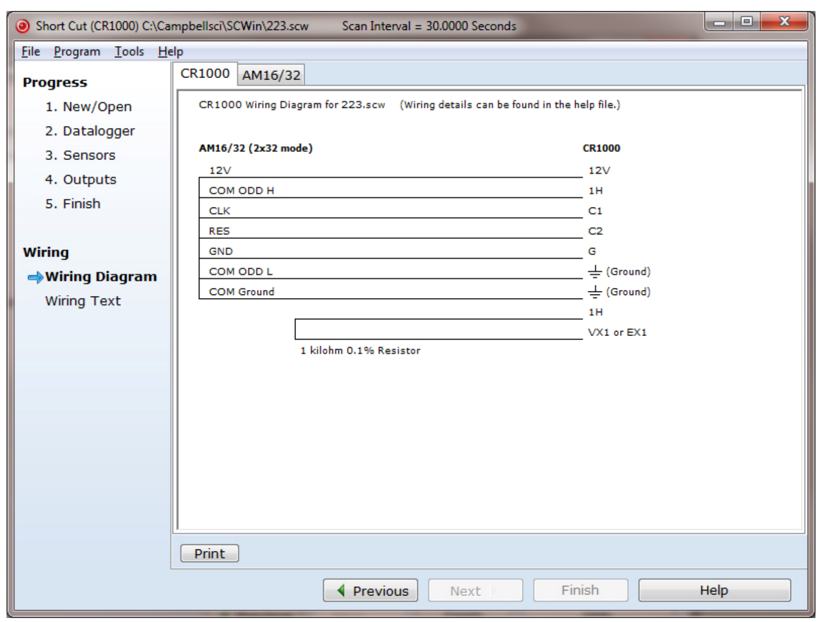
6. Choose the **Outputs** and then select **Finish**.



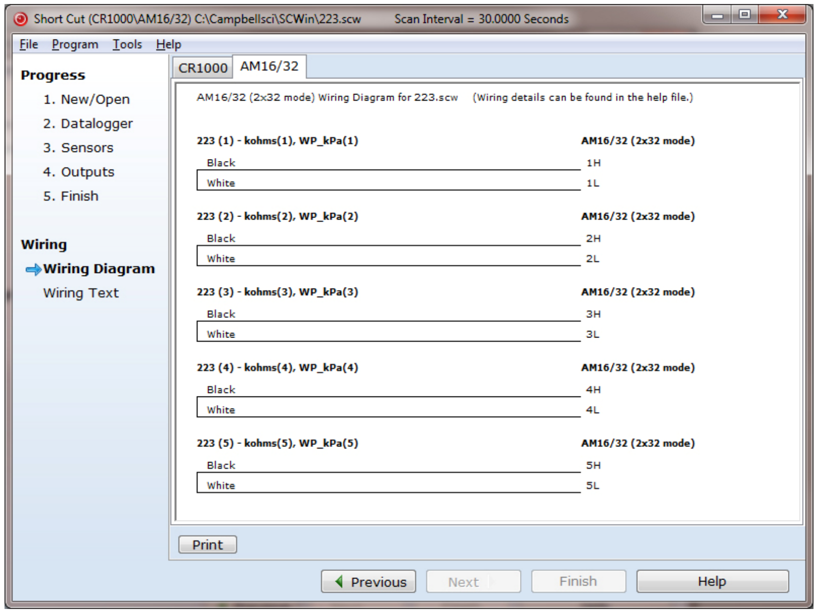
7. In the **Save As** window, enter an appropriate file name and select **Save**.

8. In the **Confirm** window, click **Yes** to download the program to the datalogger.

9. Click on **Wiring Diagram** and select the CR1000 tab. Wire the CR1000 to the AM16/32 according to the wiring diagram generated by SCWin Short Cut.



10. Select the AM16/32 tab and wire the 223 sensors to the AM16/32 according to the wiring diagram generated by SCWin Short Cut.



5. Overview

The 223 gypsum soil moisture block is configured for use with multiplexers. The –L option on the model 223–L indicates that the cable length is user specified. This manual refers to the sensor as the 223.

The Delmhorst cylindrical block is composed of gypsum cast around two concentric electrodes which confine current flow to the interior of the block, greatly reducing potential ground loops. Gypsum located between the outer electrode and the soil creates a buffer against salts which may affect the electrical conductivity. Individual calibrations are required for accurate readings of soil water potential.

The multiplexer that the 223 is connected to leaves the circuit open when no measurements are being made. This blocks direct current flow from the 223 to datalogger ground and prevents electrolysis from prematurely destroying the sensor.

The 223 should not be connected directly to the datalogger. The 227 Delmhorst soil moisture block is available for direct connection and has capacitors in the cable that block direct current flow.

Gypsum blocks typically last for one to two years. Saline or acidic soils tend to degrade the block, reducing longevity. To maximize longevity, gypsum blocks not used during the winter should be removed from the field. Shallow blocks may become frozen and crack, while blocks located below the frost line may not maintain full contact with the soil. Regardless of depth, blocks left in the field over winter are subject to the corrosive chemistry of the soil.

6. Specifications

Features:

- Compatible with multiplexers allowing measurement of multiple sensors
- Multiplexer connection prevents electrolysis from prematurely destroying the soil moisture block
- Measures a wide range of matric potential
- Buffers salts in soil
- No maintenance required
- Compatible with most Campbell Scientific dataloggers

Compatible Dataloggers: CR800
CR850
CR1000
CR3000
CR5000
CR7
CR10(X)
21X
CR23X

Diameter: ~2.25 cm (0.88 in)

Length: ~2.86 cm (1.25 in)

Material: Gypsum

Electrode Configuration: Concentric cylinders
Center electrode: Excitation
Outer electrode: Ground

Calibration: Measurements are affected by soil salinity, including fertilizer salts. Individual calibrations are required for accurate measurement of soil water potential. The soil water potential versus resistance values in TABLE 7-3 are "typical" values supplied by Delmhorst Corporation. Neither Delmhorst nor Campbell Scientific make any claim as to the accuracy of these values. The calibration equations in Section 7.2.4, *Calculate Soil Water Potential*, were fit to the values in TABLE 7-3 to allow output of an estimated water potential.

7. Operation

CAUTION 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.

7.1 Wiring

The 223 is shown in FIGURE 7-1 and TABLE 7-1. The leads from the block electrodes are connected directly to the H and L inputs on the AM16/32-series, AM32, or AM416 multiplexer. The lead from the center electrode (white stripe or solid white) connects to H and the lead from the outer electrode (black) to L. A 1k resistor at the datalogger is used to complete the half bridge measurement.

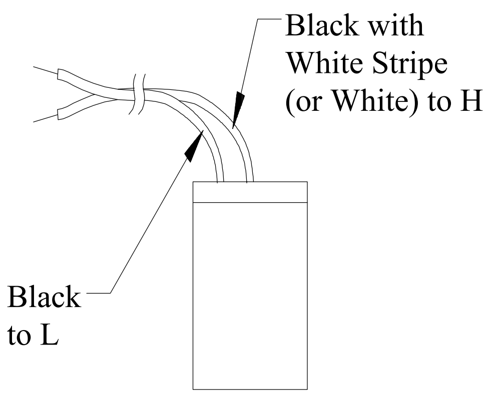


FIGURE 7-1. 223 wiring

TABLE 7-1. 223 Wiring

Color	Function	Multiplexer
Black w/ White Stripe or White	Excitation	H
Black	Signal Ground	L

7.2 Programming

NOTE This section describes using CRBasic or Edlog to program the datalogger. See Section 4.2, *Use SCWin to Program Datalogger and Generate Wiring Diagram*, if using Short Cut.

Dataloggers that use CRBasic include our CR800, CR850, CR1000, CR3000, and CR5000. Dataloggers that use Edlog include our CR10(X), 21X, CR23X, and CR7. CRBasic and Edlog are included with LoggerNet, PC400, and RTDAQ software.

The datalogger program needs to control the multiplexer, measure the sensor, calculate the sensor resistance, and convert the resistance to potential in bars. Example programs are provided in Section 7.2.5, *Example Programs*.

7.2.1 Control the Multiplexer

When a multiplexer is used, the measurements are placed within a loop. Each pass through the loop, the multiplexer is clocked to the next channel and the sensors connected to that channel are measured. The programming sequence for using the multiplexer is shown in Section 7.2.1.1, *CRBasic*, and Section 7.2.1.2, *Edlog*. For more information, see the multiplexer manual.

7.2.1.1 CRBasic

The generalized CRBasic programming sequence follows:

```
ACTIVATE MULTIPLEXER/RESET INDEX
        Portset (1 ,1)          'Set C1 high to Enable Multiplexer
        I=0
BEGIN MEASUREMENT LOOP
        SubScan (0,sec,16)      'This example measures 16 sets
CLOCK PULSE AND DELAY
        Portset (2,1)           ‘Set port 2 high
        Delay (0,20,mSec)
        Portset (2,0)           ‘Set port 2 low
INCREMENT INDEX AND MEASURE
        I=I+1
        ‘223 measurement instruction
        ‘Storing results in Variable(I)
END MEASUREMENT LOOP
        NextSubScan
DEACTIVATE MULTIPLEXER
        Portset (1 ,0)          'Set C1 Low to disable Multiplexer
```

7.2.1.2 Edlog

The generalized Edlog programming sequence follows:

ACTIVATE MULTIPLEXER/RESET INDEX
For the CR10(X) and CR23X, use Edlog instruction **Do (P86)** to set the port high. For the 21X and CR7, use Edlog instruction **Set Port(s) (P20)** to set the port high.
BEGIN MEASUREMENT LOOP
Use Edlog instruction **Beginning of Loop (P87)**
CLOCK PULSE AND DELAY
With the CR23X and CR10(X) the clock line is connected to a control port. Instruction **Do (P86)** with the pulse port command (71 – 78) pulses the clock line high for 10 ms. Instruction **Excitation with Delay (P22)** can be added following the **Do (P86)** to delay an additional 10 ms.
MEASURE SENSOR AND CALCULATE RESISTANCE
See Section 7.2.2, *Excite and Measure the 223*, and Section 7.2.3, *Calculate Sensor Resistance*.
END MEASUREMENT LOOP
Use Edlog instruction **End (P95)**.
DEACTIVATE MULTIPLEXER
For the CR10(X) and CR23X, use Edlog instruction **Do (P86)** to set the port low. For the 21X and CR7, use Edlog instruction **Set Port(s) (P20)** to set the port low.

7.2.2 Excite and Measure the 223

The sensor is excited and measured using the **BrHalf** instruction in CRBasic or **Instruction 5 (AC Half Bridge)** in Edlog. Recommended excitation voltages and input ranges are given in TABLE 7-2. TABLE 7-2 shows the excitation and voltage ranges used with our dataloggers.

TABLE 7-2. Excitation and Voltage Ranges

Datalogger	mV Excitation	Full Scale Range
CR800/CR850	250	±250 mV
CR1000	250	±250 mV
CR3000	200	±200 mV
CR5000	200	±200 mV
21X	500	±500 mV
CR7	500	±500 mV
CR10(X)	250	±250 mV
CR23X	200	±200 mV

The output from the **BrHalf** instruction or **Instruction 5** is the ratio of signal voltage to excitation voltage:

$$V_s/V_x = R_s/(R_s + R_1)$$

where, V_s = Signal Voltage
V_x = Excitation Voltage
R_s = Sensor Resistance
R_1 = Fixed Bridge Resistor.

7.2.3 Calculate Sensor Resistance

The sensor resistance is calculated using an expression in CRBasic or Edlog instruction **BR Transform Rf[X/(1–X)] (P59)**. The expression or Edlog instruction **BR Transform Rf[X/(1–X)] (P59)** takes the Half Bridge output (V_s/V_x) and computes sensor resistance as follows:

$$R_s = R_1(X/(1 - X))$$

where, $X = V_s/V_x$

The bridge transform multiplier would normally be 1000, representing the fixed resistor (R_1). A bridge multiplier of 1000 produces values of R_s larger than 6999 ohms causing the datalogger to overrange when using low resolution. To avoid overranging, a bridge multiplier of 1 should be used to output sensor resistance (R_s) in terms of kohms.

7.2.4 Calculate Soil Water Potential

The datalogger program can be written to store block resistance or can calculate water potential from a block calibration. The soil water potential versus resistance values in TABLE 7-3 are typical values supplied by Delmhorst Corporation.

TABLE 7-3. Typical Soil Water Potential, R_s and V_s / V_x

BARS	R_s (kohms)	V_s/V_x
0.1	0.060	0.0566
0.2	0.130	0.1150
0.3	0.260	0.2063
0.4	0.370	0.2701
0.5	0.540	0.3506
0.6	0.750	0.4286
0.7	0.860	0.4624
0.8	1.100	0.5238
0.9	1.400	0.5833
1.0	1.700	0.6296
1.5	3.400	0.7727
1.8	4.000	0.8000
2.0	5.000	0.8333
3.0	7.200	0.8780
6.0	12.500	0.9259
10.0	17.000	0.9444
11.0	22.200	0.9569
12.0	22.400	0.9573
13.0	30.000	0.9677
14.0	32.500	0.9701
15.0	35.000	0.9722

For the typical resistance values listed in TABLE 7-3, soil water potential (bars) is calculated from sensor resistance (R_s) using the 5th order polynomial (FIGURE 7-2 and TABLE 7-4). TABLE 7-5 shows the polynomial error. The nonlinear relationship of R_s to bars rules out averaging R_s directly.

The polynomial is entered as an expression in CRBasic or by using Edlog instruction **Polynomial (P55)**. The polynomial to calculate soil water potential is fit to the 0.1 to 10 bar range using a least square fit. TABLE 7-4 lists the coefficients and equation for the 0.1 to 10 bar polynomial.

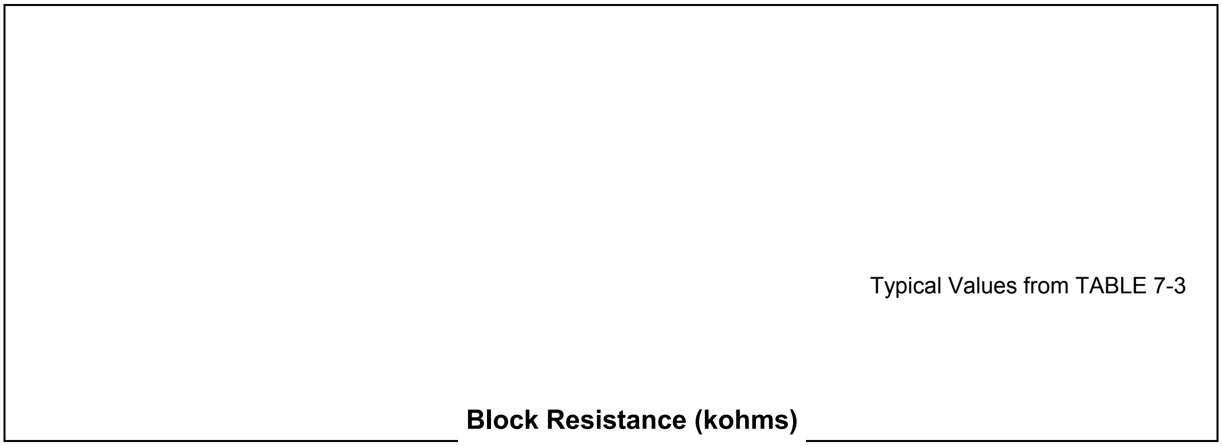


FIGURE 7-2. Polynomial fit to typical block resistance vs. water potential

TABLE 7-4. Polynomial Coefficients for Converting Sensor Resistance to Bars

$$BARS = C_0 + C_1(R_s) + C_2(R_s)^2 + C_3(R_s)^3 + C_4(R_s)^4 + C_5(R_s)^5$$

(BARS)	MULT. (R_1)	C_0	C_1	C_2	C_3	C_4	C_5
0.1–10	0.1	0.15836	6.1445	–8.4189	9.2493	–3.1685	0.33392

TABLE 7-5. Polynomial Error – 10 Bar Range

BARS	**V_s/V_x**	**R_s (kohms × 0.1)**	**BARS COMPUTED**	**ERROR**
0.1	0.0566	0.006	0.1949	0.0949
0.2	0.115	0.013	0.2368	0.0368
0.3	0.2063	0.026	0.3126	0.0126
0.4	0.2701	0.037	0.3746	–0.0254
0.5	0.3506	0.054	0.4670	–0.0330
0.6	0.4286	0.075	0.5756	–0.0244
0.7	0.4624	0.086	0.6302	–0.0698
0.8	0.5238	0.11	0.7442	–0.0558
0.9	0.5833	0.14	0.8778	–0.0222
1.0	0.6296	0.17	1.0025	0.0025
1.5	0.7727	0.34	1.5970	0.0970
1.8	0.8000	0.40	1.7834	–0.0166
2	0.8333	0.50	2.0945	0.0945
3	0.8780	0.72	2.8834	–0.1166
6	0.9259	1.25	6.0329	0.0329
10	0.9444	1.70	9.9928	–0.0072
ERROR (BARS) = TABLE 7-3 VALUES – COMPUTED VALUES				

7.2.5 Example Programs

7.2.5.1 Example CR1000 Program

Below is a CR1000 program that measures five 223 sensors, calculates resistance, and calculates soil water potential.

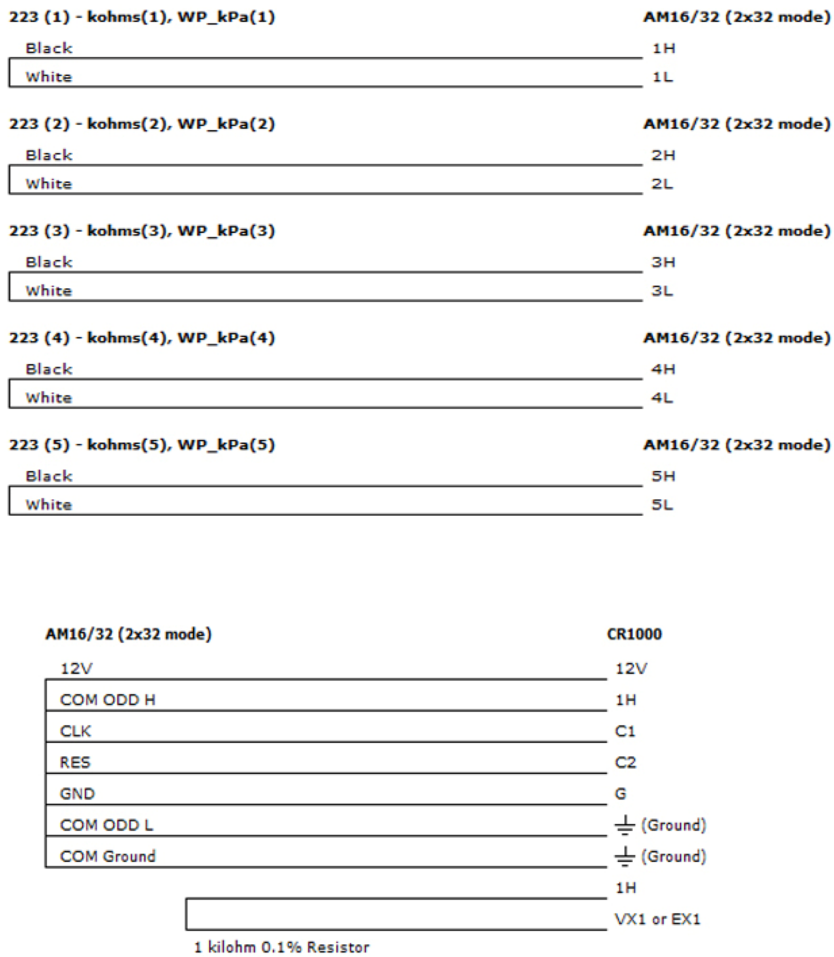


FIGURE 7-3. Wiring for CR1000 example

```
'CR1000

'Declare Variables and Units
Dim LCount
Public BattV
Public PTemp_C
Public kohms(5)
Public WP_kPa(5)

Units BattV=Volts
Units PTemp_C=Deg C
Units kohms=kilohms
Units WP_kPa=kPa
```

```
'Define Data Tables
DataTable(Table1,True,-1)
  DataInterval(0,60,Min,10)
  Sample(1,kohms(1),FP2)
  Sample(1,WP_kPa(1),FP2)
  Sample(1,kohms(2),FP2)
  Sample(1,WP_kPa(2),FP2)
  Sample(1,kohms(3),FP2)
  Sample(1,WP_kPa(3),FP2)
  Sample(1,kohms(4),FP2)
  Sample(1,WP_kPa(4),FP2)
  Sample(1,kohms(5),FP2)
  Sample(1,WP_kPa(5),FP2)
EndTable

DataTable(Table2,True,-1)
  DataInterval(0,1440,Min,10)
  Minimum(1,BattV,FP2,False,False)
EndTable

'Main Program
BeginProg
  'Main Scan
  Scan(30,Sec,1,0)
    'Default Datalogger Battery Voltage measurement 'BattV'
    Battery(BattV)
    'Default Wiring Panel Temperature measurement 'PTemp_C'
    PanelTemp(PTemp_C,_60Hz)
    'Turn AM16/32 Multiplexer On
    PortSet(2,1)
    Delay(0,150,mSec)
    LCount=1
    SubScan(0,uSec,5)
      'Switch to next AM16/32 Multiplexer channel
      PulsePort(1,10000)
      '223 Soil Moisture Sensor measurements 'kohms()' and 'WP_kPa()' on the AM16/32 Multiplexer
      BrHalf(kohms(LCount),1,mV250,1,1,1,250,True,20000,250,1,0)
      'Convert resistance ratios to kilohms and kilohms to water potential
      kohms(LCount)=kohms(LCount)/(1-kohms(LCount))
      If kohms(LCount)<17 Then
        WP_kPa(LCount)=kohms(LCount)*0.1
        WP_kPa(LCount)=0.15836+(6.1445*WP_kPa(LCount))+(-8.4189*WP_kPa(LCount)^2)+(9.2493*WP_kPa(LCount)^3)+(-3.1685*WP_kPa(LCount)^4)+(0.33392*WP_kPa(LCount)^5)
        WP_kPa(LCount)=WP_kPa(LCount)*100
      Else
        WP_kPa(LCount)=1000
      EndIf
      LCount=LCount+1
    NextSubScan
    'Turn AM16/32 Multiplexer Off
    PortSet(2,0)
    Delay(0,150,mSec)
    'Call Data Tables and Store Data
    CallTable(Table1)
    CallTable(Table2)
  NextScan
EndProg
```

7.2.5.2 Example CR10(X) Program

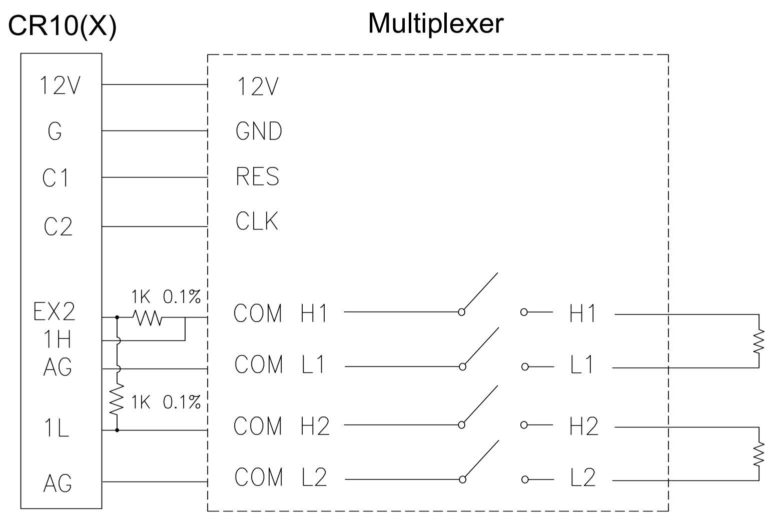


FIGURE 7-4. Wiring for CR10(X) example

```
*Table 1 Program
  01:          60.0000    Execution Interval (seconds)

01:  Do (P86)                                 ;Enable multiplexer
  1:           41         Set Port 1 High

02:  Beginning of Loop (P87)                  ;Start of measurement loop
  1:            0         Delay
  2:           16         Loop Count

03:  Do (P86)                                 ;Clock Multiplexer to next channel
  1:           72         Pulse Port 2

04:  Step Loop Index (P90)                    ;Step index by 2 each pass through loop
  1:            2         Step

05:  AC Half Bridge (P5)                      ;Measure the 2 connected 223 blocks
  1:            2         Reps
  2:           14         250 mV Fast Range
  3:            1         SE Channel
  4:            2         Excite all reps w/Exchan 2
  5:          250         mV Excitation
  6:            1--       Loc [ BlockR_1  ]   ;-- >>> advance location by index
  7:            1.0       Mult
  8:            0.0       Offset

06:  BR Transform Rf[X/(1–X)] (P59)           ;Calculate resistance from Vs/Vx
  1:            2         Reps
  2:            1--       Loc [ BlockR_1  ]
  3:            1         Multiplier (Rf)

07:  End (P95)
```

```
08:  Do (P86)                                       ;Turn off multiplexer
   1:            51         Set Port 1 Low

;The following loop checks each block resistance and calculates
;water potential if BlockR < 17 kohms. Because 2 blocks are measured
;with each pass through the previous measurement loop, it is simpler
;to use a separate loop for the calculations.
;Leave out following loop if only recording block resistance.

09:  Beginning of Loop (P87)                        ;Loop to calculate water potential
   1:             0         Delay
   2:            32         Loop Count

10:  If (X<=>F) (P89)                               ;If Rs < 17, apply polynomial
   1:             1--       X Loc [ BlockR_1  ]
   2:             4         <
   3:            17         F
   4:            30         Then Do

11:  Z=X*F (P37)                                    ;Scale Rs for polynomial
   1:             1--       X Loc [ BlockR_1  ]
   2:              .1       F
   3:            33--       Z Loc [ WatPot_1  ]

12:  Polynomial (P55)                               ;Convert Rs to bars with 10 bar polynomial
   1:             1         Reps
   2:            33--       X Loc [ WatPot_1  ]
   3:            33--       F(X) Loc [ WatPot_1  ]
   4:              .15836   C0
   5:             6.1445    C1
   6:            –8.4198    C2
   7:             9.2493    C3
   8:            –3.1685    C4
   9:              .33392   C5

13:  Else (P94)                                     ;If Rs > 17 load over range value for potential

14:  Z=F (P30)
   1:        –99999         F
   2:             0         Exponent of 10
   3:            33         Z Loc [ WatPot_1  ]

15:  End (P95)                                      ;End then do

16:  End (P95)                                      ;End loop

17:  If time is (P92)                               ;Output Resistance and Water Potential each
                                                    Hour
   1:             0         Minutes (Seconds --) into a
   2:            60         Interval (same units as above)
   3:            10         Set Output Flag High (Flag 0)

18:  Set Active Storage Area (P80)                  ;Fix the Array ID to 60
   1:             1         Final Storage Area 1
   2:            60         Array ID
```

```
19:  Real Time (P77)                              ;Output Day and Hour/Minute
  1:            220        Day,Hour/Minute (midnight = 2400)

20:  Sample (P70)                                 ;Output resistances and Water Potentials
  1:             64        Reps
  2:              1        Loc [ BlockR_1  ]
```

7.2.5.3 Example 21X Program

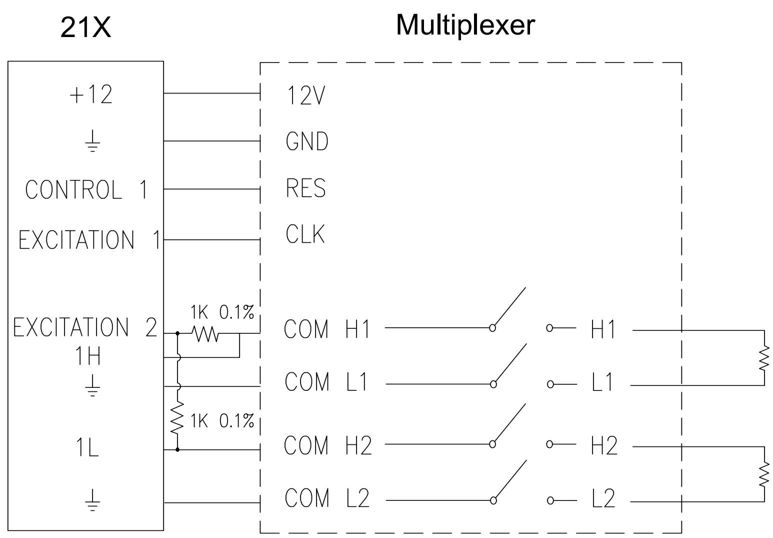


FIGURE 7-5. Wiring for example 21X program

```
*Table 1 Program
  01:            10        Execution Interval (seconds)

01:  Set Port (P20)                               ;Enable multiplexer
  1:              1        Set High
  2:              1        Port Number

02:  Beginning of Loop (P87)                      ;Start of measurement loop
  1:              0        Delay
  2:             16        Loop Count

03:  Excitation with Delay (P22)                  ;Clock Multiplexer to next channel
  1:              1        Ex Channel
  2:              1        Delay w/Ex (units = 0.01 sec)
  3:              1        Delay After Ex (units = 0.01 sec)
  4:           5000        mV Excitation

04:  Step Loop Index (P90)                        ;Step index by 2 each pass through loop
  1:              2        Step
```

```
05:  AC Half Bridge (P5)                          ;Measure the 2 connected 223 blocks
   1:            2        Reps
   2:           14        500 mV Fast Range
   3:            1        SE Channel
   4:            2        Excite all reps w/Exchan 2
   5:          500        mV Excitation
   6:            1--      Loc [ BlockR_1  ]       ; -- >>> advance location by index
   7:            1.0      Mult
   8:            0.0      Offset

06:  BR Transform Rf[X/(1–X)] (P59)               ;Calculate resistance from Vs/Vx
   1:            2        Reps
   2:            1--      Loc [ BlockR_1  ]
   3:            1.0      Mult (Rf)

07:  End (P95)

08:    Set Port (P20)                             ;Turn off AM416
   1:            0        Set Low
   2:            1        Port Number

;The following loop checks each block resistance and calculates
;water potential if BlockR < 17 kohms. Because 2 blocks are measured
;with each pass through the previous measurement loop, it is simpler
;to use a separate loop for the calculations.
;Leave out following loop if only recording block resistance.

09:  Beginning of Loop (P87)                      ;Loop to calculate water potential
   1:            0        Delay
   2:           32        Loop Count

10:  If (X<=>F) (P89)                             ;If Rs < 17, apply polynomial
   1:            1--      X Loc [ BlockR_1  ]
   2:            4        <
   3:           17        F
   4:           30        Then Do

11:  Z=X*F (P37)                                  ;Scale Rs for polynomial
   1:            1--      X Loc [ BlockR_1  ]
   2:             .1      F
   3:           33--      Z Loc [ WatPo_1   ]

12:  Polynomial (P55)                             ;Convert Rs to bars with 10 bar polynomial
   1:            1        Reps
   2:           33--      X Loc [ WatPo_1   ]
   3:           33--      F(X) Loc [ WatPo_1   ]
   4:             .15836  C0
   5:            6.1445   C1
   6:           –8.4198   C2
   7:            9.2493   C3
   8:           –3.1685   C4
   9:             .33392  C5

13:  Else (P94)                                   ;If Rs > 17 load overrange value for potential
```

```
14:  Z=F (P30)
  1:        –99999          F
  2:             33--       Z Loc [ WatPo_1   ]

15:  End (P95)                                      ;End then do

16:  End (P95)                                      ;End loop

17:  If time is (P92)                               ;Output Resistance and Water Potential each
                                                    Hour
  1:              0         Minutes (Seconds --) into a
  2:             60         Interval (same units as above)
  3:             10         Set Output Flag High (Flag 0)

18:  Set Active Storage Area (P80)                  ;Fix the Array ID to 60
  1:              1         Final Storage Area 1
  2:             60         Array ID

19:  Real Time (P77)                                ;Output Day and Hour/Minute
  1:            220         Day,Hour/Minute (midnight = 2400)

20:  Sample (P70)                                   ;Output resistances and Water Potentials
  1:             64         Reps                    ;32 reps if not outputting water potential
  2:              1         Loc [ BlockR_1  ]
```

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 8108
Garbutt Post Shop QLD 4814
AUSTRALIA
www.campbellsci.com.au • info@campbellsci.com.au

Campbell Scientific do Brasil Ltda. (CSB)
Rua Apinagés, nbr. 2018 ─ Perdizes
CEP: 01258-00 ─ São Paulo ─ SP
BRASIL
www.campbellsci.com.br • vendas@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.