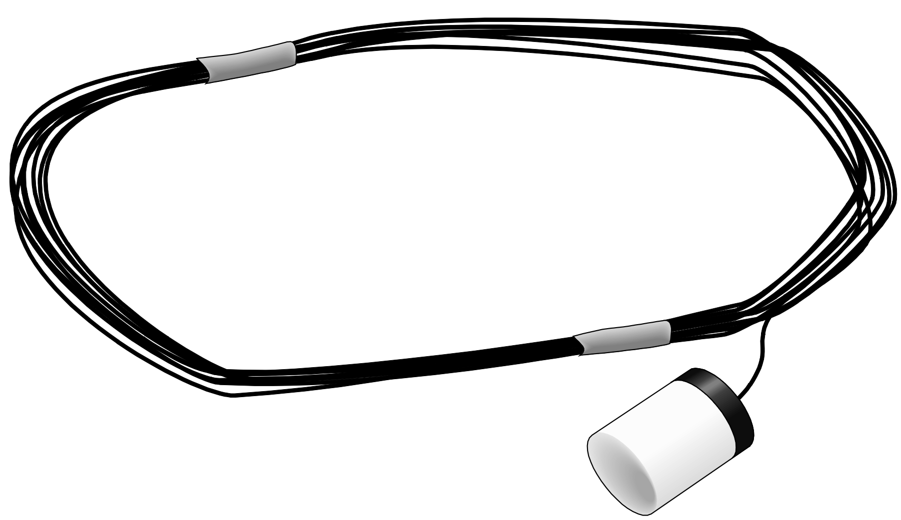
INSTRUCTION MANUAL

223 Delmhorst Cylindrical Soil Moisture Block

Revision: 6/16



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- Use only manufacturer recommended parts, materials, and tools.

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- 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.

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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.

NOTE This manual provides information only for CRBasic dataloggers. It is also compatible with our retired Edlog dataloggers. For Edlog datalogger support, see an older manual at *www.campbellsci.com/old-manuals*.

2. Precautions

- READ AND UNDERSTAND the *Safety* section at the front of this manual.
- 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

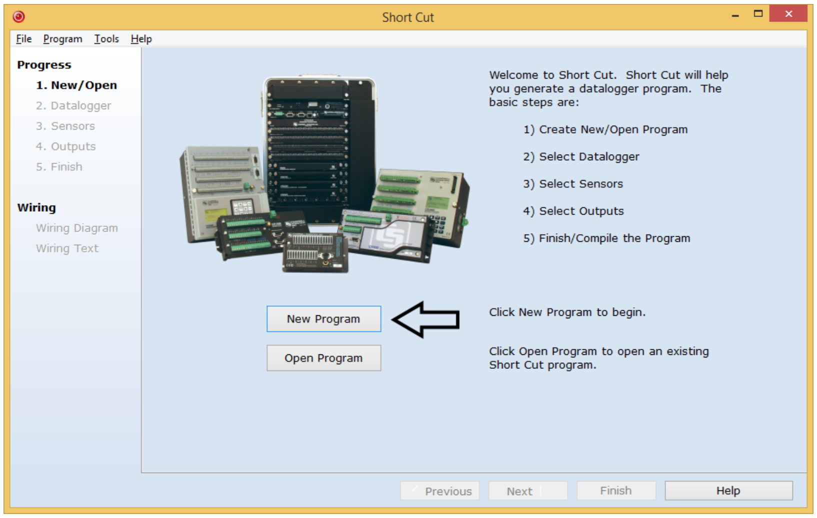
- Upon receipt of the 223, inspect the packaging and contents for damage. File damage claims with the shipping company.
- The model number and cable length are printed on a label at the connection end of the cable. Check this information against the shipping documents to ensure the correct product and cable length are received.

4. QuickStart

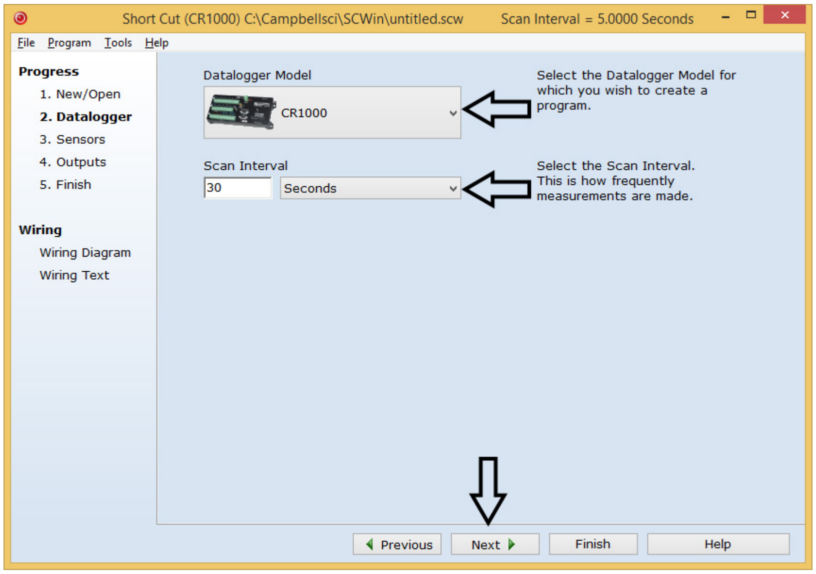
Short Cut is an easy way to program your datalogger to measure the 223 and assign datalogger wiring terminals. *Short Cut* is available as a download on *www.campbellsci.com* and the *ResourceDVD*. It is included in installations of *LoggerNet*, *PC200W*, *PC400*, or *RTDAQ*.

Use the following procedure to get started.

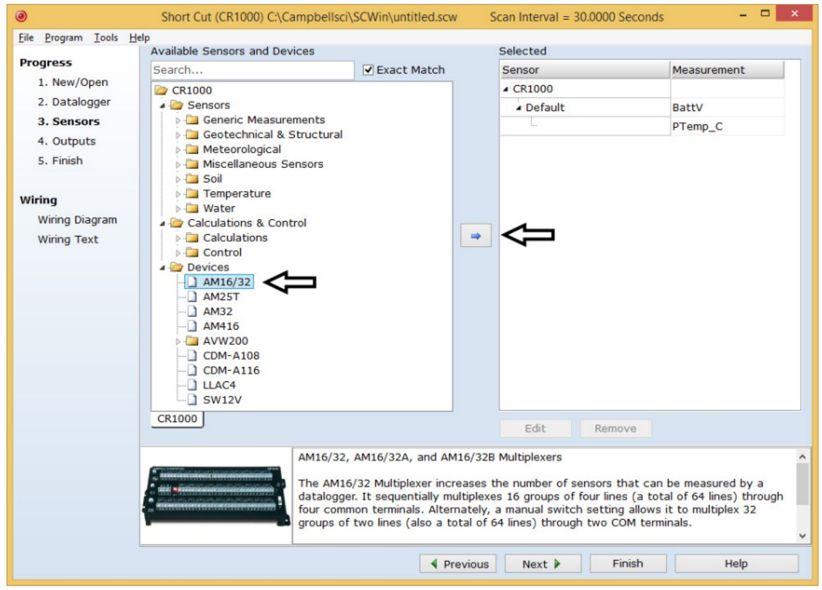
1. Open *Short Cut*. Click **New Program**.



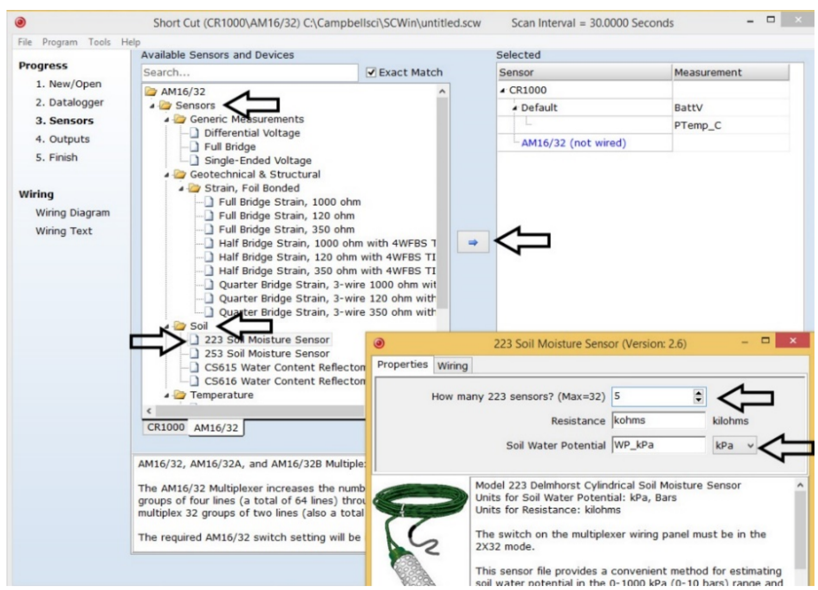
2. Select the **Datalogger Model** and enter the **Scan Interval** (a scan rate of **30** seconds or longer is recommended when using a multiplexer). Click **Next**.



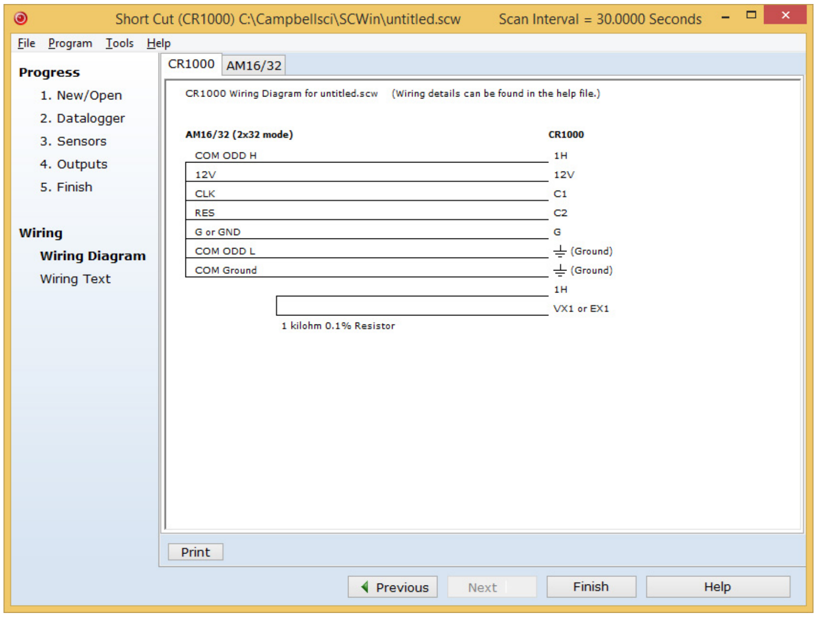
3. Under **Available Sensors and Devices** list, select **Devices | AM16/32** and click [button] to move the selection to the selected device window.



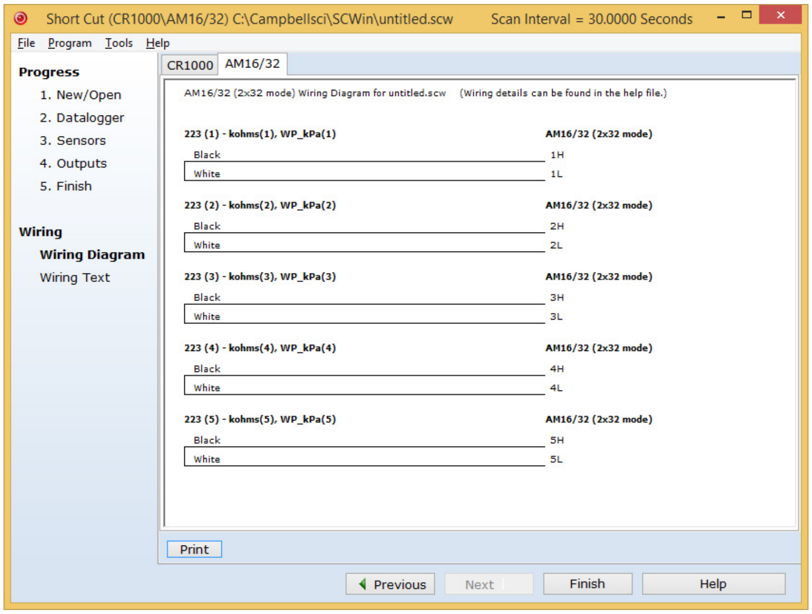
4. Under the **AM16/32** list, select the **Sensors | Soil** folder. Select **223 Soil Moisture Sensor** and click [button] to move the selection to the selected device window. Enter the number of 223 sensors being measured. Default **Soil Water Potential** units is **kPa**. This can be changed by clicking the box and selecting a different value.



5. After selecting the sensor, click **Wiring Diagram** to see how the AM16/32 is to be wired to the datalogger. The wiring diagram can be printed now or after more sensors are added.



6. Select the **AM16/32** tab to see how the sensors are to be wired to the AM16/32. The wiring diagram can be printed.



7. Select any other sensors you have, then finish the remaining *Short Cut* steps to complete the program. The remaining steps are outlined in *Short Cut Help*, which is accessed by clicking on **Help | Contents | Programming Steps**.

8. If *LoggerNet*, *PC400, RTDAQ*, or *PC200W* is running on your PC, and the PC to datalogger connection is active, you can click **Finish** in *Short Cut* and you will be prompted to send the program just created to the datalogger.

9. If the multiplexer is connected to the datalogger as shown in the wiring diagram in step 5 and the sensors are connected to the multiplexer as shown in step 6, check the output of the sensors in the datalogger support software data display to make sure they are making reasonable measurements.

5. Overview

The 223 gypsum soil moisture block is configured for use with multiplexers. 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 Campbell Scientific CRBasic dataloggers: CR6 series, CR800 series, CR1000, and CR3000.

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 8-1 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 8.2, *Calculate Soil Water Potential (p. 9)*, were fit to the values in TABLE 8-1 to allow output of an estimated water potential.

7. Installation

If you are programming your datalogger with *Short Cut*, skip Section 7.2, *Wiring (p. 6)*, and Section 7.3, *Programming (p. 7)*. *Short Cut* does this work for you. See Section 4, *QuickStart (p. 2)*, for a *Short Cut* tutorial.

7.1 Field 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. Backfill the hole, tamping lightly at frequent intervals.

7.2 Wiring

The 223 wiring 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 1 k resistor at the datalogger is used to complete the half bridge measurement.

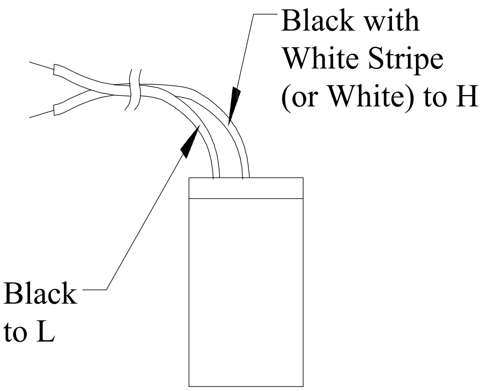


FIGURE 7-1. 223 wiring

TABLE 7-1. 223 Wiring		
Color	**Function**	**Multiplexer**
Black with White Stripe or White	Excitation	H
Black	Signal Ground	L

7.3 Programming

Short Cut is the best source for up-to-date datalogger programming code. Programming code is needed when:

- Creating a program for a new datalogger installation
- Adding sensors to an existing datalogger program

If your data acquisition requirements are simple, you can probably create and maintain a datalogger program exclusively with *Short Cut*. If your data acquisition needs are more complex, the files that *Short Cut* creates are a great source for programming code to start a new program or add to an existing custom program.

NOTE *Short Cut* cannot edit programs after they are imported and edited in *CRBasic Editor*.

A *Short Cut* tutorial is available in Section 4, *QuickStart* *(p. 2)*. If you wish to import *Short Cut* code into *CRBasic Editor* to create or add to a customized program, follow the procedure in Appendix A, *Importing Short Cut Code Into CRBasic Editor* *(p. A-1)*. Programming basics for CRBasic dataloggers are in the following section. Complete program examples for select CRBasic dataloggers can be found in Appendix B, *Example Program* *(p. B-1)*.

7.3.1 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 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
```

NOTE See the multiplexer manual for more information about using the multiplexer.

7.3.2 BrHalf CRBasic Instruction

The sensor is excited and measured using the **BrHalf** CRBasic instruction. Recommended excitation voltages and input ranges are given in TABLE 7-2.

TABLE 7-2. Excitation and Voltage Ranges

Datalogger	mV Excitation	Full Scale Range
CR6	200	±200 mV
CR800/CR850	250	±250 mV
CR1000	250	±250 mV
CR3000	200	±200 mV
CR5000	200	±200 mV

The output from the **BrHalf** instruction 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

8. Operation

8.1 Calculate Sensor Resistance

The sensor resistance is calculated using an expression in CRBasic. The expression takes the **BrHalf** 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.

8.2 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 8-1 are typical values supplied by Delmhorst Corporation.

TABLE 8-1. 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 8-1, soil water potential (bars) is calculated from sensor resistance (R_s) using the fifth order polynomial (FIGURE 8-1 and TABLE 8-2). TABLE 8-3 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. The polynomial to calculate soil water potential is fit to the 0.1 to 10 bar range using a least square fit. TABLE 8-2 lists the coefficients and equation for the 0.1 to 10 bar polynomial.

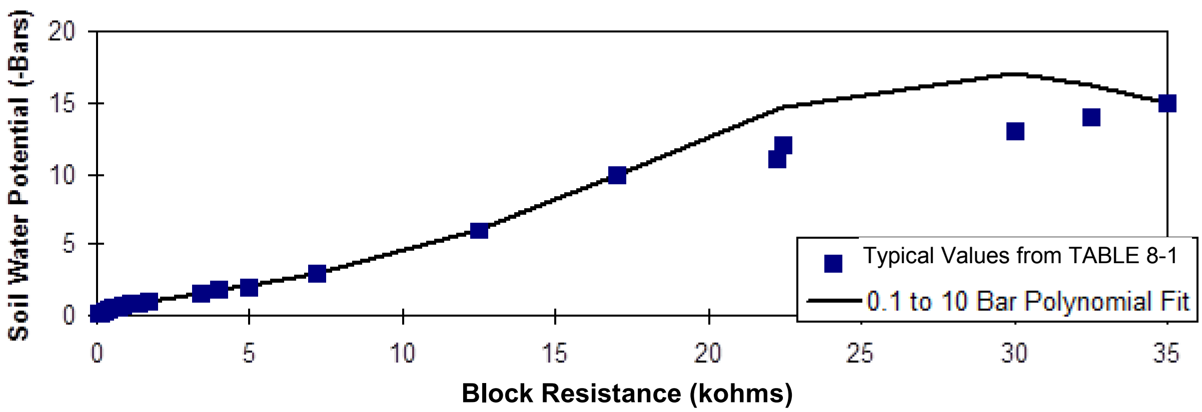


FIGURE 8-1. Polynomial fit to typical block resistance vs. water potential

TABLE 8-2. 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 8-3. 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 8-1 VALUES – COMPUTED VALUES				

Appendix A. Importing Short Cut Code Into CRBasic Editor

This tutorial shows:

- How to import a *Short Cut* program into a program editor for additional refinement
- How to import a wiring diagram from *Short Cut* into the comments of a custom program

Short Cut creates files, which can be imported into *CRBasic Editor*. Assuming defaults were used when *Short Cut* was installed, these files reside in the C:\campbellsci\SCWin folder:

- .DEF (wiring and memory usage information)
- .CR6 (CR6-series datalogger code)
- .CR8 (CR800-series datalogger code)
- .CR1 (CR1000 datalogger code)
- .CR3 (CR3000 datalogger code)
- .CR5 (CR5000 datalogger code)

Use the following procedure to import *Short Cut* code and wiring diagram into *CRBasic Editor*.

1. Create the *Short Cut* program following the procedure in Section 4, *QuickStart* *(p. 2)*. Finish the program and exit *Short Cut*. Make note of the file name used when saving the *Short Cut* program.

2. Open *CRBasic Editor*.

3. Click **File | Open**. Assuming the default paths were used when *Short Cut* was installed, navigate to C:\CampbellSci\SCWin folder. The file of interest has the .CR6, .CR8, .CR1, .CR3, or .CR5 extension. Select the file and click **Open**.

4. Immediately save the file in a folder different from C:\Campbellsci\SCWin, or save the file with a different file name.

NOTE Once the file is edited with *CRBasic Editor*, *Short Cut* can no longer be used to edit the datalogger program. Change the name of the program file or move it, or *Short Cut* may overwrite it next time it is used.

5. The program can now be edited, saved, and sent to the datalogger.

6. Import wiring information to the program by opening the associated .DEF file. Copy and paste the section beginning with heading "-Wiring for CRXXX–" into the CRBasic program, usually at the head of the file. After pasting, edit the information such that an apostrophe (') begins each line. This character instructs the datalogger compiler to ignore the line when compiling.

Appendix B. Example Program

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

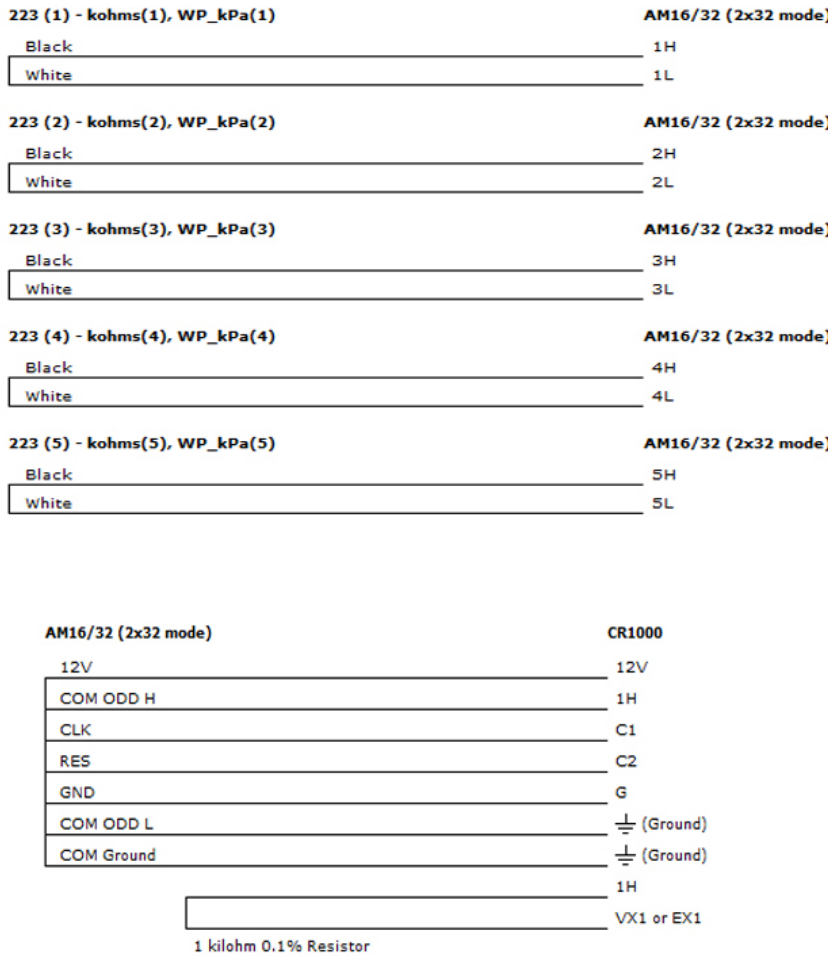


FIGURE B-1. Wiring for CR1000 example

CRBasic Example B-1. CR1000 Program Measuring Five 223 Sensors

```
'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,0,250,1,0)
      '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
```

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