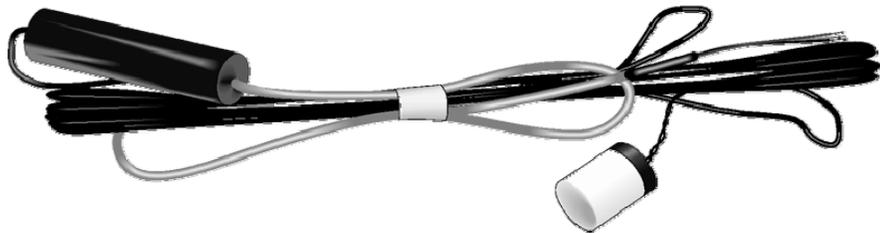


INSTRUCTION MANUAL



227 Delmhorst Cylindrical Soil Moisture Block

Revision: 5/13



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227 Delmhorst Cylindrical Soil Moisture Block

1. Introduction

The 227 is a gypsum block that determines soil water potential by measuring electrical resistance. When the 227 is wet, electrical resistance is low. As the 227 dries, resistance increases. This gypsum block connects directly to a datalogger.

The -L option on the model 227-L indicates that the cable length is user specified. This manual refers to the sensor as the 227.

Before using the 227, 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 227 in high spots or near changes in slope unless wanting to measure the variability created by such differences.
- To maximize longevity, remove the gypsum block during the winter.

3. Initial Inspection

- Upon receipt of the 227, 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.

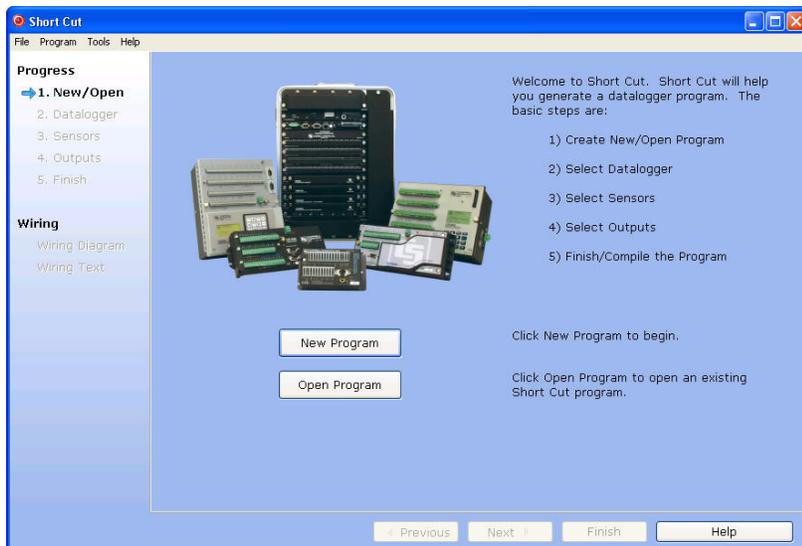
4.1 Installation

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 envelop it. This will insure uniform soil contact.
7. Back fill the hole, tamping lightly at frequent intervals.

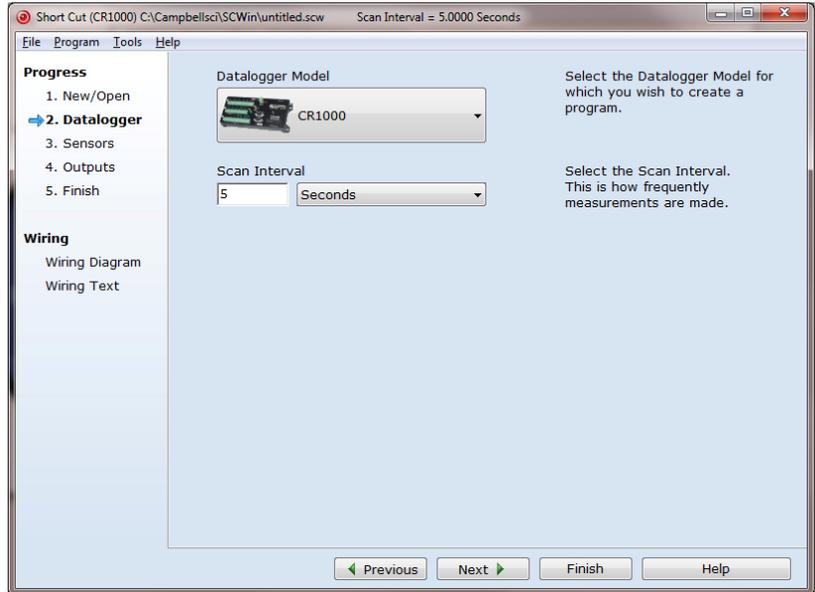
4.2 Use SCWin to Program Datalogger and Generate Wiring Diagram

The simplest method for programming the datalogger to measure the 227 is to use Campbell Scientific's SCWin Short Cut Program Generator.

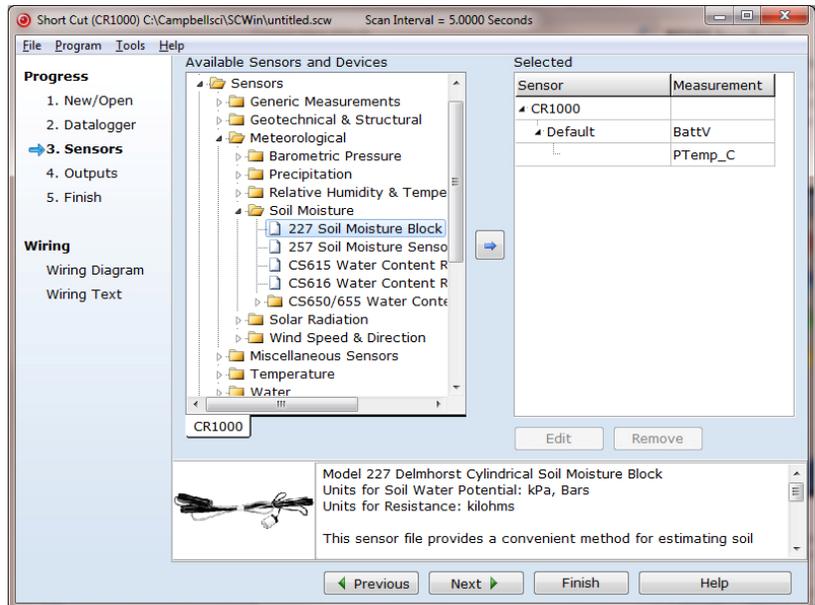
1. Open Short Cut and click on **New Program**.



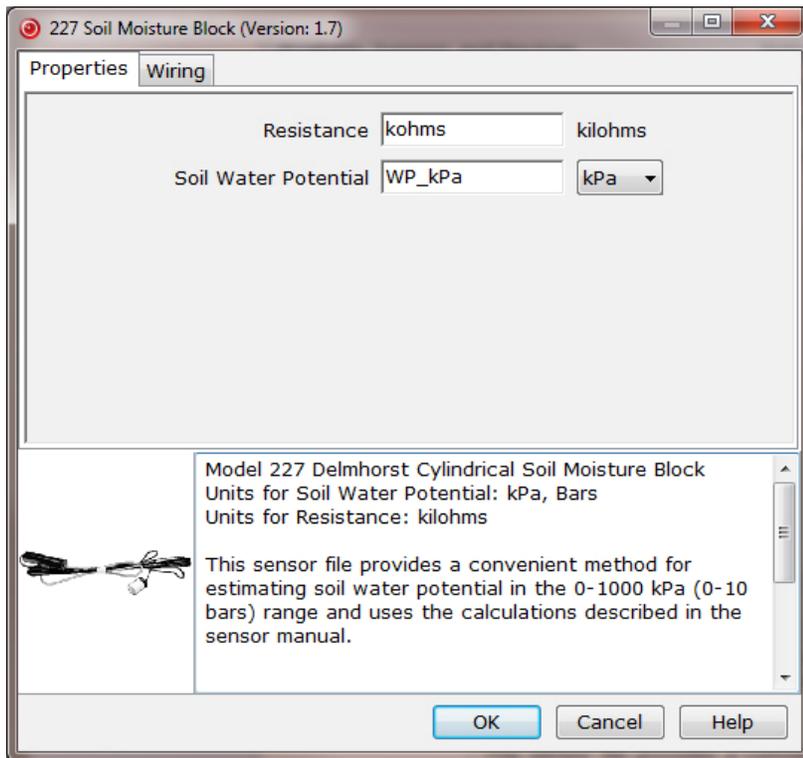
2. Select the **Datalogger Model** and enter the **Scan Interval**, and then select **Next**.



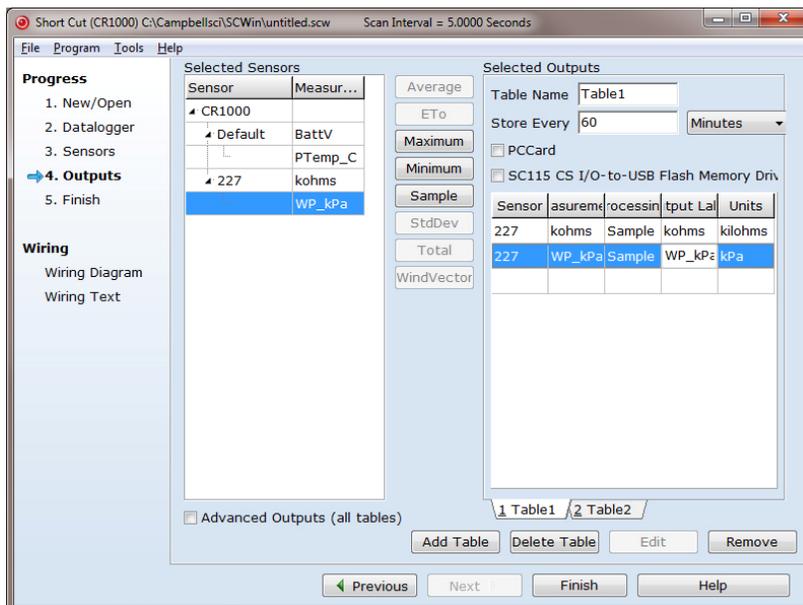
3. Select **227 Soil Moisture Block** under Meteorological | Soil Moisture, and select the **right arrow** (in center of screen) to add it to the list of sensors to be measured.



4. Enter the **Resistance** units and the **Soil Water Potential** units. After entering the information, click on **OK**, and then select **Next**.

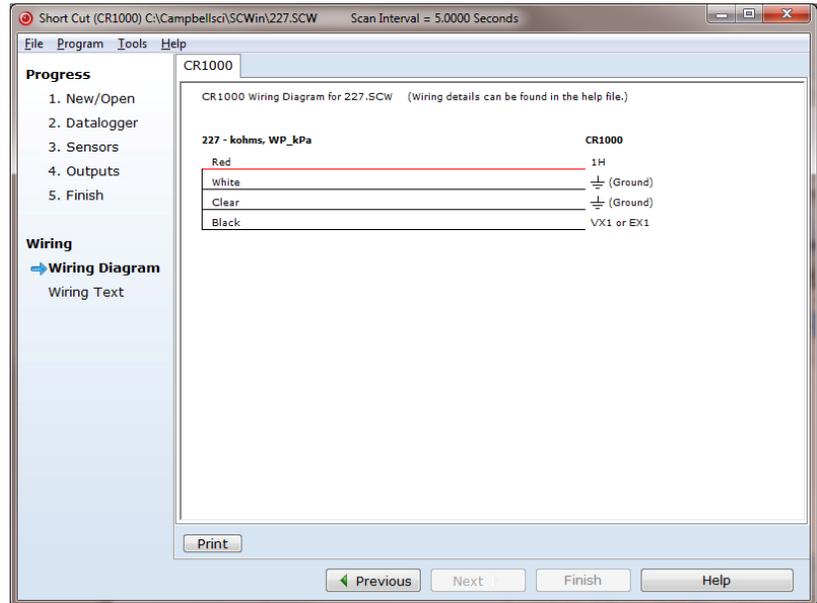


5. Choose the **Outputs** and then select **Finish**.



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 wire the 227 to the CR1000 according to the wiring diagram generated by SCWin Short Cut.



5. Overview

The 227 gypsum soil moisture block connects directly with a Campbell Scientific datalogger; it is not compatible with our CR200(X)-series.

The -L option on the Model 227-L indicates that the cable length is user specified. This manual refers to the sensor as the 227. The cable can terminate in:

- Pigtails that connect directly to a Campbell Scientific datalogger.
- Connector that attaches to a prewired enclosure (option -PW). Refer to www.campbellsci.com/prewired-enclosures for more information.

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 227 circuit has capacitors in the cable that block direct current flow from the 227 to datalogger ground. This is done to block electrolysis from prematurely destroying the sensor.

Gypsum blocks typically last for one to two years. Saline or acidic soils tend to degrade the block, reducing longevity. To maximize longevity, it is recommended that gypsum blocks not used during the winter 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:

- Contains blocking capacitors in its cable that minimizes galvanic degradation and measurement errors due to ground loops
- 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
CR9000(X)
CR500
CR510
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 7.2.3, *Calculate Soil Water Potential*, were fit to the values in TABLE 7-3 to allow output of an estimated water potential.

7. Operation

NOTE

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 227 schematic is shown in FIGURE 7-1. The capacitors block galvanic action due to the differences in potential between the datalogger earth ground and the electrodes in the block. Such current flow would cause rapid block deterioration.

The 227 uses a single-ended analog channel. TABLE 7-1 shows the datalogger wiring.

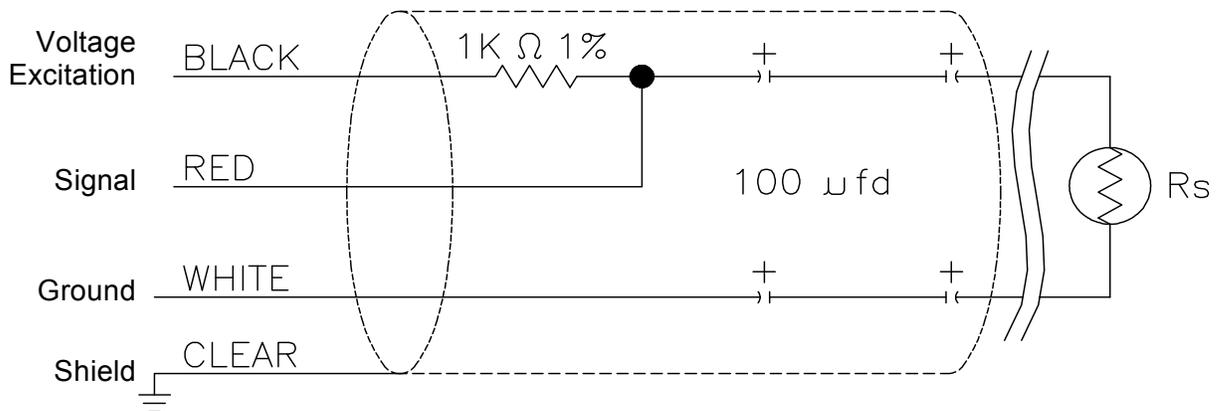


FIGURE 7-1. 227 schematic

TABLE 7-1. 227 Wiring				
Color	Function	CR10(X), CR500, CR510	21X, CR7, CR23X	CR800, CR850, CR1000, CR3000, CR5000, CR9000(X)
Black	Excitation	Switched Voltage Excitation	Switched Voltage Excitation	Switched Voltage Excitation
Red	Signal	Single-ended Channel	Single-ended Channel	Single-ended Channel
White	Signal Ground	AG	⊕	⊕
Clear	Shield	G	⊕	⊕

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 Program*, if using SCWin.

The datalogger is programmed using either CRBasic or Edlog. Dataloggers that use CRBasic include our CR800, CR850, CR1000, CR3000, CR5000, and CR9000(X). Dataloggers that use Edlog include our CR500, CR510, CR10(X), 21X, CR23X, and CR7. CRBasic and Edlog are included with LoggerNet, PC400, and RTDAQ software.

The datalogger program needs to measure the sensor, calculate the sensor resistance, and convert the transform resistance to potential in bars. Example programs are provided in Section 7.2.4, *Programming Examples*.

7.2.1 Excite and Measure the 227

The sensor is excited and measured using the **BrHalf** instruction in CRBasic or Edlog instruction **AC Half Bridge (P5)**. Recommended excitation voltages and input ranges are given in TABLE 7-2.

7.2.2 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:

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

$$\text{where, } X = V_s/V_x$$

The bridge transform multiplier would normally be 1000, representing the fixed resistor (R_1) shown in FIGURE 7-1. 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.

Datalogger	mV Excitation	Full Scale Range
CR800/CR850	250	±250 mV
CR1000	250	±250 mV
CR3000	200	±200 mV
CR5000	200	±200 mV
CR9000(X)	200	±200 mV
21X	500	±500 mV
CR7	500	±500 mV
CR500/CR510	250	±250 mV
CR10(X)	250	±250 mV
CR23X	200	±200 mV

NOTE Do not use a slow integration time as sensor polarization errors will occur.

7.2.3 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 a 5th order polynomial (FIGURE 7-2 and TABLE 7-4). 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 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.

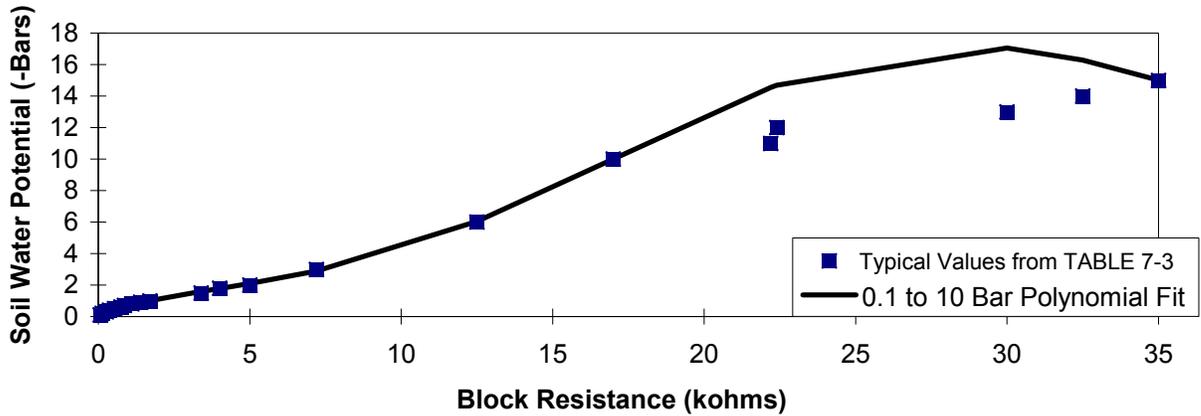


FIGURE 7-2. Polynomial fit to typical block resistance vs. water potential

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 to 10	0.1	0.15836	6.1445	-8.4189	9.2493	-3.1685	0.33392

NOTE The coefficients used for the 10 bar range require R_s to be scaled down by a factor of 0.1. In Edlog, this multiplier can be entered in the **Bridge Transform Instruction** or in **Processing Instruction 37**.

TABLE 7-5 shows errors between from the least-squares polynomial approximation and the typical water potential values.

NOTE Our manuals used to show a separate polynomial for the 0.1 to 2 bar range that had slightly smaller deviations from the typical values over the narrower range. However, the variability between blocks is much greater than the improved fit and does not warrant the more complicated program.

BARS	V_s / V_x	R_s (kohms \times 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
NOTE: ERROR (BARS) = TABLE 7-3 VALUES – COMPUTED				

7.2.4 Programming Examples

7.2.4.1 Example CR1000 Program

This example program is written for a CR1000. Programming for other CRBasic dataloggers is similar. The 227 sensor is measured with the **BrHalf()** instruction. An expression uses the result of the **BrHalf** instruction (V_s / V_x) to generate R_s in kohms. If R_s is less than 17 kohms, soil water potential is generated using the polynomial. If R_s is greater than 17 kohms, 1000 is stored in the variable.

Color	Function	CR1000
Black	Voltage Excitation	VX1 or EX1
Red	Signal	SE1
White	Signal Ground	
Clear	Shield	

```

'CR1000

'Declare Variables and Units
Public Batt_Volt
Public Rs_kOhm
Public WP_kPa

Units Batt_Volt=Volts
Units Rs_kOhm=kOhms
Units WP_kPa=kPa

'Define Data Tables
DataTable(Table1,True,-1)
  DataInterval(0,60,Min,10)
  Sample(1,Rs_kOhm,FP2)
EndTable

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

'Main Program
BeginProg
  Scan(5,Sec,1,0)
  'Default Datalogger Battery Voltage measurement Batt_Volt:
  Battery(Batt_Volt)
  '227 Soil Moisture Block measurements Rs_kOhm and WP_kPa:
  BrHalf(Rs_kOhm,1,mV250,1,Vx1,1,250,True,0,250,1,0)
  Rs_kOhm=Rs_kOhm/(1-Rs_kOhm)
  If Rs_kOhm<17 Then
    WP_kPa=Rs_kOhm*0.1
    WP_kPa=0.15836+(6.1445*WP_kPa)+(-8.4189*WP_kPa^2)+(9.2493*WP_kPa^3)+
      (-3.1685*WP_kPa^4)+(0.33392*WP_kPa^5)
    WP_kPa=WP_kPa*100
  Else
    WP_kPa=1000
  EndIf
  'Call Data Tables and Store Data
  CallTable(Table1)
  CallTable(Table2)
  NextScan
EndProg

```

7.2.4.2 Example CR10(X) Program

This program example is intended to be a portion of a larger program with instructions that are executed at a 10 second interval. It is a CR10X program but other Edlog dataloggers are programmed similarly.

The 227 sensor is measured with **Measurement Instruction (5)**. The **Bridge Transform Instruction (59)** uses the result of **Instruction 5** (V_s / V_x) to generate R_s in kohms. If R_s is less than 17 kohms, soil water potential is generated using the polynomial. If R_s is greater than 17 kohms, the overrange indicator -99999 is loaded into the water potential location.

Every 6 hours the time (day, hour, minute), sensor resistance, and calculated water potential are output.

TABLE 7-7. Wiring for CR10X Example Program		
Color	Function	CR10(X)
Black	Excitation	E1
Red	Signal	SE1
White	Signal Ground	AG
Clear	Shield	G

```

*Table 1 Program
 01: 10.0000 Execution Interval (seconds)

01: AC Half Bridge (P5) ;Measure and store Vs/Vx
 1: 1 Reps
 2: 14 250 mV Fast Range
 3: 1 SE Channel
 4: 1 Excite all reps w/Exchan 1
 5: 250 mV Excitation
 6: 1 Loc [ Rs ]
 7: 1 Mult
 8: 0 Offset

02: BR Transform Rf[X/(1-X)] (P59) ;Convert Vs/Vx to Rs
 1: 1 Reps
 2: 1 Loc [ Rs ]
 3: 1 Multiplier (Rf)

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

04: Z=X*F (P37) ;Scale Rs for polynomial
 1: 1 X Loc [ Rs ]
 2: .1 F
 3: 2 Z Loc [ WatPoten ]

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

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

```
07: Z=F (P30)
  1: -99999      F
  2: 0           Exponent of 10
  3: 2           Z Loc [ WatPoten ]

08: End (P95)                                     ;End then do

09: If time is (P92)                             ;Output every six hours
  1: 0           Minutes (Seconds --) into a
  2: 360         Interval (same units as above)
  3: 10         Set Output Flag High

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

11: Sample (P70)                                ;Output Rs and Water potential
  1: 2          Reps
  2: 1          Loc [ Rs      ]
```


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