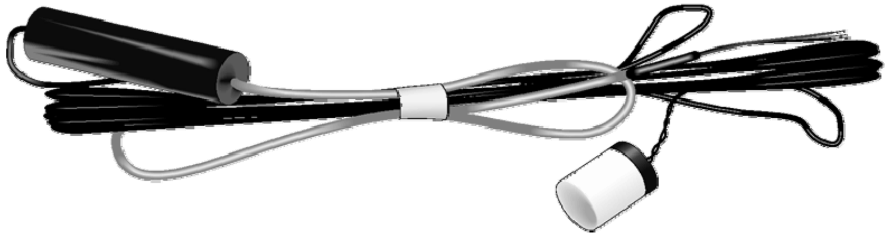
INSTRUCTION MANUAL

Model 227 Delmhorst Cylindrical Soil Moisture Block

Revision: 11/08



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Model 227 Delmhorst Cylindrical Soil Moisture Block

1. General Description

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

2. Specifications

Approximate Cylinder Dimensions	
Diameter	2.25 cm (0.88”)
Length	2.86 cm (1.25”)
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 2 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 4.5 were fit to the values in Table 2 to allow output of an estimated water potential.

3. Installation

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.

Delmhorst recommends the blocks go through two wetting-drying cycles before installation to improve block uniformity. For each cycle, the blocks should be soaked in water for one hour and allowed to dry.

Soil moisture blocks measure only the moisture they "see", therefore placement is important. Avoid depressions where the water will puddle after a rain. Likewise, don't place the blocks in high spots or near changes in slope unless you are trying to measure the variability created by such differences.

Prior to installation, soak the blocks for two to three minutes. Mix a slurry of soil and water to a creamy consistency and place one or two tablespoons into the installation hole. Insert the block, forcing the slurry to envelope the block. This will insure uniform soil contact. Back fill the hole, tamping lightly at frequent intervals.

4. Wiring

The 227 schematic is shown in Figure 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 1 shows the datalogger wiring.

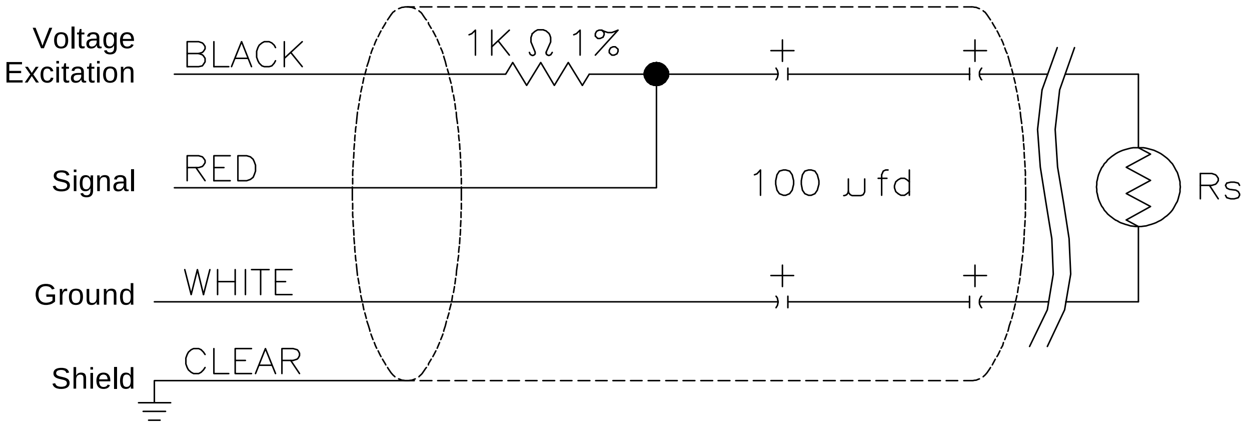

FIGURE 1. 227 Schematic

TABLE 1. 227 Wiring

Color	**Function**	**CR10(X), CR510**	**21X, CR7, CR23X**	**CR800, CR850, CR1000, CR3000, CR5000**
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	⏚	⏚

5. Programming

NOTE This section is for users who write their own datalogger programs. A datalogger program to measure this sensor can be generated using Campbell Scientific's Short Cut Program Builder software. You do not need to read this section to use Short Cut.

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 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.

5.1 Excite and Measure the 227

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 2.

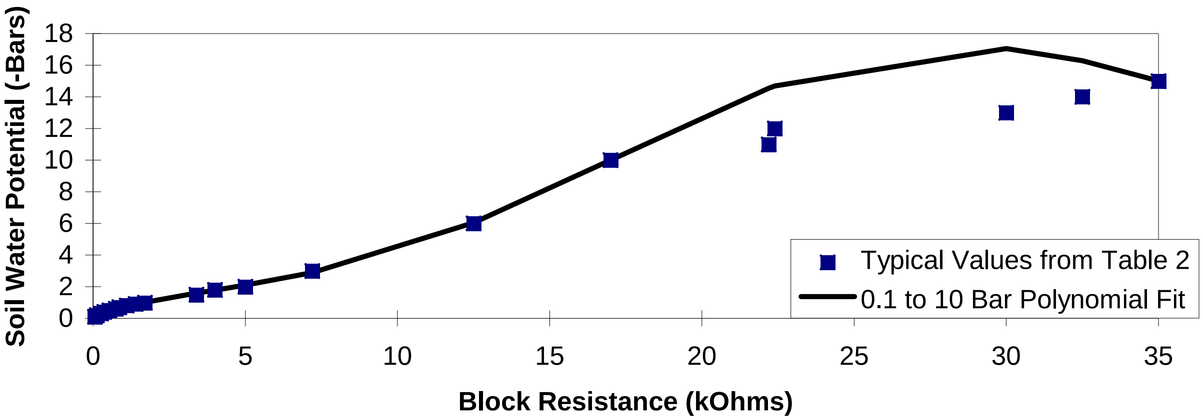

FIGURE 2. Polynomial Fit to Typical Block Resistance vs. Water Potential

5.2 Calculate Sensor Resistance

The sensor resistance is calculated using an expression in CRBasic or Instruction 59 (Bridge Transform) in Edlog. The expression or Instruction 59 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 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.

TABLE 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
CR9000(X)	200	±200 mV
21X	500	±500 mV
CR7	500	±500 mV
CR10(X)	250	±250 mV
CR23X	200	±200 mV

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

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

and, R_1 = Fixed Bridge Resistor.

Table 4 lists typical block resistance at different soil water potentials and the resulting V_S/V_X. Figure 2 is a plot of V_S/V_X versus bars. The non-linear relationship of V_S/V_X to bars precludes computing bars from an average of V_S/V_X.

TABLE 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

TABLE 4. Polynomial Coefficients for Converting Sensor Resistance to Bars

$$\text{BARS} = C_0 + C_1(R_S) + C_2(R_S)^2 + C_3(R_S)^3 + C_4(R_S)^4 + C_5(R_S)^5$$

BARS)	MULT. (R_1)	C_0	C_1	C_2	C_3	C_4	C_5
0.1-10	0.1	.15836	6.1445	-8.4189	9.2493	-3.1685	.33392

5.3 Calculate Soil Water Potential

The datalogger program can be written to store block resistance or can calculate water potential from a block calibration.

For the typical resistance values listed in Table 2, soil water potential (bars) is calculated from sensor resistance (R_S) using the 5th order Polynomial Instruction. The non linear relationship of R_S to bars rules out averaging R_S directly.

The polynomial is entered as an expression in CRBasic or by using Instruction 55 in Edlog. The polynomial to calculate soil water potential is fit to the 0.1 to 10 bar range using a least square fit. Table 4 lists the coefficients and equation for the 0.1 to 10 bar polynomial.

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 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.

TABLE 5. Polynomial Error - 10 Bar Range

BARS	V_S/V_X	R_S	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 3 VALUES - COMPUTED

5.4 Programming Examples

5.4.1 CRBasic

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 (Vs/Vx) to generate Rs in kohms. If Rs is less than 17 kohms, soil water potential is generated using the polynomial. If Rs is greater than 17 kohms, 1000 is stored in the variable.

TABLE 6. Wiring for CR1000 Example Program

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
```

5.4.2 Edlog

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. 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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