MODEL 227 DELMHORST
CYLINDRICAL SOIL MOISTURE BLOCK
INSTRUCTION MANUAL

REVISION: 1/99

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MODEL 227 DELMHORST CYLINDRICAL SOIL MOISTURE BLOCK

1. GENERAL DESCRIPTION

The 227 gypsum soil moisture block is configured for the CR10(X), 21X, CR23X, and CR7 Dataloggers. 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 and applies to the 227-L as well.

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 or 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, the red lead may be inserted into either a HI or LO input. Table 1 shows the datalogger wiring.

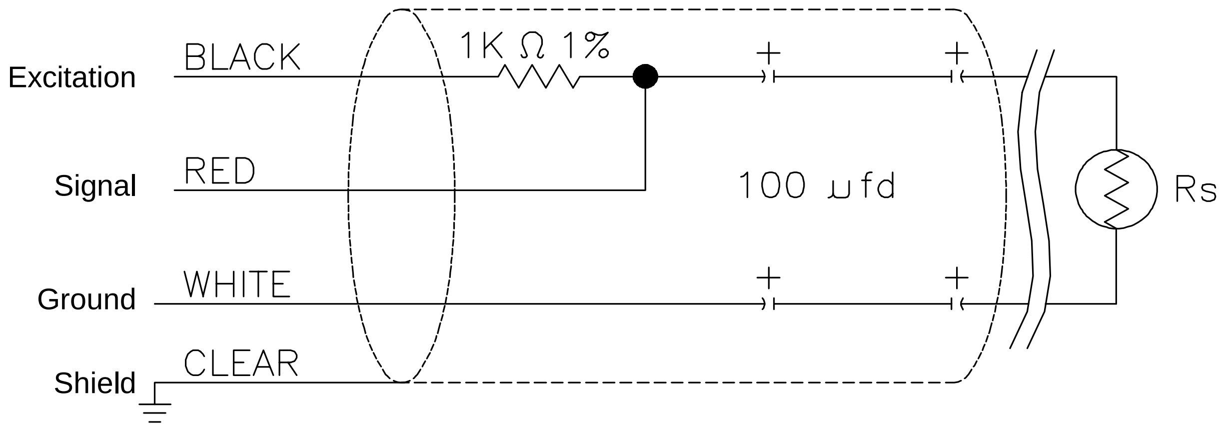

FIGURE 1. 227 Schematic

TABLE 1. 227 Wiring

Color	Function	CR10(X), CR500	21X, CR7, CR23X
Black	Excitation	Switched Excitation	Switched Excitation
Red	Signal	Single-ended Channel	Single-ended Channel
White	Signal Ground	AG	⏚
Clear	Shield	G	⏚

5. PROGRAMMING

Three programming instructions are required to measure and calculate soil water potential in bars. Instruction 5 is used to make the measurement, Instruction 59 is used to calculate resistance of the sensor, and Instruction 55 is used to transform resistance to potential in bars.

5.1 MEASUREMENT - INSTRUCTION 5

Instruction 5 (P5, AC Half Bridge) is used to excite and measure the 227. Recommended excitation voltages and input ranges are given in Table 2.

5.2 CALCULATE SENSOR RESISTANCE - INSTRUCTION 59

Instruction 59 (Bridge Transform) is used to output sensor resistance (R_S). This Instruction takes the AC 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

Data logger	MV Excitation	Range Code	Full Scale Range
21X	500	14	±500 mV
CR7	500	16	±500 mV
CR10(X)	250	14	±250 mV
CR23X	200	13	±200 mV

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

The output from 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 3 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

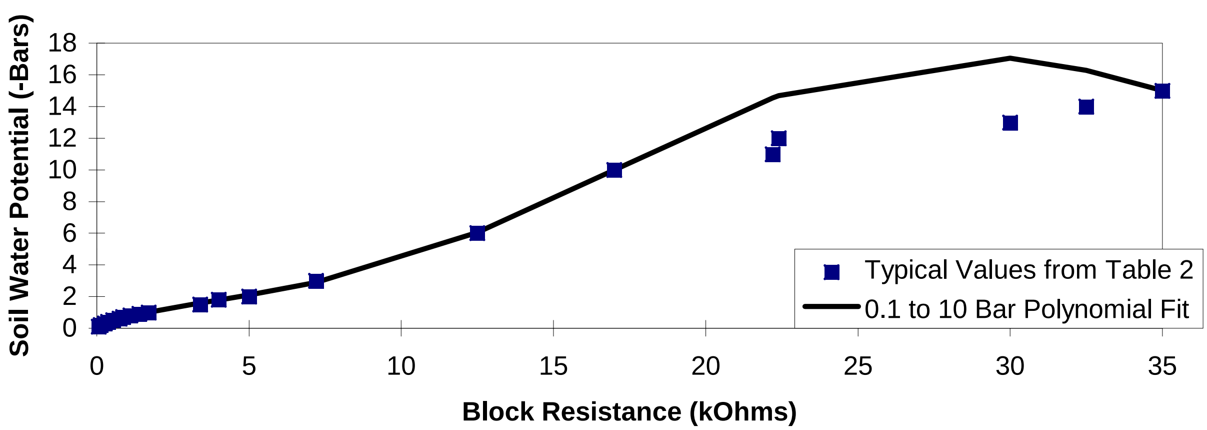

FIGURE 2. Polynomial Fit to Typical Block Resistance vs. Water Potential

TABLE 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	.15836	6.1445	-8.4189	9.2493	-3.1685	.33392

5.3 CALCULATE SOIL WATER POTENTIAL - INSTRUCTION 55

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.

A polynomial to calculate soil water potential was fit to the 0.1 to 10 bar range using a least squares fit. The coefficients used for the 10 bar range require R_S to be scaled down by a factor of 0.1. This multiplier can be entered in the Bridge Transform Instruction or in Processing Instruction 37.

Table 4 lists the coefficients for the 0.1 to 10 bar polynomial. 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 EXAMPLE FOR THE CR10(X)

This program example is intended to be a portion of a larger program with instructions that are executed at a 10 second interval.

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 6. Wiring for Example Program

Color	Function	CR10(X), CR500
Black	Excitation	E1
Red	Signal	SE1
White	Signal Ground	AG
Clear	Shield	G

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*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  ]
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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       ]
```