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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.

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.





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.

Short Cut (CR1000\AM16	/32) C:\Campbellsci\SCWin\untitled.scw	Scan Interval = 5.0000 Seconds	- • ×
<u>File P</u> rogram <u>T</u> ools <u>H</u> e	lp		
Progress	Datalogger Model	Select the [atalogger Model for
1. New/Open		which you w program.	ish to create a
🔿 2. Datalogger	CR1000	· · · · · ·	
3. Sensors			
4. Outputs	Scan Interval	Select the S	Scan Interval.
5. Finish	30 Seconds	This is how measurement	frequently its are made.
Wiring Wiring Diagram			
Wiring Text			
thing tone			
	Previous	Next Finish	Help

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

<u>File Program T</u> ools <u>H</u>	elp Augilable Concern and Davison		Coloritad	
Progress 1. New/Open 2. Datalogger ⇒3. Sensors 4. Outputs 5. Finish Wiring Wiring Diagram Wiring Text	Help Available Sensors and Devices Sensors Generic Measurements Meteorological Miscellaneous Sensors Temperature Calculations & Control Calculations & Control Calculations Octive Am16/32 AM25T AM16 AM16 AM16	=	Selected Sensor CR1000 Default	Measurement BattV PTemp_C
	CR1000 AM16/32, AM16/ The AM16/32 Mu be measured by of four lines (a t	32A, and A ltiplexer ind a datalogg btal of 64 I	Edit R M16/32B Multiplexel creases the number er. It sequentially m ines) through four c	temove rs of sensors that can ultiplexes 16 groups ommon terminals.

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.

O Short Cut (CR1000\AM16/32) C.\Campbellsci\SCWin\untitled.scw Scan Interval = 30.0000 Seconds D Content of the second					
<u>File Program Tools H</u>	<u>File Program Iools H</u> elp				
Progress	Available Sensors and Devices	S	elected		
Progress	— 🗋 Full Bridge Strain, 120 o 🔺	S	Sensor	Measurement	
1. New/Open	Full Bridge Strain, 350 o	4	CR1000		
2. Datalogger	Half Bridge Strain, 1000		 Default 	BattV	
3. Sensors	- Half Bridge Strain, 350 c		L.	PTemp_C	
Outputs	— Quarter Bridge Strain, 3—		- AM16/32 (no	ot w	
5. Finish	- Quarter Bridge Strain, 3	-	, (
	Quarter Bridge Strain, 3				
Wiring	A Soil Moisture				
Wining Discourse	223 Soil Moisture Senso	-			
wiring Diagram	- 253 Soil Moisture Senso				
Wiring Text	CS615 Water Content R				
	CS616 Water Content R				
	▲ 🗁 Temperature				
	107 Temperature Probe (3				
	107 Temperature Probe (4				
	CR1000 AM16/32				
			Edit	Remove	
	Model 223 Delmhorst Cy	lindrica	al Soil Moisture S	Sensor 🔺	
	Units for Soil Water Pot	ential:	kPa, Bars		
	Units for Resistance: kil	onms			
	The switch on the multi	plexer	wiring panel mu	st be in the 2X32	
	Previous Next Finish Help				

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**.

(223 Soil Mo	isture S	ensor (Version: 2.5)			×
ſ	Properties	Wiring				
	How	many	223 sensors? (Max=32)	5		
			Resistance	kohms	kilohms	
			Soil Water Potential	WP_kPa	kPa 🔻	
4			Model 223 Delmhorst Cyl Jnits for Soil Water Pote Jnits for Resistance: kilo	indrical Soil Moistur ntial: kPa, Bars hms	e Sensor	*
	SC	-	The switch on the multip the 2X32 mode.	olexer wiring panel r	nust be in	E
			This sensor file provides estimating soil water pot pars) range and uses the sensor manual.	a convenient meth cential in the 0-100 e calculations descr	od for 0 kPa (0-10 ribed in the	
				OK Cance	Help	

<u>File Program Tools H</u>	<u>1</u> elp			
Descence	Selected Sensors		Selected Outputs	
Progress	Sensor Measur	Average	Table Name Table1	
1. New/Open	▲ CR1000	ETo	Share Even (60	Minutes
Datalogger	Default BattV	Maximum	Store Every 100	Minutes
Sensors	PTemp_C	Minimum	PCCard	
🔿 4. Outputs	AM16/32	Minimum	SC115 CS I/O-to-USE	B Flash Memory Driv
5. Finish	▲ 1 223 kohms(1)	Sample	Sensor asuremerocessi	n tput Lal Units *
	WP_kPa	StdDev	223 WP kPa Sample	WP_kPa_kPa
Wiring	▲ 2 223 kohms(2)	Total	223 kohme// Sample	kohme (1 kilohm
Wiring Diagram	WP kPa	WindVoctor	225 Koninis(2 Sample	
Wiring Text	▲ 3 223 kohms(3)	windvector	223 WP_kPa Sample	e WP_kPa kPa
	WP kPa		223 kohms(: Sample	kohms(: kilohm
	4 223 kohms(4)		223 WP_kPa Sample	e WP_kPa kPa
	WP kPa		223 kohms(- Sample	kohms(4 kilohm
	4 5 222 kobme(5)		223 WP_kPa Sample	wP_kPa kPa
	WD kD5		223 kohms(! Sample	kohms(! kilohm
	WF_NFG		223 WP kPa Sample	WP kPa kPa
			L	
	Advanced Outputs (all tables)			
		Add Tab	le Delete Table Ed	dit Remove

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.

Short Cut (CR1000) C:\Ca	mpbellsci\SCWin\223.scw Scan Interval = 30.000) Seconds
<u>File P</u> rogram <u>T</u> ools <u>H</u> e	lp	
Progress	CR1000 AM16/32	
1. New/Open	CR1000 Wiring Diagram for 223.scw (Wiring detai	Is can be found in the help file.)
2. Datalogger		
3. Sensors	AM16/32 (2x32 mode)	CR1000
4. Outputs	12V	12V
5. Finish		1H
	RES	C1
Wiring	GND	G
→Wiring Diagram	COM ODD L	는 (Ground)
Wiring Text	COM Ground	(Ground)
		1H
	1 kilohm 0 1% Resistor	VX1 or EX1
	J	
	Print	
	Previous	ext Finish Help

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.

Short Cut (CR1000\AM16)	/32) C:\Campbellsci\SCWin\223.scw Scan Interv	al = 30.0000 Seconds
<u>F</u> ile <u>P</u> rogram <u>T</u> ools <u>H</u> e	lp	
Progress	CR1000 AM16/32	
1. New/Open	AM16/32 (2x32 mode) Wiring Diagram for 223.scw	(Wiring details can be found in the help file.)
2. Datalogger	222 (1) - kohme(1) WD kDa(1)	AM16/22 (2x22 mode)
3. Sensors	225 (1) - Konnis(1), WF_KFd(1)	AM10/32 (2x32 mode)
4. Outputs	Black	11
5. Finish	white	1
	223 (2) - kohms(2), WP_kPa(2)	AM16/32 (2x32 mode)
Wiring	Black	2H
→Wiring Diagram	White	2L
Wiring Text	223 (3) - kohms(3), WP kPa(3)	AM16/32 (2x32 mode)
wining roxe	Black	зн
	White	5.1 3L
	223 (4) - kohms(4), WP_kPa(4)	AM16/32 (2x32 mode)
	Black	4H
	White	4L
	223 (5) - kohms(5), WP_kPa(5)	AM16/32 (2x32 mode)
	Black	5H
	White	5L
	Print	
	Previous	Finish Help

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: Center electrode: Outer electrode:	Concentric cylinders Excitation 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, <i>Calculate Soil</i> <i>Water Potential</i> , 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	Н	
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=0BEGIN 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,Rs and Vs / Vx			
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.

Typical Values from TABLE 7-3

Block Resistance (kohms)

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.

223 (1) - Kohms(1), WP_kPa(1)	AM16/32 (2x32 mode)
Black	1H
White	1L
223 (2) - kohms(2), WP_kPa(2)	AM16/32 (2x32 mode)
Black	2H
White	2L
223 (3) - kohms(3), WP_kPa(3)	AM16/32 (2x32 mode)
Black	ЗН
White	3L
223 (4) - kohms(4), WP_kPa(4)	AM16/32 (2x32 mode)
Black	4H
White	4L
223 (5) - kohms(5), WP_kPa(5)	AM16/32 (2x32 mode)
Black	5H
White	5L

AM16/32 (2x32 mode)		CR1000
12V		12V
COM ODD H		1H
CLK		C1
RES		C2
GND		G
COM ODD L		느 (Ground)
COM Ground		느 (Ground)
		1H
		VX1 or EX1
	1 kilohm 0.1% Resistor	

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 Šcan
  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</pre>
       WP kPa(LCount)=kohms(LCount)*0.1
        W_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





*Table 1 Program				
01:	60.0000	Execution Interval (secon	nds)	
01: Do (P86)		;Enable multiplexer	
1:	41	Set Port 1 High		
02: Beginnii	ng 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 St I	I 1 (D0	0)		
04: Step Loc	op Index (P9	0)	;Step index by 2 each pass through loop	
1:	2	Step		
05. AC Half	Bridge (P5)		Measure the 2 connected 223 blocks	
1.	2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	Rens	, measure the 2 connected 225 bioeks	
1. 2·	14	250 mV Fast Range		
3.	1	SE Channel		
<i>4</i> .	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 Tran	sform Rf[X/	(1-X) (P59)	;Calculate resistance from Vs/Vx	
1:	2	Reps	·	
2:	1	Loc [BlockR_1]		
3:	1	Multiplier (Rf)		
07: End (P9:	5)			

08: Do (P86) 1: 51	Set Port 1 Low	;Turn off multiplexer
;The following loop chec ;water potential if Block ;with each pass through ;to use a separate loop f ;Leave out following loo	cks each block resistance an R < 17 kohms. Because 2 b the previous measurement i or the calculations. p if only recording block re	nd calculates locks are measured loop, it is simpler sistance.
09: Beginning of Loop 1: 0 2: 32	(P87) Delay Loop Count	;Loop to calculate water potential
10: If (X<=>F) (P89) 1: 1 2: 4 3: 17 4: 30	X Loc [BlockR_1] < F Then Do	;If Rs < 17, apply polynomial
11: Z=X*F (P37) 1: 1 2: .1 3: 33	X Loc [BlockR_1] F Z Loc [WatPot_1]	;Scale Rs for polynomial
12: Polynomial (P55) 1: 1 2: 33 3: 33 4: .15836 5: 6.1445 6: -8.4198 7: 9.2493 8: -3.1685 9: .33392	Reps X Loc [WatPot_1] F(X) Loc [WatPot_1] C0 C1 C2 C3 C4 2 C5	;Convert Rs to bars with 10 bar polynomial
13: Else (P94) 14: Z=F (P30) 1: -99999 2: 0 2: 22	F Exponent of 10	;If Rs > 17 load over range value for potential
5: 55 15: End (P95)	Z Loc [watPot_1]	End then do
16: End (P95)		;End loop
17: If time is (P92)		;Output Resistance and Water Potential each Hour
1: 0 2: 60 3: 10	Minutes (Seconds) into Interval (same units as ab Set Output Flag High (Fl	o a bove) ag 0)
18: Set Active Storage 1: 1 2: 60	Area (P80) Final Storage Area 1 Array ID	;Fix the Array ID to 60

19: Real 7 1:	Гіте (Р77) 220	;Output Day and Hour/Minute Day,Hour/Minute (midnight = 2400)
20: Samp	le (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 (secon	ds)
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 Dela	y (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 (P9	0)	;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 Loc [BlockR_1] ; -- >>> advance location by index 6: 1--7: 1.0 Mult Offset 8: 0.0 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 Set Low 1: 0 2: Port Number 1 ;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: Delay 0 2: 32 Loop Count 10: If $(X \le F)$ (P89) ; If Rs < 17, apply polynomial X Loc [BlockR 1] 1: 1---2: 4 < F 3: 17 4: 30 Then Do 11: Z=X*F (P37) ;Scale Rs for polynomial X Loc [BlockR 1] 1: 1--2: .1 F 3: 33---Z Loc [WatPo 1] 12: Polynomial (P55) ;Convert Rs to bars with 10 bar polynomial 1: Reps 1 2: X Loc [WatPo 1] 33---3: 33--F(X) Loc [WatPo_1] 4: .15836 C0 5: 6.1445 C1 6: -8.4198 C2 9.2493 C3 7: 8: -3.1685 C4 9: .33392 C5 13: Else (P94) ; If Rs > 17 load overrange value for potential

14: Z=F (P30)		
1: -999999	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 (Fla	ng 0)
18: Set Active Storage A	rea (P80)	Fix the Array ID to 60
1: 1	Final Storage Area 1	
2: 60	Array ID	
19: Real Time (P77)		:Output Dav and Hour/Minute
1: 220	Day,Hour/Minute (midnig	ght = 2400)
20: Sample (P70)		;Output resistances and Water Potentials
1: 64	Reps	;32 reps if not outputting water potential
2: 1	Loc [BlockR_1]	

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