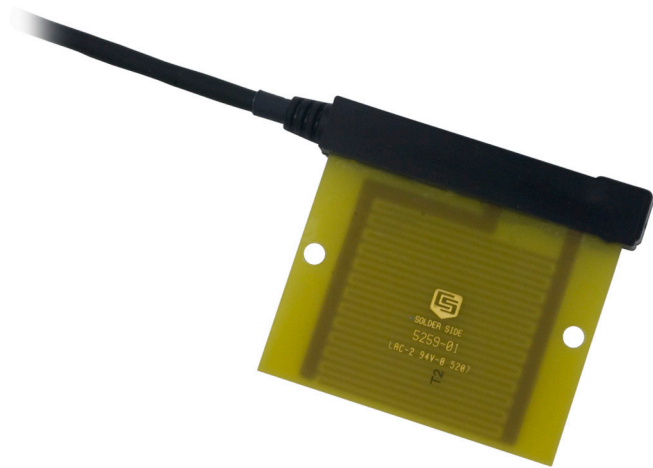


INSTRUCTION MANUAL



237 Leaf Wetness Sensor

Revision: 7/17



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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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Table of Contents

PDF viewers: These page numbers refer to the printed version of this document. Use the PDF reader bookmarks tab for links to specific sections.

1. Introduction	1
2. Precautions	1
3. Initial Inspection.....	1
4. QuickStart.....	1
5. Overview.....	3
6. Specifications.....	3
7. Installation.....	4
7.1 Sensor Preparation	4
7.2 Sensor Deployment.....	4
7.3 Wiring to Datalogger	5
7.4 Datalogger Programming.....	6
7.4.1 Measurement of Vs / Vx	6
7.4.2 Calculating Sensor Resistance	7
8. Operation.....	7
8.1 Calculating Wet Time Fraction.....	8
8.2 Calibration.....	8
9. Troubleshooting.....	9
10. References.....	9

Appendices

A. Importing Short Cut Code Into CRBasic Editor ...	A-1
B. Example Programs.....	B-1

Figures

7-1. Example 237 Field Installation	5
7-2. 237 Sensor Schematic	5

Tables

7-1. Wire Color, Function, and Datalogger Connection.....	5
---	---

7-2. Measurement Instructions, Parameters, Results 7
9-1. Symptom/Causes 9

CRBasic Examples

B-1. CR1000 Program Example..... B-1
B-2. CR200(X) Program Example B-1

237 Leaf Wetness Sensor

1. Introduction

The 237 Leaf Wetness Sensor measures leaf wetness by determining the electrical resistance on the surface of the sensor (a wet surface is less resistant). It is primarily used to determine the percentage of time that a leaf surface is wet, versus the time it is dry.

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 or contact a Campbell Scientific application engineer for assistance.

2. Precautions

- READ AND UNDERSTAND the *Safety* section at the front of this manual.
- Although the 237 is rugged, it is also a highly precise scientific instrument and should be handled as such.
- The 237 is designed for short duration ac excitation; dc excitation or continuous ac excitation may damage the sensing grid.
- 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.

3. Initial Inspection

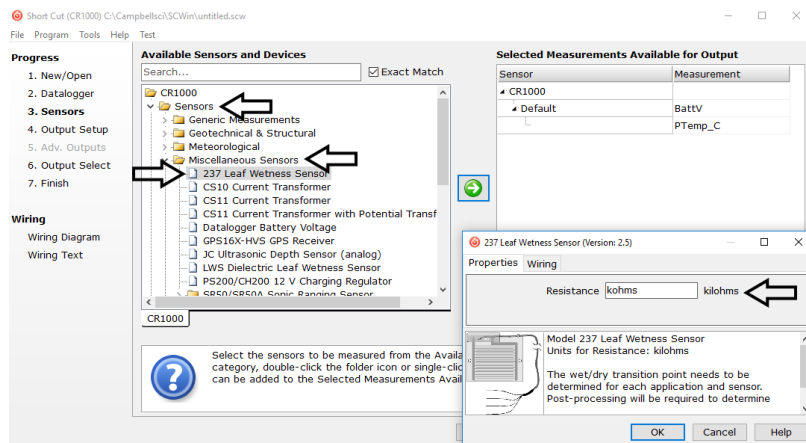
- Upon receipt of the 237, inspect the packaging for any signs of shipping damage and, if found, report the damage to the carrier in accordance with policy. The contents of the package should also be inspected and a claim filed if any shipping related damage is discovered.
- The model number is printed on a label at the connection end of the cable. Check this information against the shipping documents to ensure the correct product is received.

4. QuickStart

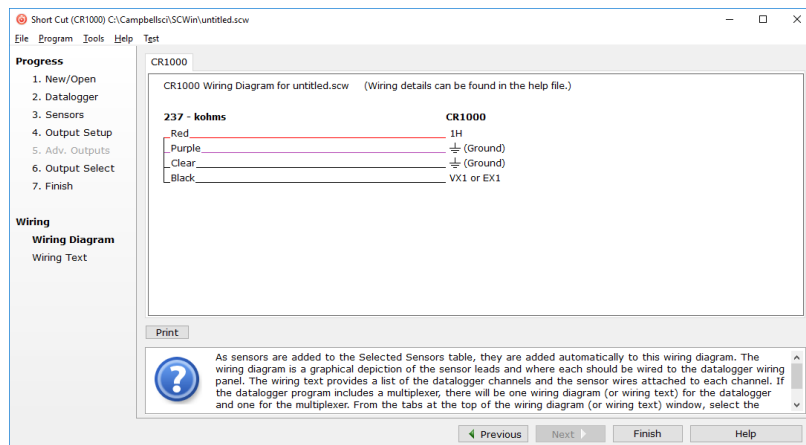
Short Cut is an easy way to program your datalogger to measure the 237 and assign datalogger wiring terminals. *Short Cut* is available as a download on www.campbellsci.com and the *ResourceDVD*. It is included in installations of *LoggerNet*, *PC200W*, *PC400*, or *RTDAQ*.

Use the following procedure to get started.

1. Open *Short Cut* and select to create a new program.
2. Double-click the datalogger model.
3. Under the **Available Sensors and Devices** list, select the **Sensors | Miscellaneous Sensors** folder. Double-click **237 Leaf Wetness Sensor** to move the selection to the **Selected** device window. The wet/dry transition point needs to be determined for each application and sensor (Section 8.2, *Calibration (p. 8)*). Post-processing will be required to determine parameters such as the percent of time wet (Section 8.1, *Calculating Wet Time Fraction (p. 8)*).



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



5. 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**.
6. 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.

7. If the sensor is connected to the datalogger, as shown in the wiring diagram in step 4, check the output of the sensor in the datalogger support software data display to make sure it is making reasonable measurements.

5. Overview

The 237 is often used for plant pathology applications because plant diseases are often associated with wet leaves. Duration of wetness and air temperature during wetness are inputs to many disease models.

The sensor emulates a leaf, thereby approximating the wetness state of surrounding foliage. To determine leaf wetness, the 237 uses a circuit board with interlacing gold-plated fingers. Condensation on the sensor lowers the resistance between the fingers, which is measured by the datalogger. Droplets must touch two fingers simultaneously to change the sensor resistance. For this reason, the 237 is typically coated with flat latex paint, which spreads water droplets.

The color and type of paint affect sensor performance. Campbell Scientific supplies the sensor unpainted because individual modifications will vary with the application. The paper listed in Section 10, *References (p. 9)*, describes the effects of paint color and sensor angle on sensors of this type.

The resistance of the sensor at the wet/dry transition point should be determined. A sharp change in resistance occurs in the wet-dry transition on the uncoated sensor; normally the transition is between 50 and 200 k Ω . Coated sensors have a poorly defined transition which normally occurs from 20 k Ω to above 1,000 k Ω . For best results, the leaf wetness sensor should be field calibrated since the transition point will vary for different areas and vegetation.

6. Specifications

Features:

- Sensor is shipped unpainted so customer can choose appropriate surface finish that best fits their application
- Imitates characteristics of a leaf
- Compatible with Campbell Scientific CRBasic dataloggers: CR200(X) series, CR300 series, CR6 series, CR800 series, CR1000, CR3000, CR5000, and CR9000(X)

Resistance at Wet/Dry

Transition: normally 50 and 200 k Ω (uncoated sensor);
normally 20 to 1000 k Ω (coated sensor)

Operational Temperature

Range: 0 to 100 °C

Short-Term Survivability

Temperature Range: -40 to 150 °C; sensor may crack when temperature drops below -40 °C

Width:	7.1 cm (2.75 in)
Length:	7.6 cm (3.0 in)
Depth:	0.64 cm (0.25 in)
Weight:	91 g (3 oz) with 10 ft cable

7. Installation

If you are programming your datalogger with *Short Cut*, skip Section 7.3, *Wiring to Datalogger* (p. 5), and Section 7.4, *Datalogger Programming* (p. 6). *Short Cut* does this work for you. See Section 4, *QuickStart* (p. 1), for a *Short Cut* tutorial.

7.1 Sensor Preparation

Water droplets that form at the onset of condensation are often too small to bridge the electrodes and so remain undetected. Droplets can be detected earlier in formation by application of a non-conductive spreader to the surface of the sensing grid. The spreader most commonly employed is flat latex paint. Campbell Scientific supplies only uncoated sensors since coating preferences vary between applications.

NOTE Campbell Scientific has not researched, nor does it recommend, paint formulations. The following information regarding paint formulation is intended only to introduce the concept.

Applying a thin coat of flat latex paint on the sensor surface is a generally accepted practice in plant disease and other applications. Besides providing some protection for the gold-plated electrodes, this paint allows tiny water droplets to spread and bridge the electrodes.

Gillespie and Kidd¹ found that paint color had significant effects on performance and found off-white worked well. Their paint was formulated with one part black pigment to 1000 parts white paint. East² found that greater precision is obtained using a high quality flat latex paint. Some researchers and agricultural weather networks do not paint the sensor.

NOTE Before painting the sensor, clean it gently with alcohol.

However the surface is prepared, the response of the sensor is, in reality, only an index against which actual leaf wetness can be estimated. While the absence of a spreader will decrease sensitivity and increase the chance of scratching the gold-plated electrodes, bare sensors may grant greater consistency and less maintenance across a network.

7.2 Sensor Deployment

The sensor should not come in contact with leaves. The sensor is not supplied with a mounting bracket. Gillespie and Kidd¹ found that sensor orientation affects performance. As with surface preparation, orientation varies across applications and users. A common practice is to mount the sensor such that it

receives minimal direct sunlight at mid-day during the growing season. Gillespie and Kidd favor a 60 degree tilt on a north facing sensor such that water runs away from the cable connection to minimize puddling on the electrodes. FIGURE 7-1 shows a simple-to-construct mounting bracket.

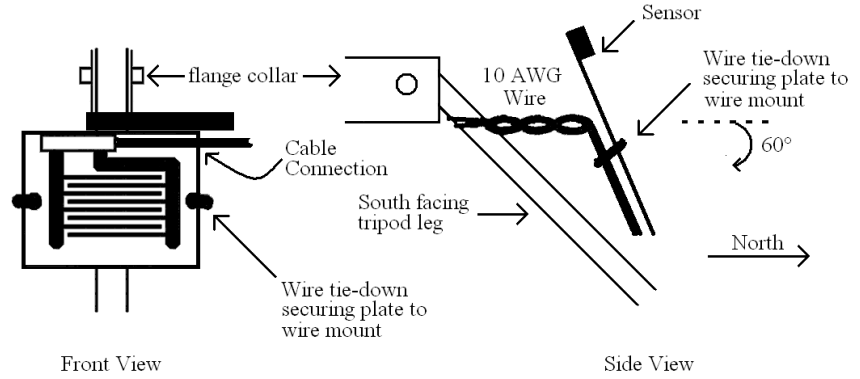


FIGURE 7-1. Example 237 Field Installation

7.3 Wiring to Datalogger

FIGURE 7-2 is a circuit schematic of the 237. TABLE 7-1 describes wiring to Campbell Scientific dataloggers.

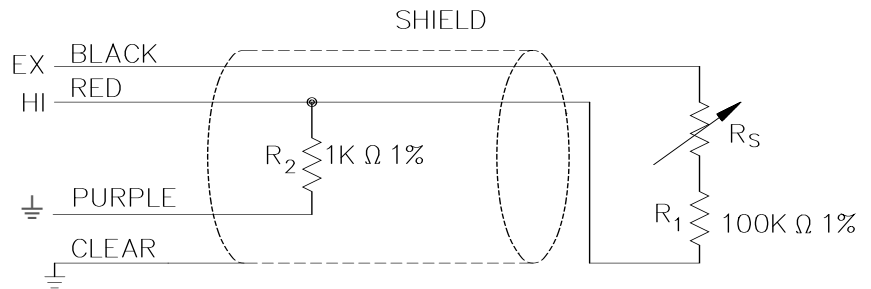


FIGURE 7-2. 237 Sensor Schematic

TABLE 7-1. Wire Color, Function, and Datalogger Connection		
Wire Color	Wire Function	Datalogger Connection Terminal
Black	Voltage-excitation input	U configured for voltage excitation ¹ , VX or EX (voltage excitation input)
Red	Analog voltage output	U configured for single-ended analog input ¹ , SE (single-ended, analog-voltage input)
Purple	Bridge resistor lead	⊥ (analog ground)
Clear	EMF shield	⊥ (analog ground)

¹U channels are automatically configured by the measurement instruction.

7.4 Datalogger 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. 1). 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 Programs* (p. B-1). Programming basics and programming examples for Edlog dataloggers are provided at www.campbellsci.com/old-manuals.

The datalogger program measures V_s/V_x and then uses this measurement to calculate resistance. Information about calculating the wet/time fraction is provided in Section 8, *Operation* (p. 7). Refer to Appendix B, *Example Programs* (p. B-1), for suggested implementation of measurement and processing concepts.

7.4.1 Measurement of V_s / V_x

The base measurement of the 237 sensor is V_s/V_x , where V_s is the voltage measured and V_x is the excitation voltage supplied by the datalogger. V_s/V_x is measured by the datalogger with the instructions and parameters listed in TABLE 7-2.

TABLE 7-2. Measurement Instructions, Parameters, Results

Datalogger	Measurement Instruction	Excitation (mV)	Input Range Code	Integration/ f _{N1}	Multiplier	Offset	Result
CR6	BrHalf ()	2500	mV200 or mV200C ¹	15000	1	0	V _s /V _x
CR300	BrHalf ()	2500	mV2500	4000 Hz	1	0	V _s /V _x
CR200(X)	ExDelSE ()	2500	n/a	500 μs	0.0004	0	V _s /V _x
CR800, CR1000	BrHalf ()	2500	mV25 or mV25C ¹	250 μs	1	0	V _s /V _x
CR3000	BrHalf ()	5000	mV50 or mV50C ¹	250 μs	1	0	V _s /V _x
CR9000X	BrHalf ()	5000	mV50	250 μs	1	0	V _s /V _x

¹ The mV200C, mV25C, and mV50C input range codes check for an open connection indicating that no sensor is connected or a cable has been cleanly cut. If an open connection occurs, NAN will be returned. A floating voltage can occur that falsely indicates the presence of a missing sensor when the mV200C, mV25C, and mV50C input range codes are not used.

7.4.2 Calculating Sensor Resistance

The CRBasic program should include an expression that calculates sensor resistance. With reference to FIGURE 7-2, sensor resistance (R_s), expressed in kΩ, is calculated as follows:

$$R_s = R_2 / (V_s/V_x) - R_2 - R_1$$

Therefore,

$$R_s \text{ (k}\Omega\text{)} = 1/(V_s/V_x) - 101$$

Except for the CR200(X), Campbell Scientific also suggests including the following after the resistance calculation:

```
If Rs > 10000 Then
  Rs = 10000
EndIf
```

The high resolution of Campbell Scientific dataloggers can pick up very small signals, which can result in an erratic signal when the sensor is dry. The wet/dry transition is less than 1000 kΩ, and therefore, 10,000 kΩ gives plenty of range outside of what one would consider to be dry.

8. Operation

An exact range of measurements is impossible to give since the 237 is field calibrated. The sensor is not precise and the quality of water bridging the electrodes varies. As demonstrated in Appendix B, *Example Programs* (p. B-1), a common practice is to measure grid resistance in kΩ using a one bin histogram to calculate at what fraction of the output interval the sensor is wet (Section 8.1, *Calculating Wet Time Fraction* (p. 8)). If resistance meets the threshold (≤150 kΩ in the example program), the grid is considered wet. Since the output

interval is 60 minutes, if the histogram fraction equals 0.33, the leaf was wet for 20 minutes during that hour.

8.1 Calculating Wet Time Fraction

Fraction of time wet are common data derived from 237 measurements. Calculating time fraction requires a wetness threshold. Refer to Section 8.2, *Calibration* (p. 8), for more information on determining the threshold.

Fraction of time wet is calculated in all current Campbell Scientific dataloggers, except the CR200(X), by using the **Histogram()** instruction with a single bin and closed form. The bin select value for the histogram is the *Variable* containing sensor resistance (Rs). The lower limit of the histogram is zero, and the upper limit is the wet / dry threshold. This will give the fraction of the output interval that the sensor is wet. A fraction of time wet of 0.33 when the output interval is one hour means that the sensor was wet for 20 minutes during that hour.

Refer to Appendix B, *Example Programs* (p. B-1), for information on calculating fraction of time wet with the CR200(X).

8.2 Calibration

A wet / dry threshold of 150 k Ω is used in Appendix B, *Example Programs* (p. B-1). While this threshold may work well, refining the threshold for a specific sensor and installation is recommended. A sharp change in resistance occurs at the threshold on uncoated sensors. A less defined threshold occurs with coated sensors. The threshold of uncoated sensors is normally between 50 and 200 k Ω . The threshold of the coated sensor is normally between 20 and 1,000 k Ω .

The transition point varies for different areas, vegetation, and water quality. Therefore, for best results, the sensor should be field calibrated using the following procedure:

1. Clean the sensor gently with alcohol. Contaminants change the sensitivity of the sensor.
2. Place the sensor in the vegetation where the wetness is to be monitored.
3. When the vegetation is at the desired wetness, measure the resistance and use that resistance as the threshold.

9. Troubleshooting

TABLE 9-1 lists the causes of unusual resistance readings.

TABLE 9-1. Symptom/Causes		
Resistive Value		Causes
IEEE4	FP2	
INF, ≥ 99999 , ≤ -99999	INF, ± 7999	The 1 k Ω bridge resistor holds the input channel at 0 mV when the sensor is completely dry. However, the measurement may intermittently deviate from zero slightly, but still be within the resolution specifications of the datalogger. When this occurs, R_s = either a very large or a very small number.
NAN, -100, -INF	NAN	NAN can indicate that no sensor is connected or a cable has been cleanly cut if the <i>mV200C</i> , <i>mV25C</i> , or <i>mV50C</i> range code was used for the BrHalf instruction. Another cause of these outputs is a highly conductive state (> 25 mV) that occurs if the sensor is very wet with very ionic water.
< 0		If the measured voltage exceeds 24.75 mV, but does not exceed the input voltage range, the result of the bridge equation becomes negative.

10. References

- ¹ Gillespie, T.J. and Kidd, G.E. 1978. Sensing duration of leaf moisture retention using electrical impedance grids. *Can. J. Plant Sci.* 58:179-187.
- ² East, David (Ohio State University). 1994. Field Testing of Phone Accessible Multi-Channel Datalogger for Tomato IPM Programs. Unpublished.

NOTE

The citation of researcher does not imply the endorsement of Campbell Scientific products by any researcher or institution.

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)
- .CR2 (CR200(X)-series datalogger code)
- .CR300 (CR300-series datalogger code)
- .CR6 (CR6-series datalogger code)
- .CR8 (CR800-series datalogger code)
- .CR1 (CR1000 datalogger code)
- .CR3 (CR3000 datalogger code)
- .CR5 (CR5000 datalogger code)
- .CR9 (CR9000(X) 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. 1). 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 .CR2, .CR300, .CR6, .CR8, .CR1, .CR3, .CR5, or .CR9 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 Programs

Each example program measures leaf wetness and outputs a sample resistance and a time fraction the sensor is wet. In these examples, the output interval is set to 60 minutes, so a time fraction wet of .33 is equivalent to 20 minutes during that hour. Wetness threshold is set at 150 kΩ.

CRBasic Example B-1. CR1000 Program Example

```
Public Vs_Vx
Public Rs_kOhms

DataTable(Wetness,true,-1)
  OpenInterval
  DataInterval(0,60,Min,10)
  Sample(1, Rs_kOhms, FP2)
  Histogram(Rs_kOhms, FP2, 0, 1, 001, 1, 0, 150) 'Enter threshold in 8th parameter
EndTable

BeginProg
  Scan(60,Sec, 3, 0)
  BRHalf(Vs_Vx, 1, mV25, 1, VX1, 1, 2500, True, 0, 250, 1, 0)
  Rs_kOhms = (1 / Vs_Vx) - 101
  If Rs_kOhms > 10000 Then
    Rs_kOhms = 10000
  EndIf
  CallTable Wetness
  NextScan
EndProg
```

CRBasic Example B-2. CR200(X) Program Example

```
'CR200(X) Series Datalogger
Public Vs_Vx
Public Rs_kOhm
Public ScanIntervalWet
Public ScanIntervalSum
Public TimeFractionWet

DataTable (Wetness,1,-1)
  DataInterval (0,60,min) 'Interval must match IfTime interval (below)
  Sample (1,Rs_kohm)
  Sample (1,TimeFractionWet)
EndTable

BeginProg
  Scan (1,Min)

  'Measure Wetness
  ExDeISE(Vs_Vx,1,1,1,mV2500,500,.0004,0)

  'Zero measurement when measurement < 0
  If Vs_Vx < 0 Then Vs_Vx = 0
  Rs_kOhm = (1 / Vs_Vx) - 101

  'Sum Scan Intervals
  ScanIntervalSum = ScanIntervalSum + 1

  'Check if Leaf wetness is below 150 kOhms transition and count as time dry
  If Rs_kohm < 150 AND Rs_kohm > 0 Then
    ScanIntervalWet = ScanIntervalWet + 1
  EndIf
```

```
'Calculate Time Fraction Wet at top of each hour
If IfTime (0,60,Min) Then 'Interval must match data table interval
  TimeFractionWet = ScanIntervalWet / ScanIntervalSum
  ScanIntervalWet = 0
  ScanIntervalSum = 0
EndIf

  CallTable (Wetness)
NextScan
EndProg
```


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