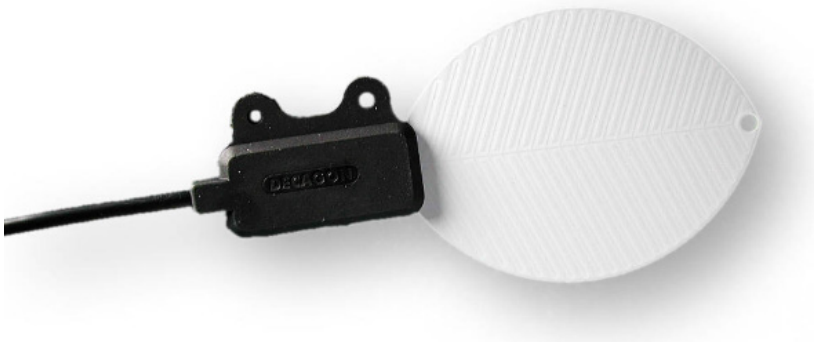
Product Manual

Sensor

LWS

Dielectric Leaf Wetness Sensor



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- Read all applicable instructions carefully and understand procedures thoroughly before beginning work.
- Wear a **hardhat** and **eye protection**, and take **other appropriate safety precautions** while working on or around tripods and towers.
- **Do not climb** tripods or towers at any time, and prohibit climbing by other persons. Take reasonable precautions to secure tripod and tower sites from trespassers.
- Use only manufacturer recommended parts, materials, and tools.

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- **You can be killed** or sustain serious bodily injury if the tripod, tower, or attachments you are installing, constructing, using, or maintaining, or a tool, stake, or anchor, come in **contact with overhead or underground utility lines**.
- Maintain a distance of at least one-and-one-half times structure height, 20 feet, or the distance required by applicable law, **whichever is greater**, between overhead utility lines and the structure (tripod, tower, attachments, or tools).
- Prior to performing site or installation work, inform all utility companies and have all underground utilities marked.
- Comply with all electrical codes. Electrical equipment and related grounding devices should be installed by a licensed and qualified electrician.

Elevated Work and Weather

- 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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LWS Dielectric Leaf Wetness Sensor

1. Introduction

Direct measurement of leaf wetness is problematic. Secure long-term attachment of a sensor to a representative living leaf is difficult. Leaf position, sun exposure, and health are in constant flux. To avoid these problems, leaf wetness sensors have been developed to estimate by inference the wetness of nearby leaves. The LWS estimates leaf surface wetness by measuring the dielectric constant of the sensor upper surface. The LWS is able to detect the presence of miniscule amounts of water or ice. Individual sensor calibration is not normally necessary.

NOTE This manual provides information only for CRBasic data loggers. For retired Edlog data logger support, see an older manual at *www.campbellsci.com/old-manuals*.

2. Precautions

- READ AND UNDERSTAND the *Safety* section at the front of this manual.
- Care should be taken when opening the shipping package to not damage or cut the cable jacket. If damage to the cable is suspected, contact Campbell Scientific.
- Although the LWS is rugged, it should be handled as a precision scientific instrument.
- Over time, the accumulation of dust and bird droppings can cause the dry output to rise. We recommend that the sensor be periodically cleaned using a moist cloth, or when you detect elevated dry output.
- The LWS is intended only for applications wherein the data logger provides short excitation, leaving the sensor quiescent most of the time. Continuous excitation may cause the sensor to exceed government specified limits on electromagnetic emissions.

3. Initial Inspection

- Upon receipt of the LWS, 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

A video that describes data logger programming using *Short Cut* is available at: *www.campbellsci.com/videos/cr1000x-datalogger-getting-started-program-part-3*. *Short Cut* is an easy way to program your data logger to measure the LWS and assign data logger wiring terminals. *Short Cut* is available as a

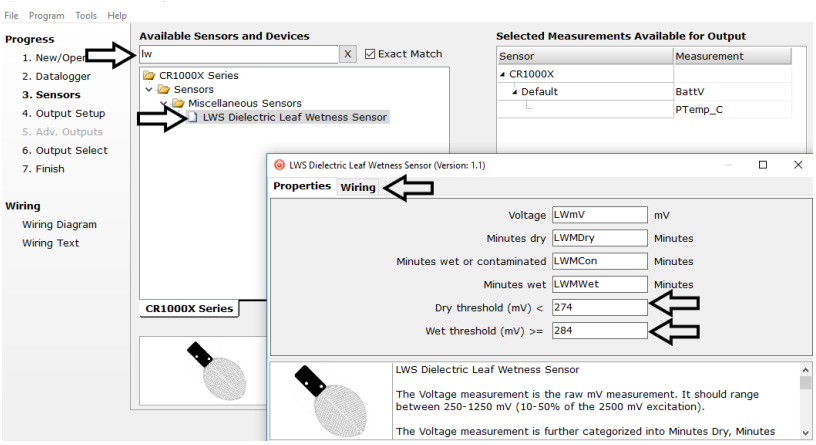
download on *www.campbellsci.com*. It is included in installations of *LoggerNet*, *PC200W*, *PC400*, or *RTDAQ*.

The following procedure also describes programming with *Short Cut*.

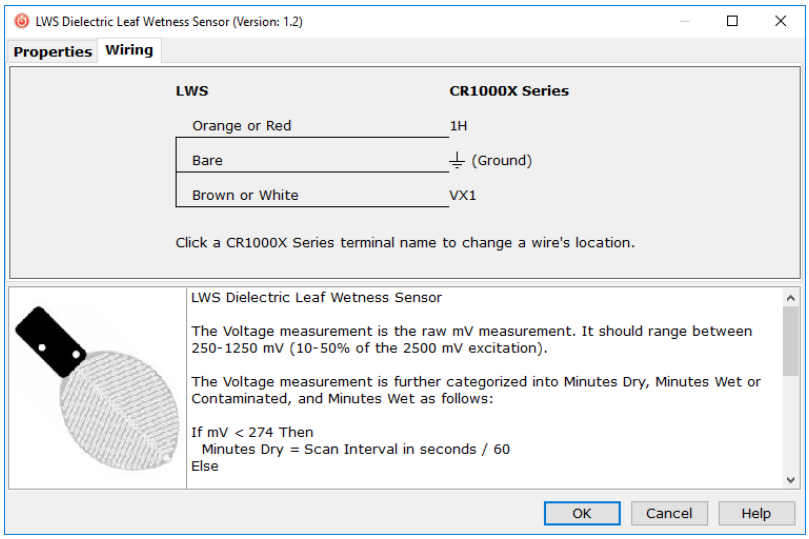
1. Open *Short Cut* and click **Create New Program**.

2. Double-click the data logger model.

3. In the **Available Sensors and Devices** box, type LWS. You can also locate the sensor in **Sensors** | **Miscellaneous Sensors** folder. Double-click **LWS Dielectric Leaf Wetness Sensor**. Enter the **Dry threshold (mV) <** and **Wet threshold (mV) >=** values (see Section 7.3.3, *Interpreting Data (p. 7)*, for information about determining the dry threshold and wet threshold values).

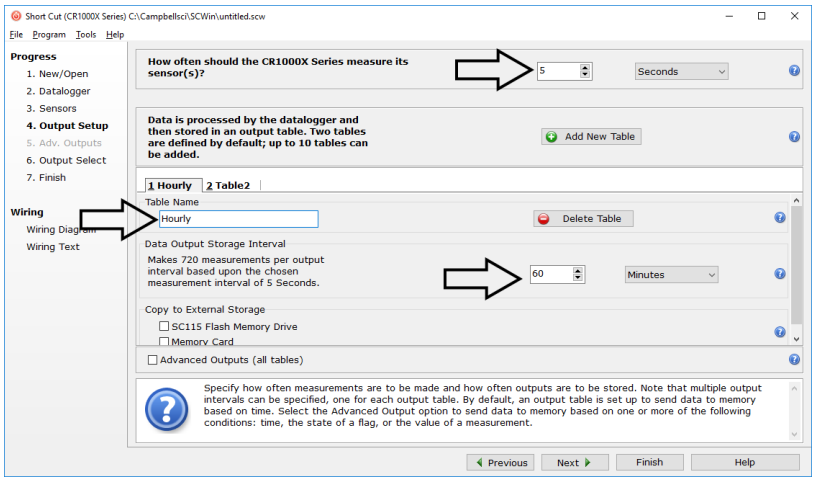


4. Click on the **Wiring** tab to see how the sensor is to be wired to the data logger. Click **OK** after wiring the sensor.

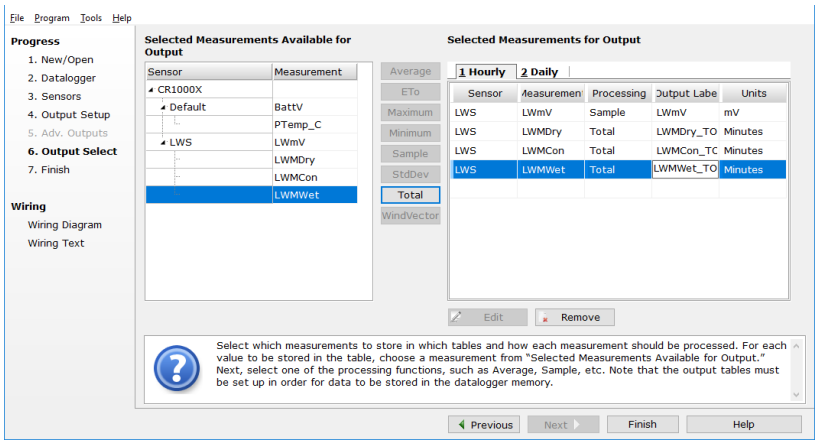


5. Repeat steps three and four for other sensors. Click **Next**.

6. In **Output Setup**, type the scan rate, meaningful table names, and the **Data Output Storage Interval**.



7. Select the output options.



8. Click **Finish** and save the program. Send the program to the data logger if the data logger is connected to the computer.

9. If the sensor is connected to the data logger, check the output of the sensor in *LoggerNet*, *PC400*, *RTDAQ*, or *PC200W* to make sure it is making reasonable measurements.

NOTE *Short Cut* uses the execution interval to make the minutes wet, dry, and contaminated calculations (Section 7.3.2, *Minutes Dry, Minutes Wet or Contaminated, and Minutes Wet* (p. 7)). You need to take this into account while editing the *Short Cut* program.

5. Overview

5.1 Measurement

The LWS measures the dielectric constant of a zone approximately 1 cm from the upper surface of the sensor. The dielectric constant of water (≈80) and ice

(≈5) are much higher than that of air (≈1), so the measured dielectric constant is strongly dependent on the presence of moisture or frost on the sensor surfaces. The sensor outputs a millivolt signal proportional to the dielectric of the measurement zone, and therefore proportional to the amount of water or ice on the sensor surface.

5.2 Leaf Mimicry

The LWS is designed to approximate the thermodynamic properties of most leaves. If the specific heat of a typical leaf is estimated at 3750 J kg^{-1} K^{-1}, density estimated at 0.95 g/cm^3, and thickness estimated at 0.4 mm, then the heat capacity of the leaf is ≈1425 J m^{-2} K^{-1}. This heat capacity is closely approximated by the thin (0.65 mm) fiberglass construction of the LWS, which has a heat capacity of 1480 J m^{-2} K^{-1}. By mimicking the thermodynamic properties of a leaf, the LWS closely matches the wetness state of the canopy.

The sensor closely matches the radiative properties of real leaves. Healthy leaves generally absorb solar radiation in much of the visible portion of the spectrum, but selectively reject much of the energy in the near-infrared. The surface coating of the LWS absorbs well in the near-infrared region, but the white color reflects most of the visible radiation. Spectroradiometer measurements indicate that the overall radiation balance of the sensor closely matches that of a healthy leaf. During normal use, prolonged exposure to sunlight can cause some yellowing of the coating, which does not affect the function of the sensor. The surface coating is hydrophobic — similar to a leaf with a hydrophobic cuticle. The sensor matches the wetness state of these types of leaves, but may not match the wetness duration of pubescent leaves or leaves with less waxy cuticles.

6. Specifications

Features:

- Imitates characteristics of a leaf
- Does not require painting or calibration of individual sensors
- Detects trace amounts of water or ice on the leaf surface
- Compatible with Campbell Scientific CRBasic data loggers: CR200(X) series, CR300 series, CR6 series, CR800 series, CR1000, CR1000X, CR3000, CR5000, and CR9000(X)

Settling Time:	10 ms
Excitation:	2.5 Vdc (2 mA) to 5.0 Vdc (7 mA)
Minimum Excitation Time:	10 ms
Output:	300 to 1250 mV (depends on excitation voltage)
Operating Temperature:	–40 to 60 °C
Length:	12.0 cm (4.7 in)
Width:	5.8 cm (2.3 in)

Height:	0.8 cm (0.3 in)
Maximum Cable Length:	75 m (246 ft)
Interchangeability:	Interchangeable without painting or individual calibration

7. Installation

If you are programming your data logger with *Short Cut*, skip Section 7.2, *Wiring* (p. 6), and Section 7.3, *Programming* (p. 6). *Short Cut* does this work for you. See Section 4, *QuickStart* (p. 1), for a *Short Cut* tutorial.

7.1 Field Installation

The LWS includes two holes for mounting the sensor on a small diameter rod by using zip ties or 4-40 bolts (FIGURE 7-1 and FIGURE 7-2). Typical deployment is in a plant canopy or on a weather station mast.

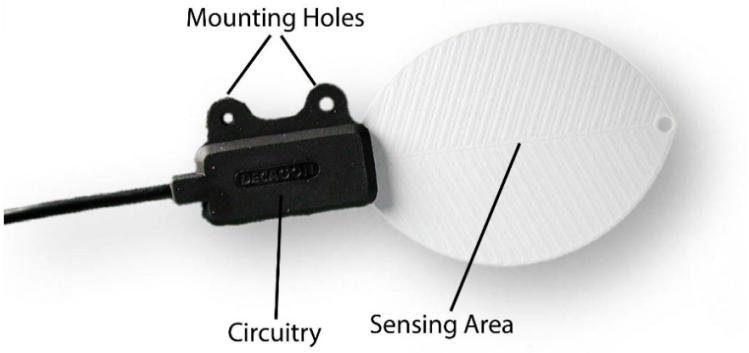


FIGURE 7-1. LWS Dielectric Leaf Wetness Sensor

FIGURE 7-2. Top view of a typical LWS installation

7.2 Wiring

TABLE 7-1. Wire Color, Wire Function, and Data Logger Connection

Wire Color	Wire Function	Data Logger Connection Terminal
Brown or White	Voltage excitation input	**U** configured for voltage excitation[1], **EX, VX** (voltage excitation)
Orange or Red	Analog voltage output	**U** configured for single-ended analog input[1], **SE** (single-ended, analog input)
Clear	Shield	⏚ (analog ground)

[1]**U** terminals are automatically configured by the measurement instruction.

7.3 Programming

Short Cut is the best source for up-to-date data logger programming code.

If your data acquisition requirements are simple, you can probably create and maintain a data logger 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 Appendix A, *Importing Short Cut Code Into CRBasic Editor* *(p. A-1)*. Programming basics for CRBasic data loggers are provided in the following sections. Complete program examples for CRBasic data loggers can be found in Appendix B, *Example Programs* *(p. B-1)*. Programming basics and programming examples for Edlog data loggers are provided at *www.campbellsci.com/old-manuals*.

7.3.1 Voltage Measurement

The LWS requires excitation voltage between 2.5 and 5 Vdc. It produces an output voltage dependent on the dielectric constant of the medium surrounding the sensor. Output voltage ranges from 10 to 50% of the excitation voltage.

Except for the CR200(X), CRBasic data loggers use the **BRHalf()** instruction to measure the sensor output. The **BRHalf()** instruction and parameters are as follows:

```
BRHalf(Dest,Reps,Range,SeChan,ExChan,MeasPEx,ExmV,RevEx,Settling,
fN1/Integ,Mult,Offset)
```

The CR200(X) uses the **ExDelSE()** CRBasic instruction to measure the sensor output. The **ExDelSE()** instruction and parameters are as follows:

```
ExDelSE( Dest, Reps, SEChan, ExChan, ExmV, Delay, Mult, Offset )
```

7.3.2 Minutes Dry, Minutes Wet or Contaminated, and Minutes Wet

The Voltage measurement can be further categorized into Minutes Dry, Minutes Wet or Contaminated, and Minutes Wet as follows:

```
If mV < 274 Then
  Minutes Dry = Scan Interval in seconds / 60
Else
  If mV >= 284 Then
    Minutes Wet = Scan Interval in seconds / 60
  Else
    Minutes Wet or Contaminated = Scan Interval in seconds / 60
  End If
End If
```

Given a 2500 mV excitation, the thresholds of less than 274 mV for dry and greater or equal to 284 mV for wet are recommended by Meter Environment. However, the thresholds can be adjusted as needed. Minutes dry, minutes wet or contaminated, and minutes wet can then be totaled and stored for any given period (table interval). Minutes wet or contaminated can be considered a wet condition or a contaminated condition depending on the user's evaluation of the sensors condition. The user may also choose to store an average of the voltage measurement for post processing later.

7.3.3 Interpreting Data

Many leaf wetness applications, such as phytopathology, require a Boolean interpretation of leaf wetness data. A Boolean threshold is determined by analyzing a few days of time-series data. The time-series data in FIGURE 7-3, was obtained using a 5 Vdc excitation. The sensor yields approximately 445 mV when dry, approximately 475 mV when frosted, and greater than 475 mV when wet. Therefore, a Boolean wetness threshold of 500 mV should serve well for interpreting these data.

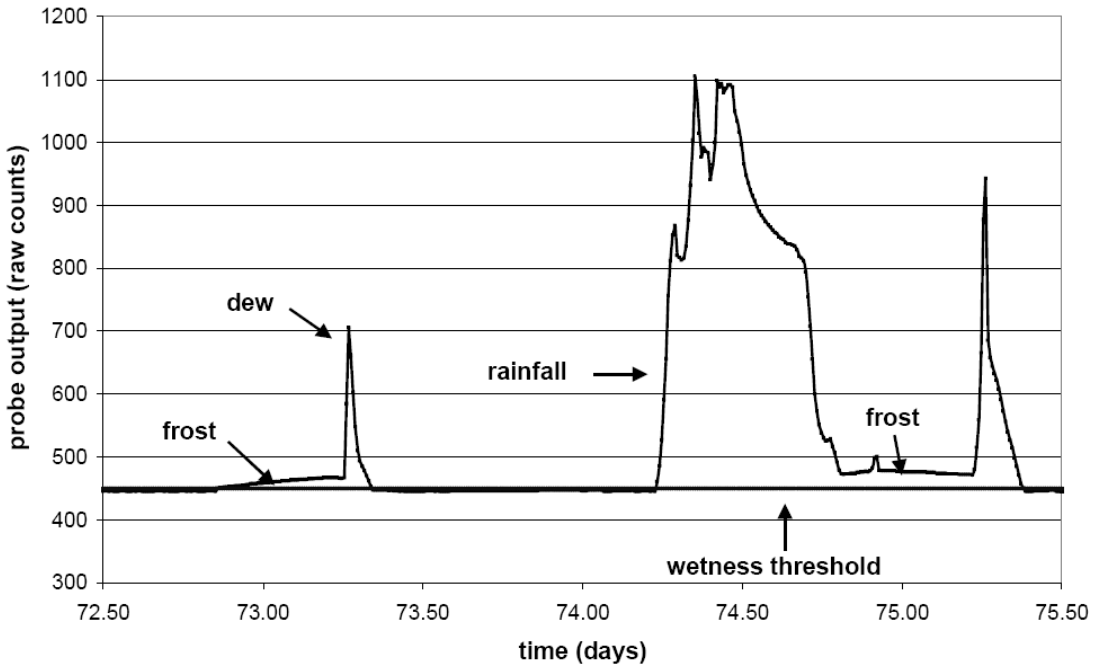


FIGURE 7-3. Typical LWS response

Duration of leaf wetness can be determined either by post processing of data, or by programming the data logger to accumulate time of wetness based on the Boolean threshold. Accumulation of dust and debris, such as avian fecal matter, will change the Boolean threshold. So, while having the data logger accumulate time of leaf wetness, or time of frost, may be convenient, assurance of data quality requires retention of the base millivolt measurements.

NOTE Collect data frequently enough to capture changes in surface wetness. A sample frequency of 15 minutes or less is usually necessary to accurately capture leaf wetness duration.

8. Maintenance

The accumulation of dust and debris will cause the dry output to increase and change the Boolean threshold. Clean the sensing surface with a moist cloth periodically or when elevated dry output is detected.

The LWS leaf wetness sensor withstands typical outdoor radiation and precipitation loads for more than two years. If using the LWS in areas with unusually high radiation loads, Campbell Scientific recommends applying Revivex UV Protectant (available from *www.gearaid.com/products/revivex-care-uv-protect*) every 45 days. Revivex UV Protectant is the only tested and approved UV blocking system for this leaf wetness sensor. Revivex UV Protectant was formerly known as Gear Aid UV Tech.

To apply Revivex UV Protectant:

1. Wipe sensor clean.
2. Spray sensor surface with Revivex UV Protectant.
3. Rub with soft cloth until dry.

9. Acknowledgement

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Appendix A. Importing Short Cut Code Into CRBasic Editor

This tutorial shows:

- Importing a *Short Cut* program into a program editor for additional refinement
- Importing 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)
- .CR1X (CR1000X-series datalogger code)
- .CR3 (CR3000 datalogger code)
- .CR5 (CR5000 datalogger code)

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. On the **Advanced** tab, click the **CRBasic Editor** button. The program opens in CRBasic with the name **noname.CR_**. Provide a name and save the program.

NOTE Once the file is edited with *CRBasic Editor*, *Short Cut* can no longer be used to edit the program it created.

2. The program can now be edited, saved, and sent to the data logger.
3. Import wiring information to the program by opening the associated .DEF file. By default, it is saved in the c:\campbellsci\SCWin folder. 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 data logger compiler to ignore the line when compiling. You can highlight several lines of CRBasic code then right-click and select **Comment Block**. (This feature is demonstrated at about 5:10 in the *CRBasic | Features* video.)

Appendix B. Example Programs

For these programs, the dry threshold is 274 and the wet threshold is 284. To determine minutes dry, minutes wet or contaminated, and minutes wet, the value 0.8333333 is used. This value was calculated based on a 5 s scan interval (scan interval/60 s). Refer to Section 7.3.2, *Minutes Dry, Minutes Wet or Contaminated, and Minutes Wet* (p. 7), for more information.

B.1 Example CR1000X Program

The wiring for the example is shown in TABLE B-1.

TABLE B-1. CR1000X Example Program Wiring

Color	Function	CR1000X
Brown or White	Excitation	**VX1**
Orange or Red	Analog Out	**SE1**
Clear	Analog Ground	⏚

CRBasic Example B-1. CR1000X Program for Measuring the LWS

```
'CR1000X

'Declare Variables and Units
Public BattV
Public PTemp_C
Public LWmV
Public LWMDry
Public LWMCon
Public LWMWet

Units BattV=Volts
Units PTemp_C=Deg C
Units LWmV=mV
Units LWMDry=Minutes
Units LWMCon=Minutes
Units LWMWet=Minutes

'Define Data Tables
DataTable(Hourly,True,-1)
  DataInterval(0,60,Min,10)
  Sample(1,BattV,FP2)
  Sample(1,PTemp_C,FP2)
  Sample(1,LWmV,FP2)
  Totalize(1,LWMDry,FP2,False)
  Totalize(1,LWMCon,FP2,False)
  Totalize(1,LWMWet,FP2,False)
EndTable

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

'Main Program
BeginProg
  'Main Scan
```

```
  Scan(5,Sec,1,0)
    'Default Data Logger Battery Voltage measurement 'BattV'
    Battery(BattV)
    'Default Wiring Panel Temperature measurement 'PTemp_C'
    PanelTemp(PTemp_C,60)

    'LWS Dielectric Leaf Wetness Sensor measurement 'LWmV'
     BrHalf(LWmV,1,mV5000,1,VX1,1,2500,False,10000,60,2500,0)

    'Determine Minutes Dry 'LWMDry', Minutes Wet or Contaminated 'LWMCon',
    'and Minutes Wet 'LWMWet'. The value 0.08333333 is the scan rate divided by
    '60 s (5 s/60 s = 0.08333333).
    LWMDry=0
    LWMCon=0
    LWMWet=0
    If LWmV<274 Then
      LWMDry=0.08333333
    Else
      If LWmV>=284 Then
        LWMWet=0.08333333
      Else
        LWMCon=0.08333333
      EndIf
    EndIf
    'Call Data Tables and Store Data
    CallTable(Hourly)
    CallTable(Daily)
  NextScan
EndProg
```

B.2 Example CR6 Program

The wiring for the example is shown in TABLE B-2.

TABLE B-2. CR6 Example Program Wiring

Color	Function	CR6
Brown or White	Excitation	**U1**
Orange or Red	Analog Out	**U2**
Clear	Analog Ground	⏚

CRBasic Example B-2. CR6 Program for Measuring the LWS

```
'CR6 Series

'Declare Variables and Units
Public BattV
Public PTemp_C
Public LWmV
Public LWMDry
Public LWMCon
Public LWMWet

Units BattV=Volts
Units PTemp_C=Deg C
Units LWmV=mV
Units LWMDry=Minutes
Units LWMCon=Minutes
Units LWMWet=Minutes
```

```
'Define Data Tables
DataTable(Hourly,True,-1)
  DataInterval(0,60,Min,10)
  Sample(1,LWmV,FP2)
  Totalize(1,LWMDry,FP2,False)
  Totalize(1,LWMCon,FP2,False)
  Totalize(1,LWMWet,FP2,False)
EndTable

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

'Main Program
BeginProg
  'Main Scan
  Scan(5,Sec,1,0)
    'Default Data Logger Battery Voltage measurement 'BattV'
    Battery(BattV)

    'Default Wiring Panel Temperature measurement 'PTemp_C'
    PanelTemp(PTemp_C,60)

    'LWS Dielectric Leaf Wetness Sensor measurement 'LWmV'
    BrHalf(LWmV,1,mV5000,U2,U1,1,2500,False,10000,60,2500,0)

    'Determine Minutes Dry 'LWMDry', Minutes Wet or Contaminated 'LWMCon',
    'and Minutes Wet 'LWMWet'. The value 0.08333333 is the scan rate divided by
    '60 s (5 s/60 s = 0.08333333).
    LWMDry=0
    LWMCon=0
    LWMWet=0
    If LWmV<274 Then
      LWMDry=0.08333333
    Else
      If LWmV>=284 Then
        LWMWet=0.08333333
      Else
        LWMCon=0.08333333
      EndIf
    EndIf

    'Call Data Tables and Store Data
    CallTable Hourly
    CallTable Daily
  NextScan
EndProg
```