Warranty and Assistance

The **237 LEAF WETNESS SENSOR** is warranted by CAMPBELL SCIENTIFIC, INC. to be free from defects in materials and workmanship under normal use and service for twelve (12) months from date of shipment unless specified otherwise. Batteries have no warranty. CAMPBELL SCIENTIFIC, INC.’s obligation under this warranty is limited to repairing or replacing (at CAMPBELL SCIENTIFIC, INC.’s option) defective products. The customer shall assume all costs of removing, reinstalling, and shipping defective products to CAMPBELL SCIENTIFIC, INC. CAMPBELL SCIENTIFIC, INC. will return such products by surface carrier prepaid. This warranty shall not apply to any CAMPBELL SCIENTIFIC, INC. products which have been subjected to modification, misuse, neglect, accidents of nature, or shipping damage. This warranty is in lieu of all other warranties, expressed or implied, including warranties of merchantability or fitness for a particular purpose. CAMPBELL SCIENTIFIC, INC. is not liable for special, indirect, incidental, or consequential damages.

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To obtain a Returned Materials Authorization (RMA), contact CAMPBELL SCIENTIFIC, INC., phone (435) 753-2342. After an applications engineer determines the nature of the problem, an RMA number will be issued. Please write this number clearly on the outside of the shipping container. CAMPBELL SCIENTIFIC’s shipping address is:

**CAMPBELL SCIENTIFIC, INC.**
RMA#_____
815 West 1800 North
Logan, Utah 84321-1784

For all returns, the customer must fill out a “Declaration of Hazardous Material and Decontamination” form and comply with the requirements specified in it. The form is available from our website at [www.campbellsci.com/repair](http://www.campbellsci.com/repair). A completed form must be either emailed to repair@campbellsci.com or faxed to 435-750-9579. Campbell Scientific will not process any returns until we receive this form. If the form is not received within three days of product receipt or is incomplete, the product will be returned to the customer at the customer’s expense. Campbell Scientific reserves the right to refuse service on products that were exposed to contaminants that may cause health or safety concerns for our employees.
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Model 237 Leaf Wetness Sensor

1. Introduction

The 237 Leaf Wetness Sensor is a simple resistive grid configured in a 3-wire half-bridge. The circuit is completed when water bridges two inter-digitate electrodes. Response is non-linear with a rapid decrease in resistance relative to an increase in wetness. The simplicity of the sensor lends it to various applications, means of preparation, and data interpretations.

1.1 Specifications

Temperature Range: Operational 0° to 100°C; Survival -40° to 150°C
Sensor may crack if temperature drops below -40°C
Dimensions: 2.75" W x 3.0" L x 0.25" D (7.1 x 7.6 x 0.64 cm)
Weight: 3 oz per 10' cable (91 g per 3.1 m cable)

2. Wiring

Figure 1 is a circuit schematic of the 237. Table 1 describes wiring to Campbell Scientific dataloggers.

![FIGURE 1. 237 Sensor Schematic](image)

<table>
<thead>
<tr>
<th>Color</th>
<th>Description</th>
<th>CR200(X)</th>
<th>CR800</th>
<th>CR5000</th>
<th>CR3000</th>
<th>CR1000</th>
<th>CR510</th>
<th>CR500</th>
<th>CR10X</th>
<th>21X</th>
<th>CR7</th>
<th>CR23X</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black</td>
<td>Excitation</td>
<td>Switched</td>
<td>Switched</td>
<td>Switched</td>
<td>Switched</td>
<td>Switched</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Purple</td>
<td>Signal</td>
<td>Ground</td>
<td></td>
<td>AG</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clear</td>
<td>Shield</td>
<td></td>
<td></td>
<td>G</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
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. Programming

Refer to programming examples in Section 4 for suggested implementation of measurement and processing concepts.

3.1 Measurement of Vs / Vx

The base measurement of the 237 sensor is Vs/Vx where Vs is the voltage measured and Vx is the excitation voltage supplied by the datalogger. Vs/Vx is measured by the datalogger with the instructions and parameters listed in Table 2.

<table>
<thead>
<tr>
<th>Datalogger</th>
<th>Measurement Instruction</th>
<th>Excitation (mV)</th>
<th>Input Range</th>
<th>Integration/Delay</th>
<th>Multiplier</th>
<th>Offset</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>CR510, CR10(X)</td>
<td>P5 AC Half Bridge</td>
<td>2500</td>
<td>±25 mV</td>
<td>fast</td>
<td>1</td>
<td>0</td>
<td>Vs/Vx</td>
</tr>
<tr>
<td>CR7</td>
<td>P5 AC Half Bridge</td>
<td>5000</td>
<td>±50 mV</td>
<td>fast</td>
<td>1</td>
<td>0</td>
<td>Vs/Vx</td>
</tr>
<tr>
<td>CR200(X)</td>
<td>ExDelSE ()</td>
<td>2500</td>
<td>n/a</td>
<td>500 µs</td>
<td>0.0004</td>
<td>0</td>
<td>Vs/Vx</td>
</tr>
<tr>
<td>CR800, CR1000</td>
<td>BrHalf ()</td>
<td>2500</td>
<td>±25 mV</td>
<td>250 µs</td>
<td>1</td>
<td>0</td>
<td>Vs/Vx</td>
</tr>
<tr>
<td>CR3000, CR9000X</td>
<td>BrHalf ()</td>
<td>5000</td>
<td>±50 mV</td>
<td>250 µs</td>
<td>1</td>
<td>0</td>
<td>Vs/Vx</td>
</tr>
</tbody>
</table>

3.2 Calculating Sensor Resistance

With reference to Figure 1, sensor resistance (Rs), expressed in kΩ, is calculated as follows:

\[ R_s = R_2 / (Vs/Vx) - R_2 - R_1. \]

Therefore,

\[ R_s (k\Omega) = 1/(Vs/Vx) - 101. \]
Model 237 Leaf Wetness Sensor

3.3 Interpreting Resistance Values

Table 3 lists 237 sensor resistance ranges and their interpretation.

<table>
<thead>
<tr>
<th>Interpretation</th>
<th>CR1000</th>
<th>CR200(X)</th>
<th>CR10X</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wet</td>
<td>0 to 150</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Slightly Wet</td>
<td>150 to ≥ 9999</td>
<td>150 to 7999</td>
<td>150 to ≥ 9999</td>
</tr>
<tr>
<td>Dry</td>
<td>INF, ≥ 9999, ≤ 9999</td>
<td>INF, ±7999</td>
<td>INF, ≥ 9999, ≤ 9999</td>
</tr>
<tr>
<td>Voltage Input Over-range</td>
<td>NAN</td>
<td>NAN</td>
<td>-100, -INF</td>
</tr>
<tr>
<td>Bridge Over-range</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Missing Sensor</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

a Input Memory
b Final Storage Memory
c The 1 kΩ 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, Rs = either a very large or a very small number.
d Voltage input over-range is a state wherein voltage from the sensor exceeds the recommended 25 mV input voltage range. This highly conductive state may occur if the sensor is very very wet with very ionic water.
e If the measured voltage exceeds 24.75 mV, but does not exceed the input voltage range, the result of the bridge equation becomes negative.
f When no sensor is connected, or a cable has been cleanly cut, a “floating” voltage can occur and falsely indicate the presence of a missing sensor. In the CR1000, this can be avoided by using the mv25c range code.

3.4 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 5.4 Calibration 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 (P75 in Edlog / Histogram () in CRBasic) with a single bin and closed form. The bin select value for the histogram is the Input Location / 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 .33 when the output interval is one hour means that the sensor was wet for 20 minutes during that hour.

Refer to programming example 4.3 for information on calculating fraction of time wet with the CR200(X).
4. Programming Examples

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.

4.1 CR1000 Program Example

```plaintext
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, 011, 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
  CallTable Wetness
  NextScan
EndProg
```

4.2 CR200(X) Programming

```plaintext
'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
    ExDelSE(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
EndProg
```
'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

4.3 CR10(X) Programming Example

*Table 1 Program
01:  60  Execution Interval (seconds)

1:  AC Half Bridge (P5)
   1:  1  Reps
   2:  13  25 mV Fast Range
   3:  1  SE Channel
   4:  1  Excite all reps w/Exchan 1
   5:  2500  mV Excitation
   6:  1  Loc [ Vs_Vx ]
   7:  1  Multiplier
   8:  0  Offset

2:  Z=1/X (P42)
   1:  1  X Loc [ Vs_Vx ]
   2:  2  Z Loc [ Rs_kOhms ]

3:  Z=X+F (P34)
   1:  2  X Loc [ Rs_kOhms ]
   2:  -101  F
   3:  2  Z Loc [ Rs_kOhms ]

4:  If time is (P92)
   1:  0  Minutes (Seconds --) into a
   2:  60  Interval (same units as above)
   3:  10  Set Output Flag High (Flag 0)

5:  Real Time (P77)
   1:  1220  Year,Day,Hour/Minute (midnight = 2400)

6:  Sample (P70)
   1:  1  Reps
   2:  2  Loc [ Rs_kOhms ]
5. Plant Pathology Application

Plant diseases are often associated with wet leaves. Duration of wetness and air temperature during wetness are inputs to many disease models. When estimating leaf wetness, the sensor emulates a leaf, thereby approximating the wetness state of surrounding foliage. The sensor does not (and should not!) come in contact with leaves. 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.

5.1 Sensor Preparation

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.

Preparing the sensor surface with a thin coat of flat latex paint is a generally accepted practice in plant disease applications. In addition to providing some protection for the gold plated electrodes, flat latex allows tiny water droplets to spread and bridge the electrodes. Gillespie and Kidd found that paint color had significant effects on performance and found off-white worked well. Their paint was formulated with 1 part black pigment to 1000 parts white paint. East found that greater precision is obtained using a high quality flat latex paint. Some researchers and agricultural weather networks do not paint the sensor.

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.
5.2 Plant Pathology Application Programming

An exact range of measurements is impossible to give since the 237 is field calibrated. The manufacture of the sensor is not precise and the quality of water bridging the electrodes varies. As demonstrated in program examples in Section 4, a common practice is to measure grid resistance in terms of kOhms using a 1 bin histogram to calculate what fraction of the output interval the sensor is wet. If resistance is $\leq 150 \text{ k}\Omega$, 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.

5.3 Sensor Deployment

The sensor is not supplied with a mounting bracket. Gillespie and Kidd\textsuperscript{1} 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 2 shows a simple-to-construct mounting bracket.

5.4 Calibration

A wet / dry threshold of $150 \text{ k}\Omega$ is used in the programming examples in Section 4. 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$\Omega$. The threshold of the coated sensor is normally between 20 and 1,000 k$\Omega$.

For best results, the sensor should be field calibrated. The transition point will vary for different areas, vegetation, and water quality. Place the sensor in vegetation, the wetness of which is to be monitored. Observe the vegetation until it reaches the desired wetness. When the vegetation is at the desired "wetness", the measured resistance can be used as a threshold. Sensitivity of the sensor is changed by contaminants such as fingerprints and smudges. Before painting and calibrating the sensor, clean it gently with alcohol.
6. References


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.
Campbell Scientific Companies

Campbell Scientific, Inc. (CSI)
815 West 1800 North
Logan, Utah  84321
UNITED STATES
www.campbellsci.com • info@campbellsci.com

Campbell Scientific Africa Pty. Ltd. (CSAf)
PO Box 2450
Somerset West 7129
SOUTH AFRICA
www.csafrica.co.za • cleroux@csafrica.co.za

Campbell Scientific Australia Pty. Ltd. (CSA)
PO Box 444
Thuringowa Central
QLD 4812 AUSTRALIA
www.campbellsci.com.au • info@campbellsci.com.au

Campbell Scientific do Brazil Ltda. (CSB)
Rua Luisa Crapsi Orsi, 15 Butantã
CEP: 005543-000 São Paulo SP BRAZIL
www.campbellsci.com.br • suporte@campbellsci.com.br

Campbell Scientific Canada Corp. (CSC)
11564 - 149th Street NW
Edmonton, Alberta T5M 1W7
CANADA
www.campbellsci.ca • dataloggers@campbellsci.ca

Campbell Scientific Centro Caribe S.A. (CSCC)
300 N Cementerio, Edificio Breller
Santo Domingo, Heredia 40305
COSTA RICA
www.campbellsci.cc • info@campbellsci.cc

Campbell Scientific Ltd. (CSL)
Campbell Park
80 Hathern Road
Shepshed, Loughborough LE12 9GX
UNITED KINGDOM
www.campbellsci.co.uk • sales@campbellsci.co.uk

Campbell Scientific Ltd. (France)
Miniparc du Verger - Bat. H
1, rue de Terre Neuve - Les Ulis
91967 COURTABOEUF CEDEX
FRANCE
www.campbellsci.fr • info@campbellsci.fr

Campbell Scientific Spain, S. L.
Psg. Font 14, local 8
08013 Barcelona
SPAIN
www.campbellsci.es • info@campbellsci.es

Please visit www.campbellsci.com to obtain contact information for your local US or International representative.