

LP02

ISO Spectrally Flat Class C (Second Class) Pyranometer



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1. Introduction

The LP02 is an ISO 9060:2018 spectrally flat Class C (second class) pyranometer that monitors solar radiation for the full solar spectrum range. It produces a millivolt signal that can be measured directly by a Campbell Scientific data logger. The LP02, manufactured by Hukseflux, provides solar radiation measurements for many meteorological applications.

For Edlog data logger support, check the availability of an older manual at www.campbellsci.com/old-manuals, or contact Campbell Scientific for assistance.

2. Precautions

- READ AND UNDERSTAND the [Safety](#) section at the back of this manual.
- Although the LP02 is rugged, it is also a highly precise scientific instrument and should be handled as such.
- 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.

3. Initial inspection

- Upon receipt of the LP02, 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.
- See [Ships with](#) (p. 1) to ensure that all of your parts are included.

3.1 Ships with

- (3) Bolts for mounting from original manufacturer
- (2) Nuts for mounting from original manufacturer
- (1) Calibration certificate (see [Calibration certificate](#) (p. 2))

3.2 Calibration certificate

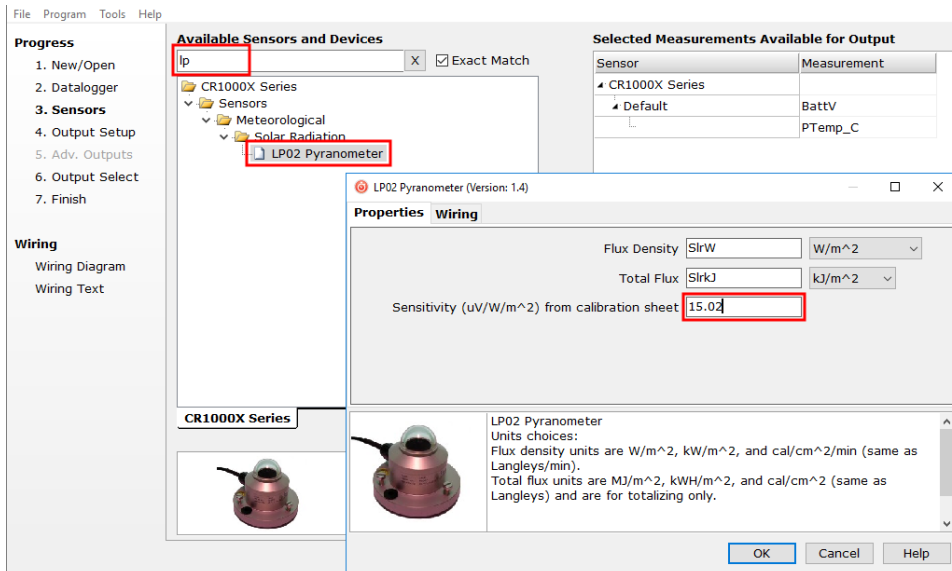
Included with the sensor is a certificate with the sensor calibration constant and serial number. Cross check this serial number against the serial number on your LP02 to ensure that the given calibration constant corresponds to your sensor.

4. QuickStart

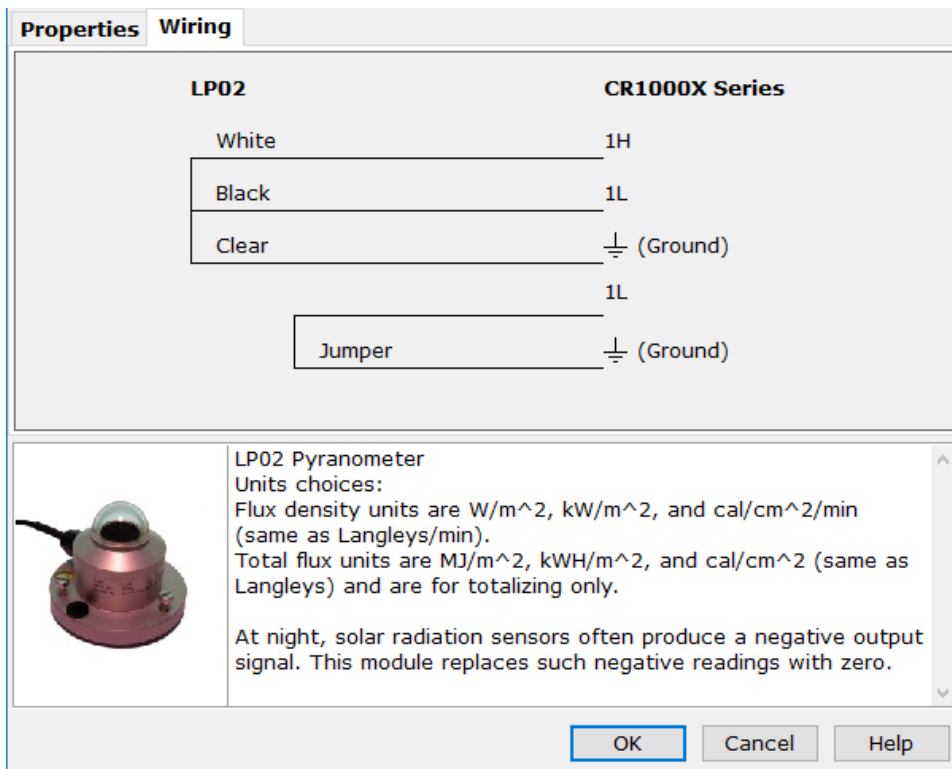
A video that describes data logger programming using Short Cut is available at: www.campbellsci.com/videos/cr1000x-datalogger-getting-started-program-part-3. Short Cut is an easy way to program your data logger to measure the sensor and assign data logger wiring terminals. Short Cut is available as a download on www.campbellsci.com. It is included in installations of LoggerNet, RTDAQ, PC400, or PC200W.

The following procedure also describes programming with Short Cut.

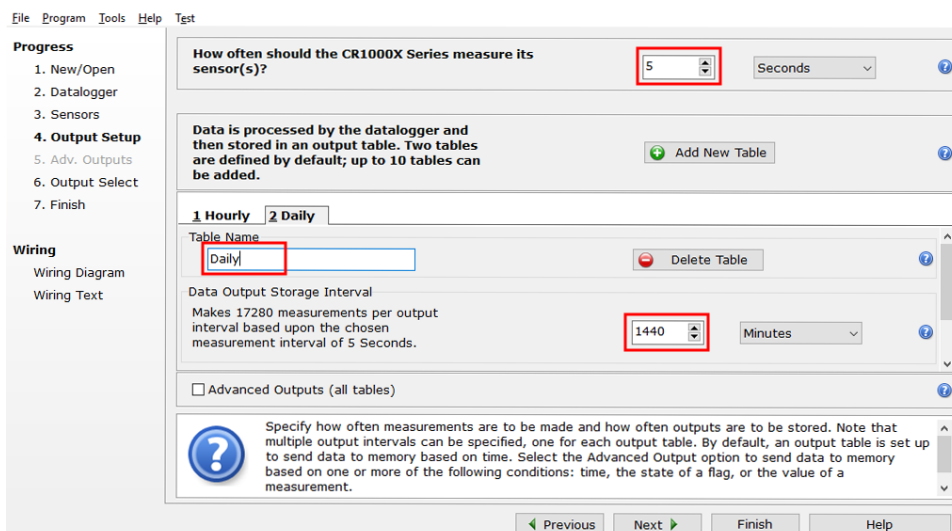
1. Open Short Cut and click **Create New Program**.
2. Double-click the data logger model.
3. In the **Available Sensors and Devices** box, type LP02 or find the sensor in the **Sensors > Meteorological > Solar Radiation** folder. Double-click **LP02 Pyranometer**. Type the **Sensitivity** supplied on the manufacturer's certificate of calibration; this calibration factor is unique to each sensor. The public variable defaults can typically be used.



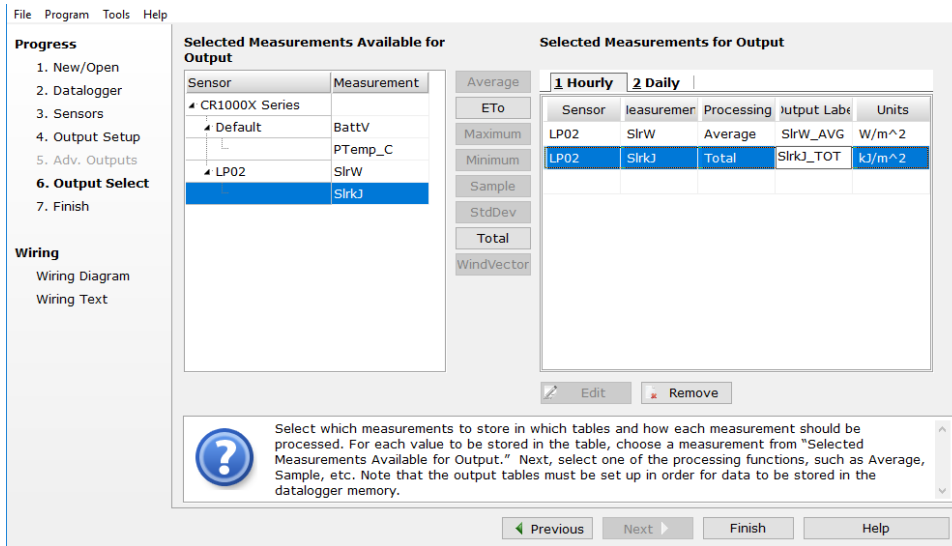
- Click on the **Wiring** tab to see how the sensor is to be wired to the data logger. Click **OK** after wiring the sensor.



- Repeat steps three and four for other sensors. Click **Next**.
- In **Output Setup**, type the scan rate, meaningful table names, and **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, as shown in the wiring diagram, check the output of the sensor in the data display in LoggerNet, PC400, RTDAQ, or PC200W to make sure it is making reasonable measurements.

NOTE:

Short Cut uses the execution interval to make total flux calculations (Table 7-2 (p. 12)). This needs to be taken into account while editing the Short Cut program.

5. Overview

The LP02 pyranometer is designed for continuous outdoor use. Due to its flat spectral sensitivity from 280 to 3000 nm, it can be used in natural sunlight, under plant canopies, in green houses or buildings, and inverted to measure reflected solar radiation. Two LP02s can be used in combination to measure albedo. The LP02 also measures most types of artificial light, such as Xenon and Halogen lamps.

The LP02 pyranometer consists of a thermopile sensor, housing, dome, and cable. The thermopile is coated with a black absorbent coating. The paint absorbs radiation and converts it to heat. The resultant temperature difference is converted to a voltage by the copper-constantan thermopile. The thermopile is encapsulated in the housing in such a way that it has a field of

view of 180 degrees and the angular characteristics needed to fulfill the cosine response requirements.

Features:

- Compatible with the following CRBasic data loggers: CR6, CR3000, CR1000X, CR800 series, CR300 series, and CR1000
- Measures reflected solar radiation when inverted
- Provides measurements in direct sunlight, under plant canopies, when the sky is cloudy, and in artificial light
- Includes bubble level and leveling screws eliminating need for a separate leveling base, which simplifies installation
- Acceptable for providing the solar radiation data used in stability estimations
- Dome protects thermopile and allows water to roll off of it

6. Specifications

ISO classification:	ISO 9060:2018 spectrally flat Class C (second class)
Response time for 95% response:	18 s
Zero offset (response to 200 W/m ² net thermal radiation):	< 15 W/m ²
Zero offset (response to 5 K/h change in ambient temperature):	< 4 W/m ²
Non-stability:	< 1% change per year
Non-linearity:	< ±1% (100 to 1000 W/m ²)
Directional response for beam radiation:	within ±25 W/m ²
Spectral selectivity:	±5% (280 to 3000 nm)
Temperature response (within an interval of 50°C):	±3% (-10 to 40 °C)
Tilt response:	within ±2%
Sensitivity (nominal):	15 μV (W/m ²)
Expected voltage output:	0.1 to +50 mV in natural sunlight
Operating temperature range:	-40 to 80 °C
Sensor resistance:	Between 40 and 60 Ω

Range:	0 to 2000 W/m ²
Cable replacement:	Cable can be replaced by the user
Spectral range:	280 to 3000 nm (50% transmission points)
Leveling:	Level and leveling feet included
Expected accuracy for daily sums:	±10%
Dome diameter:	3 cm (1.2 in)
Height:	5.9 cm (2.3 in)
Body diameter:	7.8 cm (3.1 in)
Weight with 15 ft cable:	363 g (0.8 lb)

7. Operation

If you are programming your data logger with Short Cut, skip [Wiring](#) (p. 9) and [Programming](#) (p. 10). Short Cut does this work for you. See [QuickStart](#) (p. 2) for a Short Cut tutorial.

7.1 Siting considerations

The LP02 is usually installed horizontally, but can also be installed at any angle including an inverted position. In all cases, it will measure the flux that is incident on the surface that is parallel to the sensor surface.

Site the LP02 to allow easy access for maintenance while ideally avoiding any obstructions above the plane of the sensing element. It is important to mount the LP02 such that no shadow or reflection will not be cast on it at any time. If this is not possible, try to choose a site where any obstruction over the azimuth range between earliest sunrise and latest sunset has an elevation not exceeding 5°. Diffuse solar radiation is less influenced by obstructions near the horizon. For instance, an obstruction with an elevation of 5° over the whole azimuth range of 360° decreases the downward diffuse solar radiation by only 0.8%.

7.2 Mounting

The LP02 is typically mounted to a tripod or tower using the CM225 solar sensor mounting stand. For information about mounting the LP02 to another mounting stand, refer to the Solar Radiation Sensor Mounts manual.

CAUTION:

Mounting the CM225 to a crossarm avoids reflections from the vertical pipe onto the sensor.

1. Mount the crossarm to the tripod or tower.
2. Place the CM225 U-bolt in the bottom holes and secure the CM225 to the crossarm by tightening the U-bolt nuts (see [FIGURE 7-1](#) (p. 7)).



FIGURE 7-1. CM225 bracket attached to a crossarm

- Place the LP02 in the center of the CM225 with the cable pointing to the nearest magnetic pole, and align the sensor mounting holes with correct mounting holes on the bracket (see [FIGURE 7-2](#) (p. 8) and [FIGURE 7-3](#) (p. 8)).



FIGURE 7-2. LP02 mounting hole

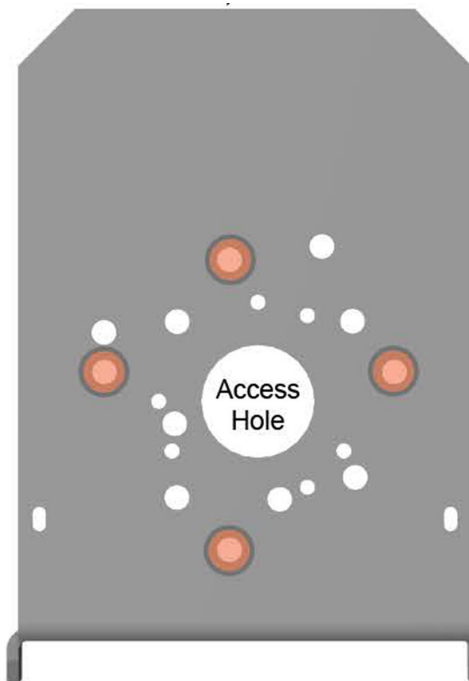


FIGURE 7-3. CM225 mounting holes used for the LP02 are indicated in orange

- Place the mounting screws in the mounting holes and slightly tighten them. The leveling screws should lightly touch the mounting plate (see [FIGURE 7-4](#) (p. 9)).

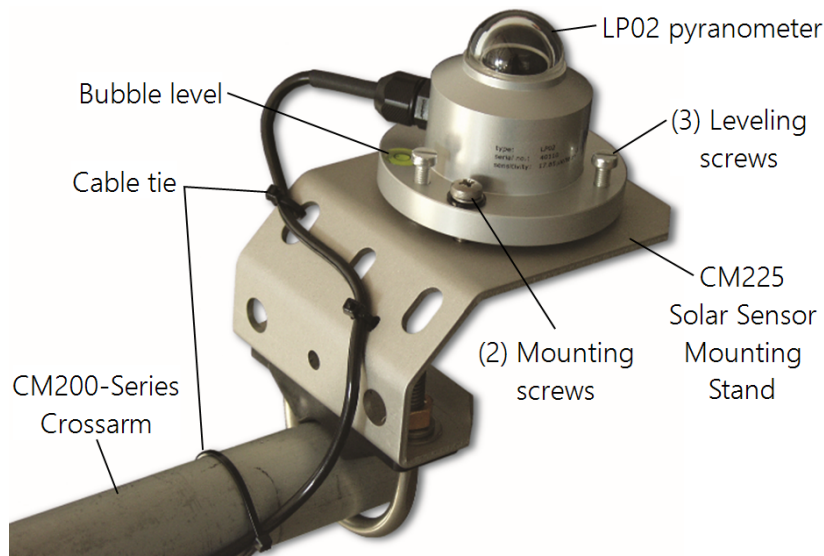


FIGURE 7-4. LP02 Pyranometer attached to CM225 Solar Sensor Mounting Stand

- Starting with the leveling screw nearest the bubble level, turn the leveling screws to bring the bubble of the bubble level within the ring (see [FIGURE 7-4](#) (p. 9)).
- Tighten the mounting screws to secure the assembly in its final position.
- Route the sensor cable to the instrument enclosure.
- Use cable ties to secure the cable to CM225 bracket and to the vertical pipe or crossarm and tripod/tower (see [FIGURE 7-4](#) (p. 9)).

7.3 Wiring

A schematic diagram of the LP02 is shown in [FIGURE 7-5](#) (p. 9).

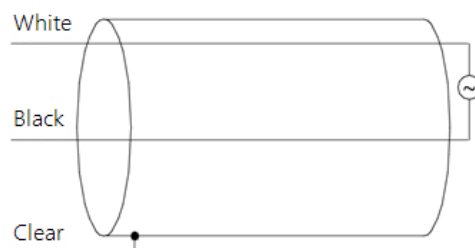


FIGURE 7-5. LP02 Schematic

A differential voltage measurement is recommended because it has better noise rejection than a single-ended measurement. If a differential terminal is not available, a single-ended measurement can be used.

Connections to Campbell Scientific data loggers are given in [Table 7-1](#) (p. 10). When using a differential measurement, connect a user-supplied jumper wire between the low side of the differential input and ground (\perp) to keep the signal in common mode range.

Table 7-1: Wire color, function, and data logger connection			
Wire color	Wire function	Differential data logger connection terminal	Single-ended data logger connection terminal
White	Signal high	U configured for differential input ¹ , DIFF H (differential high, analog-voltage input)	U configured for single-ended analog input ¹ , SE (single-ended, analog-voltage input)
Black	Signal reference	U configured for differential input ^{1,2} , DIFF L (differential low, analog-voltage input) ²	\perp (analog ground)
Clear	Shield	\perp (analog ground)	\perp (analog ground)

¹U terminals are automatically configured by the measurement instruction.

²Jumper to \perp with a user-supplied wire.

7.4 Programming

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 [QuickStart](#) (p. 2). If you wish to import Short Cut code into CRBasic Editor to create or add to a customized program, follow the procedure in [Importing Short Cut code into CRBasic Editor](#) (p. 14). Programming basics are provided in the following section. A complete program example can be found in [Example program](#) (p. 15).

Solar radiation can be reported as an average flux density (W/m^2) or daily total flux density (MJ/m^2). The appropriate multipliers are listed in [Table 7-2](#) (p. 12). Programming examples are given for both average and daily total solar radiation.

The LP02 outputs a low level voltage ranging from 0 to a maximum of up to 35 mV, in natural light, depending on the calibration factor and radiation level.

A differential voltage measurement is recommended because it has better noise rejection than a single-ended measurement. If a differential terminal is not available, a single-ended measurement can be used. The acceptability of a single-ended measurement can be determined by simply comparing the results of single-ended and differential measurements made under the same conditions.

7.4.1 Input range

The output voltage of the LP02 is usually between 10 and 35 mV per 1000 W/m². When estimating the maximum likely value of sensor output, a maximum value of solar radiation of 1100 W/m² can be used for field measurements on a horizontal surface.

Select the input range as follows:

1. Estimate the maximum expected input voltage by multiplying the maximum expected irradiance (W/m²) by the calibration factor ($\mu\text{V}/\text{W}/\text{m}^2$). Divide the answer by 1000 to give the maximum in millivolt units.
2. Select the smallest input range which is greater than the maximum expected input voltage. The exact range will depend on the sensitivity of your individual sensor and the maximum expected reading. With some data loggers, an autorange option can be used if measurement time is not critical.

The parameter code for the input range also specifies the measurement integration time. The slow or 60 Hz rejection integration gives a more noise-free reading. A fast integration takes less power and allows for faster throughput.

7.4.2 Multiplier

The multiplier converts the millivolt reading to engineering units. The calibration supplied by the manufacturer gives the output of the sensor (c) as microvolts ($\text{V} \times 10^{-6}$) per W/m². As the data logger voltage measurement instructions give a default output in mV, the following equation should be used to calculate the multiplier (m) to give the readings in W/m²:

$$m = 1000/c$$

Other units can be used by adjusting the multiplier as shown in [Table 7-2](#) (p. 12).

Table 7-2: Multipliers required for flux density and total fluxes

Units	Multipliers	Output processing
W/m ²	m	Average
MJ/m ²	m•t•0.000001	Total
kJ/m ²	m•t•0.001	Total
cal/cm ²	m•t•0.0239•0.001	Total
(cal/cm ²)/min ¹	m•1.434•0.001	Average

m = calibration factor in W/m²/mV
t = data logger program execution interval in seconds

NOTE:

The execution interval is used for the total flux calculations. This needs to be taken into account while editing the program.

7.4.3 Offset

The offset will normally be fixed at zero as the sensor should output no significant signal in dark conditions. In practice, because of the nature of thermopile detector sensors, there will be some offset in dark conditions; sometimes this offset can give negative light readings. This offset varies with several factors (for example, rate of change of sensor temperature), so it cannot be removed with a fixed offset. Some users may wish to remove small negative readings by including code after the measurement instructions that sets negative readings to zero.

7.4.4 Output format considerations

Store the data in the IEEE4 format when measurements will be totalized.

8. Maintenance

Inspect and clean the outer dome at regular intervals, for example, every week or so. Clean any accumulated dust and debris off the dome and pyranometer body using a soft cloth dampened with water or alcohol. Check that there is no condensation within the dome.

It is also important to check the data returned from the sensor as it will show the first indication of a fault. Be aware of several expected phenomena that can cause strange measurements. In particular, on clear, windless nights the outer dome temperature of horizontally placed

pyranometers can fall as low as the dewpoint temperature of the air, due to infrared radiation exchange with the cold sky. (The effective sky temperature can be 30 °C lower than the ground temperature, which results in an infrared emission of -150 W/m^2). If this happens, dew, glazed frost or hoar frost can be precipitated on the top of the outer dome and can stay there for several hours in the morning. An ice cap on the dome is a strong diffuser and can decrease the pyranometer signal by up to 50% in the first hours after sunrise.

The calibration of the LP02 may drift with time and exposure to radiation. Recalibration every two years is recommended. The sensor should be returned to Campbell Scientific, the manufacturer, or a calibration lab with facilities to calibrate radiation sensors.

9. Troubleshooting

Symptom: NAN, -9999, or radiation values around 0

1. Check that the sensor is wired to the differential terminal specified by the measurement instruction.
2. Verify that the voltage range is correct for the data logger type.
3. Measure the impedance across the sensor wires. This should be around 100Ω plus the cable resistance (typically $0.1 \Omega \text{ m}^{-1}$). If the resistance is very low, there may be a short circuit (check the wiring). Resistances somewhat lower than expected could be due to water ingress into the sensor or enclosure connectors. If the resistance is infinite, there is a broken connection (check the wiring).
4. Disconnect the sensor cable and check the voltage between pins 1 and 3 on the sensor. With the sensor located 8 inches below a 60 W incandescent light bulb the voltage should be approximately 2.5 mV. No voltage indicates a problem with the sensor.

Symptom: sensor signal is unrealistically high or low

1. Check that the right calibration factor has been properly entered into the data logger program. Please note that each sensor has its own individual calibration factor.
2. Check the condition of the sensor cable.

Symptom: sensor signal shows unexpected variations

1. Check for the presence of strong sources of electromagnetic radiation (radar, radio etc.)
2. Check the condition and the connection of the sensor shield wire.
3. Check the condition of the sensor cable.

Appendix A. Importing Short Cut code into CRBasic Editor


Short Cut creates a .DEF file that contains wiring information and a program file that can be imported into the CRBasic Editor. By default, these files reside in the C:\campbellsci\SCWin folder.

Import Short Cut program file and wiring information into CRBasic Editor:

1. Create the Short Cut program. After saving the Short Cut program, click the **Advanced** tab then the **CRBasic Editor** button. A program file with a generic name will open in CRBasic. Provide a meaningful name and save the CRBasic program. This program can now be edited for additional refinement.

NOTE:

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

2. To add the Short Cut wiring information into the new CRBasic program, open the .DEF file located in the C:\campbellsci\SCWin folder, and copy the wiring information, which is at the beginning of the .DEF file.
3. Go into the CRBasic program and paste the wiring information into it.
4. In the CRBasic program, highlight the wiring information, right-click, and select **Comment Block**. This adds an apostrophe (') to the beginning of each of the highlighted lines, which instructs the data logger compiler to ignore those lines when compiling. The **Comment Block** feature is demonstrated at about 5:10 in the [CRBasic | Features](#) video .

Appendix B. Example program

The following program measures the LP02 every 10 seconds and converts the millivolt output to W/m^2 and MJ/m^2 . A sensor calibration of $15.02 \mu V$ per W/m^2 is used for the example program. The program outputs an hourly average flux (W/m^2), and a daily total flux density (MJ/m^2).

B.1 CR1000X example program

CRBasic Example 1: CR1000X program measuring the LP02

```
'CR1000X

'Declare Variables and Units
Public Solar_Wm2
Public Solar_MJ

Units Solar_Wm2=W/m^2
Units Solar_MJ=MJ/m^2
'Hourly Data Table
DataTable(Hourly,True,-1)
  DataInterval(0,60,Min,10)
  Average(1,Solar_Wm2,FP2,False)
EndTable

'Daily Data Table
DataTable(Daily,True,-1)
  DataInterval(0,1440,Min,10)
  Totalize(1,Solar_MJ,IEEE4,False)
EndTable

'Main Program
BeginProg
  Scan(10,Sec,1,0)

  'LP02 Pyranometer measurement in W/m^2:

  'The Multiplier (m) for this example is based upon a sensor
  'calibration (c) of 15.02  $\mu V/W/m^2$ , and will be different for each
  'sensor. Multiplier (m) =  $1000/c = 66.577896$ .

  VoltDiff(Solar_Wm2,1,mV200,1,True,0,60,66.577896,0)

  'Set negative readings to zero:
  If Solar_Wm2<0 Then Solar_Wm2=0
```

CRBasic Example 1: CR1000X program measuring the LP02

*'Calculate units in MJ, where $MJ = m * t * 0.000001$. $m = \text{Solar_Wm2}$ from 'above, and $t = 10$ (scan interval)*

```
Solar_MJ=Solar_Wm2*0.00001
```

'Call Data Tables and Store Data

```
CallTable(Hourly)
```

```
CallTable(Daily)
```

```
NextScan
```

```
EndProg
```

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CAMPBELL SCIENTIFIC, INC.

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Safety

DANGER — MANY HAZARDS ARE ASSOCIATED WITH INSTALLING, USING, MAINTAINING, AND WORKING ON OR AROUND TRIPODS, TOWERS, AND ANY ATTACHMENTS TO TRIPODS AND TOWERS SUCH AS SENSORS, CROSSARMS, ENCLOSURES, ANTENNAS, ETC. FAILURE TO PROPERLY AND COMPLETELY ASSEMBLE, INSTALL, OPERATE, USE, AND MAINTAIN TRIPODS, TOWERS, AND ATTACHMENTS, AND FAILURE TO HEED WARNINGS, INCREASES THE RISK OF DEATH, ACCIDENT, SERIOUS INJURY, PROPERTY DAMAGE, AND PRODUCT FAILURE. TAKE ALL REASONABLE PRECAUTIONS TO AVOID THESE HAZARDS. CHECK WITH YOUR ORGANIZATION'S SAFETY COORDINATOR (OR POLICY) FOR PROCEDURES AND REQUIRED PROTECTIVE EQUIPMENT PRIOR TO PERFORMING ANY WORK.

Use tripods, towers, and attachments to tripods and towers only for purposes for which they are designed. Do not exceed design limits. Be familiar and comply with all instructions provided in product manuals. Manuals are available at www.campbellsci.com. You are responsible for conformance with governing codes and regulations, including safety regulations, and the integrity and location of structures or land to which towers, tripods, and any attachments are attached. Installation sites should be evaluated and approved by a qualified engineer. If questions or concerns arise regarding installation, use, or maintenance of tripods, towers, attachments, or electrical connections, consult with a licensed and qualified engineer or electrician.

General

- Protect from over-voltage.
- Protect electrical equipment from water.
- Protect from electrostatic discharge (ESD).
- Protect from lightning.
- Prior to performing site or installation work, obtain required approvals and permits. Comply with all governing structure-height regulations, such as those of the FAA in the USA.
- Use only qualified personnel for installation, use, and maintenance of tripods and towers, and any attachments to tripods and towers. The use of licensed and qualified contractors is highly recommended.
- 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.

Utility and Electrical

- **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.

Internal Battery

- Be aware of fire, explosion, and severe-burn hazards.
- Misuse or improper installation of the internal lithium battery can cause severe injury.
- Do not recharge, disassemble, heat above 100 °C (212 °F), solder directly to the cell, incinerate, or expose contents to water. Dispose of spent batteries properly.

WHILE EVERY ATTEMPT IS MADE TO EMBODY THE HIGHEST DEGREE OF SAFETY IN ALL CAMPBELL SCIENTIFIC PRODUCTS, THE CUSTOMER ASSUMES ALL RISK FROM ANY INJURY RESULTING FROM IMPROPER INSTALLATION, USE, OR MAINTENANCE OF TRIPODS, TOWERS, OR ATTACHMENTS TO TRIPODS AND TOWERS SUCH AS SENSORS, CROSSARMS, ENCLOSURES, ANTENNAS, ETC.



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