INSTRUCTION MANUAL

LP02 Pyranometer

Revision: 1/14

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LP02 Pyranometer

1. Introduction

The LP02 is an ISO-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 datalogger. The LP02 can provide solar radiation measurements for many meteorological applications. This pyranometer is manufactured by Hukseflux.

Before using the LP02, please study:

- Section 2, *Cautionary Statements*
- Section 3, *Initial Inspection*
- Section 4, *Quick Start*

2. Cautionary Statements

- 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, consult with a Campbell Scientific application engineer.

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 Section 3.1, *Ships With*, to ensure that all of your parts are included.

3.1 Ships With

(1) Bolt for mounting from original manufacturer
(2) Nuts for mounting from original manufacturer
(1) Calibration certificate (see Section 3.2, *Calibration Certificate*)
(2) Bolts for mounting from original manufacturer
(1) ResourceDVD

3.2 Calibration Certificate

Included with the sensor is a calibration 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

Please review Section 7, *Operation*, for wiring, CRBasic programming, and Edlog programming.

4.1 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 a shadow 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%.

4.2 Mounting

Below shows the steps for using the CM225 mounting bracket kit to mount the LP02 to a vertical pipe (1.0 to 2.1 in. OD), or to a CM202, CM203, CM204, or CM206 crossarm. If the sensor needs to be mounted at an angle, the CM245 Adjustable Angle Mounting Stand can be used instead (see Appendix A, *CM245 Adjustable Angle Mounting Stand*).

1. Attach the CM225 to a mast or crossarm (see FIGURE 4-1 and FIGURE 4-2).

FIGURE 4-1. CM225 Bracket Attached to a Crossarm

FIGURE 4-2. CM225 Bracket Attached to a Mast

2. Place the LP02 in the center of the CM225 with the cable pointing to the nearest magnetic pole, and align the sensor's mounting holes with two of the bracket's mounting holes (see FIGURE 4-3 and FIGURE 4-4).

FIGURE 4-3. LP02 Mounting Hole

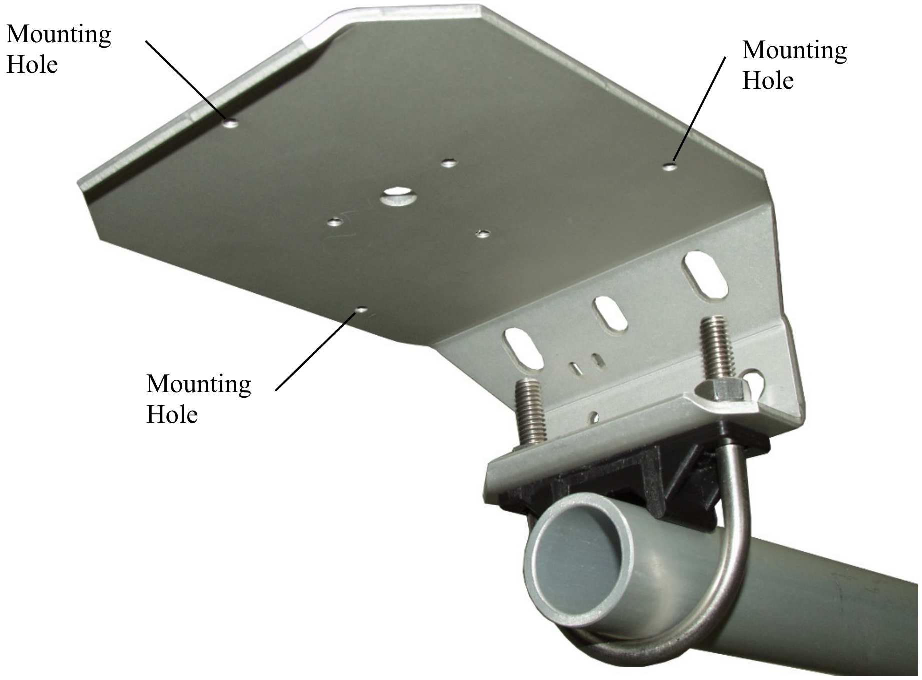


FIGURE 4-4. CM225 Bracket Mounting Holes

3. Place the mounting screws in the mounting holes and slightly tighten them. The leveling screws should lightly touch the mounting plate (see FIGURE 4-5).

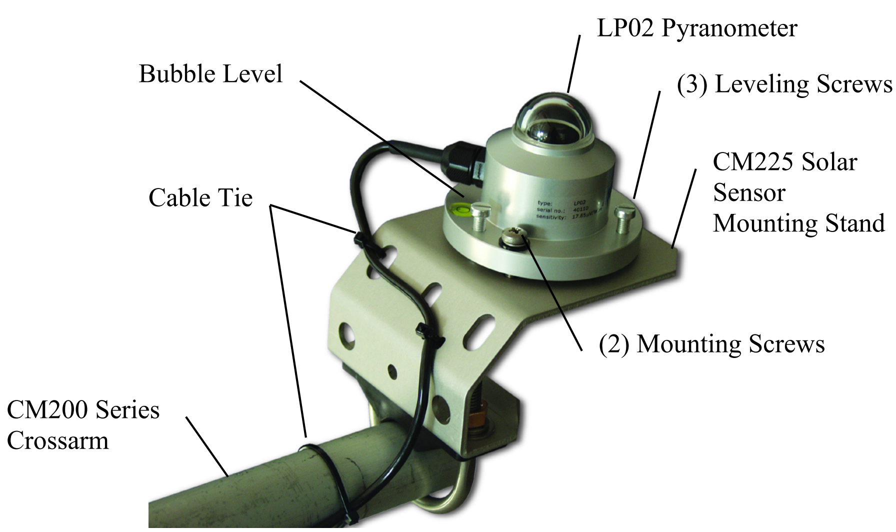


FIGURE 4-5. LP02 Pyranometer Attached to CM225 Solar Sensor Mounting Stand

4. 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 4-5).

5. Tighten the mounting screws to secure the assembly in its final position.

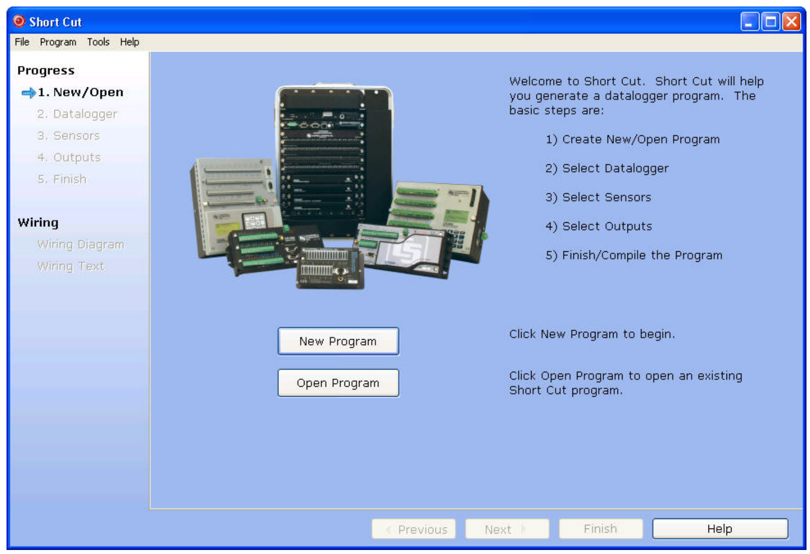
6. Route the sensor cable to the instrument enclosure.

7. Use cable ties to secure the cable to CM225 bracket and to the vertical pipe or crossarm and tripod/tower (see FIGURE 4-5).

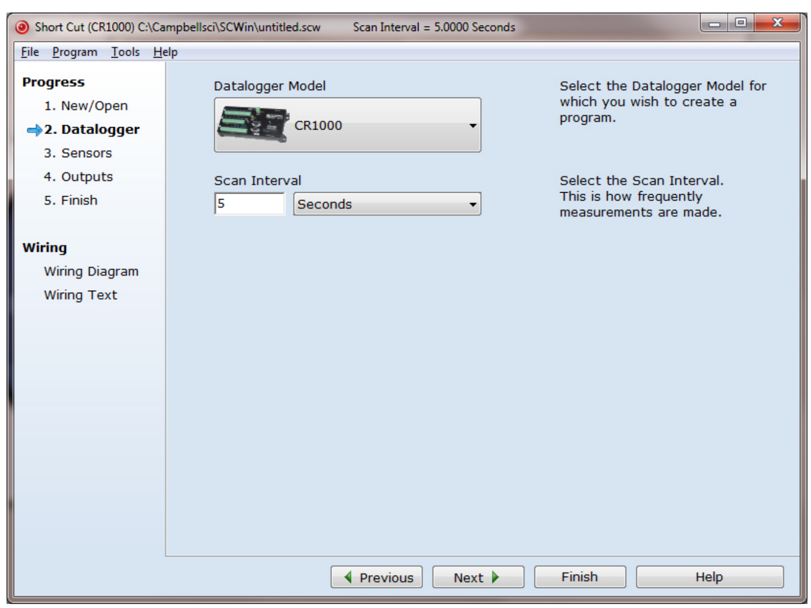
4.3 Use SCWin to Program Datalogger and Generate Wiring Diagram

The simplest method for programming the datalogger to measure the LP02 is to use Campbell Scientific's SCWin Program Generator.

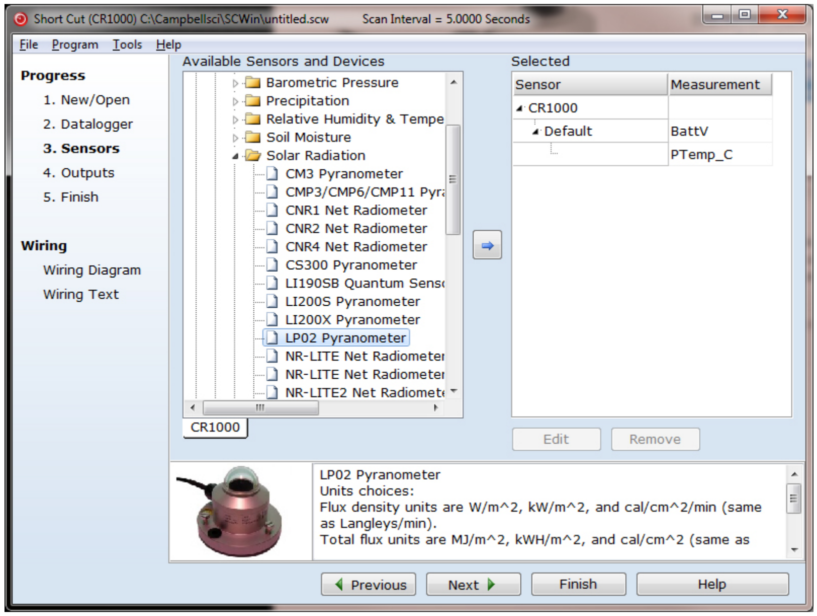
1. Open *Short Cut* and click on **New Program**.



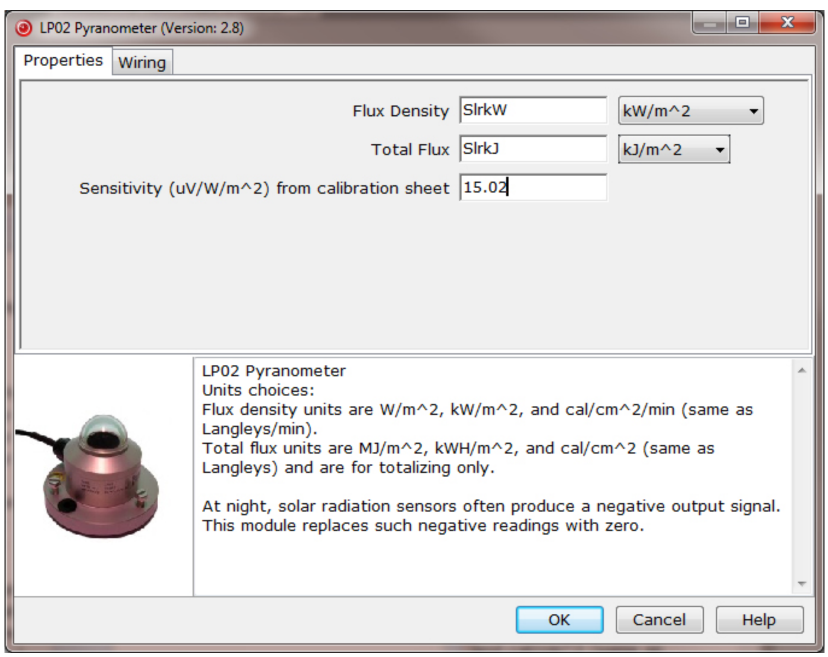
2. Select the **Datalogger Model** and enter the **Scan Interval**.



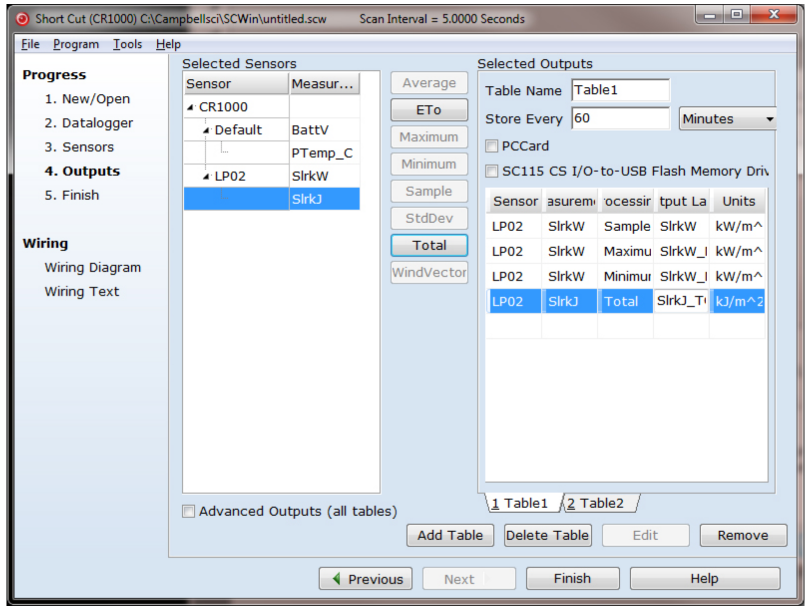
3. Select **LP02 Pyranometer**, and select the **right arrow** (in center of screen) to add it to the list of sensors to be measured, and then select **Next**.



4. Enter the **Sensitivity** supplied on the manufacturer's certificate of calibration; this sensitivity is unique to each sensor. The public variables defaults can typically be used. After entering the information, click on **OK**, and then select **Next**.



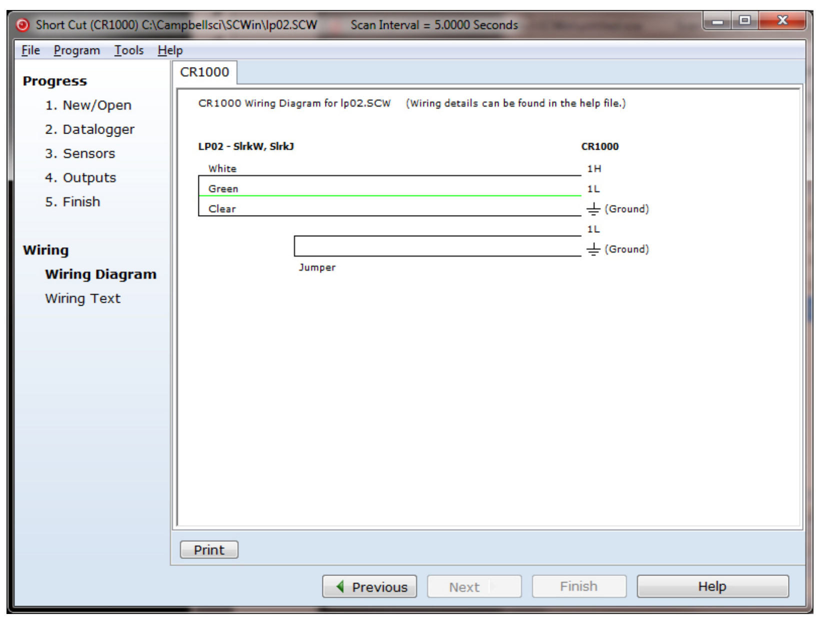
5. Choose the **Outputs** and then select **Finish**.



6. In the **Save As** window, enter an appropriate file name and select **Save**.

7. In the **Confirm** window, click **Yes** to download the program to the datalogger.

8. Click on **Wiring Diagram** and wire according to the wiring diagram generated by *Short Cut*.



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 can also be used to measure most types of artificial light (Xenon lamps, Halogen lamps, etc.).

The LP02 pyranometer consists of a thermopile sensor, housing, dome, and cable. The thermopile is coated with a black absorbent coating. The paint absorbs the 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.

The LP02's cable has a user-specified length that can terminate in:

- Pigtails that connect directly to a Campbell Scientific datalogger (cable termination option –PT).
- Connector that attaches to a prewired enclosure (cable termination option –PW).
- Connector that attaches to a CWS900 Wireless Sensor Interface (cable termination option –CWS). The CWS900 enables the pyranometer to be used in a wireless sensor network.

6. Specifications

Features:

- Compatible with most Campbell Scientific dataloggers
- 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
- Compatible with the CWS900-series interfaces, allowing it to be used in a wireless sensor network
- Acceptable for providing the solar radiation data used in stability estimations
- Dome protects thermopile and allows water to roll off of it

Compatible Dataloggers:	CR800 CR850 CR1000 CR3000 CR9000(X) CR5000 CR23X CR10(X) CR510 CR500 21X CR7
Overall classification according to ISO 9060 / WMO:	Second class pyranometer
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)

[1]*Guide to Meteorological Instruments and Methods of Observation*, fifth edition, WMO, Geneva and ISO9060

7. Operation

7.1 Wiring

A schematic diagram of the LP02 is shown in FIGURE 7-1.

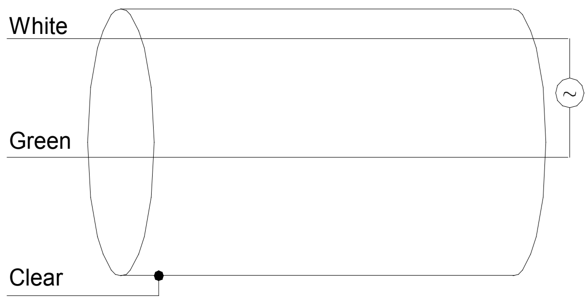


FIGURE 7-1. LP02 Schematic

When *Short Cut* is used to create the datalogger program, the sensor should be wired to the channels shown in the wiring diagram created by *Short Cut*.

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

Connections to Campbell Scientific dataloggers for a differential measurement are given in TABLE 7-1. A user-supplied jumper wire should be connected between the low side of the differential input and ground (AG or ⏚) to keep the signal in common mode range.

Connections to Campbell Scientific dataloggers for a single-ended measurement are given in TABLE 7-2.

TABLE 7-1. Differential Connections to Campbell Scientific Dataloggers

Color	**Description**	**CR9000(X) CR5000 CR3000 CR1000 CR800 CR850**	**CR510 CR500 CR10(X)**	**21X CR7 CR23X**
White	Signal (+)	DIFF Analog High	DIFF Analog High	DIFF Analog High
Green	Signal (–)	*DIFF Analog Low	*DIFF Analog Low	*DIFF Analog Low
Clear	Shield	⏚	G	⏚

* Jumper to AG or ⏚ with user supplied wire.

TABLE 7-2. Single-Ended Connections to Campbell Scientific Dataloggers

Color	Description	CR9000(X) CR5000 CR3000 CR1000 CR800 CR850	CR510 CR500 CR10(X)	21X CR7 CR23X
White	Signal (+)	Single-Ended Analog	Single-Ended Analog	Single-Ended Analog
Green	Signal (–)	⏚	AG	⏚
Clear	Shield	⏚	G	⏚

7.2 Programming

This section is for users who write their own datalogger programs. A datalogger program to measure this sensor can be created using *Short Cut*. You do not need to read this section to use *Short Cut*.

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 7-3. 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 channel 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.

7.2.1 Input Range

The output voltage of the LP02 is usually between 10 and 35 mV per 1000 W m^{-2}. When estimating the maximum likely value of sensor output, a maximum value of solar radiation of 1100 W m^{-2} 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 m^{-2}) by the calibration factor (µV/ W 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. Normally the 50 mV range for the CR3000, CR9000(X), CR5000, CR7, CR23X, 21X, and the 25 mV or 250 mV range for the CR800, CR850, CR1000, CR10X, CR510, and CR500 will be suitable. The exact range will depend on the sensitivity of your

individual sensor and the maximum expected reading. With some dataloggers, 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.

7.2.2 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 (V x 10^{-6}) per W m^{-2}. As the datalogger 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 m^{-2}:

$$m = 1000/c$$

Other units can be used by adjusting the multiplier as shown in TABLE 7-3.

TABLE 7-3. 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
kJm^{-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 m^{-2}/mV t = datalogger program execution interval in seconds		

7.2.3 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.

7.2.4 Example Programs

The following programs measure the LP02 every 10 seconds and convert the mV output to W m^{-2} and MJ m^{-2}. A sensor calibration of 15.02 µV per W m^{-2} is used for the example programs. Both programs output an hourly average flux (W m^{-2}), and a daily total flux density (MJ m^{-2}).

Wiring for the examples is given in TABLE 7-4.

TABLE 7-4. Wiring for Example Programs

Color	Description	CR1000	CR10X
White	Signal (+)	DIFF Analog High	DIFF Analog High
Green	Signal (–)	*DIFF Analog Low	*DIFF Analog Low
Clear	Shield	⏚	G

* Jumper to AG or ⏚ with user supplied wire.

7.2.4.1 CR1000 Example Program

```
'CR1000

'Declare Variables and Units
Public Solar_Wm2
Public Solar_MJ

Units Solar_Wm2=W/m²
Units Solar_MJ=MJ/m²

'Hourly Data Table
DataTable(Table1,True,-1)
    DataInterval(0,60,Min,10)
    Average(1,Solar_Wm2,FP2,False)
EndTable

'Daily Data Table
DataTable(Table2,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 Wm-2:

        'The Multiplier (m) for this example is based upon a sensor calibration (c) of
        '15.02 µV/Wm-2, and will be different for each sensor.
        'Multiplier (m) = 1000/c = 66.577896.

        VoltDiff(Solar_Wm2,1,mV25,1,True,0,_60Hz,66.577896,0)   'use the 50 mV range for the
                                                                 CR3000, CR5000 and CR9000
        'Set negative readings to zero:
        If Solar_Wm2<0 Then Solar_Wm2=0

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

        Solar_MJ=Solar_Wm2*0.00001
```

```
            'Call Data Tables and Store Data
            CallTable(Table1)
            CallTable(Table2)
      NextScan
EndProg
```

7.2.4.2 CR10X Example Program

```
;{CR10X}
*Table 1 Program
  01:  10.0000        Execution Interval (seconds)

; LP02 measurement in Wm-2

1:  Volt (Diff) (P2)
  1:   1              Reps
  2:   23             25 mV 60 Hz Rejection Range    ;use the 50 mV range for the CR7, 21X and CR23X
  3:   1              DIFF Channel                   ;use the 250 mV range for the CR10X if
  4:   3              Loc [ Solar_Wm2 ]              calibration factor is > 25 µV/Wm-2
  5:   66.5778        Multiplier
  6:   0              Offset

; Set negative values to zero

2:  If (X<=>F) (P89)
  1:   3              X Loc [ Solar_Wm2 ]
  2:   4              <
  3:   0              F
  4:   30             Then Do

3:  Z=F x 10^n (P30)
  1:   0              F
  2:   0              n, Exponent of 10
  3:   3              Z Loc [ Solar_Wm2 ]

4:  End (P95)

; Calculate units in MJ, where MJ = m * t * 0.000001.
; m = Solar_Wm2 from above, and t = 10 (scan interval).

5:  Z=X*F (P37)
  1:   3              X Loc [ Solar_Wm2 ]
  2:   .00001         F
  3:   4              Z Loc [ Solar_MJ  ]

6:  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)

7:  Set Active Storage Area (P80)
  1:   1              Final Storage Area 1
  2:   101            Array ID

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

```
9:  Average (P71)
  1:   1              Reps
  2:   3              Loc [ Solar_Wm2 ]

10:  If time is (P92)
  1:   0              Minutes (Seconds --) into a
  2:   1440           Interval (same units as above)
  3:   10             Set Output Flag High (Flag 0)

11:  Set Active Storage Area (P80)
  1:   1              Final Storage Area 1
  2:   102            Array ID

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

13:  Resolution (P78)
  1:   1              High Resolution

14:  Totalize (P72)
  1:   1              Reps
  2:   4              Loc [ Solar_MJ  ]

15:  Resolution (P78)
  1:   0              Low Resolution
```

7.2.5 Output Format Considerations

In CRBasic, store the data in the IEEE4 format if the measurements will be totalized.

When using *Edlog*, the largest number the datalogger can store in Final Storage is 6999 in low resolution mode (FP2) and 99999 in high resolution mode (if available). If the measurement value is totalized, there is some danger of over-ranging the output limits, as shown in the following example:

Example

Assume that daily total flux is desired, and that the datalogger scan rate is 1 second. With a multiplier that converts the readings to units of kJm^{-2} and an average irradiance of 0.5k W m^{-2}, the maximum low resolution output limit will be exceeded in less than four hours.

The following solutions can be used to prevent overranging:

Solution 1 – Change the multiplier in the instruction to (m•0.0001). This will totalize MJ m^{-2} instead of kJm^{-2}.

Solution 2 – Record the average flux density and later multiply the result by the number of seconds in the output interval to arrive at total flux.

Solution 3 – Record the total flux using the high resolution format. The drawback to high resolution is that it requires four bytes of memory per data point, consuming twice as much memory as low resolution. **Instruction 78** is used to switch to high resolution in the Edlog dataloggers.

8. Maintenance

Inspect and clean the outer dome at regular intervals, for example, every week or so. Clean any accumulated dust, etc. 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 channel specified by the measurement instruction.

2. Verify that the range code is correct for the datalogger type.

3. Measure the impedance across the sensor wires. This should be around 100 Ω plus the cable resistance (typically 0.1 Ω 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 datalogger 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. CM245 Adjustable Angle Mounting Stand

A.1 Installation

The CM245 includes slots that allow it to be adjusted to any angle from horizontal to vertical. If mounting the pyranometer at an angle, ensure that the crossarm is leveled horizontally before placing the bracket at its proper angle. Angle positions are included on the bracket label (see FIGURE A-1 and FIGURE A-2).

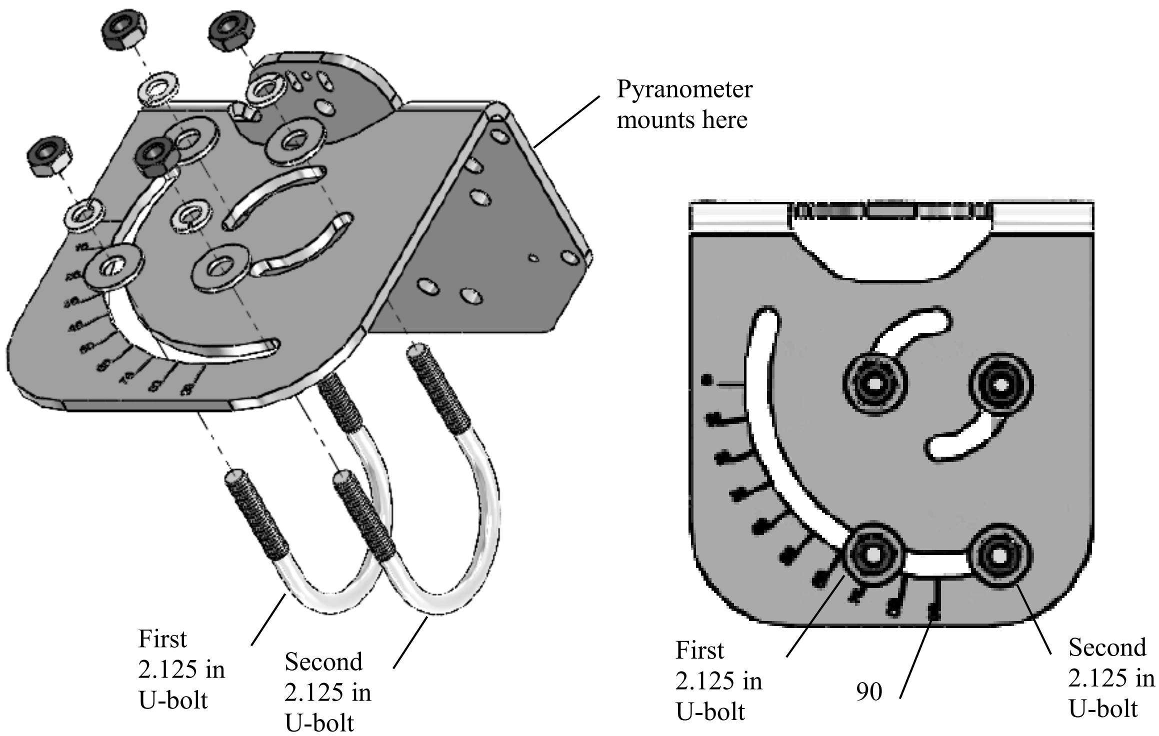


FIGURE A-1. CM245 bracket with 2.125 in. U-bolts positioned to mount the pyranometer horizontally on a crossarm

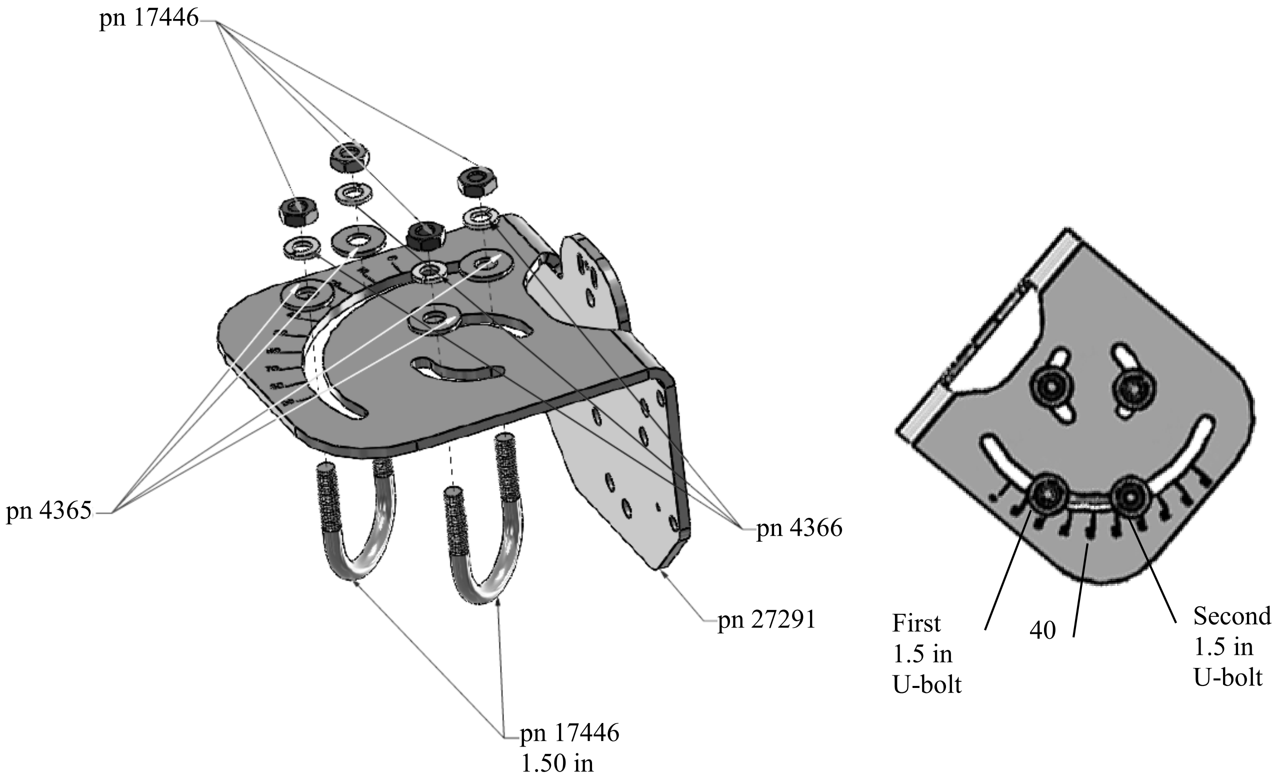


FIGURE A-2. CM245 bracket with 1.5 in. U-bolts positioned to mount pyranometer at a 40° angle on a vertical pipe

Do the following to level the pyranometer horizontally:

1. Attach the mounting stand to the crossarm.
2. Loosely mount the pyranometer on the mounting stand. Do not fully tighten the two mounting screws.
3. Turn the leveling screws as required to bring the bubble of the level within the ring.
4. Tighten the mounting screws to secure the assembly in its final position. Check that the pyranometer is still correctly leveled and adjust as necessary.

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