INSTRUCTION MANUAL

LP02 Pyranometer

Revision: 5/10

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The **LP02 Pyranometer** 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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LP02 Pyranometer

1. General Description

This manual provides information for interfacing Hukseflux's LP02 Pyranometer to various models of Campbell Scientific dataloggers.

The LP02 is shipped with an instruction manual provided by Hukseflux that contains information concerning the LP02's construction, spectral sensitivity, cosine response, and a simple sensor check out procedure. Included with the sensor and manual 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.

The LP02 pyranometer is designed for continuous outdoor use. Due to its flat spectral sensitivity from 300 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.

2. Specifications

The LP02 complies with the ISO Second class pyranometer specifications as detailed below.

LP02 ISO / WMO Specifications[1]

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	< +/- 2.5%
Directional response for beam radiation:	within +/- 25 W/m^2

Spectral selectivity	+/- 5% (305 to 2000 nm)
Temperature response (within an interval of 50°C)	within 6% (-10 to +40°C)
Tilt response	within +/- 2%

LP02 ADDITIONAL MEASUREMENT SPECIFICATIONS

Sensitivity	10-40 $\mu V/Wm^{-2}$
Expected voltage output	0.1 to + 50 mV in natural sunlight
Operating temperature	-40 to +80°C
Sensor resistance	Between 40 and 60 Ohms
Power required	Zero (passive sensor)
Standard cable length	16 ft (4.8 m)
Range	0-2000 Wm^{-2}
Cable replacement	Cable can be replaced by the user
Spectral range	305 to 2800 nm (50% transmission points)
Required datalogger channels	1 differential or 1 single ended voltage channel
Leveling	Level and leveling feet included
Expected accuracy for daily sums	+/- 10%

DIMENSIONS / SHIPPING DIMENSIONS

LP02:	3 in dia x 3 in / 8x4x10 in

WEIGHT/SHIPPING WEIGHT

LP02:	0.8 lbs / 1.2 lbs

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

3. Installation

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%.

The sensor should be mounted with the cable pointing towards the nearest magnetic pole, e.g., in the Northern Hemisphere point the cable toward the North Pole.

The CM225 Solar Sensor Mounting Stand is used to attach the LP02 to a vertical pipe (1.0 – 2.1" OD) as shown in Figure 3-1. The LP02 includes a base with three leveling screws, bubble level, and mounting screws.

Attach the LP02 to the CM225 as follows:

1. Loosely mount the pyranometer and fixture on the mounting arm, with the leveling screws lightly touching the mounting plate. Do not fully tighten the two mounting screws.
2. Turn the leveling screws as required to bring the bubble of the spirit level within the ring. (For easy leveling first use the screw nearest the spirit level.)
3. Tighten the mounting screws to secure the assembly in its final position. Check that the pyranometer is still correctly leveled and adjust as necessary.

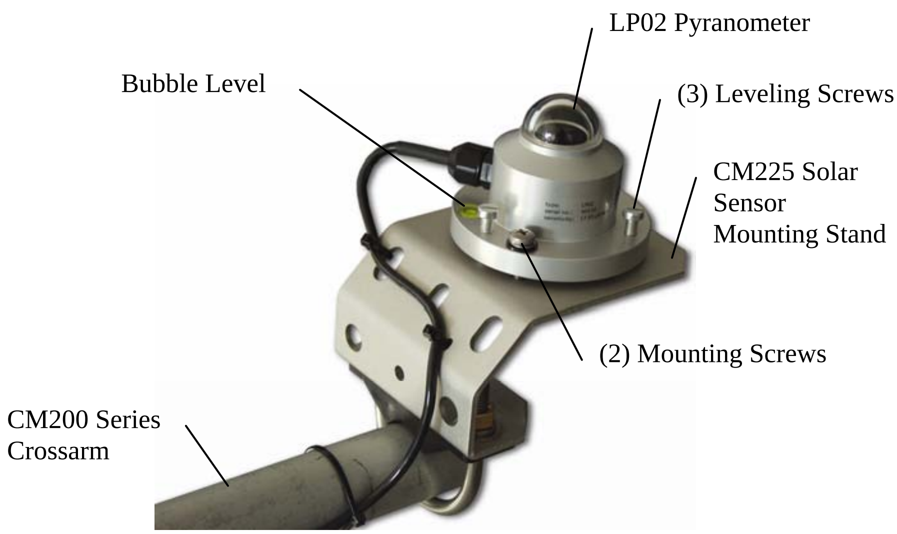

FIGURE 3-1. LP02 Pyranometer Attached to CM225 Solar Sensor Mounting Stand

4. Wiring

A schematic diagram of the LP02 is shown in Figure 4-1.

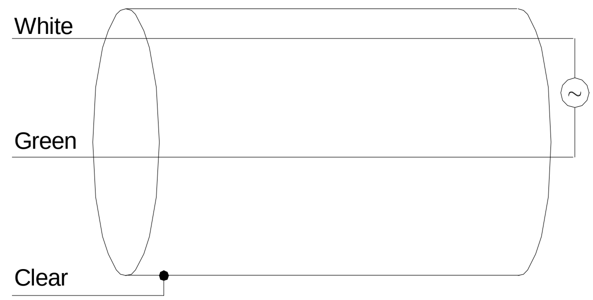

FIGURE 4-1. LP02 Schematic

When Short Cut for Windows software 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 4-1. 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 4-2.

TABLE 4-1. Differential Connections to Campbell Scientific Dataloggers

Color	**Description**	**CR9000(X)** **CR5000** **CR3000** **CR1000** **CR800**	**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 4-2. Single-Ended Connections to Campbell Scientific Dataloggers				
Color	**Description**	**CR9000(X) CR5000 CR3000 CR1000 CR800**	**CR510 CR500 CR10(X)**	**21X CR7 CR23X**
White	Signal (+)	Single-Ended Analog	Single-Ended Analog	Single-Ended Analog
Green	Signal (-)	⏚	AG	⏚
Clear	Shield	⏚	G	⏚

5. Example Programs

This section is for users who write their own datalogger programs. A datalogger program to measure this sensor can be created using Campbell Scientific's Short Cut Program Builder software. 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 5-1. 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.

5.1 Input Range

The output voltage of the LP02 is usually between 10 and 35 mV per 1000 Wm^{-2}. When estimating the maximum likely value of sensor output a maximum value of solar radiation of 1100 Wm^{-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 (in Wm^{-2}) by the calibration factor (in µV/Wm^{-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 CR23X, CR5000, CR9000 and CR7, and the 25 mV or 250 mV range for the CR510, CR10X and CR1000 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.

5.2 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 ($V \times 10^{-6}$) per Wm^{-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 Wm^{-2}:

$$m = 1000/c$$

Other units can be used by adjusting the multiplier as shown in Table 5-1.

TABLE 5-1. Multipliers Required for Flux Density and Total Fluxes

Units	Multipliers	Output Processing
Wm^{-2}	m	Average
MJm^{-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 Wm^{-2}/mV
t = datalogger program execution interval in seconds

5.3 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, e.g. 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.

5.4 Example Programs

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

Wiring for the examples is given in Table 5-2.

TABLE 5-2. 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.

5.4.1 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
```

5.4.2 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
```

5.5 Output Format Considerations

When using the Campbell Scientific floating point data format to store data, 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 $0.5kWm^{-2}$, the maximum low resolution output limit will be exceeded in less than four hours.

Solution 1 – Change the multiplier in the instruction to (m*0.0001). This will totalize MJm^{-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.

Dataloggers that are programmed in CRBasic can be programmed to store data in IEEE4 format which can represent a wider range of numbers so this is not a consideration for them.

6. Maintenance

Inspect and clean the outer dome at regular intervals, e.g. 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. When doing this you should 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 dew point temperature of the air, due to infra-red radiation exchange with the cold sky. (The effective sky temperature can be 30°C lower than the ground temperature, which results in an infra-red emission of -150 Wm^{-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 increase 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.

7. Troubleshooting

Symptom: -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 ohms plus the cable resistance (typically 0.1 ohm/m). 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” 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.

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