SP-Lite
Silicon Pyranometer

User Guide

Issued 30.7.98

Campbell Scientific Ltd. acknowledges the technical expertise provided by Kipp & Zonen in their SP-Lite Instruction Manual rev. 9607, on which this User Guide is based.

Guarantee

This equipment is guaranteed against defects in materials and workmanship. This guarantee applies for twelve months from date of delivery. We will repair or replace products which prove to be defective during the guarantee period provided they are returned to us prepaid. The guarantee will not apply to:

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- Any product which has been subjected to misuse, neglect, acts of God or damage in transit.

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Campbell Scientific Ltd,
Campbell Park, 80 Hathern Road,
Shepshed, Loughborough, LE12 9GX, UK
Tel: +44 (0) 1509 601141
Fax: +44 (0) 1509 601091

Email: support@campbellsci.co.uk
www.campbellsci.co.uk

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SP–Lite Silicon Pyranometer

The SP-Lite is a robust silicon pyranometer which can be used to measure the solar energy received from the entire hemisphere. It uses a photodiode detector which creates a voltage output that is proportional to incoming radiation.

The SP-Lite can be used in solar energy applications such as plant growth, thermal convection and evapotranspiration. It can be directly connected to a datalogger, and readout in watts per square metre (Wm^{-2}) can be readily derived. The sensor is supplied with a levelling device for accurate alignment.

1. Description

Figure 1 Bare SP-Lite Sensor without Levelling Fixture or Mounting Arm

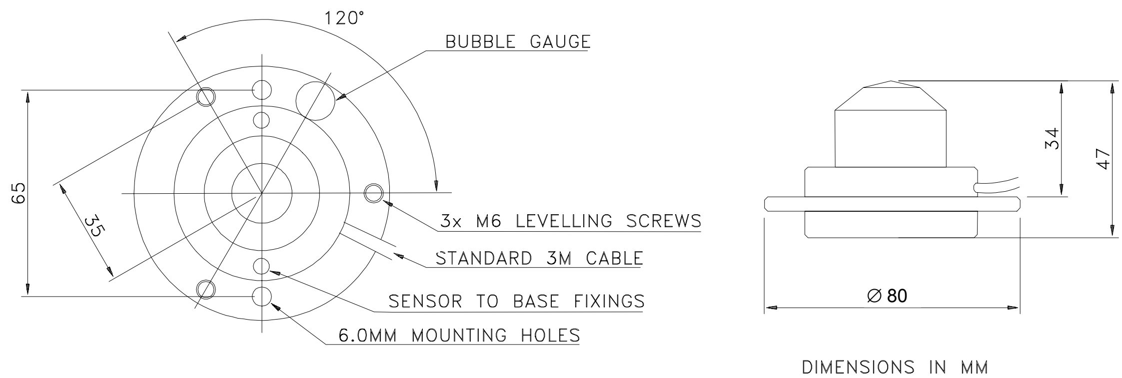

Figure 2 Dimensions of SP-Lite with Levelling Device

The SP-Lite is used for measuring solar radiation. It measures the solar energy received from the entire hemisphere – i.e. 180° field of view. The output is expressed in Watts per square metre (Wm^{-2}).

The SP-Lite is designed for continuous outside use, and its calibration is valid only for unshaded natural daylight – not for artificial light. It is most usually used to measure solar radiation being received on the horizontal plane and is equipped with a levelling device and bubble gauge so that it can be perfectly aligned. However, the SP-Lite can, if required, be used in an inverted or tilted position.

The SP-Lite fully complies with EEC directive 89/336/EEC with respect to electromagnetic radiation.

2. Properties

The SP-Lite consists of a photodiode complete with housing and cable. The circuit includes a shunt resistor for the photodiode in order to generate a voltage output. The electrical specification of the sensor is determined by the characteristics of the photodiode and resistor, while the spectral specification is determined by the photodiode and the material above it. The photodiode is encapsulated in the housing in such a way that it has a field of view of 180 degrees, and its angular characteristics fulfil the so-called ‘cosine response’ (see following sections).

2.1 Electrical Properties

The electrical circuit of the pyranometer is shown in Figure 3, below. Since the nominal output resistance of the SP-Lite is less than 50Ω the input resistance of the associated readout equipment should be at least 5000Ω in order to restrict any errors to less than 0.1%. This requirement is met by all Campbell Scientific dataloggers.

The SP-Lite cable can be extended up to 100 metres without problems, as long as the total cable resistance is less than 0.1% of the input impedance of the readout equipment.

The electrical sensitivity of the photodiode changes with temperature. A nominal value for this change is 0.2% change per °C. Calibration is carried out at 20 °C.

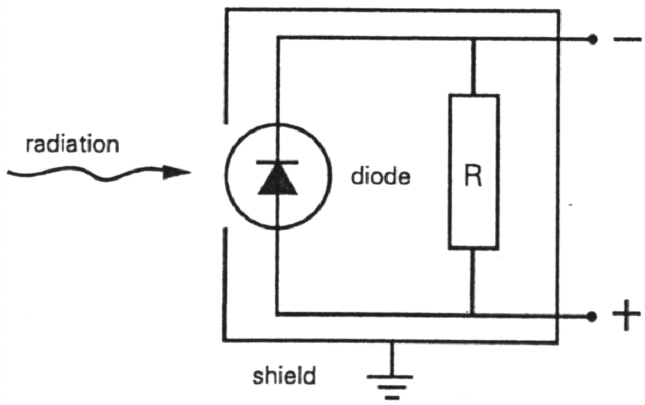

Figure 3 SP-Lite Electrical Circuit

2.2 Spectral Properties

The spectral properties of the SP-Lite are mainly determined by the spectral response of the photodiode, which is shown in Figure 4, below.

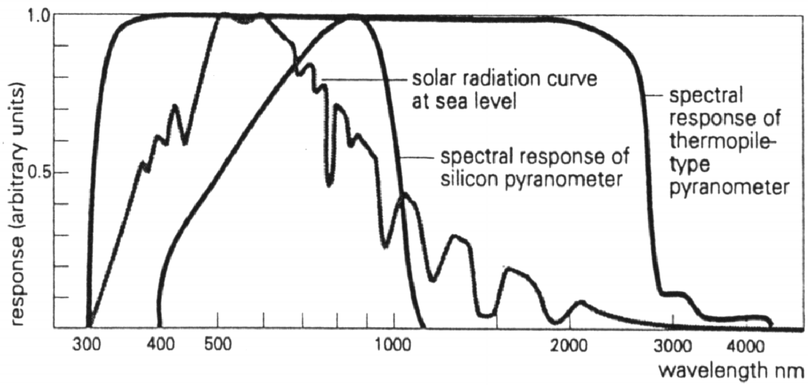

Figure 4 Spectral Sensitivity of Pyranometers Compared With Solar Radiation

The SP-Lite is calibrated for solar radiation under clear sky conditions. The spectrum for these conditions, at sea level, is also shown in Figure 4.

Unfortunately, however, the actual solar spectrum varies as a function of cloud cover, season and solar elevation. Since the pyranometer does not have a flat sensitivity across the whole solar spectrum, the accuracy of its response will vary. However, the error range across the whole spectrum has been proven to be small. The maximum total estimated error will only be in the region of ±5 percent when compared to the calibration conditions.

Both the spectral sensitivity and the photodiode sensitivity of the SP-Lite will change with temperature, and the separate effect of each of these changes cannot be easily determined.

2.3 Directional/Cosine Response

A perfect cosine response will show maximum sensitivity at an angle of incidence of zero degrees (perpendicular to the sensor surface) and zero sensitivity at an angle of incidence of 90 degrees (radiation passing over the sensor surface). At any angle between 0 and 90 degrees the sensitivity should be proportional to the cosine of the angle of incidence.

Figure 5 shows the behaviour of a typical SP-Lite. The vertical axis shows the deviation from ideal behaviour, expressed in percentage deviation from the ideal value.

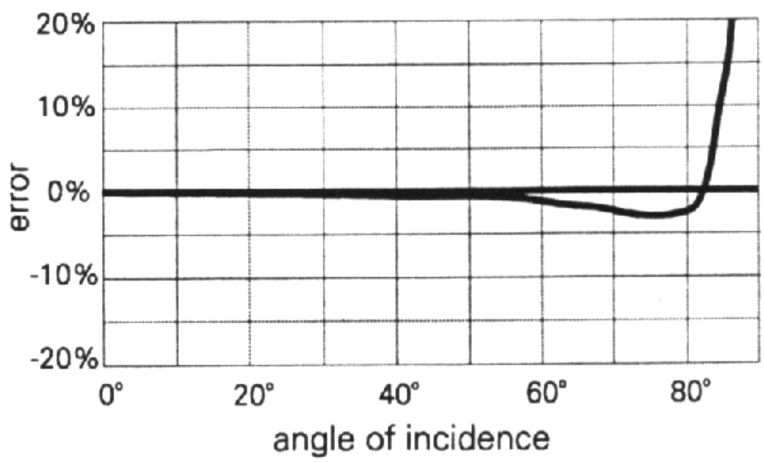

Figure 5 Cosine Response of a Typical SP-Lite Pyranometer

In Figure 5, 0 degrees zenith angle equals 90 degrees angle of incidence. The vertical axis shows the percentage deviation from ideal cosine behaviour.

3. Sensor Specifications

Electrical

Nominal Impedance:	<50Ω
Response Time:	<1 second
Sensitivity:	$10\mu V/Wm^{-2}$
Expected signal range: (under atmospheric conditions)	0 - 15mV
Stability:	<±2% per year
Non-linearity:	<±1% up to $1000Wm^{-2}$
Temperature dependence of sensitivity:	<±0.15% /°C

Spectral

Spectral range:	0.4 to 1.1µm
Detector type:	BPW 34

Directional

Cosine corrected between 80° angle of incidence, error:	within ±10%
Cosine errors averaged over opposite azimuth error (at 60° angle of incidence):	within ±10%
Tilt response:	zero error

Mechanical

Housing material:	Anodised aluminium
Cable material:	Polyurethane
Weight:	110g
Cable length:	Approx. 3 metres of free cable (can be extended up to 100m – see Section 2).
Physical Dimensions:	See Figure 2

Environmental

Working temperature:	-30 to +70°C

4. Calibration

4.1 Calibration Conditions

The SP-Lite is calibrated with reference to a Kipp & Zonen secondary standard sensor under natural sunlight during clear sky conditions.

Reference conditions are:

Mounting:	Horizontal
Incidence:	Normal
Temperature:	20°C
Irradiance:	500Wm^{-2}

The primary standard for solar radiation, against which the secondary standard pyranometer is calibrated, is the World Radiometric Reference.

4.2 Re-calibration

It is recommended that the SP-Lite is checked, and re-calibrated if necessary, every two years. The calibration can be checked by running the SP-Lite in parallel with a reference sensor for at least two sunny days, and then comparing the daily readings. The reference sensor should either be a higher standard pyranometer, or an SP-Lite that is kept stored and used solely for this purpose. If results differ by more than 5 percent, the sensor should be returned for re-calibration. Please contact Campbell Scientific or your local representative for further details.

5. Installing the SP-Lite

A new sensor will have been checked and calibrated before despatch, and so can be installed directly as shown below.

If you are going to install or re-install an older, previously used, sensor it is recommended that, before installation, you thoroughly check the sensor as described below. You can then determine and rectify any possible problems before committing the sensor to field use.

5.1 Field Installation

Install the SP-Lite onto a suitable mounting arm. When attaching to various Campbell Scientific weather stations, suitable mounting arms and brackets are supplied. See the appropriate weather station manual for further instructions.

Mount the sensor on the mounting arm so that no shadow will be cast on it at any time of day, at any time of year, from obstructions such as trees, buildings or the mast or structure on which it is mounted. In the northern hemisphere the instrument is normally oriented towards the South to avoid potential problems from shading.

NOTE The SP-Lite will only perform to specification under clear-sky conditions. It must not be mounted where it is subject to shade, beneath structures or beneath a plant canopy.

Although the SP-Lite will perform to specification only under clear-sky conditions, as stated above, it *can* be used to measure reflected radiation – for example when pointed towards the earth in an inverted position. However, since the spectrum of reflected radiation is different from that of incident radiation, significant errors may occur.

Mount the sensor on the mounting arm at a height of at least 1.5m above the ground surface to minimise shading effects and to promote spatial averaging. To ensure that the sensor can be accurately levelled, the basic SP-Lite is provided with a special adjustable mounting plate with a built-in bubble levelling gauge. Mount and adjust the sensor as follows:

1. Attach the main mounting arm to the pole or tower at the required height and secure in place. Make sure that the plate at the end of the arm is approximately level.
2. Attach the SP-Lite, complete with levelling plate, loosely to the mounting arm using the two long mounting bolts. Adjust the position of the SP-Lite by rotating the adjusting screws in the levelling plate until the bubble in the built-in level gauge is perfectly central.
3. Fully tighten the bracket, checking that the bubble remains central. If this results in the sensor becoming off-centre again, loosen the main bolts and re-adjust.

The sensor should be checked, and re-calibrated if necessary, every two years.

5.2 Checking Sensor Operation

It is always recommended that you check the operation of an older SP-Lite before installing/re-installing it at the start of a new field campaign.

To effectively check the instrument's operation, you will need:

1. The SP-Lite itself
2. A voltmeter, range 0 to 50mV, with an input impedance greater than 5000Ω. A datalogger may be used to check voltage readings if no voltmeter is readily available.
3. A light source

Position the SP-Lite so that the sensor is parallel to the surface that you want to investigate.

Follow the procedure outlined below:

1. Connect the SP-Lite wires to the voltmeter – white wire to voltmeter +ive terminal and the green wire to the -ive terminal and the shield to ground.
2. Select the most sensitive range on the voltmeter.
3. With the lamp switched off, and the sensor darkened, read the sensor output signal – this should read zero.
4. Switch on the lamp. The sensor should now produce a higher positive reading.
5. Adjust the range of the voltmeter so that the expected full scale output of the pyranometer is about the same as the range of the voltmeter. A (theoretical) way to calculate the maximum expected output for normal meteorological applications is shown below:

    Max. expected radiation +1500Wm^{-2}

    Sensitivity of the pyranometer 10µVW^{-1}m^{-2}

    Expected output range of the pyranometer is (1500x10) = 15mV

This calibration is valid only for natural daylight.

- Calculate the radiation intensity by dividing the pyranometer output by the calibration factor.

6. Wiring

You can use either single-ended or differential measurements to measure the output of the SP-Lite.

If making a differential measurement, connect the white (+) lead to the high side (e.g. 1H) of any datalogger differential channel and the green (–) lead to the low side (e.g. 1L). Also, connect a wire between the low channel and analogue ground to prevent common mode errors. Connect the shield lead to ground (G on the CR10/10X & CR500 and ⏚ on the CR23X, CR7 & 21X) .

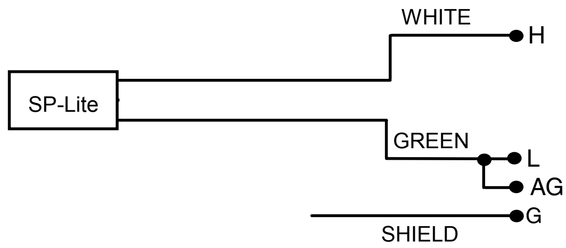

Figure 6 Wiring for Differential Measurements

If making a single-ended measurement, connect the white lead to any datalogger single-ended channel (H or L) and the green lead to analogue ground (AG on the CR10/10X & CR500 and ⏚ on the CR23X, CR7 and 21X). Connect the shield to ground as for differential measurements.

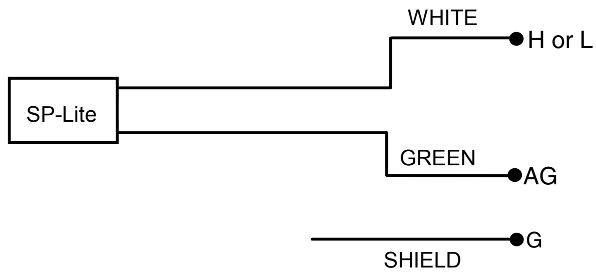

Figure 7 Wiring for Single-Ended Measurement.

7. Datalogger Programming

The SP-Lite outputs a low level voltage ranging from 0 to a maximum of about 15mV. A differential voltage measurement (Instruction 2) is recommended because it has better noise rejection than a single-ended measurement. If a differential channel is not available, a single-ended measurement (Instruction 1) 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.

7.1 Datalogger Input Range Codes

The output voltage of the SP-Lite is set to be 1.0mV per 100Wm^{-2}.

Normally the 15mV range for the 21X and CR7, the 25mV range for the CR10/10X and CR500, and the 50mV range for the CR23X are suitable.

The parameter code for the input range also specifies the measurement integration time. The slow or 50Hz rejection integration gives a more noise-free reading. A fast integration takes less power and allows for faster throughput.

7.2 Calibration Factor and Multiplier

Each SP-Lite is provided with a 'Certificate of Calibration' by the manufacturer which shows the sensor serial number and a 'sensitivity' or calibration factor. All sensors supplied to Campbell Scientific have a standard calibration of 10µV/Wm^{-2}.

The sensitivity factor provided by Kipp & Zonen is in units of µV/Wm^{-2}.

The multiplier to use in a datalogger program to give units of Wm^{-2} is 100.

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

Table 1 Multipliers Required for Flux Density and Total Fluxes

Units	Multipliers	
kJm^{-2}	m*t*0.001	(total fluxes)
kWm^{-2}	m*0.001	(flux density)
cal cm^{-2}	m*t*0.0239*0.001	(total fluxes)
cal cm^{-2} min^{-1}	m*1.434*0.001	(flux density)

where m = the calibration factor in Wm^{-2}/mV, i.e. 100
and t = the datalogger program execution interval in seconds

7.3 Partial Program Examples

The examples below give the appropriate datalogger code for the CR10/10X datalogger, using either Instruction 2 (differential) or Instruction 1 (single-ended).

7.3.1 Instruction 2 – Differential Input (Recommended)

```
{CR10X}
;

*Table 1 Program
  01: 1        Execution Interval (seconds)        ;as required

1:  Volt (Diff) (P2)
 1: 1        Reps
 2: 3        25 mV Slow Range      ;range code for CR10/10X
 3: 1        DIFF Channel
 4: 1        Loc [ Value_1   ]
 5: 100      Mult                  ;Calibration factor
 6: 0.0      Offset                ;in units of Wm-2 mV-1 (see above)
```

7.3.2 Instruction 1 – Single Ended Input

```
{CR10X}
;

*Table 1 Program
  01: 1        Execution Interval (seconds)        ;as required

1:  Volt (SE) (P1)
 1: 1        Reps
 2: 3        25 mV Slow Range       ;range code for CR10/10X
 3: 1        SE Channel
 4: 1        Loc [ Value_1   ]
 5: 100      Mult                   ;Calibration factor
 6: 0.0      Offset                 ;in units of Wm-2 mV-1 (see above)
```

7.4 Output Format Considerations

The largest number the datalogger can store in Final Storage is 6999 in low resolution and 99999 in high resolution. If the measurement value is totalised, there is some danger of overranging 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 totalise 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.

8. Maintenance

The SP-Lite is an 'all weather' instrument and is very stable, but should be handled with care. It requires little periodic maintenance, apart from cleaning the sensor surfaces carefully with a soft cloth using water or alcohol.

9. Troubleshooting

Pyranometer produces no apparent output

If your pyranometer does not appear to be working at all, do the following checks:

- Check the instrument's sensitivity to light, following the Pre-Installation Checking procedure shown in Section 5.
- If this appears to produce no results, measure the impedance of the sensor across the white and green wires. The impedance reading should be close to

50Ω. If it is less than 5Ω, a short circuit is indicated. If it is ‘infinite’, the sensor is damaged, or the cable is broken.

Readings are not as expected

- Under full sunlight the expected radiation value is about 1500Wm^{-2}. Under lamps it may be greater.
- Are you using the correct calibration factor?
  Did you convert the factor to the correct value for the datalogger program?
  (See Section 7, above).
- Check the datalogger program for errors.

If you cannot resolve your problems, please contact Campbell Scientific for further advice.