User Manual for the

Sunshine Pyranometer

type ***SPN1***

SPN1-UM-1.0

Delta-T Devices Ltd

Notices

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CE Conformity

The SPN1 Sunshine Pyranometer conforms to EU regulations regarding electromagnetic emissions and susceptibility and is CE marked by Delta-T Devices Ltd.

Warnings

To maintain conformance to CE standards, the equipment must be used as described in this manual. Modifications to the equipment may invalidate CE certifications.

Delta-T Devices Ltd reserves the right to change the designs and specifications of its products at any time without prior notice.

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Contents

Introduction

About this manual

This manual,describes the SPN1 Sunshine Pyranometer and how to use it. See also the *SPN1 Quick Start Guide*.

Appendix 1 describes the SPN1 design and includes a summary of the test results of several experimental trials of the SPN1.

The Delta-T Software and Manuals CD contains document files in Acrobat pdf format, and software. It includes this manual, the *SPN1 Quick Start Guide*, and other files relating to the SPN1. The CD also contains the SunRead software.

Description and functions

What it measures

- The SPN1 Sunshine Pyranometer is one sensor with three output channels:-
    1. Total (global) solar radiation
    2. Diffuse radiation
    3. Sunshine status.
- The SPN1 measures short wave radiation between 400nm and 2700nm in $W.m^{-2}$.
- The Direct beam component of solar radiation can be calculated from the Total minus the Diffuse component.
- The Sunshine status output indicates whether the energy in the direct beam exceeds the WMO standard threshold value of 120 $W.m^{-2}$, using an algorithm based on the Total radiation, and the ratio of Total to Diffuse radiation.
- The radiation outputs have a cosine-corrected response.

What it is used for

- Meteorological Global, Direct and Diffuse solar radiation and sunshine duration measurements.
- Solar energy monitoring, and solar collector studies.

- Architecture and building design, illumination and heat balance studies of buildings.

Advantages of SPN1

- It matches the WMO 'Good Quality' pyranometer classification.
- It requires no shadow band or solar tracker.
- There are no moving parts.
- It does not need to be adjusted or repositioned to track the sun – a distinct advantage over shade rings or mechanical trackers.
- It does not need to be oriented towards North. It will work accurately in any orientation as long as it is mounted horizontally.
- It does not require knowledge of the Latitude or Longitude, and can be used at any Latitude or Longitude.
- It measures sunshine hours as well as Total and Diffuse radiation.
- The built-in heater allows use in wet or icy conditions.

SunRead PC software

- The Delta-T Software and manuals CD contains SunRead Windows PC software that will read the SPN1 output values and status information via the PC RS232 serial port.
- SunRead also provides a basic logging capability while the SPN1 is connected to the PC.

Use with data logger

- The three outputs of the SPN1 can be logged with a suitable data logger. The Total and Diffuse radiation millivolt outputs require two analogue channels.
- The sunshine state logic output can be taken to a digital channel, or for some purposes can be connected to an analogue channel in order to give readings of sunshine duration.
- The SPN1 is a powered sensor, and requires a power supply of 2mA at 5V – 15V, from the datalogger, the heater supply, or elsewhere.
- The SPN1 heater requires a permanent power supply of 12V – 15V at up to 1.5A.

Use via serial port

- The SPN1 can be interrogated from any serial port program (eg Windows Hyper Terminal) - see Appendix B: RS232 commands.

Differences from BF2 and BF3

- The BF2 and BF3 use the same optical design as the SPN1, and have a similar set of outputs. The BF2 & BF3 use photodiodes rather than thermopile sensors and measure PAR rather than energy. They are not as rugged or as accurate as the SPN1.

Construction

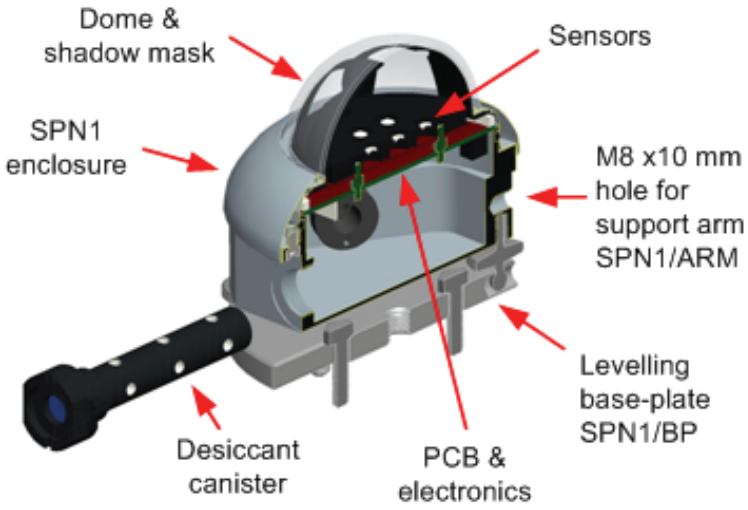
Seven thermopile sensors are mounted under cosine-corrected diffusers, all under a patterned, hemispherical dome, along with a levelling bubble, a desiccant-status indicator, and a red light emitting diode (LED). The LED flashes when the SPN1 is taking readings.

There are two external connectors, a 5-pin RS232 connector for serial communications, and an 8-pin connector for analogue signals and power.

The serial port is provided for checking real time readings, using the SunRead software, or for attachment to digital data collection systems. See also Appendix B: RS232 commands

The desiccant can be renewed by unscrewing the indicator plug from the side of the SPN1 and replacing the canister.

A fully adjustable levelling baseplate is also available.



Section through SPN1

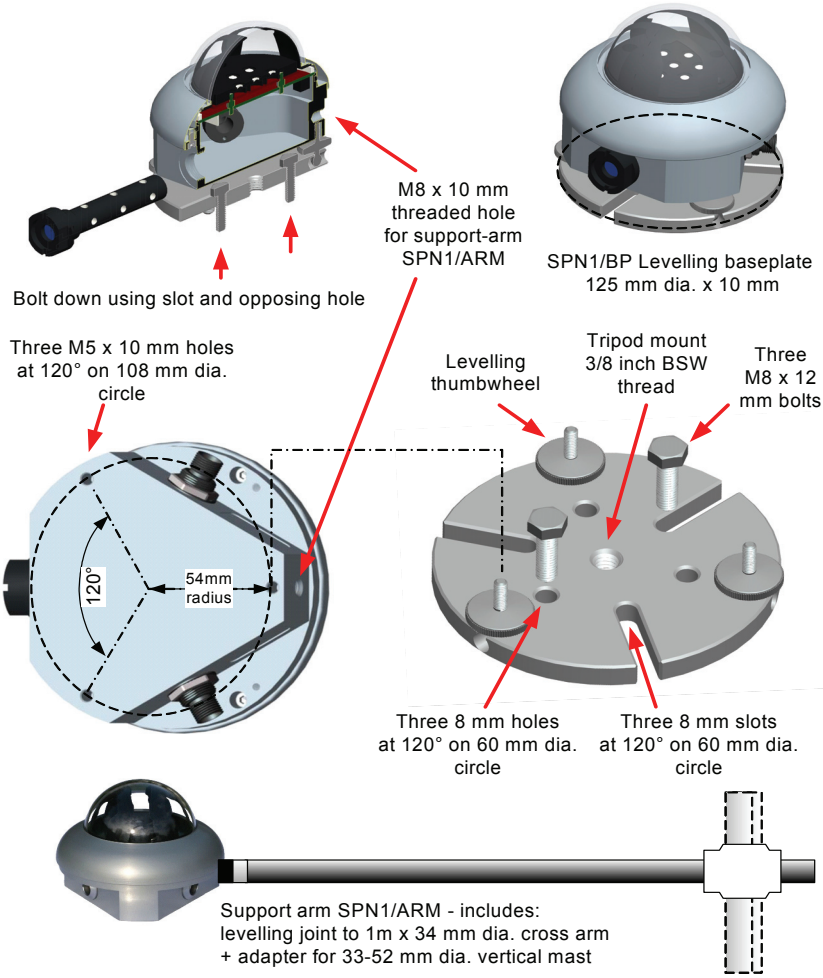
Accessories

See the Specifications on page 22 for a full list of accessories.

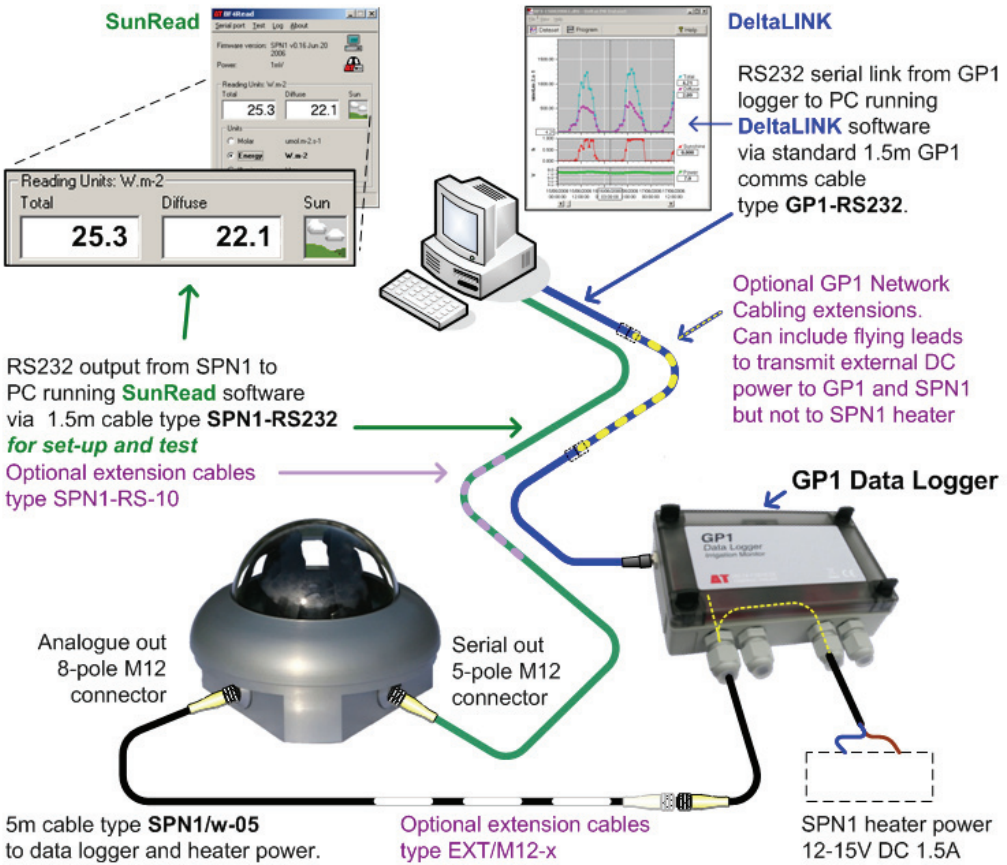
Mounting

The SPN1 may mounted either -

- directly onto a horizontal surface
- or via support arm type SPN1/ARM which includes an adapter for connecting to a vertical mast
- or on to the adjustable levelling baseplate (type SPN1/BP)



System Overview



Cables

The 8-core analogue cable type SPN1/w-05 is provided for connecting the SPN1 to a data logger and to carry power to the internal SPN1 heater. It is 5m long with a weatherproof M12 8-pole connector at the SPN1 and with bare wire flying leads at the logger end.

Analogue extension cables type EXT/M12-x, where x = 5, 10 or 25m are available for extending the cable from SPN1 to logger.

The 5-core serial cable type SPN1-RS232 is provided for connecting the SPN1 to a PC and is intended primarily for set-up and testing.
It is 1.5 m long and terminated in a 5-pole M12 connector at the SPN1 and a DB9 connector at the PC end.
Note: The DB9 connector is not weatherproof.

Serial extension cable type SPN1-RS-10 is available in 10 m lengths to extend the SPN1-RS232 cable. It terminates in IP-68 weatherproof M12 5-pole male and female connectors.

For extension cabling options from the PC to a GP1 logger see the *GP1/DL6 Network Quick Start Guide* on the Delta-T Software and Manuals CD

Power considerations

The SPN1 is a powered sensor. There are three possible sources of power:

1. Power from the data logger. This only needs to be applied when the logger takes a reading. The SPN1's Total, Diffuse and Sun outputs on the analogue output connector are valid 100ms after power is applied, and are updated every 100ms. These analogue outputs are only enabled when there is a voltage present on the data logger power input.
2. Power from the 12V heater supply.
3. Power from the serial cable. The SPN1 draws power from the PC DTR signal. Most computer serial ports will provide enough power for the SPN1 sensor electronics (but not its heater).

If more than one of these sources is present, then power is generally taken from the source with the highest voltage.

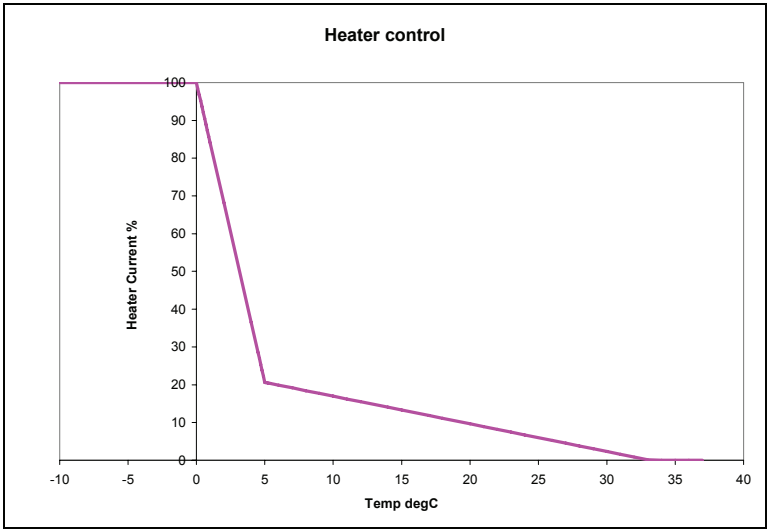
You can prevent power being drawn from the data logger by including a 10k resistor in the logger power cable, as long as power is available from elsewhere, e.g. from the heater supply.

Heater

The SPN1 is fitted with an internal thermostatically controlled heater for protection against frost and condensation. The heater is mounted on the shadow mask, which will transfer heat around the inside of the dome and the top of the enclosure.

When power is applied to the heater supply cables, it works as follows:-

- The heater current is controlled by a 4Hz pulse-width modulated switch.
- If the external temperature is below 0°C, the heater provides the full power available (up to 20W at 15V).
- Above 0°C, the power reduces smoothly to 20% at 5°C, and then down to nothing at 33°C.



At zero wind speed the dome will remain snow and ice-free down to minus 20°C.

At 2m.s^{-1} wind speed the dome will remain snow and ice-free down to minus 10°C.

In air temperatures below freezing the heater can consume 1.5A at 12V DC. A 40 Ah battery will only last about one day, so for extended data logging in cold climates, we recommended that you power the heater via a 12V DC supply powered from the mains.

Warning! Do not apply AC mains power to the SPN1.

Use with a data logger

Analogue outputs

The SPN1 is connected to a data logger via an 8-pole M12 waterproof connector using cable type SPN1/w-05. See also Cables on page 9. Additional weatherproof extension cables with M12 connectors at each end are also available (type EXT/M12-x where x = 5, 10 or 25m).

SPN1 analogue output connector pin-out (looking at pins on SPN1)

Signal Name	Pin No	SPN1/w-05 Cable	Cable Notes
Total	1 ----	White	Total output, 1mV = 1 W.m^{-2}
Diffuse	2 ----	Brown	Diffuse output, 1mV = 1 W.m^{-2}
SigGND	3 ----	Green	Signal ground (connected to DL-Gnd internally
Sun	4 ----	Yellow	Contact closure on sunshine
DL-Gnd	5 ----	Grey	Datalogger power ground
DL-Power	6 ----	Pink	Datalogger power supply 4 - 15V 2mA
Htr-	7 ----	Blue	Heater ground
Htr+	8 ----	Red	Heater power supply, 12V 1.5A max
Screen		**Screen**	Cable screen and SPN1 body

The Total, Diffuse and Sun outputs are active 100ms after a voltage is applied to the DL-Power cable, and are updated every 100ms.

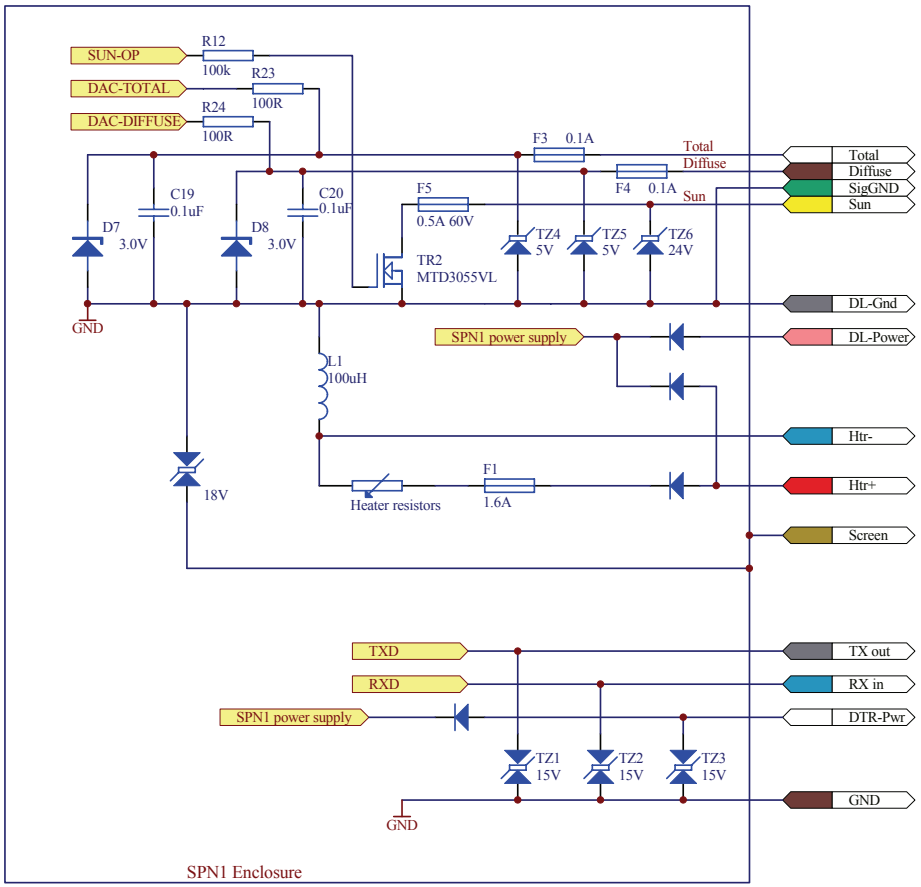
The Total and Diffuse outputs have a range of 0V – 2.5V (0V – 1.3V in normal daylight conditions), with an internal resistance of 100Ω. There is also some protection on these outputs if they are taken outside their normal range. These outputs should be measured by a high impedance voltage input channel, with SigGND taken to the negative input of the channel.

The sun output is switched by a FET (transistor) to ground. When there is no sun, this output is open-circuit. When there is sun, it is connected to ground. Any voltage applied to this output should be between 0V and 15V, with a maximum current capacity of 500mA (0.5A). If this output is used to switch more than a few milliamps, you should ensure that the current flows back through the DL-Gnd cable, and not the SigGND, otherwise there may be voltage errors in the Total and Diffuse measurements.

The DL-Power and DL-Ground connections provide power to the sensor circuitry (but not the heater), and enable the analogue output signals.

The Htr+ and Htr- cables provide power to the SPN1 heater. If this power supply is separate from the data logger power, it should be a fully isolated supply, so that no current flows between the power supply negative terminals.

Simplified output schematic



This schematic shows a simplified version of the output circuitry, protection components and grounding details.

The Total and Diffuse outputs are protected from electrostatic discharge (ESD) by the transient voltage suppressors TZ4-6, and from low voltage misconnection by the zener clamps D7 & D8, and resettable fuses F3 &

F4 (the fuses reset when the fault is removed). The Sun output has similar protection against ESD and overcurrent.

The heater circuit is protected against reverse connection and overcurrent. Htr- is connected to the main sensor ground by an inductor, to protect it from any noise in the heater circuit.

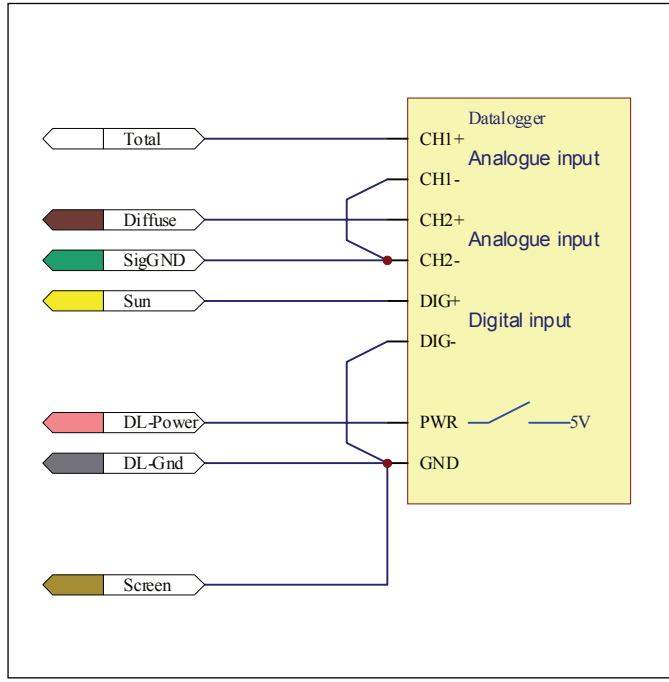
The serial port lines have basic ESD protection.

Suggested power supply connections

For use with a data logger, the DL-Power line has to be at 5V or more to enable the analogue outputs. The power required can be taken either from the DL-Power line, or the heater supply. For most logging situations, one of the following two connections is recommended.

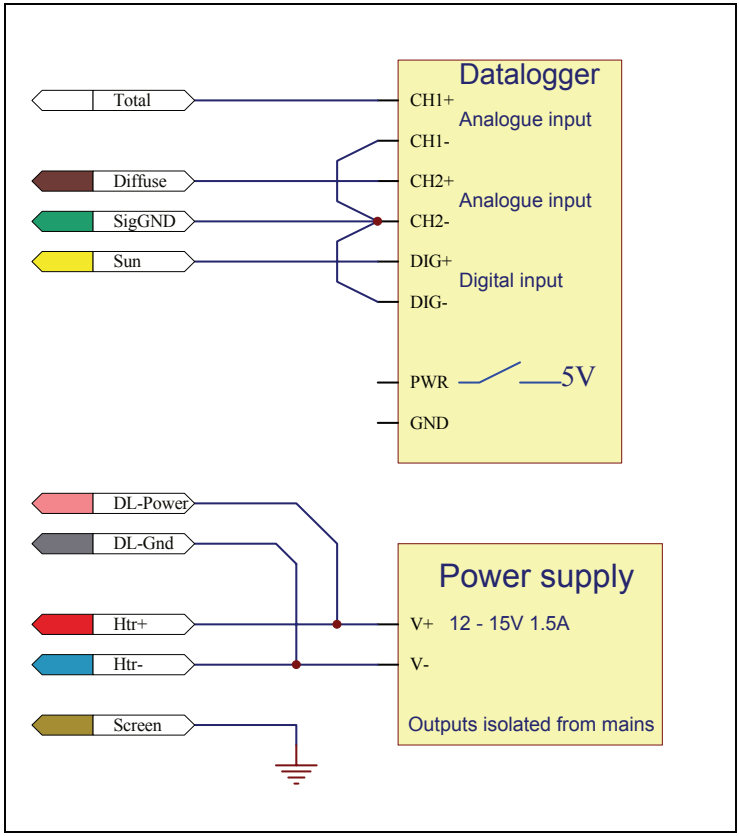
1 No heater, SPN1 powered by logger warmup

This connection would be appropriate for an isolated, battery powered logger such as the Delta-T GP1. The SPN1 heater is left disconnected. The logger must power up the SPN1 at least 100ms before the reading is taken.



2 Heater power available, SPN1 permanently enabled

This connection would be appropriate to an installation with permanent mains power available. The SPN1 heater is powered up, and the SPN1 analogue outputs are permanently enabled for logging.



Suggested Sun output connections

There are several possible ways of connecting up the SPN1 Sun output, depending on the capabilities of your data logger. The Sun output is open circuit when there is no sun, and connected to ground when there is sun.

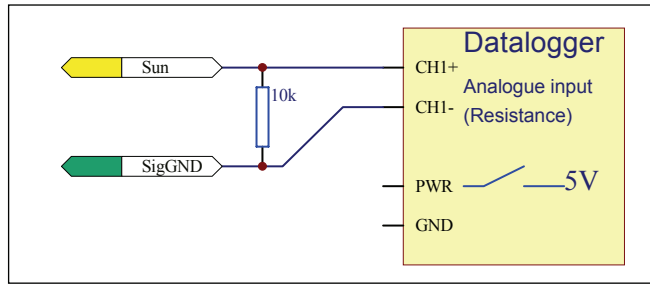
1 Logger digital input

In general this will be the simplest connection if your logger has a digital input. Connect as shown in the previous two diagrams. The logger digital input is usually referenced to logger ground, so you should take care only to connect this to SigGND if the logger is not supplying power for the SPN1. Otherwise, power supply currents may flow through the SigGND cable, which may cause voltage offsets on the Total and Diffuse readings with long cable lengths.

2 Logger resistance input

If the logger has no digital inputs, but can measure resistance, then the Sun output can be measured with a 10k resistor connected in parallel. This will be measured as 10k with no sun, and 0k with sun present. Disable any autoranging on the input.

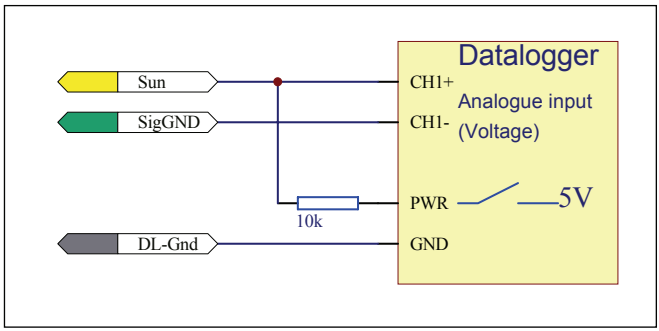
Note : The following scheme is for illustration only. Refer to your own logger user manual for the correct wiring instructions, which may be different.



3 Logger voltage input with pull-up resistor

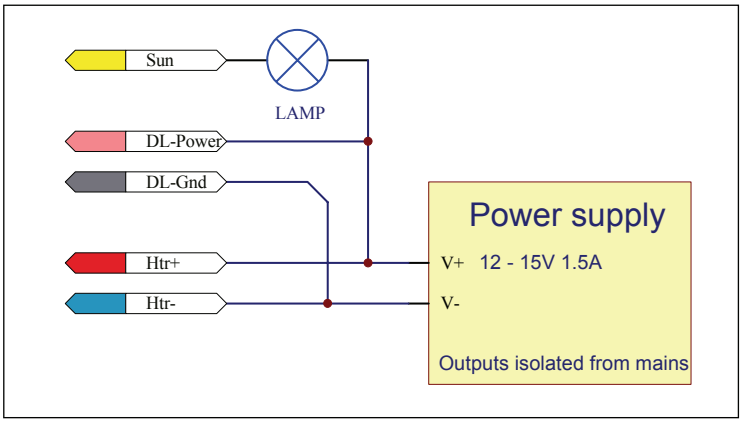
Alternatively, if a stable voltage is available in the logger, you can use a 10k pull-up resistor, and measure the Sun output with a voltage channel.

Sun present = 0 V, no sun = 5 V.
Note: Your logger must be able to read the voltage going into the resistor. If it is too high, use a potential divider.



4 Switching an external load

If for any reason you want to use the Sun output to switch a high current load, you should make sure that the current return path is through the DL-Gnd wire, and not the SigGND wire, otherwise you may see large offset voltages on your Total and Diffuse readings.



Ground and screen connections

Ground connections

There are three different ground connectors in the SPN1 analogue output cable (and another one in the serial cable), so it is possible to create offsets in the readings if these are used without care, especially with long cables. You also need to think about how the data logger ground is connected internally.

Some key principles to remember are:

- Ensure that no return currents flow in the SigGND wire. This should only go to the –ve terminal of a differential voltage input channel.
- Ensure that the current returns for the DL-Pwr wire and the Sun wire are through the DL-Gnd wire.
- Ensure that the current return for the Heater current (Htr+) is through the Htr- wire.
- If you use a logger and a separate power supply, then one of them must be able to float relative to the other, or they must share a common ground connection.

Earthing and screen connections

The braided screen of the 8-core analogue cable type SPN1/w-05 is connected to the SPN1 enclosure internally, creating a continuous screen around the sensor electronics and output connectors. The screen is connected to the sensor ground by an 18V transient suppressor - to minimise the possibility of high voltages relative to the internal circuitry if there are nearby lightning strikes.

In general the screen (black wire) should be connected to local earth near the logger. The SPN1 may also be connected to earth at its mounting point. If there is a lightning strike nearby, there may be large transient voltages induced between earth points, and in the sensor cabling. Some of this may also appear on the signal wires. Because of this, the logger should either be free to float relative to local ground, or should have some form of transient protection on its inputs to avoid damage.

The 5-core serial cable type SPN1-RS232 is screened. The screen is connected to the 5-pole M12 connector shell but not to the DB9 shell.

The 5-core serial extension cable type SPN1-RS-10 is also screened. The screen connects the M12 connector shells at both ends.

Delta-T data logger connections

GP1 logger

See the *SPN1 Quick start Guide* for a description of how to connect to and use a GP1 logger.

DL2e logger

See SPN1-DL2e wiring connections in the online sensor library of the Ls2Win PC software SR5 (service release 5) on the *Delta-T Software and Manuals CD.*

Note: If upgrading from an earlier service release of Ls2Win you will need to reinstall the sensor library. This is described in the online *Ls2Win Release Notes* installed with Ls2Win and which can be found from the **Start** menu under **Programs, Ls2Win, Documents.**

DL6 logger

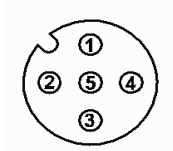
The DL6 logger is not suitable for use with the SPN1. The input voltage range is insufficient and we provide no SPN1 sensor types or program for it.

Warning: Do not attempt to attach an SPN1 to a DL6 via the 8 pole M12 connector on the DL6. It may damage the sensor.

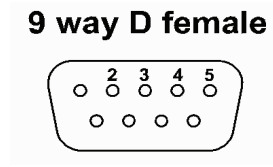
Use with a PC or serial device

Connect the SPN1 to a PC or other serial device via the 5-pole M12 waterproof connector.
Use the 1.5 m serial cable type SPN1-RS232 to connect directly to a PC serial port. This cable has a 5-pole mating connector and 9-pin D connector for the PC.
Note: The D connector is not weather proof, so should not be permanently used outside.

Use extension cable type SPN1-RS-10 for longer cable runs and for outside use – it terminates in weatherproof male and female 5-pole M12 connectors.



SPN1 serial connector pinout
(looking at pins on SPN1)



(solder side)

Signal Name	M12 Pin No	Cable colour	9 pin D female	Cable Notes
Gnd	1 ----	Brown	5	Ground
Power in	2 ----	White	4	Power from PC DTR line
RX in	3 ----	Blue	3	RS232 RX in to SPN1
SDI-12	4	Black		Not used
TX out	5 ----	Grey	2	RS232 TX out of SPN1

The SPN1 uses the serial connector for reporting readings, upgrading software, and for factory setup and testing.

The SunRead software on the Delta-T Software and Manuals CD can be used to give an immediate display of the SPN1 outputs, and to give a very basic logging capability.

The SPN1 sensor (not the internal heater) can take its power from the DTR signal of the PC serial port (about 4mA at 12V). Most PC serial ports will supply this. If you have problems communicating with the SPN1, then try using a USB-RS232 converter, or power up the SPN1 via the analogue cable type SPN1/w-05 (DL-Power or Htr+) from a logger or from an external power supply.

For power requirements see Other specifications on page 21.

See also: Appendix B: RS232 Commands on page 37.

Accuracy and errors

Overall accuracy limits are given in the specifications, which give the expected performance in normal use. There are some specific circumstances which may show unexpected results.

Spectral response

Because the SPN1 spectral response runs from 400nm upwards, it misses out some of the blue end of the solar spectrum, and this may show an under-reading of the diffuse component under very clear blue skies, or at high altitudes.

Cosine response

In relative terms, the cosine response error increases when the sun is close to the horizon. This may appear as an overall sensitivity error in clear-sky conditions when the sun is very low. This is true for all cosine-corrected sensors.

Errors due to inaccurate levelling also show up in these conditions – while a 0.5° levelling error has very little effect when the sun is high in the sky, or under overcast conditions, it can give a 5% output error when the sun is bright and 10° above the horizon.

Offsets

Most thermopile pyranometers show a negative output during the night, due to radiative cooling of the earth into space. The construction of the SPN1 includes three separating elements between the atmosphere and the thermopiles, so this effect is minimal. The electronics within the SPN1 will only measure and output positive signals, so the output should never go below zero. In general, there will be a small positive output ($<3 W.m^{-2}$) in dark conditions, due to the effects of noise in the system.

The SPN1 is sensitive to fast changes in temperature, and these will create a positive error on cooling, or a negative error on warming. This may be visible if you move the sensor from a warm room into a cold atmosphere outside, until the sensor reaches ambient temperature.

Thermopile matching

The SPN1 outputs are based on 7 individual sensor readings. The sensors are closely matched at calibration, but will never be exactly identical in all respects. These small variations will sometimes show up as small steps in the output time series, as the shadowmask shades or exposes different sensors.

Technical reference

Specifications

The SPN1 matches the WMO 'Good Quality Pyranometer' classification.

The following accuracy figures give 95% confidence limits, i.e. 95% of individual readings will be within the stated limits under normal climatic conditions.

Overall accuracy: Total (Global) and Diffuse radiation	±5% Daily integrals ±5% ±10 $W.m^{-2}$ Hourly averages ±8% ±10 $W.m^{-2}$ Individual readings
Resolution	0.6 $W.m^{-2}$ = 0.6 mV
Range	0 to >2000 $W.m^{-2}$
Analogue output sensitivity	1 mV = 1 $W.m^{-2}$
Analogue output range	0 – 2500 mV
Sunshine status threshold	120 $W.m^{-2}$ in the direct beam

Other specifications

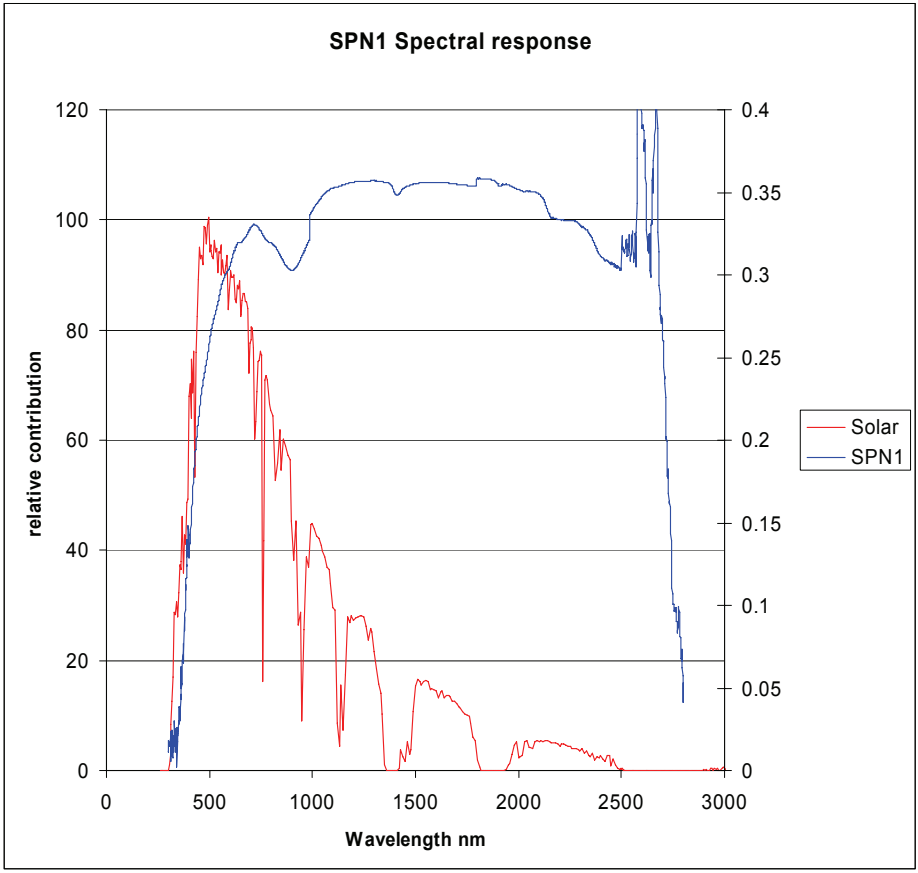
Accuracy: Sunshine status	±10% sun hours with respect to the threshold
Accuracy: Cosine correction	±2% of incoming radiation over 0-90° Zenith angle
Accuracy: Azimuth angle	± 5% over 360° rotation
Temperature coefficient	± 0.02% per °C typical
Temperature range	-20 to + 70°C
Stability	Recalibration recommended every 2 years
Response time	< 200 ms
Spectral response	400 - 2700 nm
Spectral sensitivity variation	10% typical
Non-linearity	< 1%
Tilt response	negligible
Zero offsets	< 3 $W.m^{-2}$ for a change of 5°C/hr in ambient temperature < 3 $W.m^{-2}$ dark reading
Latitude capability	-90° to + 90°

Environmental sealing	IP67
Sunshine status output	No sun = open circuit Sun = short circuit to ground
Power requirement	2 mA (excluding heater power), 5V – 15V DC
Heater power	12 V - 15 V DC, up to 1.5 A
Heater control	Continuously variable up to 20W output for external temperatures below 0°C
Lowest snow & ice-free temperatures (with heater in use)	-20°C at 0 m/s wind speed -10°C at 2 m/s wind speed
Mounting options	3 x M5 tapped holes in base at 108 mm dia, 120°spacing
Size & Weight	126 mm dia. x 94 mm high, 786g

Part numbers and order codes

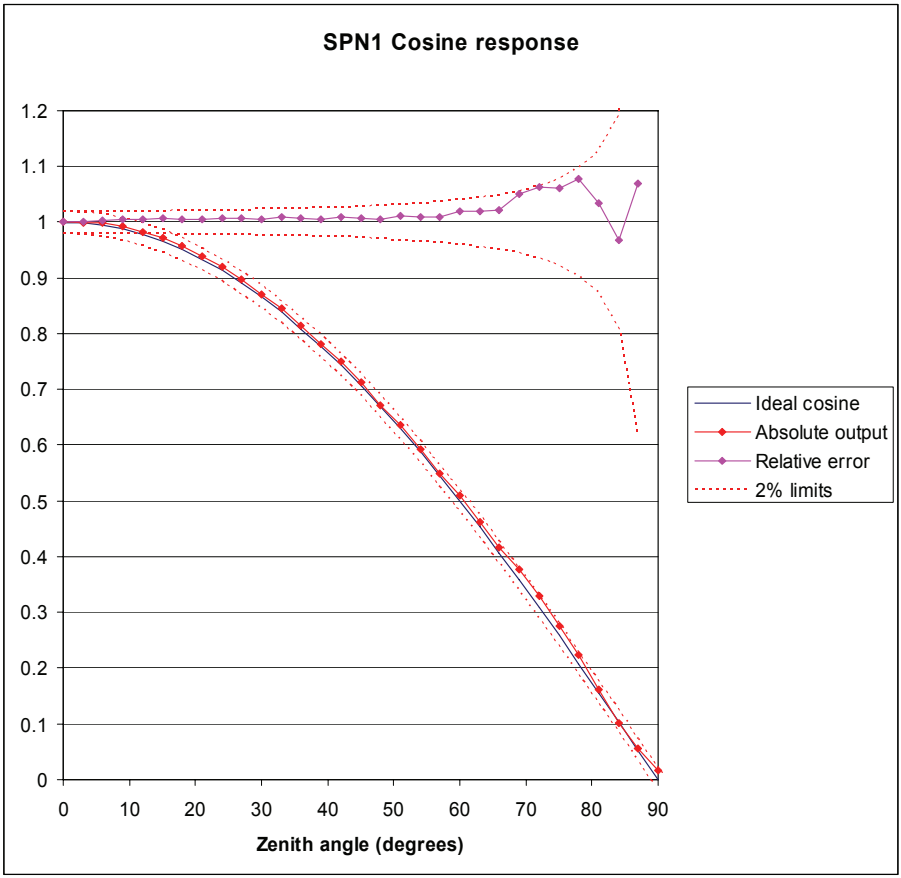
SPN1	Sunshine Pyranometer. Fitted with 5 and 8-pole M12 plugs. Supplied with 5m analogue signal and power cable type SPN1/w-05, 1.5 m serial cable type SPN1-RS232, SPN1 Quick Start Guide, calibration certificate and Delta-T Software and Manuals CD. Does not include leveling base-plate or support arm.
SPN1-RS-10	10m weatherproof RS232 extension cable. IP68 M12 5-pole male to female connectors. Connects SPN1 to SPN1-RS232 cable or to another SPN1-RS-10 cable.
SPN1/BP	Leveling base-plate. 125 mm dia. 10 mm thick plate with 3 M5 x thumbscrews and 3 M8 x 25 mm stainless steel bolts. See page 7
SPN1/ARM	Support arm for SPN1 with leveling joint. Length 1m, dia 34 mm with adapter for attaching to 33-52 mm dia. mast. Supplied with instruction sheet. See page 7
SPN1-SD	Spare desiccant for SPN1. 2 spare desiccant canisters (does not include RH indicator plug).
SPN1-UM	SPN1 user manual.
SPN1/w-05	5m analogue signal and power cable. 8 pole IP68 M12 connector (f) to bare wires. Connects SPN1 to data logger and/or power supply. Supplied as standard with Sunshine Pyranometer.
SPN1-RS232	1.5m RS232 cable. 5 pole IP68 M12 connector to 9-pole D sub connector. Connects SPN1 to PC serial port. Supplied as standard with Sunshine Pyranometer.
SPN1-CAL	SPN1 recalibration and service. Factory recalibration and 2 year servicing of SPN1.
EXT/M12-05 **EXT/M12-10** **EXT/M12-25**	5m / 10m / 25m SPN1 extension cables. 8 pole IP68 M12 female to male connectors. Connects SPN1 to SPN1/w-05 cable, or to any EXT/M12 cable.

SPN1 spectral response



This shows the spectral response of the Sunshine Pyranometer (thermopile, diffusers and dome combined), shown with the solar spectrum at ground level

SPN1 cosine response



This graph shows the typical cosine response of the Sunshine Pyranometer compared to the ideal cosine curve. The upper curve shows the relative accuracy

Routine maintenance

Desiccant

The humidity of the air inside the actual SPN1 dome is indicated by a coloured panel under the dome. The dessicant indicator plug has two more indicators. Blue indicates dry, pink indicates a humidity threshold has been exceeded. Renew when either the 50% RH indicator or the upper indicator in the dome goes pink

Check the desiccant indicators every 3 months. In most conditions, the desiccant should last over 6 months and usually for several years before it needs changing.

To replace or regenerate the desiccant

Remove the indicator plug from the SPN1, using a 24mm A/F spanner, or a wide flat-blade screwdriver. Unscrew the canister from the plug and replace it with a fresh one. Check the O-ring seal in the indicator plug is in good condition. Smear a very small amount of silicone grease on the O-ring to improve its sealing when you reinstall it. Fresh desiccant canisters are available from Delta-T.

The desiccant canister can be regenerated by heating. Heat the canister in a ventilated oven (not a microwave) for four hours at about 100ºC. Allow it to cool down away from moisture before reinstalling it.

Old desiccant can slowly lose its capacity (due to pollutants which bind permanently). To check it, weigh before and after drying. Saturated Si gel can carry 25% of its weight as water, so the 6gm in the canister should lose up to 1.25 gm if it dries from saturation, or ~0.6 gm drying from 50%.

If in doubt, replace with a fresh canister.

Make sure no dust or moisture gets into the SPN1 while the plug is unscrewed.

Maintaining the dome

Air pollution and residues in rain and snow can make the dome quite dirty.

A clean dome is essential to maintain the accuracy of the SPN1.

The dome is made of borosilicate glass. Clean it when necessary with a damp cloth moistened with mild detergent or isopropyl alcohol.

Treatment with a water-repellent coating such a “RainX” can reduce the amount of water and dirt on the dome. These are often sold for treatment of car windows or bathroom mirrors.

Environment and moisture protection

The SPN1 is designed for long-term outdoor use, and is sealed to IP67. It will withstand brief periods of full immersion, but should not be immersed continuously in water.

Internal condensation will be avoided if you keep the desiccant fresh.

Use the sealing caps supplied to protect any connectors you are not using from water and dust.

The SPN1 is robust, but does not have a drop test rating. The glass dome will break if you hit it. Do not drop it.

Calibration procedure and traceability

Factory calibration procedure

The SPN1 is calibrated at the factory against a transfer standard SPN1. Calibration is done before the shadow mask is fitted, so that all the thermopile sensors can be uniformly exposed. Units are calibrated in a 12 inch integrating sphere with a light source which approximately matches bright sunlight in intensity and spectral composition. The calibration factors required for each of the seven sensors are calculated and programmed into the SPN1. This matches the production unit to the reference, and spreads any cosine response variations evenly over the whole range of zenith angles.

After the shadow mask is fitted, the SPN1 reading is checked again in the calibration lamp rig.

The transfer standard SPN1s are periodically checked outside over a period of several weeks and a range of climatic conditions, against a solar tracker and shading disk system using two Kipp CM6B double dome reference pyranometers. These references are calibrated against UK national standards via a Kipp CM21 secondary transfer standard.

Recalibration of SPN1

We recommend that SPN1s are returned every 2 years to Delta-T for recalibration. A calibration certificate similar to that on the next page will be provided.

A full recalibration of the SPN1 is not possible without disassembling the SPN1, and requires special light sources.

Calibration Certificate

This is to certify that the Sunshine Pyranometer type SPN1 identified below has been calibrated in accordance with Delta-T Devices Ltd standard production procedures, and conforms to the specifications as detailed.

Serial Number	A100
Date	1 January 2007
Authorised Signature	

We recommend that this instrument is recalibrated every 2 years.

Traceability

The SPN1 is calibrated under a uniform light source which simulates the solar spectrum against a transfer standard SPN1. The transfer standard is calibrated outdoors against a Kipp CM21 secondary standard pyranometer (calibration traceable to the World Radiometric Reference), with solar tracker and shading disk for diffuse measurement.

Accuracy, Total (Global) and Diffuse radiation

When correctly calibrated, the expected accuracy is given in the table below. The figures give 95% confidence limits, i.e. 95% of individual readings will be within the stated limits under normal climatic conditions.

Overall accuracy:	±5% daily integrals ±5% ±10 $W.m^{-2}$ hourly averages ±8% ±10 $W.m^{-2}$ individual readings
Range	0 to >2000 $W.m^{-2}$
Analogue output sensitivity	1mV = 1 $W.m^{-2}$

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Warranty and service

Terms and conditions of sale

Our Conditions of Sale (ref: COND: 1/00) set out Delta-T's legal obligations on these matters. The following paragraphs summarise Delta-T's position but reference should always be made to the exact terms of our Conditions of Sale, which will prevail over the following explanation.

Delta-T warrants that the goods will be free from defects arising out of the materials used or poor workmanship for a period of **twelve months** from the date of delivery.

Delta-T shall be under no liability in respect of any defect arising from fair wear and tear, and the warranty does not cover damage through misuse or inexpert servicing, or other circumstances beyond our control.

If the buyer experiences problems with the goods they shall notify Delta-T (or Delta-T's local distributor) as soon as they become aware of such problem.

Delta-T may rectify the problem by replacing faulty parts free of charge, or by repairing the goods free of charge at Delta-T's premises in the UK, during the warranty period,

If Delta-T requires that goods under warranty be returned to them from overseas for repair, Delta-T shall not be liable for the cost of carriage or for customs clearance in respect of such goods. However, we much prefer to have such returns discussed with us in advance, and we may, at our discretion, waive these charges.

Delta-T shall not be liable to supply products free of charge or repair any goods where the products or goods in question have been discontinued or have become obsolete, although Delta-T will endeavour to remedy the buyer's problem.

Delta-T shall not be liable to the buyer for any consequential loss, damage or compensation whatsoever (whether caused by the negligence of the Delta-T, our employees or distributors or otherwise) which arise from the supply of the goods and/or services, or their use or resale by the buyer.

Delta-T shall not be liable to the buyer by reason of any delay or failure to perform our obligations in relation to the goods and/or services, if the delay or failure was due to any cause beyond the Delta-T's reasonable control.

Service and spares

Users in countries that have a Delta-T Distributor or Technical Representative should contact them in the first instance.

Spare parts for our own instruments can be supplied from our works. These can normally be despatched within a few working days of receiving an order.

Spare parts and accessories for sensors or other products not manufactured by Delta-T, may have to be obtained from our supplier, and a certain amount of additional delay is inevitable.

No goods or equipment should be returned to Delta-T without first obtaining the agreement of Delta-T or our distributor.

On receipt at Delta-T, the goods will be inspected and the user informed of the likely cost and delay. We normally expect to complete repairs within a few working days of receiving the equipment. However, if the equipment has to be forwarded to our original supplier for specialist repairs or recalibration, additional delays of a few weeks may be expected.

Technical support

Technical Support is available on Delta-T products and systems. Users in countries that have a Delta-T Distributor or Technical Representative should contact them in the first instance.

Technical Support questions received by Delta-T will be handled by our Tech Support team. Your initial enquiry will be acknowledged immediately with a “T number” and an estimate of time for a detailed reply (normally a few working days). Make sure to quote our T number subsequently so that we can easily trace any earlier correspondence.

In your enquiry, always quote instrument serial numbers, software version numbers, and the approximate date and source of purchase where these are relevant.

Contact details:

Tech Support Team
Delta-T Devices Ltd
130 Low Road, Burwell, Cambridge CB25 0EJ, U.K.
email for technical support: tech.support@delta-t.co.uk
email for repairs: repairs@delta-t.co.uk
web: www.delta-t.co.uk
Tel: +44 (0) 1638 742922
Fax: +44 (0) 1638 743155

Problems

Problem reports

Always try to isolate the source of the difficulty. It will help considerably if you can mention as many relevant details as possible. In particular:

- A description of the fault, its symptoms, or error messages
- If logging, what logger you are using, details of the logging program and any other devices connected to it
- Details of any PC you are using
- Software version numbers and hardware serial numbers (see below)

Locating version and serial numbers

The SPN1 serial number label is on the lower part of the case. The internal software (firmware) version number is displayed in the About box using SunRead.

Troubleshooting

SPN1 not responding

The red LED inside the SPN1 bezel will flash when the SPN1 is taking readings.

If using the RS232 cable check that you are using the correct cable, and that it is plugged into the same serial port on your PC that you have selected in the SunRead software.

If logging, check the logger cable and compare with your logger wiring connection diagram. Make sure that the DL-Power wire is connected to >5V to enable the analogue outputs.

Check also your logger. For Delta-T loggers check the sensor configuration, power warm-up relay wiring connection and warm-up relay program configuration.

Unexpected output readings

Pay particular attention to the power supply and grounding arrangements.

Try operating without the heater connected and see if that affects the readings.

Try logging the SPN1 direct to a PC using the SunRead software.

Make sure the desiccant is fresh and the dome is clean.

Appendix A: Design and test summary

This appendix gives a brief description of how the SPN1 design works and a summary of the results of the test program. More detailed versions of these are available from Delta-T.

Introduction

Measurement of Direct and Diffuse components of solar radiation has many applications - in modelling the interaction of light with crop canopies, studying the energy balance of structures, or as a meteorological indicator. Instruments that make these measurements have generally been expensive and require considerable attention.

One common approach has been to have two sensors, one measuring radiation from the whole sky, the other measuring the whole sky apart from the sun. The shading is generally done using a shade ring, adjusted to match the track of the sun across the sky for that day, or using an occluding disk held on a robot arm. Both of these approaches require accurate alignment to the Earth's axis, and regular adjustment.

Another well established approach is the Campbell-Stokes recorder, which uses a glass sphere to focus the Direct solar beam onto a recording chart causing a burn, which indicates Direct beam strength.

Design objectives

The aim of the SPN1 design was to measure the Direct and Diffuse components of incident solar radiation, and provide a measure of sunshine hours, in a sensor that used no moving parts, and required no specific polar alignment or routine adjustment. The outputs should be compatible with electronic data loggers, and work at any latitude.

How the design evolved

The prime requirement for this design was to create a system of radiation sensors and a shading pattern such that wherever the sun is in the sky:

- at least one sensor was always exposed to the full solar beam
- at least one was always completely shaded
- all sensors receive equal amounts of Diffuse light from the rest of the sky hemisphere.

A basic layout of 7 sensors on a hexagonal grid, covered by a patterned hemispherical dome was chosen. The dome pattern was generated by computer, using a specially designed evolutionary algorithm.

Calculation of outputs

The shadow pattern consists of equal areas of black and clear bands. This means that all of the sensors receive 50% of the Diffuse radiation, sampled from all over the sky, and at least one sensor receives only this radiation. At least one sensor also receives the full amount of Direct radiation from the sun. Which particular sensors these are depends on the position of the sun in the sky, but the fully exposed one is always the sensor which receives the most radiation, and the fully shaded one the least. All the sensors are measured by the electronics, and the maximum and minimum of the seven readings are used. The maximum reading represents the Direct radiation + half of the Diffuse radiation, the minimum reading represents half of the Diffuse radiation. The outputs are calculated as follows:

Diffuse = 2 * MIN

Direct = MAX - MIN

Total = Direct + Diffuse = MAX + MIN

The Total and Diffuse values are used for the instrument output.

Note: This analysis is independent of the spectral characteristics of the individual sensors, or their spatial response.

Calculations – SPN1 outputs

Let MAX and MIN be the largest and smallest thermopile reading of the seven thermopiles, after being adjusted for any calibration factors (calibration is done in the solar lamp integrating sphere against a transfer standard SPN1)

Then TOTAL = MAX + MIN

DIFFUSE = 2 x MIN x 1.02 (the extra 2% takes away a small systematic bias due to there being typically a 1%-2% spread between sensors under identical lighting conditions).

IF (DIFFUSE > TOTAL) then DIFFUSE = TOTAL (a sanity check as Diffuse obviously can't ever be greater than Total in reality)

There is then a further correction due to the spectral response of the sensors giving a different sensitivity to direct and diffuse light in most conditions:

DIRECT = (TOTAL - DIFFUSE) x 0.99

DIFFUSE = DIFFUSE x 1.14

TOTAL = DIRECT + DIFFUSE. (TOTAL & DIFFUSE are output)

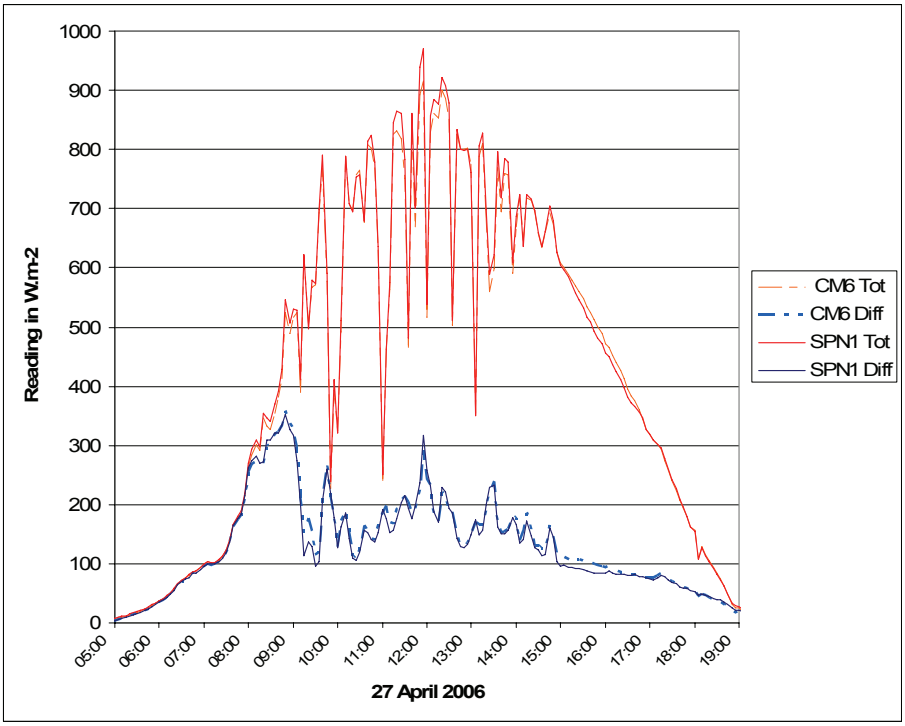
The sunshine presence output is calculated using the ratio of Total and Diffuse:

SUNSHINE if TOTAL/DIFFUSE > RATIO AND TOTAL > 24 $W.m^{-2}$

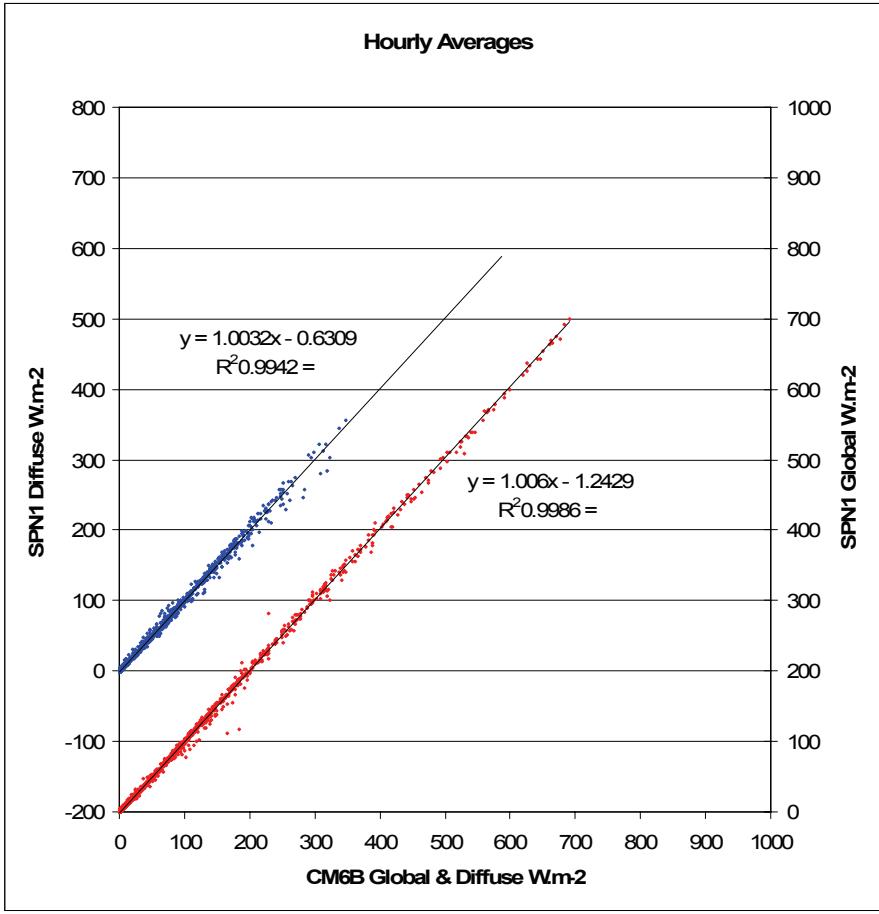
The value of RATIO is 1.35 for a standard SPN1 with a 120 W.m^{-2} direct beam threshold, and 1.55 for the MeteoSwiss variant of the SPN1 which has a 200 W.m^{-2} direct beam threshold. The 24 W.m-2 value cuts out times when the radiation is so low that there cannot be any direct sunshine, but the TOTAL/DIFFUSE value may be high due to noise or offsets dominating the low reading values.

Test results

SPN1 output

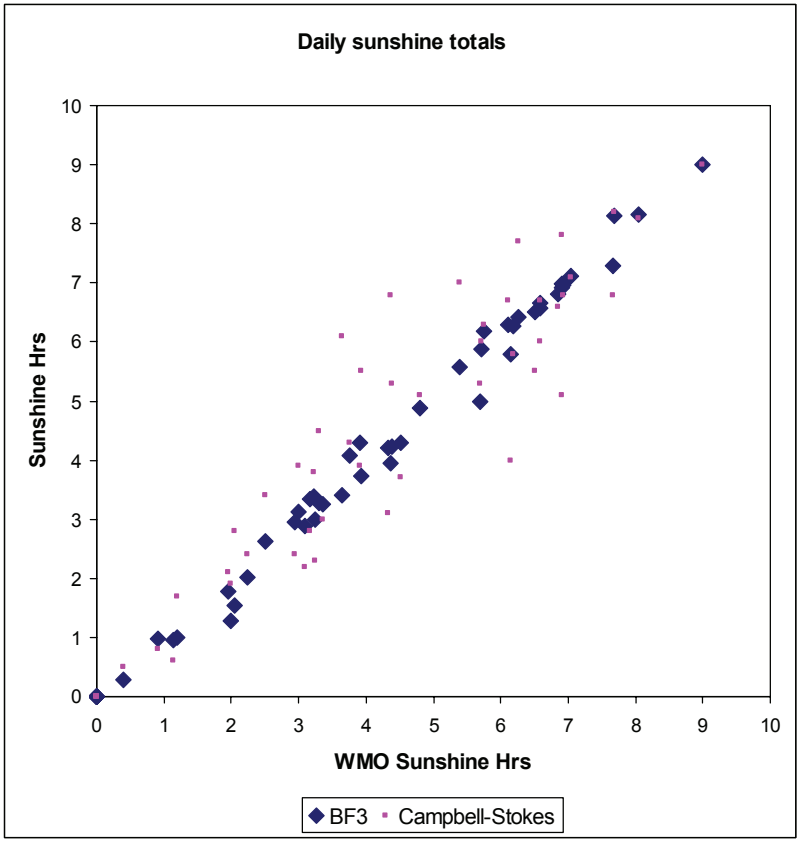


This graph shows a typical daily output from the SPN1. It is plotted against two Kipp CM6 pyranometers, one shaded by a disk on a solar tracking arm. This day started overcast, with cloud breaking up during the middle of the day, followed by a cloudless evening.



This graph shows SPN1 Total (lower trace) and Diffuse (upper trace) outputs compared with two Kipp CM6s and a solar tracking shade disk. Data recorded at Winster, Derbyshire between September and December 2004. The graph plots hourly averages of readings every 5 seconds. Note the offset Y-axis to separate the Total and Diffuse plots.

Sunshine state



This graph shows daily sunshine totals measured by a BF3, compared to the WMO definition of 120 W.m-2 in the Direct beam. Data recorded at Napier University, Edinburgh between February and July 2001. Comparable data from an adjacent Campbell-Stokes recorder is also plotted. The SPN1 uses a very similar algorithm, and will give comparable results.

Appendix B: RS232 commands

All digital information can be output via the RS232 port (9600,N,8,1). This can be used for reading the sensor, as well as for production test and calibration functions.

Operating modes and serial commands

The SPN1 can be interrogated from any serial port terminal program such as Windows HyperTerminal.
Set the RS232 settings to 9600 baud, No parity, 8 Data bits, 1 stop bit., Flow control: none.
In HyperTerminal, also set 'Append line feeds to incoming line ends' in Settings > ASCII setup

A terminal screen option is also available in the SunRead software.
To access it , run the SunRead program from the command line as follows:-
Run SunRead.exe /e (Note the space before "/e").
Select **Test, Terminal** to open the Terminal mode

In the following tables, commands TO the sensor via RS232 are in **bold**, responses (also via RS232) are in normal weight. All RS232 input characters are echoed back except for the 'R' command.
For commands with more than one input character, a command is abandoned if the input is not within appropriate range, or 1 minute after a key press.
Unrecognised and aborted commands return '?'.

Sleep mode

Processor is in its lowest power state.
If the sensor is asleep when the DL-POWER pin goes high, then the sensor will wakeup and start to output the analogue values, as described above.
Any RS232 input will wake the sensor up for long enough to respond to the command. The suggested procedure is to send an '**R**', wait for the '»' response, then send the desired command, and wait for the terminating <CR>.

RS232 Input	Response	
R	» (ASCII 175)	For BF3 compatibility
S	tttt.t,dddd.d,s<CR>	Send the current reading, in comma separated ASCII. tttt.t & dddd.d are the Total & Diffuse readings, in $W.m^{-2}$. s is sunshine presence 0 or 1. A one off reading is taken when the command is received.

I	SPN1 v1.03 Mar 13 2007<CR> Units: W.m^{-2}<CR> 1mV radio off <CR> A106<CR> <CR>	Status information – code version Output units - W.m^{-2} Battery voltage, radio link status. (Neither normally installed in SPN1) Instrument serial number
T	TEST:	Enter TEST mode.
Z	2006/01/10 00:09:52	Displays a date and time (reset at power up)
?	I Status Info<CR> S Send data<CR> T TEST: mode<CR> Z Date & Time<CR>	A reminder of the command set
SOP		SOP (ASCII 15) marks a Start of Packet (used for downloading new firmware)
Any unrecognised character	? »	Any unrecognised character also causes the sensor to recalibrate its internal oscillator.

TEST mode

The sensor is permanently awake, and the analogue outputs are not updated. It will return to Sleep mode after 15 minutes with no key pressed. After completion of any command, <CR> and the TEST: prompt will be echoed. Any unrecognised character or incorrectly formatted input will return the sensor to Sleep mode. This mode is designed for manufacturing and technical support purposes, and is not intended to be accessed by the user or user software. The format of these commands may change without maintaining backwards compatibility.

WARNING – some of these commands can permanently affect the calibration of the instrument

RS232 Input	Response	Action
R	» (ASCII 175)	Returns to Normal mode.
Yyyyy/mm/dd	2007/03/14 00:45:39	Set the date
Hhh:mm:ss	2007/03/14 17:47:00	Set the time
Anr	A11 = 0806	Read the value of A/D n. r=0 reads with reference to Vcc, r=1 reads wrt 2.5V. Output is in A/D units 0000 – 4095
Bn	B1 145 38 249 235 231	Read the output of thermopile n. Output is in A/D units, and is updated every 250ms until receipt of another character. Backspace characters used to overwrite the display.

Cnnnn	OK	Calibrates thermopiles to value nnnn.(nnnn is any integer between 0000 and 2500 in $W.m^{-2}$). Updates values in user calibration area. If nnnn = 0000, then calibrate to average value of the 7 thermopiles.
CLEAR	OK	Resets the user calibration values to unity. Any previous calibration information is lost! (was 'K' previous to v1.03)
DEFAULT	OK	Copies contents of factory calibration area to user calibration area. (was 'D' previous to v1.03)
E	User: 04096 04096 … Factory: 04096 04096 …	Displays 7 calibration values (one for each thermopile) held in user and factory default areas. The displayed value should be divided by 4096 to give the actual value.
F	DCO 928 kHz	Reports frequency of main CPU clock
G	DCO 949 kHz	Calibrates frequency of main CPU clock
I	Therm temp 20.4øC Chip temp 34.5øC Batt 0 mV Ext 5874 mV Vcc 3299 mV 2006/01/10 00:02:43	Reports temperature of PCB thermister and internal CPU temp (can be very inaccurate) Reports battery voltage (not usually fitted on SPN1), external supply, and regulated Vcc. Also reports if DL-POWER or HTR-POWER inputs are active. Reports date & time (reset on power up)
Nc,nnnnn	OK	Sets user calibration factor for individual thermopile 'c' to 'nnnnn'. 04096 represents unity
Onnnn,nnnn		Sets DAC0 (Total output) and DAC1 (Diffuse output) to nnnn (0 – 4095, 2.5V full scale)
Pn.nx	<CR> or =X<CR>	If x is 0 or 1, sets CPU pin Pn.n to x If x is '=', reads value of pin Pn.n
Q	0 214 186 206 246 263 ….	Reports 8 raw A/D readings from thermopile channel 0 (ground) and 7 thermopiles.
S	266.7, 217.2,0 (1 195 170 187 226 242 163 154)	Reports calculated Total, Diffuse & sun outputs, and the raw thermopile readings used to generate them.
Tn.nn	<CR>ratio 1.35	Sets sunshine threshold ratio to n.nn (range 1.00 to 2.50) T<CR> just reports ratio.

WRITE	OK <CR>	Copies contents of user calibration area to factory calibration area. (Was 'W' previous to v1.03)
Xnccc<CR> **X<CR>**	string 0 A100 0: A100 1: 09-Mar-07 2: 7300-934 3: 8400-234 4: 5: 6: 7:	The sensor records 8 text strings of up to 16 characters each. Xnccc<CR> sets string 'n' to 'ccc' X<CR> reports all 8 strings. String 1 is serial number String 2 is calibration date String 3 & 4 are Main & thermopile PCB serial numbers Others as yet unused
?	Yyyyy/mm/dd Date Hhh:mm:ss Time An0, An1 read ADCn Vcc/Vref Bn read PD Cnnnn Calibrate CLEAR Set cal to 1 DEFAULT Restore default cal E cal values F Get DCO Freq G Set DCO to 1MHz I Status Info Nc,nnnnn set cal c to nnnnn Onnnn,nnnn set DACs Pn.nx read/set pin x is 01= Q Scan PDs R Reset to normal S Send data Tn.nn Sunshine ratio WRITE user cal to default XncccCR Write ccc to string Xn	A reminder of the TEST: command set.

Glossary

Azimuth angle - the horizontal angle between the sun, or a light source simulating the sun, and North, increasing in the direction NESW. The SPN1 does **not** have to be aligned towards North for correct operation (unlike most other devices).

Beam fraction - the fraction of Total incident radiation in the Direct beam.

Cosine response - the response of a sensor in which the sensitivity to a ray of light is proportional to the cosine of the angle of incidence of the ray (measured from the perpendicular to the sensor surface).

Diffuse light - light from parts of the sky other than directly from the sun, from scattering in the atmosphere or reflection from clouds.

Direct beam - light coming directly from the sun, with no scattering. Usually treated as if it comes from a point source.

Energy - radiation measured with equal sensitivity to the energy content regardless of wavelength. It is measured in units of $W.m^{-2}$. The normal daylight maximum is a little over 1000 $W.m^{-2}$.

Sunshine - the threshold for *bright* sunshine, defined by the WMO, is 120 W m^{-2} of Direct beam solar radiation, measured perpendicular to the direction of the beam. It is defined this way in order to ensure historical continuity with Campbell-Stokes recorders.

Total radiation - the sum of Direct beam and the Diffuse light.

Zenith angle - the angle between the centre of the sun and the point directly overhead.

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