APPLICATION NOTE

Eppley PSP
Precision Spectral Pyranometer

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Eppley PSP
Precision Spectral Pyranometer

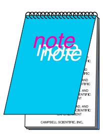
This application note describes interfacing a Campbell Scientific CR510, CR10(X), 21X, CR23X, or CR7 datalogger to an EPPLEY Precision Spectral Pyranometer (PSP). The PSP is a high quality pyranometer used for extremely accurate solar radiation measurements. It is often used as a standard to calibrate other pyranometers.

An instruction manual provided by EPPLEY contains the sensor calibration constant and serial number. Compare the manual's serial number with your PSP's serial number ensuring the calibration constant corresponds to your sensor.

Programming

The PSP outputs a low level voltage ranging from 0 to ~12 mV depending on sensor calibration and radiation level. A differential voltage measurement (Instruction 2) is recommended because it has better resolution and noise rejection than a single-ended measurement.

If a differential channel is not available, a single-ended measurement (Instruction 1) can be used. To determine the acceptability of a single-ended measurement, make both a single-ended and differential measurement then compare the results.



NOTE

NOTE FOR 21X USERS: *Slight ground potential differences are created along the 21X analog terminal strip when the datalogger power supply is powering external peripherals. If the peripherals draw 30 mA or greater, the PSP must be measured differentially.*

Selecting the Input Range

To choose the input range, estimate the maximum input voltage by using the following equation:

Max input voltage = (sensor calibration constant)(1.5 kW m^{-2} or maximum expected solar radiation)

The sensor calibration constant is listed in your EPPLEY instruction manual.

Once the maximum input voltage has been estimated, select the smallest input range that is greater than the maximum input voltage.

Example

A CR10X is used to measure a PSP. The calibration sheet for the PSP lists the following:

sensor calibration = 8.61 μV W^{-1} m^2

Since μV W^{-1} m^2 = mV kW^{-1} m^2, the estimate for the maximum input voltage is:

$$\text{max input voltage} = (8.61 \text{ mV kW}^{-1} \text{ m}^2)(1.5 \text{ kW m}^{-2})$$
$$= 12.91 \text{ mV}$$

The input ranges available for the CR10(X) are ±2.5 mV, ±7.5 mV, ±25 mV, ±250 mV, and ±2500 mV. Choose the ±25 mV range because it's the smallest input range that is greater than 12.91 mV.

Selecting the Integration Time

Measurement integration time is specified in the input range parameter code. A more noise-free reading is obtained with the slow or 60 Hz rejection integration and is recommended. See your datalogger manual for a complete discussion of integration time.

Calculating the Multiplier

The multiplier converts the millivolt reading to engineering units. Table 1 shows the multipliers used to convert the readings to various engineering units.

TABLE 1. Multipliers

UNITS	MULTIPLIERS
kJ m^{-2}	(1/C)*t
kW m^{-2}	(1/C)
cal cm^{-2}	(1/C)*t*(0.0239)
cal cm^{-2} min^{-1}	(1/C)*(1.434)

C = (EPPLEY calibration)
t = datalogger program execution interval in seconds

NOTE

If the irradiation is averaged, convert the mV reading to units of energy per unit time (e.g., kW m^{-2}, cal cm^{-2} min^{-1}). If the irradiation is totalized, convert the mV reading to units of energy (e.g., kJ m^{-2}, cal cm^{-2}).

Output Format Considerations

The largest number the datalogger can output in the low resolution format is 6999. If the measurements are totalized, the output may exceed the low resolution limit. There are two possible solutions:

Solution #1 - Record an average then, in the PC's post processing, multiply the result by the number of seconds in the output interval to get a totalized value.

Solution #2 - Record the measurements using the high resolution format which allows numbers as large as 99999 to be output. Use Instruction 78 to change this setting.

NOTE

The high resolution format consumes four bytes of Final Storage memory per data point, the low resolution consumes two.

For some totalized measurements (e.g., daily totals), the output may exceed even the high resolution limit (99999).

Example

To determine daily total flux, a scan rate of 1 second is used and the readings are converted to kJ m^{-2}. If the average irradiance is .5 kW m^{-2}, the maximum low resolution output will exceed the low resolution limit in less than four hours. One of the above solutions should be used.

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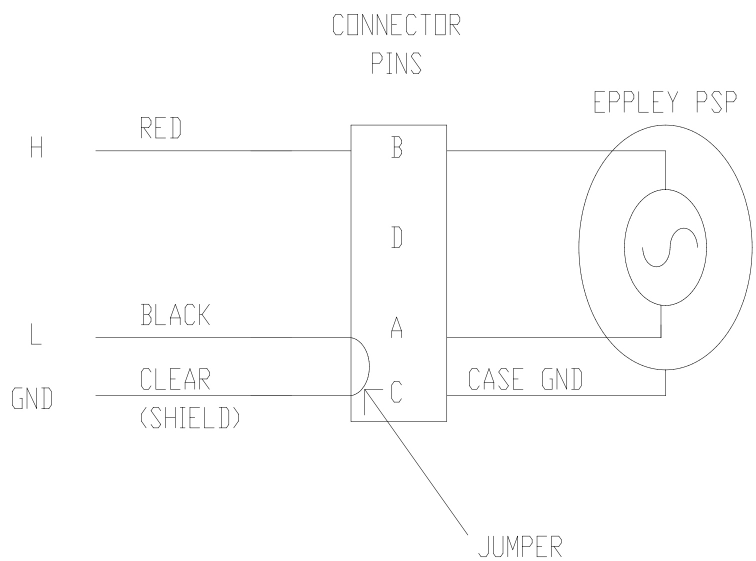
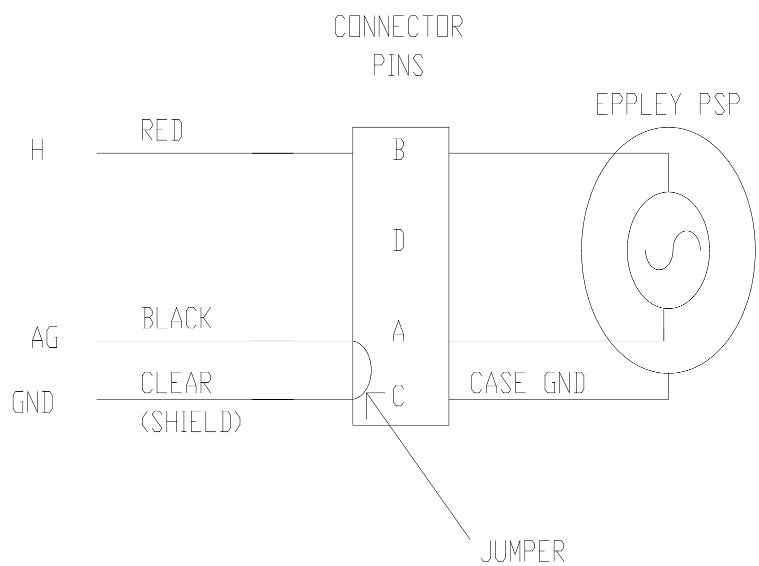
Wiring

Differential



The low side of the signal is jumpered to AG to keep the signal in the datalogger's common mode range

Single-Ended



Resolution

The Eppley PSP outputs approximately 13 mV at 1500 W m^{-2} (solar constant).

The resolution of measurements after the mV value has been converted to engineering units can be calculated using the following equation:

PSP Resolution = (DL resolution)(multiplier)

Where:

DL Resolution = the datalogger's resolution for the chosen input voltage range

Multiplier = the multiplier used to convert the mV signal to engineering units (see Table 1)

Examples:

The following examples assume the mV signal is converted to W m^{-2} and the calibration constant is 8.61 μV w^{-1} m^2. Since the mV reading is converted to W m^{-2}, the multiplier is 1/8.61 mV $W^{-1}m^2$.

CR10(X)

The best choice for the input range when the calibration constant is 8.61 μV W^{-1} m^2 is the ±25 mV range (see the Selecting the Input Range section).

The CR10(X) resolution for the ±25 mV range is 3.33 μV for differential measurements and 6.66 μV for single-ended measurements. The PSP resolution is:

PSP differential resolution = (±3.33 μV)(1/8.61 μV W^{-1} m^2)
= ±0.387 W m^{-2}

PSP single-ended resolution = (±6.66 μV)(1/8.61 μV W^{-1} m^2)
= ±0.773 W m^{-2}

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21X

The best choice for the input range when the calibration constant is 8.61 $\mu V\ W^{-1}\ m^2$ is the ±15 mV range. The 21X resolution for the ±15 mV range is 1 μV for differential measurements and 2 μV for single-ended measurements. The PSP resolution is:

PSP differential resolution $= (\pm 1\ \mu V)(1/8.61\ \mu V\ W^{-1}\ m^2)$
$= \pm 0.116\ W\ m^{-2}$

PSP single-ended resolution $= (\pm 2\ \mu V)(1/8.61\ \mu V\ W^{-1}\ m^2)$
$= \pm 0.232\ W\ m^{-2}$

System Accuracy

CR10(X) accuracy:
±0.2% of Full Scale Range $= \pm(0.002 * 25\ mV)\ (1/0.00861\ mV\ W^{-1}\ m^2)$
$= 5.81\ W/m^2$

21X accuracy:
±0.1% of Full Scale Range $= \pm(0.001 * 15\ mV)\ (1/0.00861\ mV\ W^{-1}\ m^2)$
$= 1.74\ W/m^2$

Eppley temperature dependence:
±1% over range from -20° to +40°C

Eppley linearity:
±5% over range from 0 to 2800 $W\ m^{-2}$

Eppley cosine response:
±1% over 0° to 70° range
±3% over 70° to 80° range

System accuracy calculation example:

When solar radiation is 1117 $W\ m^{-2}$ at 10°C from normal (1100 $W\ m^{-2}$ at 0°C) and the temperature is 25°C.

Calculate the system accuracy by taking the square root of the sum of the squares of random individual component accuracies.

$$= \pm[(5.8\ W\ m^{-2})^2 + (11\ W\ m^{-2})^2 + (5.5\ W\ m^{-2})^2 + (11\ W\ m^{-2})^2]^{-2}$$

$$= \pm 17.5\ W\ m^{-2} = \pm 1.6\%\ \text{of reading}$$

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