Biospherical Instruments Inc.

APPLICATION NOTE:

Sensitivity and Dynamic Range in ASCII Output Sensors

Application Note #: AN-2012-0005-Rev1

BSI DCN: 006413KA

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Sensitivity and Dynamic Range in ASCII Output Sensor

This application note applies to the Biospherical Instruments Inc. QSP, MCP, and QSR sensors with model numbers ending in 2150 and 2155.

BSI has a variety of output options available for single channel optical sensors, including linear-analog, log-analog, binary-digital, and ASCII-digital output. This application note discusses sensitivity and noise levels for the 2150 and 2155 series ASCII-encoded digital output, single channel sensors.

These sensors incorporate a 24-bit analog-to-digital converter (ADC), combined with a low-drift, electrometer-quality amplifier, and a precision instrumentation-grade silicon photodiode. A microprocessor controls the ADC, enabling digital averaging of multiple ADC readings, and application of the calibration equation to produce readings in "engineering units" using:

$$\textit{Output in ASCII} = \frac{\textit{ADC reading} - \textit{Dark reading}}{\textit{Calfactor}}$$

The ADC reading and dark reading are both expressed in volts, and the calibration factor (*Calfactor*) is in units per volt, where the units vary depending on the sensor design. For QCP, QSP, and QSR PAR[1] sensors, the units are usually microEinsteins per meters squared per second (μE m^{-2} s^{-1}), where an Einstein is a mole of photons or quanta. Circuit design constraints force the dark reading to values of a few millivolts positive.

The sensitivity of these sensors is set so that the maximum signal level is approximately twice that of full sunlight. In the case of a QSP-2150, the sensor is set to saturate at about 4700 μE m^{-2} s^{-1}—about twice the level of bright sunlight. The ADC operates at an internal rate of 125 Hz. Operating the sensor to report samples at 1 Hz (125 samples averaged), with the device capped and dark, returns a noise equivalent irradiance (NEI) of 0.00127 μE m^{-2} s^{-1}, which implies that the dynamic range is around 3.6 million. The resolution of the system is approximately 0.00056 μE m^{-2} s^{-1}.

1 Photosynthetically Active Radiation

The minimum meaningful signal level in actual operation of these sensors is determined by the stability of the readings when dark. This is controlled by the circuit design and components used, as well as their temperature stability. A typical QSP-2150 sensor, temperature cycled in the dark over a period of days (Fig. 1), exhibited a temperature coefficient of around 0.0008 μE m^{-2} s^{-1} per degrees Celcius (°C).

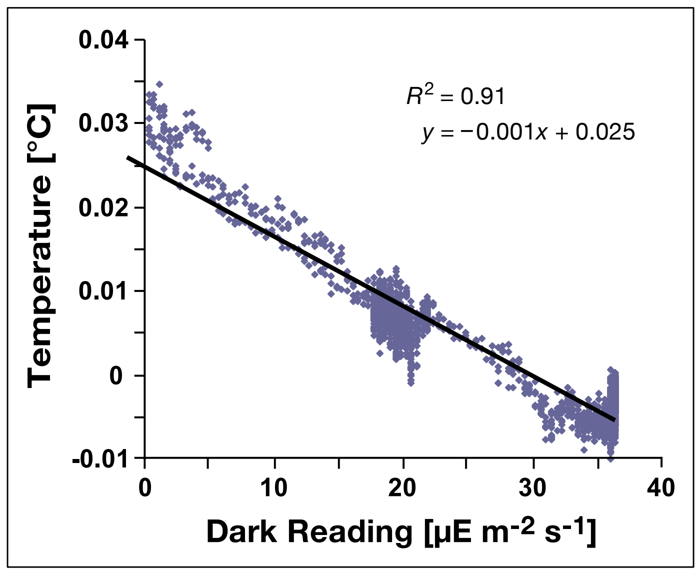

Figure 1. Temperature stability of the dark offset of a QSP-2150 sensor.

To put this in perspective, a QSP typical noise floor is about 0.002 μE m^{-2} s^{-1}. A sunny day can have a typical scalar PAR value of 2000 μE m^{-2} s^{-1}, which means that measurements with a signal-to-noise ratio (SNR) of 100 can be made down to 0.2 μE m^{-2} s^{-1}—a factor of 1/10,000 times full sunlight. Using the same assumptions, but operating over a temperature range of ±10°C relative to the temperature where the dark offset was measured, decreases this range to (20×0.0008 = 0.016) 2000 to 1.6 µE m^{-2} s^{-1} or 1/1,250 times full sunlight. These sensors easily measure light over the full euphotic zone. Some applications, such as fish migration studies, require a greater range, and characterization of the temperature response of the dark offsets can considerably improve the dynamic range.

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