PAR Sensor

(PAR-BTA)

The PAR (Photosynthetically Active Radiation) Sensor measures photosynthetic light levels in both air and water. The sensor responds to visible light in the spectral range that is used by plants in photosynthesis (400–700 nm). It features a waterproof sensor head and reports the Photosynthetic Photon Flux Density (PPFD), which is measured in $\mu\text{mol m}^{-2}\text{ s}^{-1}$ (micromoles of photons per meter squared per second). The sensor is calibrated for use in sunlight, but can also be used to measure PPFD from electric light sources. This sensor is ideal for experiments that investigate photosynthesis and primary productivity and can also be used in many agricultural and environmental science applications.

What is Included with the PAR Sensor

- Vernier PAR Sensor
- Cover for the lens of the PAR sensor

NOTE: Vernier products are designed for educational use. Our products are not designed nor are they recommended for any industrial, medical, or commercial process such as life support, patient diagnosis, control of a manufacturing process, or industrial testing of any kind.

Collecting Data with the PAR Sensor

This sensor can be used with the following interfaces to collect data.

- Vernier LabQuest® 2 or original LabQuest as a standalone device or with a computer
- Vernier LabQuest Mini with a computer
- Vernier LabPro® with a computer or TI graphing calculator
- Vernier Go!®Link
- Vernier EasyLink®
- Vernier SensorDAQ®
- CBL 2™
- TI-Nspire™ Lab Cradle

Here is the general procedure to follow when using the PAR Sensor.

1. Connect the PAR Sensor to the interface.
2. Start the data-collection software.
3. The software will identify the PAR Sensor and load a default data-collection setup. You are now ready to collect data.

Data-Collection Software

This sensor can be used with an interface and the following data-collection software.

- **Logger *Pro* 3** This computer program is used with LabQuest 2, LabQuest, LabQuest Mini, LabPro, or Go! Link. Version 3.8.6.2, or newer, is required for use with the PAR Sensor.
- **Logger Lite** This computer program is used with LabQuest 2, LabQuest, LabQuest Mini, LabPro, or Go! Link.
- **LabQuest App** This program is used when LabQuest 2 or LabQuest is used as a standalone device. Version 2.2.1, or newer, is required if you are using LabQuest 2. Version 1.7.1, or newer, is required if you are using the original LabQuest.
- **DataQuest™ Software for TI-Nspire™** This calculator application for the TI-Nspire can be used with the EasyLink or TI-Nspire Lab Cradle.
- **EasyData App** This calculator application for the TI-83 Plus and TI-84 Plus can be used with CBL 2, LabPro, and Vernier EasyLink. We recommend version 2.0 or newer, which can be downloaded from the Vernier web site, www.vernier.com/easy/easydata.html, and then transferred to the calculator. See the Vernier web site, www.vernier.com/calc/software/index.html for more information on the App and Program Transfer Guidebook.
- **DataMate program** Use DataMate with LabPro or CBL 2 and TI-73, TI-83, TI-84, TI-86, TI-89, and Voyage 200 calculators. See the LabPro and CBL 2 Guidebooks for instructions on transferring DataMate to the calculator.
- **LabVIEW™** National Instruments LabVIEW™ software is a graphical programming language sold by National Instruments. It is used with SensorDAQ and can be used with a number of other Vernier interfaces. See www.vernier.com/labview for more information.

This sensor is equipped with circuitry that supports auto-ID. When used with LabQuest 2, LabQuest, LabQuest Mini, LabPro, Go! Link, SensorDAQ, TI-Nspire™ Lab Cradle, EasyLink, or CBL 2™, the data-collection software identifies the sensor and uses pre-defined parameters to configure an experiment appropriate to the recognized sensor.

Sensor Orientation

Sensor orientation is important for getting the best results from the PAR Sensor. When measuring PAR outdoors, the sensor head should be level, with the white lens pointing straight up toward the sky and with the cord pointing toward the north (in the Northern Hemisphere) or toward the south (in the Southern Hemisphere).

When measuring PAR from an artificial light source, the sensor head should be placed with the lens of the sensor facing the center of the light path.

Mounting the PAR Sensor

The PAR Sensor can be permanently mounted to a surface for continuous outdoor use. The sensor head is waterproof and the black electronics box is weatherproof. Care should be taken to keep the electronics box as dry as possible.

For best results, the sensor head should be leveled during mounting. The nylon 10–32″ x 3/8″ mounting screw found on the bottom of the sensor head can be used for attaching the PAR Sensor to a solid object.

The sensor should also be mounted such that obstructions do not shade the sensor (e.g., trees, weather station, cell phone tower). Once mounted, the protective cap should be removed from the sensor. The protective cap can still be used as a covering for the sensor when it is not in use.

Cleaning the PAR Sensor

Debris on the PAR Sensor lens will partially block the optical path and will lead to low readings. Dust and other organic deposits are best removed using water or window cleaner. Never use an abrasive cleaner on the lens. Salt deposits can also accumulate on the sensor lens over time due to evaporation from sea spray, sprinkler irrigation water, or wave splash. Salt deposits should be dissolved with vinegar and then removed using soft cloth or cotton swabs.

Specifications

PAR range		0 to 2000 µmol m^{-2} s^{-1} (in full sun)
Absolute accuracy		±5% (full scale)
Repeatability		±1%
Long-term drift		Less than 2% per year
Cosine response		
45º		±2%
75º		±5%
Spectral range		410–655 nm
Resolution LabPro, LabQuest, LabQuest 2, LabQuest Mini, Go!Link		1 µmol m^{-2} s^{-1}
Sensor dimensions		2.4 cm diameter by 2.75 cm height
Materials		Anodized aluminum with cast acrylic lens
Operating environment		–40 to 70˚ C 0–100% relative humidity Sensor head and cable can be submerged in water to electronics box.
Stored calibration values		
	slope	500 µmol m^{-2} s^{-1}/ V
	intercept	0

PAR Terminology

Radiation that drives photosynthesis is called photosynthetically active radiation (PAR) and is defined as the total amount of radiation across a spectral range of 400 to 700 nm. This means that an ideal PAR sensor would respond equally to all wavelengths of light between 400–700 nm. The summed amount of light across this range is called the photosynthetic photon flux density (PPFD) and is measured in units of micromoles per square meter per second (µmol m^{-2} s^{-1}). The term PPFD is often shortened to PPF (photosynthetic photon flux) by plant physiologists. The two terms (PPFD and PPF) are interchangeable.

Plant physiologists also refer to sensors that measure PPFD as quantum sensors. A quantum, in this case, refers to the minimum quantity of light (one photon) that is available for absorption by the photosynthetic pigments of plants. In other words, one photon is a single quantum of light that can be used by plants for photosynthesis. Based on this definition, the Vernier PAR Sensor is a quantum sensor.

How the PAR Sensor Works

The Vernier PAR Sensor consists of a waterproof Apogee Instruments SQ series quantum sensor and 5 m cable. The end of the cable is attached to a voltage amplifier located inside a black electronics box. A cable from the electronics box is then connected to the data-collection interface. The sensor head consists of an acrylic lens, filter, photodiode, and signal processing circuitry that is mounted in a waterproof aluminum housing that can be used for continuous PPFD measurements. The sensor head is cosine corrected. This allows the sensor to maintain accuracy when light hits the sensor head at different angles. Light hitting the lens of the sensor head produces an analog voltage that is amplified by the electronics box. This amplified voltage is then converted to PPFD by the data-collection software. The spectral response profile of the Vernier PAR Sensor is shown in Figure 1.

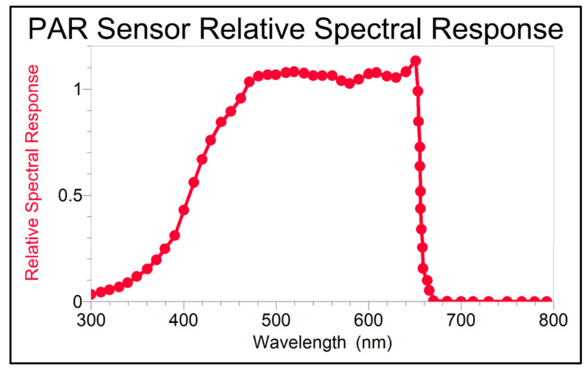

Figure 1

Calibration

The Vernier PAR Sensor is calibrated before shipping and should not need user calibration.

Optional Calibration Check

The Vernier PAR Sensor should not need to be calibrated, but you can verify the calibration using the Clear Sky Calculator (www.clearskycalculator.com). The Clear Sky Calculator for Quantum Sensors reports the theoretical PPFD at any time of day at any location in the world on a cloudless day. The application is most accurate at solar noon in the spring and summer.

Adjusting the Calibration Equation for use with Electric Lights

To measure PPFD from electric lights the slope of the calibration equation needs to be decreased by 14% (from 500 to 430). The instructions for adjusting the slope of the calibration equation are dependent on the data-collection software used.

Adjusting the Slope of the Calibration Equation using Logger *Pro* 3

1. Connect the PAR Sensor to a Vernier computer interface (LabPro, Go! Link, LabQuest Mini, LabQuest or LabQuest 2).
2. Choose Calibrate ▸ CH1: PAR from the Experiment menu.
3. Select the Equation tab in the Sensor Settings dialog box.
4. Change the slope from 500 to 430, then click Apply.
5. (Optional) If you wish to store the calibration on the sensor itself, click the Calibration Storage tab. If you wish to use the calibration only for the current experiment, skip to Step 8.
6. Click Set Sensor Calibration. Make sure the Default Page corresponds to your new calibration. Click Set.
7. Click Done. You will be prompted by the message, "Warning: You are about to change information in your sensor. Configuration data stored on the sensor will be lost. Pressing 'Write' will apply your changes to the sensor." Click Write.
8. Click Done to complete the calibration process. The PAR Sensor is now calibrated to measure PPFD from electric lights.

You have now stored the calibration on the sensor itself. This new calibration will be used from now on, until you replace it by conducting another calibration or by reverting to the factory calibration.

You can set the PAR Sensor back to its factory calibration by following these steps:

1. Choose Calibrate ▸ CH1: PAR from the Experiment menu.
2. Click the Calibration Storage tab.
3. Click Set Sensor Factory Defaults.

Adjusting the Slope of the Calibration Equation with LabQuest App

1. Connect the PAR Sensor to LabQuest. The PAR reading will be displayed.
2. Choose Calibrate ▸ CH1: PAR from the Sensors menu and tap Calibrate Now.
3. Select the Equation tab in the Sensor Settings dialog box.
4. Change the slope from 500 to 430. Tap Done.
5. (Optional) If you wish to store the calibration on the sensor itself, tap the Storage tab at the top of the screen. If you wish to use the calibration only for the current experiment, skip to Step 7.
6. On the Storage page, tap Save Calibration to Sensor. A message will appear: "Saving this calibration to the sensor will result in it being the new Custom Calibration 1". Tap OK to proceed.
7. Tap OK to complete the calibration process.
8. The PAR Sensor is now calibrated to measure PPFD from electric lights.

After you store a calibration to the PAR Sensor, this new calibration will be used automatically, regardless of the interface to which the PAR Sensor is connected.

You can set the PAR Sensor back to its factory calibration by following these steps:

1. Choose Calibrate ▸ CH1: PAR from the Sensors menu.
2. Tap the Storage tab.
3. Tap Restore Sensor Factory Defaults.

Suggested Experiments

Measure how PAR changes during the course of the day

In this activity, the PAR Sensor is mounted to a surface and placed outside. PAR measurements are then recorded during the course of the day. As shown in Figure 2, students can see how PAR levels reach their maximum near midday (12–1 pm) and then decrease during the afternoon. Students can make similar measurements over the course of several days, months, or the year to see how PAR levels change with the seasons, cloud cover, or other environmental variables.

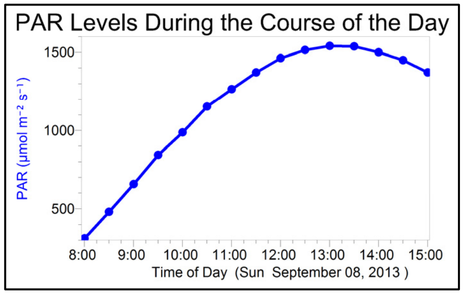

Figure 2

Measure how PAR changes with water depth

In this activity, the PAR Sensor is attached to an object, such as a Secchi disk. The PAR Sensor is then lowered into a body of water and the resulting PAR value is measured at different depths. As shown in Figure 3, students can quickly see how PAR decreases as a function of water depth. Students can repeat this study over the course of the year to determine how light levels in a body of water change seasonally. Students can also compare different bodies of water such as nutrient rich and poor lakes. Students could also add PAR measurements to any study that investigates the physical profile of a lake.

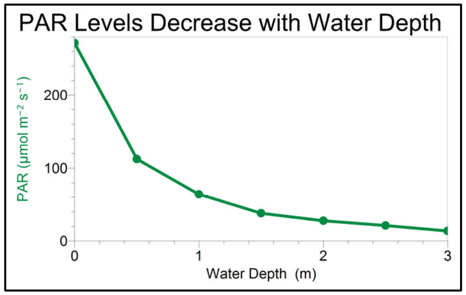

Figure 3

Investigate the role of PAR in Photosynthesis using leaves and a CO_2 Gas Sensor in the classroom

In this experiment, students measure the rate of photosynthesis at different PAR levels using a CO_2 Gas Sensor. Spinach leaves are placed in a respiration chamber and the CO_2 Gas Sensor is placed in the top of the bottle. The chamber is then placed next to an artificial light source. The PAR level is measured and then the rate of photosynthesis is determined over a period of 10–15 minutes. The experiment is repeated several times as the chamber is placed farther away from the light source. The PAR level at each distance is measured during the course of the experiment. As

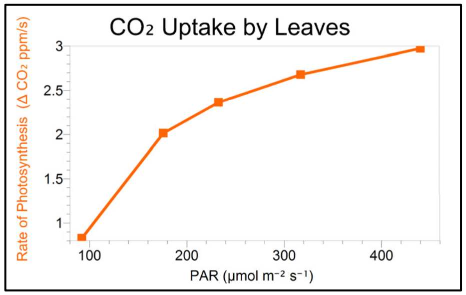

Figure 4

shown in Figure 4, students can determine that CO_2 consumption by the spinach leaves is directly related to PAR level.

Investigate the role of PAR in Primary Productivity

Samples of water containing algae (*Chlorella*) are exposed to different light levels for 21 hours. The PAR sensor is used to measure the PAR level to which each sample is exposed. Gross and net productivity are then calculated for each sample. As shown in Figure 5, primary productivity increases as the PAR level increases. This activity is similar to Experiment 17 in *Investigating Biology through Inquiry*.

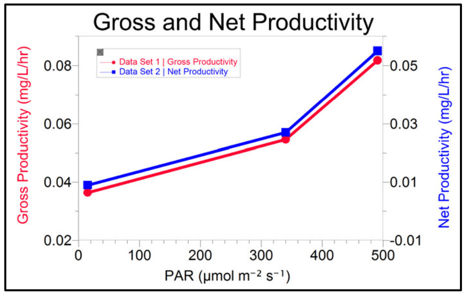

Figure 5

Related Products

Name	Order code
Optical Dissolved Oxygen Probe	ODO-BTA
Carbon Dioxide Gas Sensor	CO2-BTA
Extra-Long Temperature Probe	TPL-BTA
pH Sensor	PH-BTA
Conductivity Sensor	CON-BTA
Salinity Sensor	SAL-BTA
Water Quality Bottles	WQ-BOT

Warranty

Vernier warrants this product to be free from defects in materials and workmanship for a period of five years from the date of shipment to the customer. This warranty does not cover damage to the product caused by abuse or improper use.

Vernier

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Vernier Software & Technology

13979 S. W. Millikan Way • Beaverton, OR 97005-2886

Toll Free (888) 837-6437 • (503) 277-2299 • FAX (503) 277-2440

info@vernier.com • www.vernier.com

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