CO₂ Gas Sensor
(Order Code CO2-BTA or CO2-DIN)

The Vernier CO₂ Gas Sensor is used to monitor gaseous carbon dioxide levels in a variety of biology and chemistry experiments. It can measure small changes in carbon dioxide concentration in photosynthesis and respiration experiments. It measures gaseous carbon dioxide levels in the range of 0 to 5000 ppm by recording the amount of infrared radiation absorbed by carbon dioxide molecules. The CO₂ Gas Sensor allows students to
• measure increases in carbon dioxide levels from small animals and insects, such as crickets or worms.
• monitor the changes in carbon dioxide concentration in a plant terrarium during photorespiration and photosynthesis cycles.
• measure CO₂ levels during cellular respiration of peas or beans.
• measure changing carbon dioxide levels in a classroom.
• monitor the rate at which carbon dioxide is removed from an enclosed atmosphere using sodium hydroxide or potassium hydroxide.
• measure the rate of production of carbon dioxide in a chemical reaction between hydrochloric acid and sodium bicarbonate.
• determine the rate at which carbon dioxide gas diffuses through a gas diffusion tube.
• monitor production of carbon dioxide during fermentation or respiration of sugars.

NOTE: This product is to be used for educational purposes only. It is not appropriate for industrial, medical, research, or commercial applications.

Inventory of Items Included with the CO₂ Gas Sensor
Check to be sure that each of these items is included with your CO₂ Gas Sensor:
• 250-mL gas sampling bottle (Nalgene bottle with lid)
• Split rubber stopper to attach the gas sampling bottle to the sensor tube of the CO₂ Gas Sensor
• CO₂ Gas Sensor booklet

Using the CO₂ Gas Sensor with a Computer
This sensor can be used with a Macintosh® or PC computer and any of the following lab interfaces: Vernier LabPro™, Universal Lab Interface, or Serial Box Interface. Here is the general procedure to follow when using the CO₂ Gas Sensor with a computer:
1. Connect the CO₂ Gas Sensor to the appropriate port on the interface.
2. Start the data collection software on the computer. If you are using a Power Macintosh or Windows® computer, run the Logger Pro™ software. If you are using older Macintosh, MS-DOS®, or Windows 3.1 computers, run the Data Logger program.
3. Open an experiment file for the CO₂ Gas Sensor and you are ready to collect data.
Using the CO$_2$ Gas Sensor with Graphing Calculators

This sensor can be used with a TI Graphing Calculator and any of the following lab interfaces: LabPro, CBL 2, or CBL. Here is the general procedure to follow when using the CO$_2$ Gas Sensor with a graphing calculator:

1. Load a data-collection program onto your calculator:
   - LabPro or CBL 2 - Use the DataMate program. This program can be transferred directly from LabPro or CBL 2 to the TI Graphing Calculator. Use the calculator-to-calculator link cable to connect the two devices. Put the calculator into the Receive mode, and then press the Transfer button on the interface.
   - Original CBL - Use the CHEMBIO program. This program is available free on our web site at www.vernier.com. Our programs can also be obtained on disk. (Contact us for more information.) Load the program into a calculator using TI-GRAPH LINK™.

2. Use the calculator-to-calculator link cable to connect the interface to the TI Graphing Calculator using the I/O ports located on each unit. Be sure to push both plugs in firmly.

3. Connect the CO$_2$ Gas Sensor to any of the analog ports on the interface. In most cases, Channel 1 is used. Start the data-collection program.

Taking Measurements

Follow these steps to collect data using the CO$_2$ Gas Sensor:

4. Allow the CO$_2$ Gas Sensor to warm up for about 90 seconds, then start collecting data. Note: Since the CO$_2$ Gas Sensor updates its reading every second, do not set the data rate faster than 1 reading per second. Once you have started collecting data, you should see the red LED on the sensor box turn on each time the sensor takes a new reading—about once every second.

5. When you have finished collecting data, simply remove the sensor from the gas sampling bottle. We recommend that you leave the slit rubber stopper on the sensor tube. Store the sensor in the box it was shipped in.

Additional Information

- Whenever possible, we recommend that you connect the AC Adapter to the computer or calculator interface when using the CO$_2$ Gas Sensor. The large current required by the CO$_2$ Gas Sensor results in a significant decrease in battery life.
- The sensor cannot take readings at a CO$_2$ concentration higher than 5000 ppm. Once the CO$_2$ concentration reaches this level, the computer or calculator will continue to display a reading of ~5000 ppm until the actual level drops below 5000 ppm again.
- Even though the sensor responds rather quickly to changes in CO$_2$ concentration, remember that gas has to diffuse through the holes in the sensor tube before any changes in concentration can be detected. Since diffusion of gases is a fairly slow process, the sensor will not respond immediately to changes in the environment.

---

Note: While the CO$_2$ Gas Sensor is warming up, you will see readings increase to ~5000 ppm and then slowly decrease back to the CO$_2$ level the sensor is exposed to.
process, there is a resulting delay in the readings. Likewise, if you expose the sensor to higher levels of CO$_2$ (such as exhaled breath, which can be > 50,000 ppm of CO$_2$), then it may take a minute or more for the CO$_2$ chamber to exchange the higher concentration of CO$_2$ for lower concentrations in its surroundings. Fanning air toward the sensor tube can speed up this process.

- To collect data in a controlled environment, we recommend that you use the slit rubber stopper and the 250-mL Nalgene collection bottle that is included with your sensor.

- **Very important:** Do not place the sensor tube directly into any liquid. The sensor is intended only for measuring *gaseous*, not aqueous, CO$_2$ concentration.

- **Important Tips for Original CBL Users:** The CO$_2$ Gas Sensor needs to warm up for 90 seconds *any time* power is interrupted. Even if the sensor has been plugged into the CBL continuously, the CBL Automatic Power Down feature (ADP) results in a power interrupt each time you advance to a new part of the CHEMBIO program, and the sensor will need to go through a 90-second warm-up period again.

**Specifications**

- Measurement range of CO$_2$ Gas Sensor: 0–5000 ppm CO$_2$
- Accuracy (at standard pressure, 1 atm):
  - ±100 ppm in the range of 0–1000 ppm
  - ±10% of reading in the range of 1000–5000 ppm range
- Resolution:
  - with 12-bit interface (LabPro, ULI, SBI, MPLI): 2.44 ppm CO$_2$
  - with 10-bit interface (CBL): 9.77 ppm CO$_2$
- Response time: 95% of full-scale reading in 120 seconds (faster when air currents are provided)
- Warm-up time (connected to powered interface): 90 seconds (maximum)
- Pressure effect: 0.19% of reading/mm of Hg from standard pressure
- Output signal range: 0–2.5 V
- Output impedance: 1 kΩ
- Input potential: 5 V (±0.25 V)
- Gas sampling mode: diffusion
- Normal operating temperature range: 25°C (±5°C)
- Operating humidity range: 5–95%, non-condensing
- Storage temperature range: -40 to 65°C
- Calibration information:
  - slope (gain): 2000 ppm/V
  - intercept (offset): 0 ppm
  - live calibration: performed by push button in outdoor ambient air (~400 ppm)

---

If you purchased the CO2-BTA, you will find a DIN-BTA adapter in the box with your sensor. Use the adapter to connect the sensor to a Vernier LabPro™, CBL 2™, or CBL™.
How the CO\textsubscript{2} Gas Sensor Works

The Vernier CO\textsubscript{2} Gas Sensor measures gaseous carbon dioxide levels in the range of 0 to 5000 ppm by monitoring the amount of infrared radiation absorbed by carbon dioxide molecules. The sensor uses a hot metal filament as an infrared source to generate infrared radiation (IR). The IR source is located at one end of the sensor’s shaft (shown in the lower part of Figure 3). At the other end of the shaft is an infrared sensor that measures how much radiation gets through the sample without being absorbed by the carbon dioxide molecules. The detector measures infrared radiation absorbed in the narrow band centered at 4260 nm. The greater the concentration of the absorbing gas in the sampling tube, the less radiation will make it from the source through the sensor tube to the IR detector. The temperature increase in the infrared sensor produces a voltage that is amplified and read by a Vernier interface or the CBL System. Carbon dioxide gas moves in and out of the sensor tube by diffusion through the eight vent holes in the sensor tube. When the sensor is collecting data, you can see the IR source blinking on and off. It takes a new reading about once every second.

The CO\textsubscript{2} Gas Sensor typically measures gaseous carbon dioxide concentration in units of parts per million, or ppm. In gaseous mixtures, 1 part per million refers to 1 part by volume in 1 million volume units of the whole. A concentration of 600 ppm for CO\textsubscript{2} would simply mean that there is 600 L of CO\textsubscript{2} gas for every 1,000,000 L of air (or 0.6 mL of CO\textsubscript{2} per 1 L of air). As a comparison, the level of carbon dioxide in the earth’s troposphere has gradually increased from 317 ppm in 1960 to current levels of nearly 370 ppm. Exhaled human breath has a carbon dioxide concentration of about 50,000 ppm.

Do I Need to Calibrate the CO\textsubscript{2} Gas Sensor? “No”

We feel that you should not have to perform a new calibration when using the CO\textsubscript{2} Gas Sensor in the classroom. We have set the sensor to match our stored calibration before shipping it. You can simply use the appropriate calibration file that is stored in your data-collection program from Vernier in any of these ways:

1. If you are using the Logger Pro software (version 2.0 or newer) on a Power Macintosh or Windows computer, open an experiment file for the CO\textsubscript{2} Gas Sensor, and its stored calibration will be loaded at the same time. \textbf{Note:} If you have an earlier version of Logger Pro, a free upgrade is available from our web site.

2. If you are using Data Logger software, version 4.5 or newer, on an older PC or Macintosh computer, open an experiment file for the CO\textsubscript{2} Gas Sensor, and its stored calibration will be loaded at the same time. \textbf{Note:} If you have an earlier version of Data Logger, contact us about a free upgrade.

3. Any version of the DataMate program (with LabPro or CBL 2) has stored calibrations for this sensor.

4. All versions of the CHEMBIO, PHYSICS, or PHYSCI programs (for CBL), version 4/1/00 or newer, have stored calibrations for this sensor. Go to our web site, www.vernier.com, to download a current version.
If you do find that you need to calibrate your CO$_2$ Gas Sensor, it can be calibrated using one known CO$_2$ level. Note: This calibration method is different than the usual two-point calibration performed using other Vernier sensors. To calibrate the CO$_2$ Gas Sensor in units of parts per million (ppm):

• Place the 250-mL collection bottle (included with your sensor) in the air outside your building long enough to ensure that its contents are replaced with fresh air. The calibration will be based on this sample having a carbon dioxide concentration of about 400 ppm. While still outdoors (with the slit rubber stopper on the sensor tube of the CO$_2$ Gas Sensor, as shown in Figure 2), insert the stopper into the gas sampling bottle containing fresh outside air. Do this by holding the stopper, not the probe box. You can now take the bottle and sensor to the location where the calibration is to be done (either outside or back in the classroom).

• Connect the CO$_2$ Gas Sensor to Port 1 of a Vernier interface or Channel 1 of the Texas Instruments CBL or CBL 2. Load (or select) an experiment file for the CO$_2$ Gas Sensor. Let the sensor warm up by collecting data for at least 90 seconds. You can monitor the CO$_2$ reading by simply observing the live display on the computer data-collection software, or by selecting Monitor Input in the CBL data-collection program, CHEMBIO.

• When the CO$_2$ Gas Sensor has warmed up (readings should have stabilized), use a paper clip or the point of a mechanical pencil to press down the calibration button (see Figure 3). Release the button immediately after the Red LED blinks rapidly three times. After about 30 seconds, the reading should stabilize at a value of approximately 400 ppm (±50 ppm). If the reading is significantly lower or higher than 400 ppm, simply press the button again to repeat the process.

**Temperature Considerations**

Your Vernier CO$_2$ Gas Sensor is designed to operate between 20°C and 30°C. The CO$_2$ Gas Sensor can be used outside of this temperature range; however, you should be aware that there will be a loss in accuracy of readings, even if you do the 1-point calibration at the lower or higher temperature. This does not prohibit taking readings using incubation temperatures or outdoor readings at temperatures warmer or colder than the 20 to 30°C range. Allow enough time for your CO$_2$ Gas Sensor to stabilize at the desired operating temperatures.

---

2 The carbon dioxide concentration in the earth’s atmosphere has steadily increased throughout the 20th century to an average level of just below 370 ppm in 1997. Levels in your area may be slightly higher due to localized influences such as automobile or industrial emissions of carbon dioxide.
Suggested Experiments

The following experiments are from *Biology with Computers* and *Biology with Calculators* lab manuals.

**Cell Respiration**

In this experiment, students investigate cellular respiration, the process of converting the chemical energy of organic molecules into a form immediately usable by organisms:

\[
\text{C}_6\text{H}_{12}\text{O}_6 + 6 \text{O}_2(\text{g}) \rightarrow 6 \text{H}_2\text{O} + 6 \text{CO}_2(\text{g}) + \text{energy}
\]

To measure the rate of cellular respiration, the carbon dioxide produced by peas is measured using the CO\textsubscript{2} Gas Sensor. Allow the seeds to germinate for three days prior to the experiment. Prior to the first day, soak them in water overnight. On subsequent days, roll them in a moist paper towel and place the towel in a paper bag. Place the bag in a warm, dark place. Both germinating and non-germinating peas are tested in this experiment. Additionally, cellular respiration of germinating peas at two different temperatures can be investigated. Here are some sample data collected using the CO\textsubscript{2} Gas Sensor:

![CO\textsubscript{2} concentration from germinating and non-germinating peas (CBL data)](image)

**Respiration of Sugars by Yeast**

In this lab, students determine whether yeast are capable of metabolizing a variety of sugars. When yeast respire sugars aerobically, carbon dioxide gas is produced in the reaction. The respiration of glucose can be described by the following equation:

\[
\text{C}_6\text{H}_{12}\text{O}_6 + 6 \text{O}_2(\text{g}) \rightarrow 6 \text{H}_2\text{O} + 6 \text{CO}_2(\text{g}) + \text{energy}
\]

The CO\textsubscript{2} Gas Sensor is used to monitor carbon dioxide concentration changes in this experiment. Yeast solutions are prepared by dissolving 7 g (1 package) of dried yeast for every 100 mL of water. The yeast suspension is incubated in 37 to 40°C water for at least 10 minutes. After the 10-minute incubation period, transfer the yeast to dispensing tubes. To prepare the 5% sugar solutions, add 5 g of sugar per 100 mL of solution. Sugars used in the sample data shown here include lactose, fructose, glucose, and sucrose. About 1 mL of yeast suspension and 1 mL of a sugar solution are combined in the 250-mL gas sampling bottle.

![Rate for four sugars](image)
Effect of Temperature on Respiration

Effect of temperature on respiration rates can be studied with the procedure described in Respiration of Sugars by Yeast above, using water baths in the range of 5° to 50°C. The yeast are placed in water baths of different temperatures. The yeast and sugar solutions (1 mL of each) are placed in the gas sampling bottle and CO₂ data are collected. Here are sample data from the experiment:

![Graph of Carbon dioxide vs. time for various temperatures](image1.png)

![Graph of Rate of respiration vs. temperature](image2.png)

Effect of Temperature on Cold-Blooded Organisms

In this experiment, crickets are used to study the effect different temperatures have on the metabolism of cold-blooded organisms. Students determine how quickly the crickets produce carbon dioxide at different temperatures. This is done by placing crickets in the gas sampling bottle along with the CO₂ Gas Sensor (using the slit rubber stopper that comes with the sensor). The gas sampling bottle is submerged in a 1-liter water bath. Sample data from the experiment are shown here.

Plant Respiration and Photosynthesis Cycles

In the graph shown at the right, a CO₂ Gas Sensor and a Light Sensor were both placed into a closed terrarium. Carbon dioxide levels were monitored as a grow light was alternately turned on and off. In the bottom graph, you can see when the light is turned on or off. Notice in the top graph how carbon dioxide concentration slowly decreases when the light is turned on (photosynthesis), or increases with the light turned off (photorespiration).

More about Carbon Dioxide Concentration

The average increase in the concentration of carbon dioxide in the earth’s atmosphere has been well documented. The graph below shows that the concentration increased from about 320 to over 360 ppm during the past 40 years. Locally, especially in urban areas, it is not uncommon for this concentration to be above 380 ppm due to emissions from fossil fuel combustion. The calibration value of 400 ppm

3 Cecie Starr and Ralph Taggart, *Biology: The Unity and Diversity of Life*, 6th ed., Belmont, CA; Wadsworth, 1992
for ambient outside air used with the CO₂ Gas Sensor is very close to these values. The ability of carbon dioxide to act as a greenhouse gas by absorbing increasing amounts of infrared radiation is a growing environmental concern.

![Graph showing carbon dioxide levels over time](image)

You can use the CO₂ Gas Sensor within your classroom or other parts of your school building to demonstrate to students the increased levels of carbon dioxide that occur in confined spaces. We often find that carbon dioxide levels within offices with several people will reach as high as 1000 to 1200 ppm CO₂. You can even use the sensor to show that levels are generally higher in lower regions of a room than in the upper reaches. It is also possible to show the effect of turning on air conditioning, room ventilation, or simply opening a car window.

**Warranty**

All Vernier CO₂ Gas Sensors are warranted to be free from defects in material and workmanship for a period of twelve (12) months from the date of purchase, provided the electrode has been used in accordance with this instruction manual and used under normal laboratory conditions. The warranty does not apply when the CO₂ Gas Sensor has been subjected to accident, alternate use, misuse, or abuse in any manner. In the event of a defect in material or workmanship within the twelve (12) month period, Vernier will either repair or replace the sensor at no expense to the user other than freight charges. Returned sensors will not be accepted unless authorization has been issued by Vernier. For warranty service, please write or call Vernier directly.

Vernier Software & Technology
13979 S.W. Millikan Way
Beaverton, Oregon 97005-2886
(503) 277-2299 • FAX (503) 277-2440
info@vernier.com • www.vernier.com

Rev. 7/19/00

Vernier LabPro and Logger Pro are trademarks of Vernier Software & Technology. CBL, CBL 2, and TI-GRAPH LINK are trademarks of Texas Instruments. Windows and MS-DOS are registered trademarks of Microsoft Corporation. Macintosh is a registered trademark of Apple Computer, Inc.