Using the LI-830 and LI-850 Gas Analyzers

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LI-COR®

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Gas Analyzers

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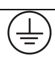
Notes on Safety

This LI-COR product has been designed to be safe when operated in the manner described in this manual. The safety of this product cannot be guaranteed if the product is used in any other way than is specified in this manual. The product is intended to be used by qualified personnel. Read this entire manual before using the product.

Equipment markings:	
	The product is marked with this symbol when it is necessary for you to refer to the manual or accompanying documents in order to protect against injury or damage to the product.
	The product is marked with this symbol when a hazardous voltage may be present.
	The product is marked with this symbol if a Chassis Ground connection is required.
WARNING	Warnings must be followed carefully to avoid bodily injury.
CAUTION	Cautions must be observed to avoid damage to your equipment.
Manual markings:	
WARNING	Warnings must be followed carefully to avoid bodily injury.
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NOTE	Notes contain important information and useful tips on the operation of your equipment.

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This product is a CE-marked product. For conformity information, contact LI-COR Support at envsupport@licor.com. Outside of the U.S., contact your local sales office or distributor.

California Proposition 65 Warning

WARNING: This product contains chemicals known to the State of California to cause cancer and birth defects or other reproductive harm.

Federal Communications Commission Radio Interference Statement

WARNING: This equipment generates, uses, and can radiate radio frequency energy and if not installed in accordance with the instruction manual, may cause interference to radio communications. It has been tested and found to comply with the limits for a Class A computing device pursuant to Subpart J of Part 15 of FCC rules, which are designed to provide a reasonable protection against such interference when operated in a commercial environment. Operation of this equipment in a residential area is likely to cause interference in which case the user, at his own expense, will be required to take whatever measures may be required to correct the interference.

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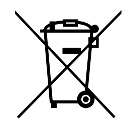
This symbol indicates that the product is to be collected separately from unsorted municipal waste. The following applies to users in European countries: This product is designated for separate collection at an appropriate collection point. Do not dispose of as household waste. For more information, contact your local distributor or the local authorities in charge of waste management.



Contents

Section 1. General description

Section 2. Configuring the gas analyzer

Section 3. Troubleshooting

Section 4. Maintenance

Appendix A. Equation Summary

Appendix B. Specifications

Appendix C. Warranty

Section 1.
General description

This section introduces the LI-830 CO_2 analyzer and LI-850 CO_2/H_2O analyzer. The LI-830 and LI-850 both measure CO_2 in air at concentrations from 0 to 20,000 ppm. The instruments differ in that the LI-850 measures water vapor in air as well, and the LI-830 does not. As a consequence of the water vapor measurement, the LI-850 is able to measure CO_2 concentrations with greater accuracy. Regardless of this difference, operating both instruments is essentially the same.

Online resources

In addition to the contents of your box, you may be interested in the following resources. All are available from www.licor.com/env/support. Select the **LI-830 and LI-850 Analyzer**.

Application software

Required to configure the instrument through a graphical interface, the software is available for both Windows® and macOS® operating systems. The software is used to configure the instrument, read measurements, and configure data logging to a computer.

Integrator's guide

The Integrator's Guide describes how to control the instrument using a terminal program and read data in a command-line interface.

Instruction manual

A .pdf version of this document can be downloaded to your computer.

What's what

The LI-830 and LI-850 include a core set of components and each may include optional components. These are described below.

Gas analyzer

This is the gas analyzer in an enclosure. It may include an optional built-in pump and display.

- **Power** indicator: Illuminates when the instrument is powered on.
- **Low Battery** indicator: Illuminates if the power supply voltage drops below 10.5 volts. The instrument will continue to operate with a low battery, but expect a corresponding decline in performance.
- **Alarm** indicators illuminate if an alarm threshold has been crossed. See *Using alarms* on page 2-8.
- **RS-232 Serial** and **USB** connectors to connect with a computer or serial device.
- **Air In**let and **Air Out**lets are shipped with covers in place. Keep the covers so you can put them back over the ports when the analyzer is not in use.
- **Power In:** Compatible with 12 to 30 VDC power supplies.
- The **Terminal Strip** has another power connector and outputs for alarms and digital-to-analog converters (DAC).

Accessories kit

Accessories kit: Part Number 9980-065

The instrument includes a standard accessories kit, which has accessories and some replacement parts for your gas analyzer. The accessories kit includes:

Description	Quantity	Part Number
Universal power supply; Input: 100 to 240 VAC, 50 to 60 Hz; Output: 12 VDC, 2.5 amps	1	591-13032
Outlet adapter kit for universal power supply	1	591-13033
USB cable; Standard 1.8 m USB-A to USB-B[a]	1	392-06652
RS-232 null modem, cross-over cable kit[a]	1	9975-016
14-pin terminal block; Includes label sticker (250-05340)	1	331-05273
Tube fitting nuts for air inlet and outlet	2	9861-036
Bev-a-line IV plastic tubing; 3.6 meter roll	1	222-01824
Air filters	2	9967-008
Quick-connect straight unions	2	300-03123
Cleaning kit	1	9980-066
3" Source and detector cleaning swabs	5	610-05314
5" Optical path cleaning swabs	5	610-05315
O-Rings (AS-018 Nitrile 70)	4	192-00226
Black polyurethane feet	4	234-02268

Air pump (optional)

An optional air pump is available for the gas analyzer. The pump (if applicable) is installed in the gas analyzer case. If you want to add a pump, you can order one later.

Display (optional)

An optional display is available. The display shows CO_2 concentration, H_2O concentration (LI-850 only), bench temperature, and pressure. You can get a display as a retrofit option, if desired.

[a]The use of cables other than those provided may result in improper electrical performance.

Connecting with the analyzer

The following tutorial describes the basic steps you'll follow when you turn on the LI-830 or LI-850 for the first time.

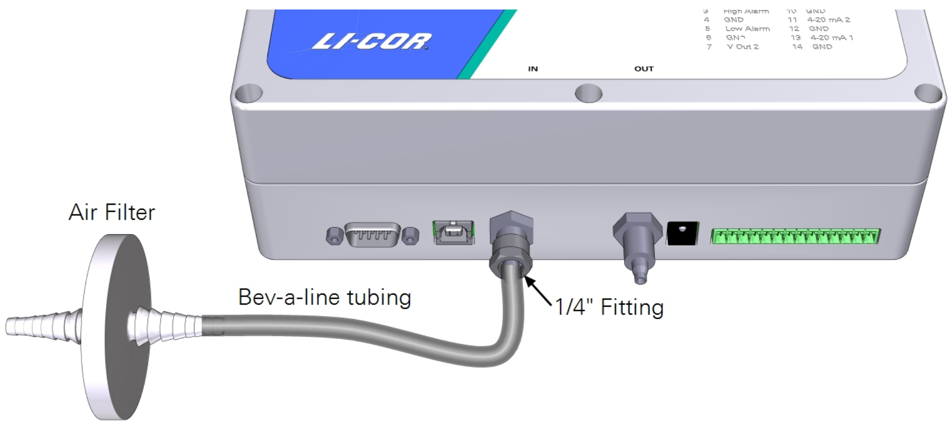
1 Install the software on your computer

The software is used to configure data communication, analog and digital outputs, alarms, data logging, and to verify the calibration.

2 Install an air filter on the air-in port

> **Caution:** Always install an air filter on the input air before operating the LI-830 or LI-850. Failure to use a filter will cause contamination of the optical bench.

Retrieve an air filter and tubing from the accessories kit. Cut a 5 to 10 cm piece of tubing. Attach the filter and tubing to the air-in port. Observe the arrow on the filter and be sure that the air flow is in the proper direction.



3 Install the USB cable

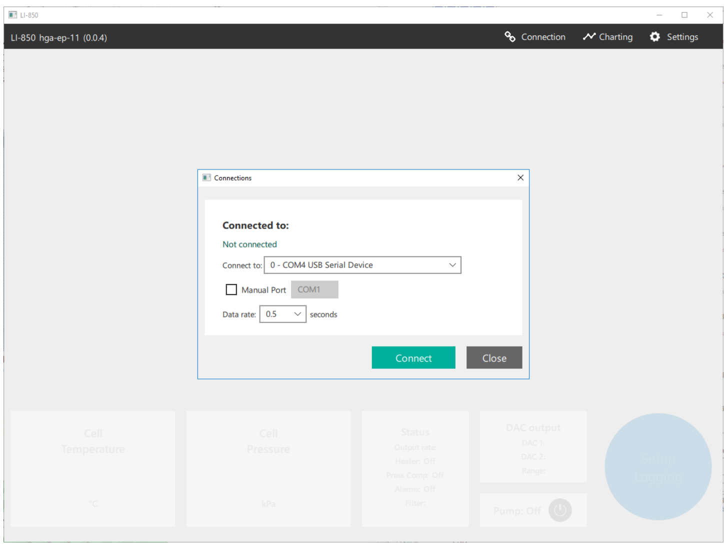
The USB connection is the simplest way to connect the analyzer with a computer. If you want to use the RS-232 serial connection instead, connect the cable to the serial port, and install a serial-to-USB adapter on the serial cable, if needed.

4 Power on the gas analyzer

The LI-830 and LI-850 will turn on when power is supplied, so plug in the power cable to turn it on. If you use an alternative power supply, it must be able to source a minimum of 1.2 A at 12 VDC while the instrument warms up. After the warmup, the instrument will draw about 0.3 A at 12 VDC.

5 Connect with the gas analyzer

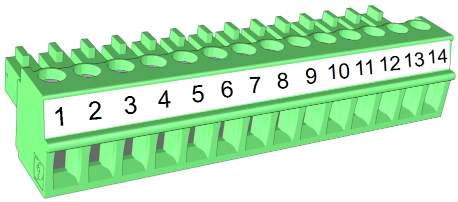
Start the software.



Click the **Connection** button in the upper right of the display. Select your instrument from the list, set the data rate, then click **Connect.** Data will populate the window after connecting. You can enter the COM port manually by checking Manual Port and setting the port number (COM#).

The terminal strip

The terminal strip connects to the front panel of the instrument. The pin assignments are given on the top of the instrument, and there is a sticker in the accessories kit that you can use to help identify which terminal is which.



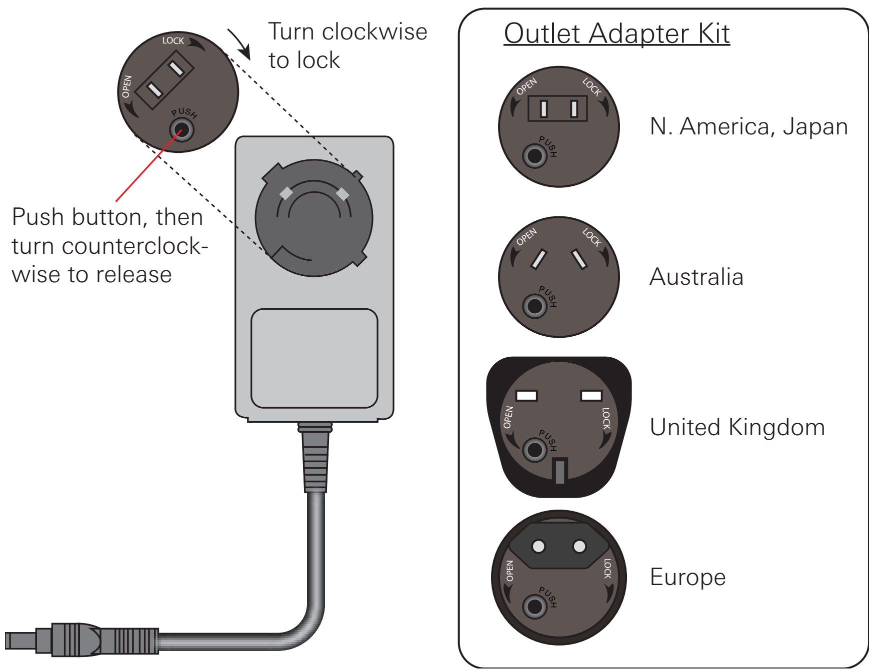
Terminal	Label	Description
1	12-30 VDC	Voltage In, 12-30 VDC
2	GND	Ground
3	High Alarm	High Alarm
4	GND	Ground
5	Low Alarm	Low Alarm
6	GND	Ground
7	V OUT 2	Voltage output channel 2
8	GND	Ground
9	V OUT 1	Voltage output channel 1
10	GND	Ground
11	4-20 mA 2	Current output channel 2
12	GND	Ground
13	4-20 mA 1	Current output channel 1
14	GND	Ground

Powering the LI-830 and LI-850

A power supply—either a battery or the universal power adapter—can be connected to the LI-830 and LI-850 power jack or to pins 1 and 2 on the terminal strip. The instruments require 12 to 30 VDC. The power supply must be able to provide 14 watts (1.2 A at 12 V) during warmup and about 3.6 watts (0.3 A at 12 V) during normal operation.

Using the universal power adapter

The included power supply is compatible with mains power in most localities globally (input 100 to 240 VAC, 50 to 60 Hz; output 12 VDC, 2.5 amps). You may need to install different blades from the outlet adapter kit to fit your wall outlets.



Using the terminal strip power connectors

The terminal strip has connectors for any power supply that has bare leads. Pin 1 is the positive (+) terminal, and pin 2 is the negative (-) terminal.

Storing the gas analyzer

When you are done using the gas analyzer, follow these practices to be sure that it is ready to use the next time you need it.

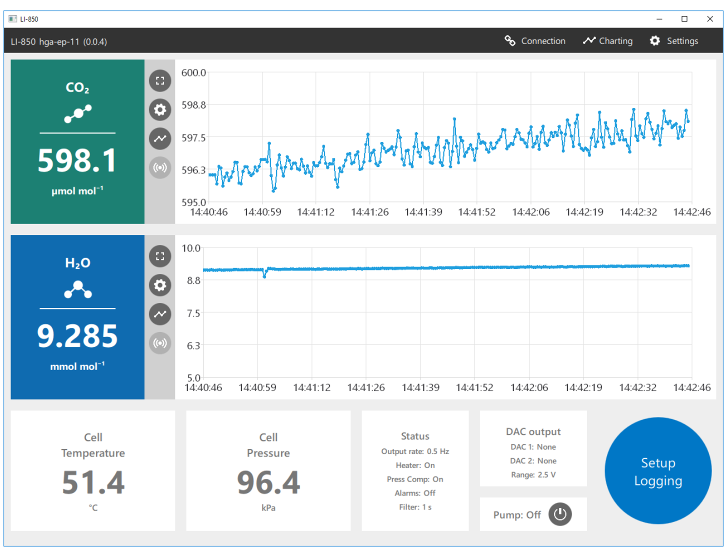
- Install the covers over the air inlet and outlet. This will keep dust, bugs, and other contaminants out of the optical cell.
- Disconnect the power supply and power wires.

Section 2.
Configuring the gas analyzer

This section describes the basic operating procedures for the LI-830 and LI-850 gas analyzers. This section depends upon the instrument software, which can be downloaded from the LI-COR technical support web site: www.licor.com/env/support.

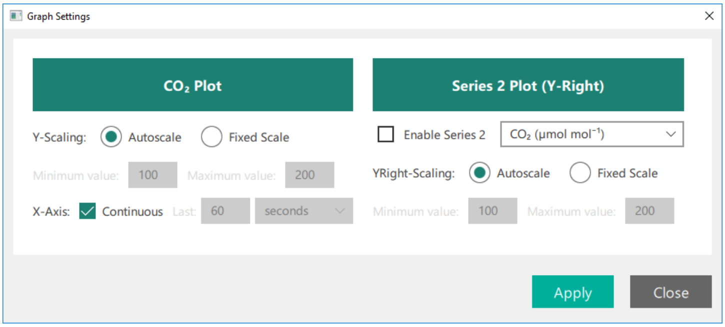
Overview of the software

After connecting, the software presents you with live data and graphs. With the LI-830, you'll have CO_2; with the LI-850, you'll have both CO_2 and H_2O.



Configuring graphs

The software will always display a graph on the main page (two with the LI-850), and you can configure the graphs by clicking the **Charting** button or any of the **Chart Settings** buttons beside a particular chart. The options available are the same, regardless of how you get to them.



The graphs display a fixed variable: CO_2 and H_2O with the LI-850. You can configure the settings for each graph and add a second variable. The options are:

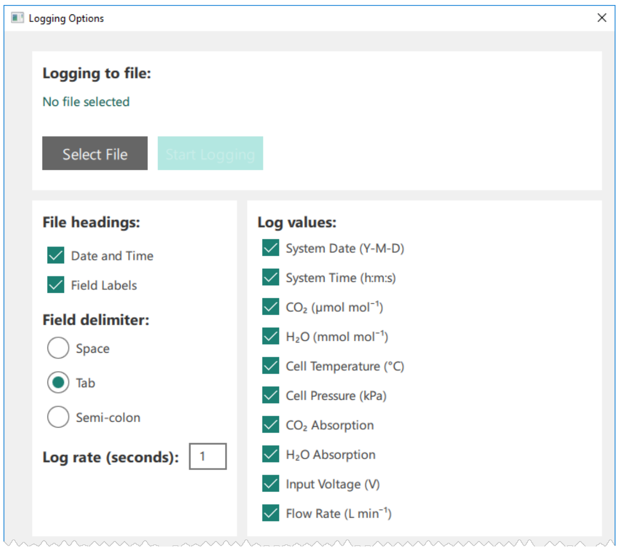
Y-Scaling: Choose **Autoscale** or **Fixed Scale**. With **Fixed Scale**, you can set the minimum and maximum value for each variable displayed.

X-Axis: With **Continuous** checked, the graph will display all of the data from the time you connect to the instrument, rescaling the x-axis when needed. With **Continuous** cleared, the graph can be configured to display the most recent data for a time period.

Series 2 is an option to plot a second variable on the graph with scaling on the right axis. When checked, you can choose from CO_2 concentration, cell temperature, cell pressure, CO_2 absorption, or input voltage. With the LI-850, the H_2O concentration, H_2O dewpoint, and H_2O absorption will also be available.

Logging data to a PC

The instrument can log data as a text file, which will be stored to the connected computer. Configure the log file under **Settings > Logging Options.** To log data:



1 Create a file.

Click **Select File**, then choose the directory where you want to store the file, and name the file.

2 Configure the log parameters.

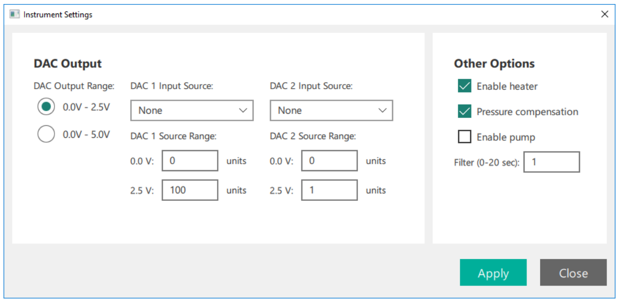
- **File headings:** When checked, the **Date and Time** and **Field Labels** for data columns will be included in the data file header.
- **Field delimiter**: Choose between a space, tab, or semi-colon delimited text file.
- **Log rate (seconds)**: How often a value is recorded. This can be 0.5, 1, 2, 3, 4, 5, 10, or 20 measurements per second. It is independent of the **Filter** setting (described in *Other options* on page 2-7).
- **Log values**: Select the values you want in the log file.

3 Click **Start logging.**

The instrument will create a text file according to the parameters you set. You can open the logged data in a text editor or most spreadsheet programs.

Instrument settings

Under **Instrument > Settings**, you'll find the **DAC** (digital-to-analog) **Outputs** (0 to 2.5 V, 0 to 5 V, and 4 to 20 mA), and **Other Options**, including the heater controls, pressure compensation control, pump control, and the digital signal filter.



Configuring the DAC outputs

This section describes how to configure the voltage and current outputs. Both voltage and current outputs are configured at the same time, in the same place:

- **DAC 1** configures **V Out 1** (pin 9) and **4-20 mA 1** (pin 13) on the terminal strip
- **DAC 2** configures **V Out 2** (pin 7) and **4-20 mA 2** (pin 11) on the terminal strip

Optimizing the DAC resolution

When configuring the analog outputs, keep in mind that the selected ppm range will affect the resolution of data that is sent over the analog outputs.

Think of it like this: The 16-bit DACs can output a fixed number of values (65,536 to be exact). If a DAC is configured to output 0 to 5000 mV, you will have resolution of 0.076 mV per count.

$$\frac{5000\ mV}{65536\ counts} = 0.076\ mV/count \tag{2-1}$$

With the 0 to 5 volt output range corresponding with a 0 to 20,000 ppm CO_2 concentration range, the finest change in concentration that can be resolved is equal to 0.31 ppm.

$$\frac{20000\ ppm\ range}{65536\ counts} = 0.31\ ppm/count \tag{2-2}$$

If you are measuring concentrations between 0 and 10,000 ppm, the range is 10,000 ppm. By configuring the DAC range for 0 V = 0 ppm CO_2 and 5 V = 10,000 ppm, the DAC output will have twice the resolution as it would in the previous configuration.

$$\frac{10000\ ppm\ range}{65536\ counts} = 0.15\ ppm/count \tag{2-3}$$

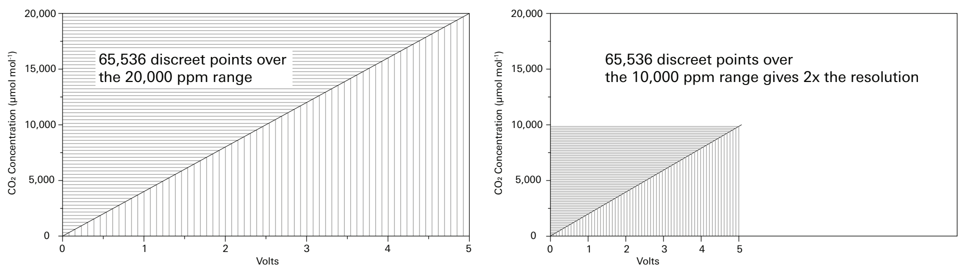


Figure 2-1. The resolution of the analog outputs depends upon the range. If the DACs are configured to output data over the full 0 to 20,000 ppm range, the data output over the DACs will have lower resolution (left). If the DACs are configured to output data over a narrower range (for example, 0 to 10,000 ppm as shown on the right), the data output over the DACs will have higher resolution.

Also keep in mind that the instrument will not output meaningful information over the DACs if the measured value is outside of the configured output range.

Computing readings from the DAC output

Here we give some example computations.

Example 1: Computing CO_2 from a voltage output; 0 to 500 ppm range

The CO_2 concentration is calculated from the DAC output. In this example, let's configure the output range for 0 V = 0 ppm and 5 V = 500 ppm. The concentration is computed from:

$$CO_2 = V_{output}\left(\frac{CO2_{range}}{V_{range}}\right) \tag{2-4}$$

If the output voltage is 2.9 V, then

$$CO_2 = 2.9\ V\left(\frac{500\ ppm}{5\ V}\right) = 290\ ppm \tag{2-5}$$

Example 2: Computing CO_2 from a voltage output; 300 to 500 ppm range

In this example, let's configure the output range for 0 V = 300 ppm and 5 V = 500 ppm, so the full range is 200 ppm, and notably, 0 V is no longer 0 ppm.

$$CO_2 = V_{output}\left(\frac{CO2_{max} - CO2_{min}}{V_{range}}\right) + CO2_{min} \tag{2-6}$$

$CO2_{max}$ is the reading that corresponds with the high voltage output (500 ppm in this case), and $CO2_{min}$ is the reading that corresponds with the low voltage output (300 ppm in this case). With an output voltage of 2.9, the concentration is:

$$CO_2 = 2.9\ V\left(\frac{200\ ppm}{5V}\right) + 300\ ppm = 416\ ppm \tag{2-7}$$

Example 3: Computing CO_2 from a current output; 0 to 500 ppm range

Unlike the voltage outputs, which are 0 to 2.5 or 0 to 5 V, the current outputs are from 4 to 20 mA. Therefore, the range is always 16 (20 - 4), and the offset is always 4. Electrical current is indicated with *I*. In this example, let's configure the output range for 4 mA = 0 ppm and 20 mA = 500 ppm. The concentration is computed from:

$$CO_2 = I_{output} - 4\left(\frac{CO2_{range}}{I_{range}}\right) \tag{2-8}$$

If the current is 16.25 mA, then

$$CO_2 = (16.25\ mA - 4) \times \left(\frac{500\ ppm}{16\ mA}\right) = 382.8\ ppm \tag{2-9}$$

Example 4: Computing CO_2 from a current output; 300 to 500 ppm range

In this example, let's configure the output range so that 4 mA = 300 ppm and 20 mA = 500 ppm. Now, we need an offset that corresponds with the minimum CO_2 reading (300 ppm).

$$CO_2 = (I_{output} - 4) \times \left(\frac{CO2_{max} - CO2_{min}}{16\ mA}\right) + CO2_{min} \tag{2-10}$$

If the current is 16.25 mA, then

$$CO_2 = (16.25\ mA - 4) \times \left(\frac{200\ ppm}{16\ mA}\right) + 300\ ppm = 453\ ppm \tag{2-11}$$

Example 5: Computing cell temperature from a voltage output

Cell temperature (T in °C) is calculated from the DAC output with the following:

$$T = (X_F - X_Z)\frac{V}{V_{max}} + X_Z \tag{2-12}$$

where X_F is the full scale temperature value that corresponds to the high voltage, X_Z is the temperature value that corresponds to the low voltage, V is the voltage reading, and V_{max} is the output range (either 2.5 V or 5 V).

Example 6: Computing cell pressure from a voltage output

Cell pressure (kPa) can be computed from a voltage output with the following:

$$Pressure = (X_F - X_Z)\frac{V}{V_{max}} + X_Z \tag{2-13}$$

where X_F is the full scale pressure value that corresponds to the high voltage, X_Z is the pressure value that corresponds to the low voltage, V is the voltage reading, and V_{max} is the output range (either 2.5 V or 5 V).

Other options

Enable heater: The heater should be enabled to maintain the optical bench temperature. Normally the optical bench will be about 51.4 °C. If you disable the heater, the instrument will not perform as specified.

Pressure compensation: Pressure compensation should be applied to ensure that the instrument compensates for changes in pressure. Disabling pressure compensation will lead to less accurate measurements.

Enable pump: If your instrument is equipped with a pump, this box will be interactive. Check it to turn the pump on. Clear it to turn the pump off.

Filter: The digital filter instructs the instrument to average the readings. A value of 0 means no averaging, whereas a value of 20 instructs the instrument to average the previous 20 seconds of measurements. Increasing the averaging time will decrease the variation in each reported value, but will also reduce the instrument response time.

Using alarms

The alarms can be set for CO_2 or H_2O (in the LI-850). In either case, each alarm features an activation level and a deadband. The low alarm is activated if the measured concentration drops below a threshold. The deadband is the range above the low level over which the alarm remains activated. The high alarm is activated if the measured concentration exceeds a threshold. The deadband is the range below the high level over which the alarm remains activated.

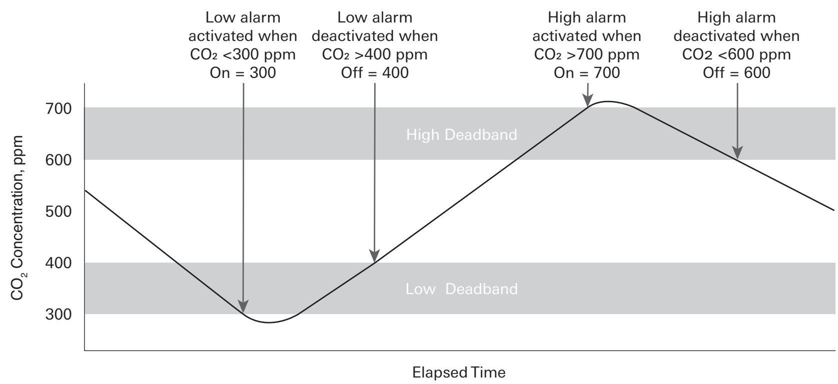


Figure 2-2. An alarm is triggered when a concentration is outside of a threshold. For example, the low alarm is activated if the concentration drops below 300 ppm and is deactivated when the concentration rises above 400 ppm. The high alarm is activated if the CO_2 concentration exceeds 700 ppm. The alarm remains activated until the concentration drops below 600 ppm.

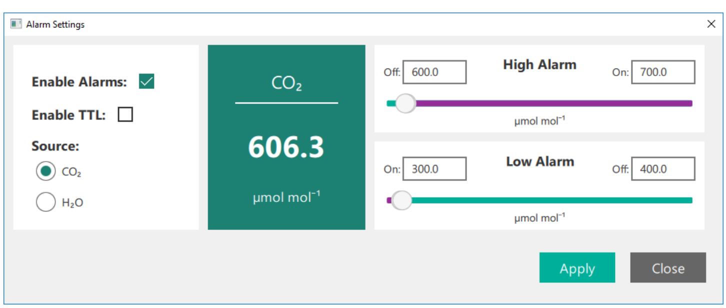


Figure 2-3. The **Alarm Settings** *window is where you configure alarms. The settings shown here will give the behavior shown in Figure 2-2 above.*

When an alarm is activated, the instrument sends a 5 volt signal (TTL) over pin 3 (low alarm) or 5 (high alarm) in the terminal strip. The signal can be used to activate an audible alarm or a relay switch that controls another device, for example.

Alarms are configured under **Settings > Alarm Thresholds**. To configure the alarms:

1 Check **Enable Alarms**.

Select whether the alarm should be for CO_2 or H_2O (with the LI-850). Alarms can be set for one or the other, not both.

2 Configure the **High Alarms**.

- The **ON** settings is the high level at which the alarm is activated.
- The **OFF** setting is the level at which the alarm is deactivated. The deadband is the range between the ON and OFF settings.

3 Configure the **Low Alarms**.

- Again, the **ON** setting is the low level at which the alarm is activated.
- The **OFF** setting is level at which alarm is deactivated. The deadband is the range between the ON and OFF settings.

4 Click **Apply** when you are done.

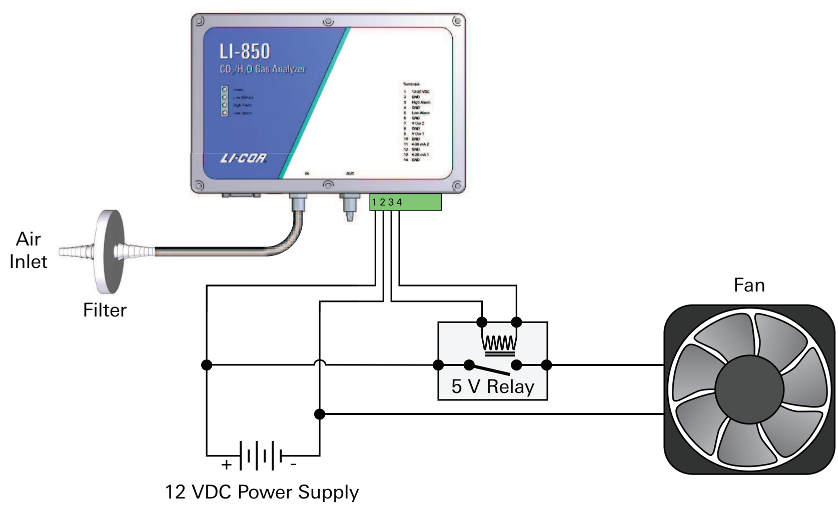


Figure 2-4. In this example, the high alarm is used to activate a relay, which turns on a fan.

Using the Pump

For instruments that are equipped with the LI-COR-installed pump, the pump is activated through the interface.

Note: The pump will not run until the optical cell has reached the operating temperature of about 50 °C, regardless of the setting. If the cell temperature drops below 50 °C, the instrument will disable the pump temporarily until the cell warms back up.

To turn on the pump from the main window, click the pump button so it reads **Pump: On.** Or, click **Settings > Instrument** and check **Enable pump.**

Section 3. Troubleshooting

In this section, we describe how to identify some potential problems. If you can't find a solution here, contact your local distributor or LI-COR technical support for more help.

Instrument will not power on

Power supply adequate? The power supply should source at least 1.2 amps at 12 VDC (minimum of 14 watts during warmup).

Blown fuse? The instrument can be powered from the power jack or pins one and two on the terminal strip. Each connection has its own fuse.

- If you are unable to power on the instrument using the jack, but can power it on using the terminal strip, you probably have a blown power jack fuse.
- If the opposite is true, you probably have a blown terminal strip fuse.
- If you can't power it using either connection, you may have blown both fuses.

Check the resistance across the fuse contacts using an ohm meter. A reading of 0 means that the fuse is good; a reading of 1 indicates that the fuse is blown.

See *Replacing a fuse* on page 4-6 for complete instructions.

Unable to span or zero the instrument

Dirt in the optics? If the optical cell becomes contaminated, the instrument will drift in either the zero or span.

See *Cleaning the optical bench* on page 4-4 for complete instructions.

Instrument reports -50 ppm CO_2 or measurements jump around

If the instrument measures -50 ppm or the measurements are going between negative and positive values, or just simply not making any sense, the optical source may have failed or be in the midst of failure. Contact technical support for additional troubleshooting help.

Section 4.
Maintenance

The LI-830 and LI-850 will require little maintenance. Typical maintenance procedures are described in this section.

User calibration

If the instrument is not measuring as expected, or if you have disassembled the optical bench for any reason, you should check the zero and span settings and set them if necessary. The zero and span are an offset and slope. The zero value ensures that the instrument shows zero when the gas has a zero concentration. A change in the zero will affect every measurement. The span setting ensures a correct measurement at a known non-zero concentration. A change in the span affects higher concentration measurements more than lower ones.

Setting the CO_2 zero

Always perform the zero first. To set the zero, you'll need either a tank of dry air that is free of CO_2 or a CO_2 scrubbing chemical such as wet soda lime and a desiccant such as Drierite.

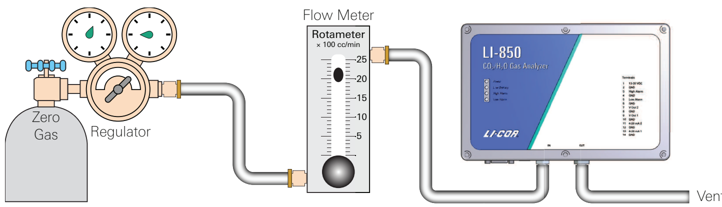
1 Plumb the zero-gas tank or scrubber to the air inlet.

Be sure to use an air filter to prevent contaminants from entering the optical path.

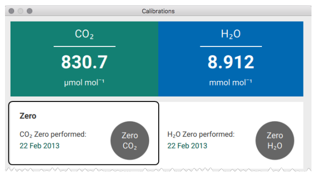
- If using tank air, the pressure of the tank is sufficient to flow the gas through the analyzer. Allow at least 0.75 liters per minute to flow through the cell (no more than 1.0 lpm).
- If using a scrubbing chemical, use a pump to draw air through the analyzer.

2 Install a 10 to 20 cm length of tubing to the air outlet.

This vent prevents ambient air from diffusing upstream into the optical cell.



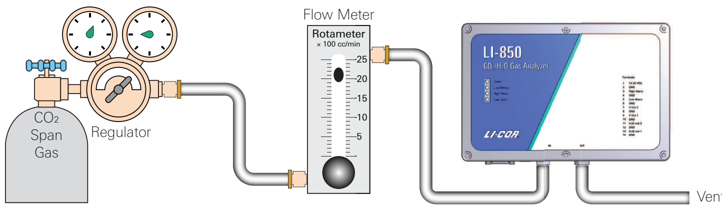
3 When the CO_2 concentration has stabilized, click the **Zero CO_2** button.



Setting the primary CO_2 span

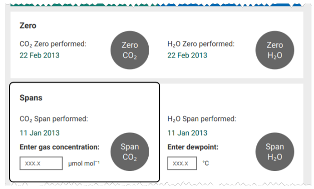
When choosing a span gas, we recommend a gas concentration that is close to the upper limit of what you expect to measure. For example, if you are measuring near-ambient levels, choose a span gas that is near 400 ppm CO_2 (as opposed to 18,000 ppm). Similarly, if you are measuring concentrations near 15,000 ppm CO_2, a span gas with 100 ppm would not be ideal.

4 After zeroing, flow a gas with a known CO_2 concentration through the analyzer at a rate of 0.5 liters per minute.



5 Enter the CO_2 concentration of the span gas into the software

6 When the CO_2 reading has stabilized, click **Span CO_2**.



Setting the secondary CO_2 span

You can set a second span (using a gas that has a CO_2 concentration that is higher or lower than the primary span gas) to improve the precision of the analyzer. The process is exactly the same as setting the primary span, only you'll enter a different concentration and click **Span2 CO_2**.

Setting the H_2O zero and spans (LI-850 only)

The water vapor span can be set with a dew point generator such as the LI-610. The procedure is the same as setting the CO_2 zero and spans, only this uses known concentrations of water vapor rather than CO_2.

> **Caution:** Setting the zero and span incorrectly for either CO_2 or H_2O will adversely impact the performance of your instrument. If you do not have the proper equipment to span the analyzer, it is best to leave it alone.

Recovering from a bad zero or span

If your attempt to zero or span does not go as planned, you can restore the factory default zero and span settings. The information you need is provided on the calibration sheet (included with the instrument or available for download from www.licor.com/env/support/). Under **Settings > Calibrations > Advanced**, enter the factory zero and span values for your instrument.

Cleaning the optical bench

The optical bench can be removed and cleaned if necessary. If, for example, you are unable to set the span, the optics may be contaminated. Generally speaking, don't undertake this procedure unless you've ruled out other potential problems. You'll have to set the instrument zero and span after reassembling the optical bench.

1 Turn off the instrument.

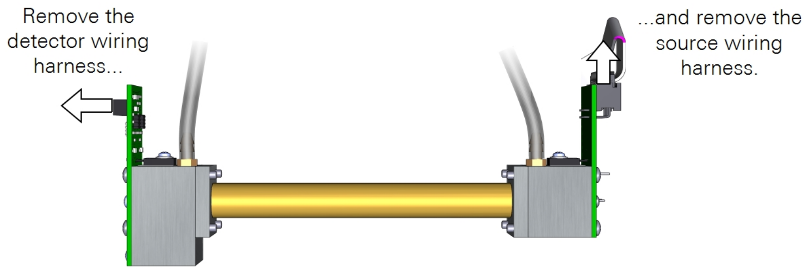
Unplug the power cable.

2 Remove the top cover.

It is attached with 6 captive screws. Loosen each of the screws until the top cover is free of the bottom. If your instrument has a display, carefully rotate the top cover out of the way without straining the cable, and then unplug the display cable. Set the cover aside, being careful not to strain the ribbon cable.

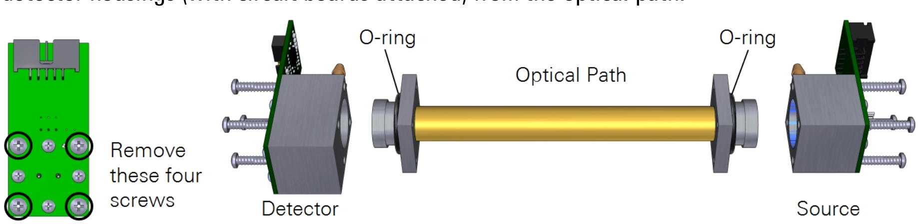
3 Remove the cables from the source and detector.

Gently grasp the plug and pull it free of the assembly. Leave the tubes in place.

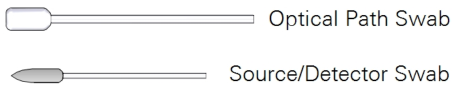


4 Carefully lift the optical bench out of the foam.

5 Remove the screws that secure the source and detector (4 each), then separate the source and detector housings (with circuit boards attached) from the optical path.



6 Clean the parts.



Retrieve an optical path swab from the accessories kit. Dip one end into a 50:50 ethanol-water mixture (mild dish washing soap and water will work too) and carefully swab both ends of the optical path. Dip a Source/Detector swab into the solution and then swab around the source and detector to remove any residue.

> **Caution:** Do not use abrasive cleansers. Abrasive cleaners can irreparably damage the gold plating on the optical path, source, or detector.

7 Inspect the hose barbs and tubing.

If the tubes are dirty or damaged, replace them with new tubes (available from LI-COR, part number 6580-041). Carefully remove them from the hose barbs. If the tubes are in good condition and clean, you may be able to reuse them. If the hose barbs are dirty, remove them and clean them with rubbing alcohol or soapy water. Use caution: Do not scratch the hose barbs because scratches may cause leaks.

8 Inspect the O-rings.

If they are smashed flat or damaged in any way, replace them with new O-rings (part number 192-00226) from the accessories kit.

9 Let the optical bench components dry.

10 Reassemble the optical bench.

Attach the source and detector. The orientation of the optical path cylinder is unimportant — either end can be inserted into the source and detector housing. Tighten each of the screws snugly.

11 Place the optical bench in the foam, plug in the source and detector connectors, and re-assemble the case.

Be sure the foam insulation on the top cover is positioned over the optical bench. It is required for thermal stability.

12 Perform a zero and span calibration. See *User calibration* on page 4-1.

Replacing a fuse

The power supply and terminal strip are both protected by fuses. The instrument has one extra fuse (Littel Fuse 476 Series Nano2® 6.3 amp fuse) that can be used in the event that one of the fuses blows. If you are able to power on the instrument using one of these two ways—but not the other—a fuse may be blown. If you can't power the instrument using either way, both fuses may be blown (or you may have a power supply issue).

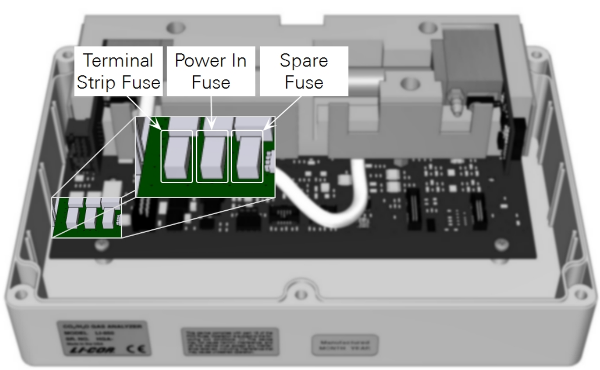
Before simply replacing a fuse, be sure to identify the problem that caused the fuse to blow in the first place. Otherwise, you'll just blow the spare fuse, in which case, you'll still have the problem and you'll be out of spare fuses. After identifying and solving the problem that caused the fuse to blow, replace the fuse:

1 Open the case.

Loosen each of the six top cover screws until the top cover is free of the bottom. If your instrument has a display, carefully rotate the top cover out of the way without straining the cable, and then unplug the display cable. Set the cover aside.

2 Locate the fuses.

With the air-in and -out ports facing away from you, the fuses are mounted to the lower left corner of the lowest circuit board. In the image, ribbon cables and tubes have been removed for clarity.



3 Using a needle-nose pliers, grasp the blown fuse and remove it from the holder.

4 Replace it with a spare fuse.

5 Power on the instrument to verify that the issue is resolved.

Appendix A. Equation Summary

The LI-830 and LI-850 compute CO_2 concentrations using an equation of the form:

$$c = f(\alpha g(\alpha, P) S(\alpha))\,(T + 273.15) \qquad \text{A-1}$$

where c is concentration, $f()$ is the calibration function, α is the absorptance, $g(\alpha,P)$ is the pressure correction, $S(\alpha)$ is the span, and T is the temperature (°C) of the gas in the cell, typically 51.5 °C. Absorptance is computed from

$$\alpha = \left(1 - \frac{V}{V_o} Z\right) \qquad \text{A-2}$$

where V and V_o are the raw detector sample and reference readings, and Z is the zeroing parameter. Span is a linear function of absorptance.

$$S(\alpha) = S_0 + S_1 \alpha \qquad \text{A-3}$$

H_2O Equations (LI-850 only)

Absorptance α_ω for water vapor is computed from

$$\alpha_w = \left(1 - \frac{V_w}{V_{wo}} Z_w\right) \qquad \text{A-4}$$

where V_w and V_{wo} are the sample and reference raw detector readings and Z_w is the zero parameter. The pressure correction for water vapor is an empirical function $g_w()$ of absorptance and pressure P:

$$g_w(\alpha_w, P) = \frac{P_o}{P\left(1 + 0.8\alpha_w\left(\frac{P_o}{P} - 1\right)\right)} \qquad \text{A-5}$$

The value of P_o is 99 kPa. When the pressure correction is not enabled, $g_w()$ is simply 1.0.

Water vapor concentration W (mmol mol^{-1}) is computed from

$$W = f_w\left(\alpha_w g_w(\alpha_w, P) S_W(\alpha_w)\right)(T + 273 - 15) \tag{A-6}$$

where $f_w(x)$ is a third order polynomial whose coefficients are given on the calibration sheet.

$$f_w(x) = a_{w1}x + a_{w2}x^2 + a_{w3}x^3 \tag{A-7}$$

CO_2 Equations

The measurement of CO_2 is a bit more complicated than for H_2O because of the influence of water vapor. There is a slight direct cross sensitivity in the CO_2 signal to H_2O. This is measured at the factory and accounted for in the computation of absorptance (equation A-8). There is also a band broadening effect that is accounted for in the computation of concentration (equation A-12).

CO_2 absorptance αc is computed from

$$\alpha_c = \left(1 - \left(\frac{V_c}{V_{co}} + X_{wc}\left(1 - \frac{V_w}{V_{wo}}\right)\right) Z_c\right) \tag{A-8}$$

where V_c and V_{co} are the raw detector signals for sample and reference, Z_c is the CO_2 zero parameter, and X_{wc} is a cross sensitivity parameter for the effect of water vapor on CO_2. Its value is reported on the calibration sheet as **XS**.

The empirical pressure correction function $g_c()$ depends on CO_2 absorptance and pressure:

When $P = P_o$, $g_c() = 1$.

When $P < P_o$

$$g_c(\alpha_c, P) = X$$

$$X = \frac{1}{A + B\left(\frac{1}{z-\alpha_c} - \frac{1}{z}\right)} + 1$$

$$A = \frac{1}{a(p-1)} \tag{A-9}$$

$$B = \frac{1}{\frac{1}{b+cp}+d}$$

$$p = \frac{P_0}{P}$$

where a = 1.10158, b = -6.1217 * 10^{-3}, c = -0.266278, d = 3.69895, and z is the asymptotic value of absorptance, obtained from the calibration coefficients (equation A-13).

$$z = a_{c1} + a_{c3} \qquad \text{A-10}$$

When $P > P_0$

$$g_c\left(\alpha_c, P\right) = \frac{1}{X}$$

$$P = \frac{P}{P_0} \qquad \text{A-11}$$

where X, A, and B are computed as in equation A-9.

CO_2 concentration C (μmol mol^{-1}) is computed from

$$C = f_c\left(\frac{\alpha_c g_c(\alpha_c,P)}{\psi(W)} S_c\left(\alpha_c\right)\right)\psi(W)(T + 273.15) \qquad \text{A-12}$$

where $f_c(x)$ is a function whose inverse is a double rectangular hyperbola, and whose coefficients ($a1 \ldots a4$) are given on the calibration sheet.

$$f_c^{-1}\left(C\right) = \frac{a_{c1}C}{a_{c2}+C} + \frac{a_{c3}C}{a_{c4}+C} \qquad \text{A-13}$$

Solving equation A-13 for C yields the calibration function

$$f_c\left(x\right) = \frac{\left(a_2a_3+a_1a_4\right)-\left(a_2+a_4\right)x-\sqrt{\left(a_2-a_4\right)^2x^2+Dx+\left(a_2a_3+a_1a_4\right)^2}}{2(x-a_1-a_3)} \qquad \text{A-14}$$

Where

$$D = 2\left(a_2 - a_4\right)\left(a_1a_4 - a_2a_3\right) \qquad \text{A-15}$$

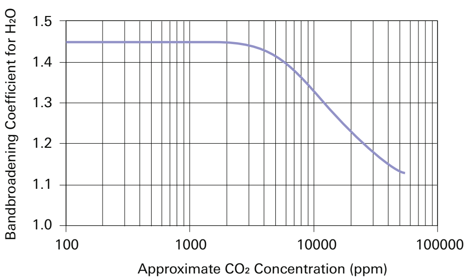
$\psi(W)$ accounts for band broadening by water vapor.

$$\psi(W) = 1 + (h(\alpha_c) - 1)\frac{W}{1000} \tag{A-16}$$

The band broadening coefficient $h(\alpha_c)$ has been determined to be 1.45 for the instrument for CO_2 concentrations near ambient. At higher concentrations, the value decreases. We capture this behavior with an empirical relationship (equation A-17).

$$h(\alpha_c) = \frac{1}{(0.64b_w - 0.64)e^{-3\left(\frac{z}{\alpha_c} - 1\right)} + \frac{1}{b_w}} \tag{A-17}$$

Where z is from equation A-10, and b_w is the low concentration band broadening coefficient: 1.45. This is the value shown on the calibration sheet as BB = 1.45. The typical relationship between $h(\alpha_c)$ and CO_2 concentration is illustrated below. ('Typical' because the exact relationship depends on the relationship between absorptance and CO_2, which is the calibration curve.)



> **Note:** We formulated equation A-17 with $0.64b_w - 0.64$ instead of the simple equivalent (0.29) because this allows band broadening corrections to be turned off by setting b_w to 1. When $b_w = 1$, $h(\alpha_c) = 1$ everywhere. Also, to avoid computational problems (underflows, overflows, and division by zero) we constrain the argument α_c when computing $h(\alpha_c)$ to be $0.1 < \alpha_c \le z$. α_c - 0.1 is typically equivalent to about 600 ppm.

Calibration Equations

Zeroing H_2O (LI-850 only)

When the command for zeroing water is received, the LI-850 computes the water zero from equation A-18, where $\overline{V}_w$ and $\overline{V}_{wo}$ are averaged for 5 seconds.

$$Z_w = \frac{\overline{V}_{wo}}{\overline{V}_w} \qquad \text{A-18}$$

Zeroing CO_2

When the command for zeroing CO_2 is received, the instrument computes the CO_2 zero term from equation A-19, where $\overline{V}_c$, $\overline{V}_{co}$, $\overline{V}_w$, and $\overline{V}_{wo}$ are averaged for 5 seconds.

$$Z_c = \frac{1}{\left(\frac{\overline{V}_c}{\overline{V}_{co}} + X_{wc}\left(1 - \frac{\overline{V}_w}{\overline{V}_{wo}} Z_w\right)\right)} \qquad \text{A-19}$$

Spanning H_2O (LI-850 only)

When the command for setting the span for H_2O is received, along with the target concentration W_T, the LI-850 computes S_{w0} from equation A-20 , where $\overline{\alpha}_w$is averaged over five seconds.

$$S_{w0} = \frac{\beta_w}{\overline{\alpha}_w} - S_{w1}\overline{\alpha}_w \qquad \text{A-20}$$

where

$$\beta_w = \frac{f_w^{-1}\left(\frac{W_T}{T+273.15}\right)}{g_w(\overline{\alpha}_w, P)} \qquad \text{A-21}$$

The instrument retains the following values, which are used for subsequent secondary spans:

$$\alpha_{w1} = \overline{\alpha}_w \qquad \text{A-22}$$

$$\beta_{w1} = \beta_w \qquad \text{A-23}$$

Secondary Span H_2O (LI-850 only)

When the secondary span command for H_2O is received, the instrument computes new values for both S_{w0} and S_{w1}. First, it measures a new $\overline{\alpha}_w$ and computes a new β_w from equation A-21. Then, it uses these plus the retained values (α_{w1} and β_{w1} from the previous normal span) to compute

$$S_{w1} = \frac{\frac{\beta_w}{\overline{\alpha}_w} - \frac{\beta_{w1}}{\alpha_{w1}}}{\overline{\alpha}_w - \alpha_{w1}} \qquad \text{A-24}$$

Given the new span slope S_{w1}, update the span offset S_{w0} by equation A-20.

Spanning CO_2

When the command for setting the CO_2 span is received, along with the target concentration C_T, the instrument computes S_{c0} from equation A-25, where $\overline{\alpha}_c$ and $\overline{W}$ are averaged for 5 seconds.

$$S_{c0} = \frac{\beta_c}{\overline{\alpha}_c} - S_{c1}\overline{\alpha}_c \tag{A-25}$$

where

$$\beta_c = \frac{f_c^{-1}\left(\frac{C_T}{(T+273.15)\psi(\overline{W})}\right)\psi(\overline{W})}{g_c(\overline{\alpha}_c, P)} \tag{A-26}$$

Note that

$$\psi(\overline{W}) = 1 + \left(h\left(\overline{\alpha}_c\right) - 1\right)\frac{\overline{W}}{1000}$$

$$= \left(1 + \left(1/\left(0.64b_w + 0.64\right)e^{-3\left(\frac{z}{\overline{\alpha}}-1\right)} + 1/b_w\right)\frac{\overline{W}}{1000}\right) \tag{A-27}$$

The instrument retains the following values which are used for subsequent secondary spans, if necessary:

$$\alpha_{c1} = \overline{\alpha}_c \tag{A-28}$$

$$\beta_{c1} = \beta_c \tag{A-29}$$

Secondary Span CO_2

When the secondary span command for CO_2 is received, the instrument computes new values for both S_{c0} and S_{c1}. First, it measures a new $\overline{\alpha}_c$ and computes a new β_c from equation A-26. Then it uses these, plus the retained values (α_{c1} and β_{c1} from the previous normal span) to compute

$$S_{c1} = \frac{\frac{\beta_c}{\overline{\alpha}_c} - \frac{\beta_{c1}}{\alpha_{c1}}}{\overline{\alpha}_c - \alpha_{c1}} \tag{A-30}$$

Given the new span slope S_{c1}, update the span offset S_{c0} by equation A-25.

Appendix B.
Specifications

CO_2 measurements

Measurement range: 0 to 20,000 ppm

Accuracy

LI-850: Within 1.5% of reading

LI-830: Within 3% of reading

Calibration drift

Zero drift[1]: <0.15 ppm per °C

Span drift[2]: <0.03% per °C

Total drift at 370 ppm[3]: <0.4 ppm per °C

RMS noise at 370 ppm with 1 sec signal filtering: <1 ppm

Sensitivity to water vapor (LI-850 only): <0.1 ppm CO_2 / mmol mol^{-1} H_2O

Lower limit of detection: 1.5 ppm

H_2O measurements (LI-850 only)

Measurement range: 0 to 60 mmol mol^{-1}

Accuracy: Better than 1.5% of reading

Calibration drift

Drift at 0 mmol mol^{-1}: <0.003 mmol mol^{-1} per °C

Span drift at 10 mmol mol^{-1}: <0.03% per °C

Total drift at 10 mmol mol^{-1}: <0.009 mmol mol^{-1} per °C

RMS noise at 10 mmol mol^{-1} with 1 sec signal filtering: <0.01 mmol mol^{-1}

Sensitivity to CO_2: <0.0001 mmol mol^{-1} H_2O / ppm CO_2

Lower limit of detection: 0.015 mmol mol^{-1}

---

[1]Zero drift is the change with temperature at 0 concentration.

[2]Span drift is the residual error after re-zeroing following a temperature change.

[3]Total drift is the change with temperature without re-zeroing or re-spanning.

General

Output rate: Up to 2 measurements per second

Response time (T90)

  CO_2: <3.5 seconds from 0 to 375 ppm

  H_2O (LI-850 only): <3.5 seconds from 0 to 21 mmol mol^{-1}

Measurement principle: Non-Dispersive Infrared

Traceability

  CO_2: Traceable gases to WMO standards from 0 to 3,000 ppm; traceable gases to EPA protocol gases from 3,000 to 20,000 ppm

  H_2O (LI-850 only): NIST traceable LI-610 Portable Dew Point Generator

Pressure compensation range: 50 to 110 kPa

Maximum gas flow rate: 1 liter min^{-1}

Output signals: Two analog voltage (0 to 2.5 V or 0 to 5 V) and two current (4 to 20 mA)

Digital outputs: TTL (0 to 5 V) or Open Collector

DAC resolution: 16 bits across user-specified range

Power requirements

  Input voltage: 12-30 VDC

  After warmup: 0.3 A @ 12 VDC (3.6 W) average

  During warmup: 1.2 A @ 12 VDC (14 W) maximum

Operating temperature range: -20 to 45 °C

Relative humidity range: 0 to 95% RH, Non-condensing

Dimensions: 22.23 cm W × 15.25 cm D × 7.62 cm H

Weight

  No pump, no display: 1.0 kg

  No pump, with display: 1.02 kg

  With pump, no display: 1.3 kg

  With pump, with display: 1.32 kg

Internal optical cell volume: 14.5 mL

Pump specifications (preliminary; optional)

Nominal flow rate: 0.75 liters minute^{-1}

Power consumption: <0.75 W

Display specifications (optional)

Dimensions: 6.7 cm corner-to-corner

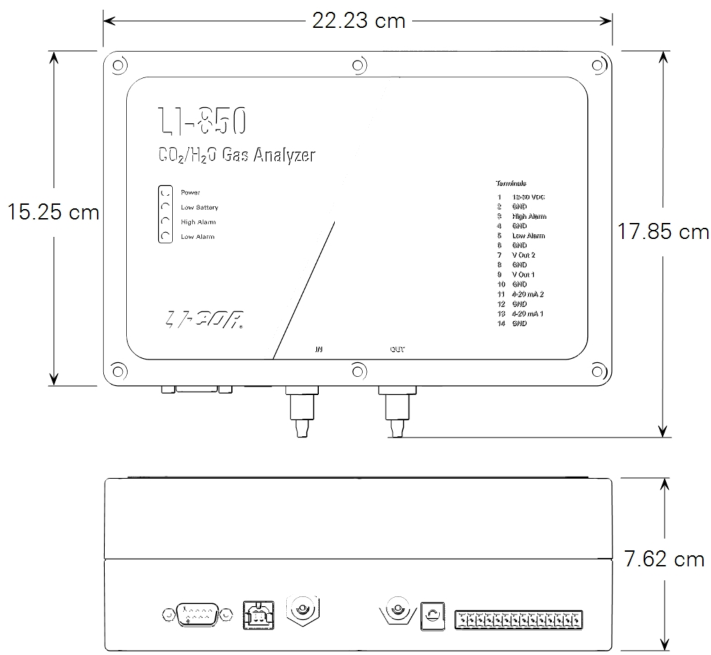
Resolution: 400 × 200 px; monochrome

Power consumption: <200 μW

Displayed Variables: CO_2 reading, H_2O reading (LI-850 only), optical bench temperature, and pressure.

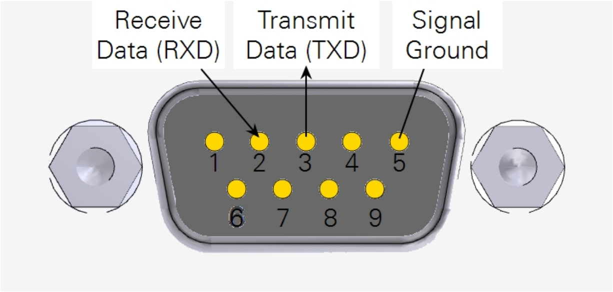
Specifications subject to change without prior notice.

Dimensional drawings



Serial cable pin assignments

The image below shows the pin assignments for the 9-pin RS-232 serial connector.



Serial communication parameters

The LI-830 and LI-850 can communicate through a RS-232 serial port on the front of the instrument. You may need to set the communication parameters on your computer or your terminal emulator program. The RS-232 port is configured as Data Terminal Equipment (DTE) with no hardware handshaking. It is bi-directional, meaning information can be transferred both into and out of the instrument. The port is configured as follows:

- Baud Rate: 9600 bps
- Data Bits: 8
- Parity: None
- Stop Bits: 1
- Flow Control: None

Appendix C.
Warranty

Each LI-COR, Inc. instrument is warranted by LI-COR, Inc. to be free from defects in material and workmanship; however, LI-COR, Inc.'s sole obligation under this warranty shall be to repair or replace any part of the instrument which LI-COR, Inc.'s examination discloses to have been defective in material or workmanship without charge and only under the following conditions, which are:

1. The defects are called to the attention of LI-COR, Inc. in Lincoln, Nebraska, in writing within one year after the shipping date of the instrument.
2. The instrument has not been maintained, repaired or altered by anyone who was not approved by LI-COR, Inc.
3. The instrument was used in the normal, proper and ordinary manner and has not been abused, altered, misused, neglected, involved in an accident or damaged by act of God or other casualty.
4. The purchaser, whether it is a DISTRIBUTOR or direct customer of LI-COR or a DISTRIBUTOR'S customer, packs and ships or delivers the instrument to LI-COR, Inc. at LI-COR Inc.'s factory in Lincoln, Nebraska, U.S.A. within 30 days after LI-COR, Inc. has received written notice of the defect. Unless other arrangements have been made in writing, transportation to LI-COR, Inc. (by air unless otherwise authorized by LI-COR, Inc.) is at customer expense.
5. No-charge repair parts may be sent at LI-COR, Inc.'s sole discretion to the purchaser for installation by purchaser.
6. LI-COR, Inc.'s liability is limited to repair or replace any part of the instrument without charge if LI-COR, Inc.'s examination disclosed that part to have been defective in material or workmanship.

There are no warranties, express or implied, including but not limited to any implied warranty of merchantability of fitness for a particular purpose on underwater cables or on expendables such as batteries, lamps, thermocouples, and calibrations.

Other than the obligation of LI-COR, Inc. expressly set forth herein, LI-COR, Inc. disclaims all warranties of merchantability or fitness for a particular purpose. The foregoing constitutes LI-COR, Inc.'s sole obligation and liability with respect to damages resulting from the use or performance of the instrument and in no event shall LI-COR, Inc. or its representatives be liable for damages beyond the price paid for the instrument, or for direct, incidental or consequential damages.

The laws of some locations may not allow the exclusion or limitation on implied warranties or on incidental or consequential damaged, so the limitations herein may not apply directly. This warranty gives you specific legal rights, and you may already have other rights which vary from state to state. All warranties that apply, whether included by this contract or by law, are limited to the time period of this warranty which is a twelve-month period commencing from the date the instrument is shipped to a user who is a customer or eighteen months from the date of shipment to LI-COR, Inc.'s authorized distributor, whichever is earlier.

This warranty supersedes all warranties for products purchased prior to June 1, 1984, unless this warranty is later superseded. To the extent not superseded by the terms of any extended warranty, the terms and conditions of LI-COR’s Warranty still apply.

DISTRIBUTOR or the DISTRIBUTOR's customers may ship the instruments directly to LI-COR if they are unable to repair the instrument themselves even though the DISTRIBUTOR has been approved for making such repairs and has agreed with the customer to make such repairs as covered by this limited warranty.

Further information concerning this warranty may be obtained by writing or telephoning Warranty manager at LI-COR, Inc.

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